Plant-based ground beef alternatives in comparison to ground beef of various fat percentages

by

Samuel Garret Davis

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Travis G. O’Quinn

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Abstract

The objective of this study was to determine of current plant-based protein ground beef alternatives (GBA) offer similar subjective and objective characteristics to ground beef (GB) patties of varying fat percentages. Fifteen different production lots (*n* = 15 / fat level) of 1.36 kg GB chubs of three different fat levels (10%, 20%, and 30%) were collected from retail markets in the Manhattan, KS area. Additionally, GBA products including a soy and potato-protein based Foodservice GBA (FGBA), a pea-protein based Retail GBA (RGBA), and a Traditional soy-protein based GBA (TGBA), (*n* = 15 production lots / product) currently available through commercial channels were collected from retail markets and a commercial foodservice chain. All GB and GBA treatments were formed into 151-g patties and frozen at -40°C. Patties were thawed 12-24 h prior to cooking and were cooked to 71°C, cut into six equally sized wedges, and served to consumers. Consumers (*n* = 120) were fed six samples in a random order and evaluated sample appearance, juiciness, tenderness, overall flavor liking, beef flavor liking, texture liking, and overall liking. Additionally, the following assays were conducted: color analysis, texture profile analysis (TPA), shear force (SF), pressed juice percentage (PJP), fat percentage, and moisture percentage. Patties used for TPA and SF were cooked to 71°C and cores were taken from each patty for TPA and two strips taken from each patty for SF. Patties were evaluated for L*, a*, and b* both in the raw, precooked state as well as after cooking for both external and internal color. Pressed juice percentage measured the percentage of weight lost from cooked samples. During cooking for TPA, SF, and PJP, patty weights, diameters and thicknesses were measured for determination of size change through cooking. All three GB samples rated higher ($P < 0.05$) than the three GBA samples for appearance, overall flavor, beef flavor, and overall liking. Retail GBA rated lowest ($P < 0.05$) for appearance, overall flavor, texture, and overall

liking. Of the GBA samples, FGBA rated highest ($P < 0.05$) for juiciness, beef flavor, and texture liking, and TGBA rated lowest ($P < 0.05$) for juiciness. Moreover, of the GBA samples, FGBA and TGBA rated similar ($P > 0.05$) for appearance, tenderness, overall flavor liking, and overall liking. Among the GB samples, no differences ($P > 0.05$) were found for appearance, juiciness, overall flavor liking, beef flavor liking, or overall liking. When evaluating raw color, TGBA had the highest ($P < 0.05$) a* value and were redder when compared to all other treatments. Traditional GBA and RGBA had the highest ($P < 0.05$) a* value, while FGBA, and 30% and 10% fat GB had the lowest ($P < 0.05$) a* value for cooked surface color. Additionally, 30% and 20% fat GB had higher ($P < 0.05$) L* values for internal cooked color than all other treatments, with all GBA patties having the lowest ($P < 0.05$) L* values. For texture attributes, RGBA and FGBA had lower ($P < 0.05$) values for cohesiveness, gumminess, hardness, and chewiness. For SF, the three GBA were more tender ($P < 0.05$) than all three GB treatments, with FGBA and RGBA being more tender ($P < 0.05$) than all treatments. The three GB treatments had greater ($P < 0.05$) PJP values than all GBA, indicating the GB was juicier than any of the GBA evaluated. Finally, during cooking, the three GB treatments had a greater ($P < 0.05$) cook loss percentage and decrease in patty diameter and thickness than the three GBA, with FGBA and RGBA increasing in thickness during cooking. This clearly indicates the eating experience provided by the GBA is different than that provided by traditional GB. Thus, consumers who purchase GBA should not expect the same eating quality as they would receive with GB.

Tables of Contents

List of Tables

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Chapter 1

Review of Literature

History of Ground Beef

Ground beef plays a major role in the United States beef market. The origins of ground beef are widely speculated, with many historians pointing to various forms of beef tartare as a starting point (Filippone, 2020). At some point in history, raw beef tartare became a cooked product. The term 'hamburger' originates from the city of Hamburg, Germany, and hamburger first showed up in the United States in 1834 (Filippone, 2020). The Delmonico Restaurant in New York sold 'Hamburg Steak', which was a chopped and formed beef steak. During the Civil War, James Salisbury utilized a chopped beef, seasoned and broiled patty to cure soldiers of diarrhea (Filippone, 2020). The modern hamburger became prevalent at the 1904 St. Louis World's Fair, and White Castle became the first modern 'hamburger stand' in Wichita, Kansas in 1921 (Filippone, 2020).

Ground Beef Today

Ground beef and hamburger are found far beyond hamburger stands today. Fast-food chains, restaurants, institutions, and at-home consumers use make ground beef a popular protein source. But how do beef carcasses become hamburgers in a restaurant? Ground beef is derived from 'trimmings'. These trimmings are a result of basic processing of the beef carcass and cuts. In the processing facility, trimmings are sorted based on general lean-to-fat ratio, what portion of the carcass they were derived from (i.e. round or chuck), and if they meet any breed or branded beef program standards (Julson, 2018). These sorted trimmings may be mixed together to reach a desired overall fat percentage (North American Meat Institute, 2019). To determine fat content, rapid infrared analysis can be used to ensure the ground beef is the correct lean-to-fat ratio

(Science Direct, 2010). The process is a continuous grinding, blending, and forming system (Science Direct, 2010). The grinding process is key to eliminating lingering bone particles in the trimmings. In the instance patties are being formed, rapid cryogenic freezing methods are commonly used to minimize cook loss and improve flavor of the final products (Science Direct, 2010).

Today, most consumers use the terms ‘ground beef’ and ‘hamburger’ interchangeably. According to the Code of Federal Regulations, Ground or Chopped beef is defined as “Chopped fresh and/or frozen beef with or without seasoning, with beef fat addition of not more than 30%, with no added water, binders, phosphates, or extenders (USDA, 2005).” The Standards of Identity for hamburger are very similar to ground beef. However, ground beef can only be made using fat from beef trimmings. Hamburger is able to have pure beef fat added into a lean mixture to reach a desired fat level (The Meat We Eat, 2017). Lean-to-fat ratios found in ground beef vary greatly in order to fit each consumer’s needs. 30% fat is the maximum amount allowed in any ground beef or hamburger product. To qualify for ‘lean’ labeling standards, fat levels must be less than 10 grams of fat within each 100 grams, or 10% (The Meat We Eat, 2017). Many varieties of ground beef lean-to-fat ratios are meant to target specific consumers, and ultimately encourage more people to consume beef.

Additionally, the price of ground beef has changed relative to other cuts, such as steaks. Over the past 20 years, ground beef prices have increased approximately 20% (USDA, 2020). According to Beef Magazine, the all-steaks price relative to ground beef historically held a ratio of 2.5:1. However, due mainly to ground beef price increase, the ratio is now closer to 1.5:1 (Rutherford, 2014).

Ground Beef Consumption

No matter what form consumers are eating ground beef in, it is enough to make America the number one ground beef consumer in the world. Ground beef comprises an estimated 60% of all beef consumption in the U.S (Rutherford, 2014). According to Statista (2020), Americans consumed 27.3 billion pounds of beef in 2019 (Shahbandeh, 2020). Based on 60% of this being ground beef, Americans consumed just over 16 billion pounds of ground beef last year. To meet this demand, 72% of all beef imports into the U.S. are in the form of lean trimmings (Oklahoma State University, 2019).

The U.S. ground beef supply relies heavily on imports. This is primarily due to the type of trimmings produced in the U.S. versus other parts of the world. Most domestic trimmings are classified as ‘50’s’, referring to being 50% lean to 50% fat. Most imported trimmings mainly come in the form of ‘90’s’, or 90% lean trim. In general, cattle slaughtered in the U.S. produce fatter trim than other countries. Without these imported 90’s, the U.S. supply of 50’s would be too high in fat content for ground beef, sending much of the 50’s into waste streams (Elam, 2018).

The import of ground beef trimmings is crucial for not only optimizing usage of domestic product, but for maintaining an affordable protein source. Over the last 4 years, the average retail ground beef price was $3.74 per pound (Cook, 2020). However, there are other benefits which go along with consuming ground beef.

Ground Beef Nutrition

Aside from the economic benefits, ground beef is a source for many positive nutritional attributes. According to the USDA ARS, compared to ground turkey, 3 ounces of ground beef has 26 fewer calories, 17 milligrams less of cholesterol, and 1.1 milligrams more of iron. 3 ounces of ground beef provides 10 essential nutrients, as well as half of the body's daily protein requirement (Beef Checkoff, 2017).

History of Ground Beef Research

Ground beef research in general is limited. In 1983, *Guidelines for sensory, physical, and chemical measurements for ground beef* was published by the American Meat Science Association. This served as a general set of recommendations when studying various aspects surrounding ground beef. During the 1990's, there was a notable rise in ground beef research. Much of this research was in response to the 1993 Jack in the Box *E. coli* outbreak. Prior to the outbreak, the official government guidelines for doneness were cook until it is "brown". Due to contaminated hamburger patties, which were not cooked to 155 degrees Fahrenheit, over 700 people in four states became ill (Food Safety News, 2017). 171 people were hospitalized, and four people died as a result of the outbreak. This prompted research of microbiological issues with the U.S. ground beef supply, and research of *E. coli* O157:H7 and the toxins it produces (Science Direct, 2010). However, there are recent studies focusing more on the subjective attributes of ground beef.

Ground Beef Patty Consumer and Trained Panel Research

Ground beef consumer research has taken on several different questions. As a cheaper source of beef than many whole muscle cuts, many studies have attempted to add value to ground beef. One of these is the relationship between grain and grass-fed ground beef. A study done by (Najar et al.,2019) compared Angus grain-fed, commodity grain-fed, and grass-fed ground beef. 98 consumers were asked to rank samples on a continuous line scale anchored at both ends. The anchors were extremely tough, extremely dry, and dislike extremely, to extremely tender, extremely juicy, and like extremely. Consumers were also asked to give information on their knowledge of Omega-3-rich ground beef products. Due to the success HEB grocers had marketing Omega-3 fortified foods, researchers decided to analyze the effect of Omega-3 enhancement in beef products. Grass-fed ground beef has been known to have 20 to 30 milligrams of Omega-3 fatty acids in a five-ounce serving. In the (Najar et.al) study, consumers preferred Angus and commodity beef over grass-fed beef. This was correlated to differing fatty acid compositions affecting consumer eating experience. Another important outcome of this study was 80% of panelists noted they would be willing to spend extra (\$0.86 ± \$0.49) to purchase omega-3 rich ground beef products.

Laird et al. (2017) conducted a study to examine the impacts of final grind diameter, forming, fat content, patty thickness, cooking, and holding on ground beef patty descriptive flavor and texture using trained sensory analysis. The ground beef was selected from mature grain-fed cattle at two different fat levels. These were then segmented into three grind groups: bowl chopped, 0.95 centimeter, and 0.64 centimeter. They were then formed into two patty thicknesses: 0.64 centimeter or 2.54 centimeters. Next, the patties were cooked either by dry heat cooking or by steam cooking on a clam-shell grill. After cooking all patties to 70 degrees Celsius, they were held for various time ranging from zero, one, and three hours in a steam table. A total of 506 trained panelists determined patty thickness impacted flavor, with the 2.64-centimeter-thick patty having greater ($P < 0.05$) beef identity, sweetness, browned/roasted flavor, and fat-like flavor. Patties with higher fat content (20% versus 5%) had higher levels of beef identity flavor and umami taste. This is probably the most important finding as it relates to the current research being conducted. Overall, the study determined ground beef patty manufacturing and cooking methods can improve flavor and maximize the consumer acceptability of ground beef.

Pena et al. (2019) conducted consumer panels to assess variability of beef flavor among various beef cuts, including 80/20 ground beef. The study is unique for the fact beef was obtained from Miami, Los Angeles, Portland, New York, and Denver. Ground beef was formed into 150-gram patties and cooked to 71 degrees Celsius. Trained panelists were asked to evaluate beef flavor and texture attributes. When compared to chuck roasts, top sirloin steaks, and top loin steaks, the 80/20 ground beef patties offered fat-like, overall sweet, green hay, and buttery flavors.

From these studies, several conclusions can be made. First, ground beef fairs well when compared with various beef cuts. Consumers are generally accustomed to eating ground beef. If more varieties, such as fortified ground beef, were offered, consumers would take advantage of it. And finally, ground beef patties are not created equal. The process of making a high-quality ground beef patty should not be taken lightly. More research needs to be conducted, presumably with consumer panels, to determine what patty attributes they prefer. This may or may not include fat content, grind diameter, patty diameter, patty thickness, ground beef source, and cookery method.

Ground Beef Objective Research

Objective analysis of ground beef is crucial, especially with the many varieties of ground beef available to the consumer. While there is only one ingredient present in ground beef, the processing can take on many different forms.

Texture profile analysis (**TPA**) can be a useful tool for measuring how these different processing factors affect the final ground beef patty. Wilfong et al. (2016) specifically analyzed how six ground beef treatments reacted to TPA. The treatments included 90/10 Certified Angus Beef (**CAB**) ground sirloin, 90/10 ground beef, 80/20 CAB ground chuck, 80/20 ground chuck, 80/20 ground beef, and 73/27 CAB ground beef. The separate chubs were formed into 151-gram patties utilizing a patty former. As fat level decreased, hardness, cohesiveness, gumminess, chewiness, and shear force all increased. In a separate portion of this study, consumer panels were held and the TPA results were compared against consumer texture liking for the patty. It is interesting to note the panel did not detect the differences found with the TPA. This may indicate consumers have a vast acceptability of cooked ground beef patty texture, or the TPA results are not representative of consumer preference.

Objective color analysis of ground beef is another important measure, especially when the lean sources of ground beef can be derived from many different beef specimens. Lean trimmings can come from a variety of physiological ages, breeds, and sexes of cattle. Apple et al. (2017) looked at the impact incorporating lean bull trimmings had on cooked color or precooked ground beef patties. 80/20 ground beef was formulated with 0, 25, 50, 75, or 100% mature bull trimmings. The patties were cooked to 71 degrees Celsius, stored at -20 degrees Celsius, and reheated to 71 degrees Celsius. Instrumental color was then measured on raw patties, initially cooked patties, and reheated patties. The raw patties and initially cooked patty internal color was not affected by any level of bull trimmings. However, as bull trimmings increased in reheated patties, internal patty redness increased. The study concluded adding high levels of bull trimmings to raw ground beef had no effect on ground beef color. However, at the highest proportions of bull trimmings, patties appeared to be undercooked, even after reheating to 71°C.

As important as it is to study how different processing methods and types of cattle affect ground beef, it is also critical to keep in mind how the consumer will utilize their ground beef product. For example, some consumers may prefer to grill their burgers on propane rather than charcoal. Another preference consumers may have was studied at a USDA Agriculture Research Center by Berry et al. (1998). Ground beef from high pH (>6.0) beef was cooked directly from a frozen state as well as from a thawed state. This is relevant to not only consumers at home, but food service establishments which may be cooking burger directly from a frozen state. The research specifically looked at instrumental color. Ground beef with 5,10, 15, 20, and 25% fat was pattied and cooked to 71°C. Fat content and state of patties did not significantly influence color of the cooked patties. The important points to conclude from this research is cooking patties from a frozen or thawed state does not have an influence on final cooked color. However, conducting shear force and texture analysis would be a logical next step in determining how the quality of these patties is affected by these handling methods.

Premature Browning

As mentioned before, prior to Jack in the Box in 1993, the guidelines for a fully cooked hamburger were "brown". Once *E. coli* research began on ground beef patties, premature browning was found to be a major issue in ground beef, particularly from a food safety standpoint. Work continues on searching for a solution to premature browning. Ramanathan et al. (2019) set out to determine consumer practices of cooking, methods to determine doneness, and the types of packaging the consumers purchased their ground beef in. The online survey had 1,030 participants. From this survey, 67% indicated they determine degree of doneness of ground beef patties by visual observation. 18% identified doneness by a length of cooking time, and only 13.5% use a meat thermometer. 69% stated they liked a brown interior color of cooked patties. Only 5.7% of respondents purchased ground beef patties in a vacuum package. 60% purchased them in a film wrapped tray or package. It is evident over 20 years of USDA education has been less than effective. The consumer practices indicated in the survey provide reason for concern, and their practices increase the likelihood of premature browning and food safety issues.

Packaging type is a major contributor to premature browning. This was specifically found by Djimsa et al. (2010). The study assessed the effects of packaging and final cooked temperature of metmyoglobin reducing activity (**MRA**). The greater the MRA, the more stable the ground beef color will be. The less MRA, the greater the color has been oxidized and is unable to return from a brown color. Patties were separated into vacuum packaging or high-oxygen modified atmosphere packaging. Patties from each of these packaging groups were assigned to 65- or 71-degree Celsius endpoint cooking temperatures. The main discovery relevant to this review was the role vacuum packaging played in preserving MRA. Modified atmosphere packaging led to unpredictable final cooked color, often leading to premature browning. From these conclusions, it seems the easiest way to prevent premature browning in ground beef is to vacuum package all products.

In 2013, Sorheim et al. (2013) took a different approach to solving the premature browning issue. Additives such as rosemary extract, ascorbic acid, sodium lactate, polyphosphate, and lingonberry juice were added to fresh ground beef, and patties were cooked to 62°C. The only additive which reduced premature browning was polyphosphate, and this was attributed to the increase in pH as a result of adding it to the ground beef. The study also cooked vacuum packaged ground beef patties with deoxymyglobin to 62, 69, and 75°C. None of the patties expressed premature browning. In conclusion, it again seems the most effective way to combat premature browning is through vacuum packaging ground beef.

Plant Based Proteins

Proteins are defined as a macronutrient composed of organic compounds called amino acids, which are made of carbon, hydrogen, nitrogen, oxygen, or sulfur (Szalay, 2015). Protein has been a main focus in human diets since ancient times, whether the protein is meat or plants. In fact, most early protein sources came in the form of plants. Eating meat began opportunistically as hunters were able to occasionally kill game for food. Eventually, hunting in groups for larger game led to meat consumption on a regular basis (Larsen, 2003). As civilizations have developed, so have their sources of protein. With current developed societies, protein is readily available at reasonable costs to consumers. Along with this abundance comes many choices consumers can make. A vegetarian or 'flexitarian' diet is not a new concept. Vegetarianism dates back to ancient Egyptian civilization. Meat replacements date back to the year 925 with the development of Tofu in China (North American Meat Institute, 2018). However, commercialization of plant-based protein is a relatively modern concept. Looking specifically at commercial plant-based meat alternatives, three distinct waves of innovation can be seen in history.

The first wave came at the end of the 1800's. One of the first attempted commercial developments of a plant-based meat alternative was by John Kellogg, the creator or the corn flake. Due to religious reasons, he developed what was called 'Protose', a steamed mixture of peanut butter, mashed beans, water, and corn starch (Connors, 2019). However, this new food was mainly a success within his religious group. Cookbooks were created in order for families to make gravies and side dishes to improve the taste of Protose (Prichep, 2017).

Fast-forward to 1969, the second wave of innovation can be seen. The first written proof of a vegetable burger appeared as part of a dry soybean article (Shurtleff, 2013). During the 1970's, many people considered vegetarianism to be part of the 'hippy' culture. The publication of '*Diet for a Small Planet* (1971)' convinced people meat consumption was wasteful and contributed to environmental issues (Smith, 2014). This inherently made being a vegetarian trendy, and by the late 1970's, the term 'Vege' and 'Veggie' entered the lexicon (Smith, 2014). One of the first meatless patties has been traced to a macrobiotic restaurant in the United Kingdom. Made popular by John Lennon and Yoko Ono, the restaurant began making the patties by kneading flour under running water, flavoring with tamari, mixing it with beans and oat flakes, and forming patties (Smith, 2014). After expanding to wholesale natural food distribution, the restaurant owner decided to create a 'VegeBurger' to supplement income. One of the most important goals the developer had was keeping the Vegeburger cheaper than ground beef patties. To achieve this, he created a dehydrated patty mix which sold for 56 pence compared to 75 pence for ground beef. While this was not the first plant-based alternative patty created, it was the first to reach the commercial natural foods market.

In the commercial retail market, others became aware of the success of Vegeburger. Gardenburger, Inc. and Boca Burger, Inc created vegetable-based patties, and by 2002, Kraft Foods had acquired Boca Burger, Inc (Prichep, 2017). These products were placed in the frozen food section, an attempt to get them in closer proximity to frozen beef burgers.

Morningstar Burger

Kellogg's is still active in the alternative protein market through Morningstar Farms. In particular, the Morningstar Grillers Veggie Burgers are offered in many supermarket frozen food sections.

The Grillers Veggie Burger ingredients include water, wheat gluten, soy flour, vegetable oil, egg whites, calcium caseinate, cornstarch, onion powder, soy sauce powder (soybeans, salt, wheat), methylcellulose, cooked onion and carrot juice concentrate, salt, natural flavor, soy protein isolate, garlic powder, spices, sugar, gum acacia, whey, yeast extract, xanthan gum, potato starch, tomato paste (tomatoes), onion juice concentrate.

The third wave of innovation has focused on much more than simply creating another soy burger for the frozen foods section. Silicon Valley has been the source of several meat alternatives, and the funding, engineering, and manpower behind these products is far beyond the first two waves of meat alternative innovation. The third wave of these products are also tackling something none of the others have; they are aiming at meat-eaters (Tugend, 2019). Not only are they producing plant-based alternatives to meat, but they want to mimic meat in such a way it will be appealing to meat-eaters themselves (Tugend, 2019). To achieve this goal, companies are looking at different ingredients and processing options.

Alternative Proteins Today

Beyond Meat prides themselves on the ingredients they use. One of their goals is to eliminate any animal-based ingredients in their products (Beyond Meat, 2020). Their products are Non-GMO Project Verified, Soy Free, Kosher, Halal, and vegan. Beyond Meat is primarily located in grocery stores. However, they have entered some food service channels as well. Their products can be found at the following retail stores: ShopRite, Giant, Safeway, Sprouts, Target, Publix, Meijer, and Harris Teeter. Their products can be found at the following food service establishments: TGI Fridays, BurgerFi, Organic Bareburger, VeggieGrill, Carl’s Jr., A & W, Del Taco, and Dunkin’ Donuts. Beyond occupies additional grocers and food service establishments, and they offer partnership agreements off their website. Aside from the Beyond Burger, they have developed several other plant-based meat substitutes. These include breakfast sausage, Beyond Beef, sausage, and Beyond Beef Crumbles.

Beyond Burger Ingredients

Beyond focuses on the 5 essential nutrients: protein, fat, minerals, carbohydrates, and water. On their label, the first ingredient is water. Ground beef consists of 55-65% moisture depending on fat percentage (USDA, 2011). Presumably, Beyond Burger would be similar in percentage. The second ingredient is Pea Protein Isolate. Pea protein is derived mainly from yellow-split peas. The peas are most often finely ground, mixed with water to separate fiber and starch, and the remaining paste is dried and ground as the protein source (Livestyle Nutrition, 2019). In 20 grams of pea protein isolate, there are 20 calories, 15 grams of protein, and 230 milligrams of sodium. While pea protein provides nine essential amino acids, these amino acids are not as easily digested as soy or chickpea, and especially not meat amino acids (Julson, 2012). Antioxidants such as phytates and polyphenols can bind the beneficial zinc, calcium, and iron in many plant products. Processing minimizes some of these effects (Julson, 2012). Pea protein also has low allergenicity, offering many vegetarians an alternative to soy-based protein (Lam, 2017). The third ingredient is expeller-pressed canola oil. Canola oil typically undergoes processing by using hexane to extract oil from the seeds, often called solvent extracting. This oil is then refined and bleached to give it a lighter color and reduce odors (Cook's Illustrated, 2014). Expeller pressing involves a screw-type press using friction and pressure to squeeze oil from the canola seeds (Cook's Illustrated, 2014). This method is far less efficient, but fewer chemical changes are undergone by the oil. This allows producers to sell this oil at a premium. For example, expeller-pressed canola oil commonly sells for $9.99 for 32 ounces. Traditional canola oil sells for around $3.50 for the same amount. The fourth ingredient is refined coconut oil. All coconut oil is derived from the meat of the coconut. Virgin coconut oil is extracted using expeller pressing and is accomplished by quick-drying the coconut meat before squeezing out the oil. This unrefined version of the oil still has slight coconut flavor and odor due to the low-heat extraction method (Builder, 2018). To get refined coconut oil, the dried coconut meat undergoes a high-heat process. The final product is termed RBD coconut oil, or 'refined, bleached, and deodorized'. This product does not have coconut flavor or odor. The fifth ingredient is rice protein. Rice protein contains large amounts of the amino acid lysine. Many extraction methods have been studied to isolate the protein from the rice bran. An alkali hydrolysis method has been utilized since the 1970's. However, a water hydrolysis method has shown higher protein yields in recent studies (Khir, 2019). Nutritionally, rice protein does not provide all essential amino acids, and bioavailability of these amino acids is limited. The sixth ingredient is natural flavor. According to the FDA, a natural flavoring means the essential oil, oleoresin, essence or extractive, protein hydrolysate, distillate, or product of roasting which contains the flavoring constituents derived from a spice, fruit or fruit juice, vegetable or vegetable juice, edible yeast, herb, bark, bud, root, leaf, meat, seafood, poultry, eggs, dairy products, whose significant function is flavoring rather than nutritional (Code of Federal Regulations, 2019). The seventh ingredient is cocoa butter. Cocoa butter is often found in lip balms, lotions, and creams. It is extracted from cocoa beans by fermenting, drying, roasting, and pressing the beans. The additional product of this process is cocoa powder. In one tablespoon of cocoa butter there are 120 calories and 13.6 grams of fat, mainly saturated and monounsaturated fats (Cobb, 2019). The eighth ingredient is mung bean protein. Mung beans are a legume which have been consumed by humans for around 4,500 years (Pape, 2016). Mung bean protein is extracted by milling mung beans into flour, mixing with water, adding pH adjusting chemicals, and centrifuging the slurry. The protein is spray dried to achieve a final moisture content of less than 5% (Pape, 2016). The mung bean protein powder is abundant with various amino acids and low in starch. The ninth ingredient is methylcellulose. Methylcellulose is a compound derived from cellulose, and it is not digestible or an allergen risk. Cellulose provides structure and rigidity to plant cell walls and is considered the most abundant organic substance on Earth. It is also a fiber source in the human diet. Cellulose has become a trendy food additive in recent years (Moncel, 2019). It can add fiber and substance to a food without sacrificing flavor. Methylcellulose is yet another thickener and emulsifier (Food Additives, 2020). In water, methylcellulose swells and creates a gel. This gel can thicken under heat processing and extend the shelf life of products it is added to. The FDA has approved Methylcellulose for use as an emulsifier, flavor enhancer, stabilizer, or thickener in food products (Food Additives, 2020). The tenth ingredient is potato starch. Potato starch is a finely textured powder from the starchy portion of potatoes. Due to the low amounts of lipid and protein in the starch, it is often used in clear, tasteless pastes. When hydrated, starches can perform many functions. In meat products, it can act as a moisture binder, extend shelf life, and improve texture and mouthfeel of restructured products (Cargill, 2019). The eleventh ingredient is apple extract. To produce 1 kilogram of extract requires 500-600 Fuji apples. The extract usually only has a slight apple aroma (NutriPharma, 2019). Apple extract may also be used as a free radical scavenger. The twelfth ingredient is salt. The functions of salt are vast: preservation, flavoring, water activity control, microbial growth inhibitor, and protein extractor are just a few (Man, 2014). The thirteenth ingredient is potassium chloride. Potassium Chloride, or potash, is a naturally occurring mineral usually brought to the surface of the ground via potash mining (Cargill, 2020). Although it is mainly used as a fertilizer, potassium chloride is widely used as a salt replacement in food. Usage levels are not limited in food, meaning it is self-limiting and non-toxic (Cargill, 2020). The fourteenth ingredient is vinegar. Vinegar is made by fermenting liquids with sugar in them, such as wine. In meat products, vinegar is used to add flavor and act as a preservative due to its acetic acid content and low pH (ScienceDirect, 2013). The fifteenth ingredient is lemon juice concentrate. Similar to vinegar, the low pH of lemon juice concentrate can assist with the preservation of food products (ScienceDirect, 2003). The sixteenth ingredient is sunflower lecithin. Lecithin in general is an emulsifier, acting to stabilize mixture. Lecithin occurs naturally in plants (Cargill, 2019). Being a phospholipid, lecithin creates strong oil-in-water and water-in-oil emulsions (Cargill, 2019). In the food industry, there are hundreds of variations of lecithin. Sunflower lecithin is often used as a replacement for soy lecithin due to its low allergy risk. It is slightly more expensive than soy lecithin, but it fits the goal of Beyond Meat being Non-GMO Project Verified. The seventeenth ingredient is pomegranate fruit powder. In recent years, the demand for natural antioxidants and antimicrobials has risen drastically. Aside from the health benefits of pomegranate, the concentrated powder has high acidity and has shown to decrease lipid oxidation, increase antioxidant activity, and decrease microbial activity in several processed meats (Kandylis, 2020). The eighteenth and final ingredient in Beyond Burger is Beet Juice Extract. On the label, it states this ingredient is added for color.

The vast array of ingredients present in the Beyond Burger is paled in comparison to the numerous functionalities they have. In order for the patty to function similar to a ground beef patty on the grill, it takes eighteen ingredients. In conclusion, these ingredients are to bind the patty together, add protein, add flavor, aid in antioxidant and antimicrobial function, and add color.

Impossible is another product created during the third wave of alternative protein invention. Their mission is to save meat and save the Earth. They are making meat from plants so they never have to use animals again (Impossible Foods, 2020). Impossible is targeted towards food service channels. They offer three products to restaurants: a five-pound Impossible Burger brick, quarter pound patties, and third pound patties. They also sell promotional items for restaurants to use, from table tents to window decals. Most notably, Impossible has been promoted by Burger King, Qdoba, and Red Robin. As of September 2019, Impossible began selling products in the retail market, beginning regionally in Safeway, Vons, Jewel-Osco, and Wegmans. Their target market is not vegetarians; they are selling to meat eaters. One of their major selling points is how their product ‘bleeds’ like real beef. Like the Beyond Burger, there are numerous ingredients and technologies which make this happen.

Impossible Burger Ingredients

The first ingredient is water. The second ingredient is textured wheat protein. Dating back to ancient China, wheat protein has been used as a meat alternative for many years (Srgad, 2020). When the protein is hydrated, it offers a meat-like texture. This can result in partial or complete meat replacement. With two parts of water, the replacement ratio for textured wheat protein to meat is 1:1. The flavor is neutral, which negates the need to mask any off-flavors (Srgad, 2020). The third ingredient is coconut oil. Similar to Beyond Burger, coconut oil serves as a fat source for the Impossible Burger. The third ingredient is potato protein. Potato protein amino acid content has been compared to egg whites (Peska, 2009). Potato proteins can have very low pH’s, and these proteins can be precipitated at a pH of 3-4 (Peska, 2009). The fourth ingredient is natural flavors. The fifth ingredient is leghemoglobin. Impossible specifically uses soy leghemoglobin, which functions as an oxygen carrier in plants. It also carries heme protein. Leghemoglobin is comparable to hemoglobin found in the blood. Leghemoglobin is found in micromolar concentrations in nitrogen fixing root nodules of legumes (Sharma, 2019). Leghemoglobin is not identical in structure to hemoglobin, but they are similar (Sharma, 2019). According to Pat Brown, founder of Impossible, “Discovering and imitating the molecular interactions that make meat delicious is the most important scientific question in the world right now." It is with this idea in mind Impossible discovered soy heme as a suitable replacement for beef flavor. The issue then arose of how to obtain large quantities of leghemoglobin needed for large scale production. Over a year was spent developing systems to separate soybean nodules from roots as well as purifying leghemoglobin (Wolf, 2019). None of these were the solution. The Impossible group then turned to recombinant protein production, which uses yeast as a 'factory' for housing proteins. *Pichia pastoris* is the specific yeast used for the large-scale production. Upon picking a suitable yeast, the team then had to pick a heme source. Hemoglobin and myoglobin were initially tested, even though the group preferred a non-animal option (Wolf, 2019). However, leghemoglobin performed the best. Leghemoglobin is highlighted as the key ingredient in the Impossible Burger. Cited as what makes the Impossible Burger taste like beef, it also allows it to 'bleed' like beef. The purge found in packages of meat is a mixture of water and myoglobin. Myoglobin is water soluble and gives meat its red color (Yancey, 2017). Leghemoglobin acts in a similar manner in the Impossible Burger by giving it its red 'bloody' color. The sixth ingredient is yeast extract. Yeast extract is the same cell as fresh yeast but without the cell wall (Pletcher, 2015). This is accomplished by adding sugar to yeast in a warm environment. This allows the cell wall to soften. The mixture is centrifuged, and the cell walls are separated from the cell contents (Pletcher, 2015). Yeast extract is popular as a sandwich spread in Europe and Australia, traveling under the name Vegemite. For the Impossible Burger, yeast extract could be added to create the umami flavor. It is also interesting to note yeast extracts contain glutamates. The most common glutamate is monosodium glutamate (MSG). Yeast extracts contain glutamates, and per the FDA products with yeast extract cannot be labeled as "No MSG" (Pletcher, 2015). Products containing yeast extract also cannot be labeled as gluten-free (Dennis, 2018). The seventh ingredient is salt. Similar to the Beyond Burger, salt has numerous functions and is not limited in product formulations. The eighth ingredient is soy protein isolate. Soy protein isolates are primarily used in the food industry. They are low cost and can easily be blended with other protein sources (Ma, 2015). Current technology is able to remove soy flavors and colors, making it functional in multiple ways. In the meat industry, soy protein isolate is primarily used to change texture profiles. It may also aid in moisture retention and stabilizing emulsions (Bookwalter, 1978). Soy protein isolates are also yet another source of protein for the Impossible Burger. The ninth ingredient is konjac gum. Konjac is a tuber, and through drying and milling, its fiber can be ground into a flour. Additional extracting and drying steps yield Konjac glucomannan (Colony Gums, 2019). Konjac dissolves easily in water, and one chain particle of Konjac can swell to 200 times its original volume. Hydration then results is a viscous liquid. Konjac can have multiple functions. As a thickener, Konjac has the highest molecular weight, density, and viscosity of any dietary fiber available to humans. Similar to Carrageenan or Xanthan Gum, Konjac gels are very cohesive and elastic. As a stabilizer, Konjac is non-ionic, meaning salt does not affect its character or function (Colony Gums, 2019). In a finished product, Konjac gum can add mouth feel, stabilize emulsions, enhance shelf life, bind water, and many other functions. The tenth ingredient is xanthan gum. Similar to konjac gum, xanthan gum is a high molecular weight polysaccharide. It comes from the fermentation of bacterial carbohydrates. Xanthan gum is easily hydrated and creates viscous solutions at low concentrations (Angioloni, 2014). It is stable in acidic and alkaline conditions. Xanthan gum is also very compatible with konjac gum, with gel strength and viscosity increasing when the two are mixed (Colony Gums, 2019). Xanthan gum is not an emulsifier, but it acts as a stabilizer and is commonly found in salad dressings and sauces. The eleventh ingredient is thiamin. Thiamin, also known as vitamin B1, is a water-soluble vitamin involved in many bodily functions. Some of those include changing carbohydrates into energy, muscle contraction, nerve signal conduction, and metabolizing pyruvate (US National Library of Medicine, 2020). Thiamin is found naturally in many foods, including beef, pork, eggs, legumes, wheat germ, and enriched, fortified, whole grain breads (US National Library of Medicine, 2020). Impossible Burger may be supplemented with Thiamin to make it closer in nutritional value to beef. The twelfth ingredient is zinc. Zinc is a vital trace mineral, its concentration second only to iron in the body (US National Library of Medicine, 2020). Zinc in key for immune system function, and assists with cell growth, cell division, wound healing, and carbohydrate breakdown. Animal protein, especially red meat species, are the best sources of zinc (US National Library of Medicine, 2020). Additional sources include nuts, whole grains, and legumes. The thirteenth ingredient is niacin. Niacin, or vitamin B3, is yet another water-soluble vitamin. All niacin in the body is converted to a metabolically active form, the coenzyme NAD. NAD is required in over 400 enzymes to catalyze bodily reactions (US Department of Health and Human Services, 2020). Even at high intake levels, niacin is highly absorbed by the body. Niacin is the most present in animal-based foods such as beef, poultry, and fish. Moreover, these sources provide niacin directly in the form of NAD, making it extremely bioavailable (US Department of Health and Human Services, 2020). Nuts, legumes, and grains provide niacin as well, but mainly in the form of nicotinic acid. It is interesting to note the liver can convert the amino acid tryptophan into NAD when the amount of tryptophan exceeds what is needed for protein synthesis (US Department of Health and Human Services). The fourteenth ingredient is vitamin B6. Vitamin B6 is another coenzyme involved in over 100 enzymatic reactions. Most of these reactions are related to protein metabolism (US Department of Health and Human Services, 2020). Vitamin B6 is also involved in immune system function and hemoglobin formation (US Department of

Health and Human Services, 2020). The richest sources of vitamin B6 are fish, beef (especially organ meats), potatoes, and non-citrus fruits (US Department of Health and Human Services, 2020). Vitamin B6 is also fortified in many cereals. The fifteenth ingredient is riboflavin. Riboflavin, also known as vitamin B2, is yet another water-soluble vitamin. In the body, it is found as one of two coenzymes: FMN or FAD. Both of these are key in energy production for cellular growth, development and function, and metabolism of fats (US Department of Health and Human Services, 2020). Riboflavin in the diet is mainly found in eggs, organ meats, lean meat, milk, and leafy greens (US Department of Health and Human Services, 2020). It is interesting to note the populations most associated with riboflavin deficiencies are vegetarian athletes, pregnant women, and vegans (US Department of Health and Human Services, 2020). This is a strong indicator of why Impossible chose to fortify their product with riboflavin. The sixteenth ingredient is vitamin B12. Vitamin B12 is crucial for keeping nerve and blood cells healthy, and it assists with the formation of DNA (US Department of Health and Human Services, 2020). B12 is absorbed via two steps; first, hydrochloric acid separates B12 from its protein carrier in the stomach. Second, B12 combines with a protein known as intrinsic factor and is absorbed. Vitamin B12 is found abundantly in beef liver, clams, and in fish, meat, eggs, and dairy products (US Department of Health and Human Services, 2020). Plant foods contain zero vitamin B12 unless they are fortified.

Unlike Beyond Burger, Impossible is highly fortified. However, it does not qualify for as many product claims as Beyond. Beyond Burger is Non-GMO Project Verified, soy-free, nut/tree nut free, and gluten free.

Why Replace Meat?

The driving force behind the third wave of plant-based meat alternatives is eliminating animal production. According to a 2019 study conducted by Quantis and Impossible, "Animals convert plants into meat and dairy. Yet do so within the constraints of an animal metabolism, thus losing the vast majority of the protein and calories in the plants consumed. This report focuses on the resource-sparing potential of bypassing the animal entirely and creating equivalent products directly from plants (Khan, 2020)." The issue with this logic is bioavailability of the protein and calories offered by plants. These plants may offer a lot of protein and calories, but it is unusable by humans. Cellulose is indigestible in the human body. However, through fermentation in the rumen, ruminants are able to convert cellulose into one of the most nutrient-rich, high-quality protein sources known to man.

Conclusion

Ground beef is a key protein source for the United States. Although it is only one ingredient, it has proven difficult to replicate. Ground beef research is mainly concentrated to microbiological interventions to prevent E. coli outbreaks. Several studies have shown even within the same lean-to-fat ratios, there is variability in ground beef patties. This is an area of weakness which needs studied further. The biggest area of weakness for alternative proteins is the lack of research. With the third wave of alternative proteins, these new products have not been compared to anything. Impossible claims to have conducted consumer panels, but this information is unpublished. There is also a wide variation of environmental studies regarding the impact livestock production has on the environment. A conscience effort needs to be put forth to provide the most complete, factual data possible. The objective of this study is to compare ground beef to alternative protein patties trying to replicate it by conducting consumer sensory panels, trained sensory panels, texture profile analysis, instrumental raw, cooked internal and external color, Warner-Bratzler shear force, pH, fat content, moisture content, percent juice press, and patty shrink. By measuring all these factors, it will provide insight into whether alternative protein companies have succeeded or failed in their quest to replicate ground beef.

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Chapter 2

Plant-based ground beef alternatives in comparison to ground beef of various fat percentages

Introduction

Plant-based proteins have been a part of human diets for thousands of years. However, these proteins have been used to develop products to mimic and imitate meat in the food system (Hensel, 2020). No controlled studies have been conducted outside of private companies' research labs comparing these plant-based alternatives to traditional meat products.

Ground beef (**GB**) comprises of 60% of all beef consumption in the U.S. (Rutherford, 2014). Plant-based alternative companies have specifically focused on beef alternative products first because beef has "the largest global detriment to the food world" (Hensel, 2020). Alternative protein companies have made considerable investments in ground beef alternative (**GBA**) products (Good Food Institute, 2020). Cost of these products have steadily decreased over the past five years. More and more retail case space is being dedicated to plant-based meat alternatives, residing directly adjacent to meat products (Nelson, 2020).

Again, while these products are being placed next to each other, no research has been conducted on how they actually compare. It is plausible that these products offer consumers a meat-eating experience similar to ground beef, though this claim is, to date, unsubstantiated with rigorous scientific investigation.

Therefore, the objective of this study was to determine if current GBA's offer similar subjective and objective characteristics to GB patties of varying fat percentages.

Materials and Methods

The Kansas State University (**KSU**) Institutional Review Board approved the procedures used in this study (IRB #7440.7, 2021).

Treatments and sample preparation

Three GB (IMPS #136) treatments (15 - 1.36-kg chubs / treatment) were purchased from four supermarkets in the Manhattan, KS area over a three-month period. The variety of fat levels included (lean / fat percentage): 90 / 10 ground beef, 80 / 20 ground beef, and 70 / 30 ground beef. Fifteen replicates were purchased for each GB treatment of differing production lot numbers and / or freeze-by dates. Upon purchase, each 1.36 kg chub was assigned an individual identification number and frozen at 0 - 4°C prior to patty formation. Ground beef was stored frozen at the Kansas State University Meat Laboratory in Manhattan, KS prior to patty fabrication.

Additionally, three commercially available plant-based GBA treatments (15 production lots / treatment) were purchased from various suppliers. The first plant-based ground beef alternative was a GBA traditionally sold at food service establishments. Therefore, this product was identified as a Food Service Ground Beef Alternative (**FGBA**). The primary protein source for the FGBA was comprised of soy and potato proteins. The raw FGBA was procured from three restaurants in the Kansas City, KS area in 2.27-kg chubs over a two-month period. Fifteen 2.27-kg chubs were procured and stored at the KSU Meat Laboratory in the same manner as the GB prior to fabrication. The second GBA was predominantly available in retail settings and was thus identified as a Retail Ground Beef Alternative (**RGBA**). The primary protein in the RGBA was a pea protein. Fifteen production lots (6 227-g packages) of raw RGBA were procured from supermarkets in the Manhattan, KS area over a three-month period. The third GBA was a “traditional” soy-based patty, which was identified as a Traditional Ground Beef Alternative (**TGBA**). The TGBA was primarily comprised of soy protein and, unlike the FGBA and RGBA, the TGBA was a fully cooked patty at purchase. Fifteen lots (4 256-g packages) of TGBA was procured over a three-month period from supermarkets in the Manhattan, KS area.

Prior to fabricating GB and GBA treatments into patties, all treatments were thawed for 12 hours at 3°C. Upon thawing, each production lot was unpackaged, hand mixed for approximately 10 s, weighed into 114-g balls, and hand-pressed using a table-top 11-cm wide, 1.2-cm thick patty forming dye. After forming, patties were randomly assigned to consumer sensory panels, trained sensory panels, shear force analysis, texture profile analysis, or estrogen content and toxicology (data not reported). Patties were placed on trays and crust frozen for approximately 30 min and then individually packaged using a rollstock packaging machine (Model Bulldog 42a 300, Ultrasource, Kansas City, MO) and frozen (-20°C) until analysis.

Consumer sensory testing

Consumer sensory testing was conducted at KSU. Panelists (N = 120) were recruited from the Manhattan, KS area and paid for their participation. Consumers sampled GB and GBA patties under florescent lighting in a large lecture-style room. Five sessions of panels were conducted with 24 consumers at each panel session. Each panel lasted approximately 1 h.

Patties for each panel were thawed at 4°C for 24 h prior to cooking. Patties were cooked to 71°C on a Cuisinart Griddler Deluxe clam-shell style grill (Stamford, Connecticut, USA) Endpoint temperature was verified using a Beckman Industrial Doric 205 thermocouple thermometer (Brea, California, USA). Patties were then cut into 8 equally sized wedges with one wedge being immediately served to each predetermined consumer.

Consumers were asked to complete a demographic questionnaire which included questions related to gender, household size, marital status, age, income level, education level, ethnicity, palatability trait preferences, preferred degrees of doneness, and ground beef consumption habits. Consumers were also asked to rank ground beef purchasing motivators on a 100-point line scale (0 = least emphasis; 100 = most emphasis). Consumers were given utensils, an expectorant cup, a Lenovo TB-850SF handheld electronic tablet with an electronic ballot, and palate cleansers for use between samples (unsalted crackers and apple juice). Prior to testing, participants were given verbal instructions regarding the tablet and ballot, testing procedures, and the use of palate cleansers.

Ground beef and GBA samples were all served blind, with no information given to consumers prior of evaluation. Consumers evaluated one sample from each of the six treatments in a random order. Each sample was evaluated for appearance liking, juiciness, tenderness, overall flavor liking, beef flavor liking, texture liking, and overall liking. Each trait was evaluated on a continuous line scale anchored with descriptive terms at the ends and mid-points: 100 = extremely juicy, tender, and like appearance/overall flavor/beef flavor/texture/overall extremely; 50 = neither juicy nor dry, tough nor tender, or neither like or dislike appearance/overall flavor/beef flavor/texture/overall; 0 = extremely dry, tough, and dislike appearance/overall flavor/beef flavor/texture/overall extremely. Additionally, consumers rated each trait as either acceptable or unacceptable. Consumers also identified each sample as unsatisfactory, everyday quality, better than everyday quality, or premium quality following sample evaluation.

Trained sensory testing

Panelists were trained using the *Research Guidelines for Cookery, Sensory Evaluation, and Instrumental Tenderness Measurements of Meat* (AMSA, 2015). Each panelist was required to attend a minimum of 3 training sessions in the two weeks prior to the beginning of panels. In each training session, panelists evaluated and were trained for sensory ratings from samples across all experimental treatments. For sample cooked color evaluation, the panelists were trained using the ground beef patty cooked color guide, as presented by Marksberry et al. (1990). Based on the guide, the numbers one through five correlated with different degrees of doneness based on the amount of red color remaining in the internal center of the patty. Each sample was evaluated for juiciness, tenderness, beef flavor, beef flavor intensity, off flavor, and texture (Table 2-1). Each characteristic was evaluated on a continuous line scale. Anchors were set at 0 and 100 with a midpoint of 50. The 0-anchor was labeled as: extremely dry, extremely tough, extremely un-beef-like, extremely bland, extremely soft. The midpoint anchor was labeled as: neither juicy nor dry, neither tough nor tender, neither soft nor hard. The 100-anchor was labeled as: extremely juicy, extremely tender, extremely beef-like, intense flavor, extremely hard. For off-flavor, panelists had a "not applicable" option if none were detected.

Patties were thawed at 2 to 4°C approximately 24 h prior to sensory panel evaluation. Patties were cooked in the same manner as described for consumer sensory panel evaluations. Each trained sensory panel consisted of 8 panelists, with a total of 15 panels conducted. To begin the panel, the white 800 lumen incandescent lights were left on and each panelist evaluated the same single wedge of each treatment, one at a time and in a random order, for cooked internal color. Upon completion of evaluating all six treatment samples, panelists were served in individual booths under red, low intensity (< 107.64 lumens), incandescent lights. For odor evaluation,the panelists were then given a closed jar with one cut sample from each treatment inside separate Ball 4 oz. Quilted Crystal glass jelly jars. The panelists evaluated the beef odor and non-beef odor for each sample. Samples were passed from panelist to panelist with the jar lids closed, with each panelist opening the jar just briefly enough to evaluate the sample for odor characteristics.

Once the odor evaluation was complete, a warmup sample was evaluated to provide panel calibration for the panelists and prevent panel drift. Each panelist was provided deionized water, cut apple slices, and unsalted crackers to cleanse the palate, an expectorant cup, and a napkin. Each panelist evaluated six samples (one from each treatment) in random order. An electronic tablet (Lenovo TB-850SF) was used along with an online digital survey (Qualtrics Software, Provo, UT) for the recording of sensory panel evaluation scores.

Shear force

Patties for shear force analysis were prepared and cooked as previously described for consumer sensory evaluation. Methods from the *Research guidelines for cookery, sensory evaluation, and instrumental tenderness measurements of meat* (AMSA, 2015) were used for shear force testing of GB and GBA patties. Following cooking, samples were allowed to cool to room temperature (21 - 23°C) prior to testing. Shear force was measured on two strips (2.5-cm wide × patty thickness) removed from the center across the width of the patty. Each strip was sheared straight through the perpendicular cooked patty surface with the patty laying horizontally, three times using a straight edge slice-shear force blade attached to an INSTRON Model 5569 testing machine (Instron, Canton, MA). Shear force values were recorded in kg and six readings were averaged for each patty.

Pressed Juice Percentage

Ground beef and GBA patties designated for instrumental juiciness were evaluated using pressed juice percentage (**PJP**) method modified from Lucherk et al. (2016). Patties were thawed at 2 - 4°C for 12 h prior to evaluation. Preparation and cooking methods were the same as consumer evaluation. Immediately following cooking, one 1-cm patty-width slice was cut across the diameter of the patty. From each patty-width slice, samples were removed perpendicular to the outer cooked surface to create three 1 cm^3 samples. Each sample was placed on two sheets of filter paper (VWR Filter Paper 415, 12.5 cm, VWR International, Radnor, PA) and was compressed for 30 s at 8-kg of force using an INSTRON Model 5569 testing machine. The percentage of weight lost through compression for each sample was calculated as PJP. The three measurements for each patty were averaged.

Texture profile analysis

Texture profiling of GB and GBA patties was conducted using methods described by the American Meat Science Association (2015). Following cooking, patties were allowed to cool to room temperature (21 - 23°C). Three 2.54-cm cores were removed, perpendicular to the cooked surface, in the center of each patty. Each core was compressed to 70% of its original height in two cycles using an INSTRON Model 5569 testing machine. Chewiness, springiness, gumminess, hardness, and cohesiveness were calculated using the methods of Bourne et al. (1978).

Instrumental color analysis

Raw instrumental color (L*, a*, b*) was obtained during sample preparation and patty formation of the GB and GBA lots. Once lots were formed into patties, patties were allowed to bloom for 30 min. Next, six scans were taken from the center of the horizontal surface exposed to air of six different patties from each GB and GBA lot using a Hunter Lab Miniscan spectrophotometer (Illuminant A, 2.54-cm aperture, 10° observer; Hunter Associates Laboratory, Reston, VA). The six scan readings were averaged for L*, a*, and b* values. Cooked surface color was obtained on patties utilized for texture profile analysis and shear force. Approximately 10 min after cooking, surface color was measured by scanning three areas on the surface of each patty of GB and GBA using the same method and equipment as was used for the raw color measurements. The three scan readings were averaged for L*, a*, and b* values. Next, a three cm^2portion of each GB and GBA patty center was sliced parallel to the cooked surface, exposing a 3 × 3 cm square of the cooked interior of the patty. Using the same method and equipment as was used for the cooked surface color, cooked internal color was measured by scanning three areas on the exposed internal patty surface. The three scan readings were averaged for L*, a*, and b* values.

Fat and moisture percentage

Patties designated for fat and moisture analysis were thawed at 2 - 4°C for approximately 24 h. Patties were then cut into 1-cm^3 cubes, submerged in liquid nitrogen and homogenized using a commercial four blade blender (Model 33BL 79, Waring Products, New Hartford, CT). Powdered samples were then placed in Whirl-Pac (Nasco, Ft. Atkinson, WI) bags and stored (-80°C) until further analysis. The procedures followed for lipid extraction are described by Martin et al. (2013). Moisture content was determined using the AOAC approved oven drying method (AOAC, 2005).

Statistical analysis

Statistucal analysis was completed using SAS (Version 9.4 SAS inst., Inc., Cary, NC) PROC GLIMMIX. Treatment comparisons were considered significant with an α of 0.05.

Statistical analyses were performed using GB and GBA chub as the experimental unit. All data was analyzed as a completely randomized design.

Results

Demographics and purchasing motivators

Consumer demographic information from panelists who sampled GB and GBA samples can be found in Table (2-1). Panelists' genders were almost evenly spilt, with 50.8% of panelists being male and 49.2% female. The large majority of panelists were Caucasian/White (84%), married (66.4%), and had a household size of between two and four people (78.4%). Furthermore, over half of panelists (59.7%) had an annual household income greater than 75,000, and 89.9% of panelists had accomplished at minimum some college/ technical school. The most important palatability trait when consuming ground beef was identified as flavor (71.4%). Panelists were split on preferred degree of doneness for ground beef, with 24.4% preferring medium-rare, 26.7% preferring medium, 29.4% preferring medium-well, and 17.7% preferring well-done. The majority of panelists (84.2%) consumed ground beef one to three times per week.

Purchasing motivators of consumer panelists can be found in Table (2-6). Consumers who participated in sensory panels considered "price", "lean to fat ratio", "color", "fat content", "healthfulness", and "proteins" to be more ($P < 0.05$) important than "environmental claims", "natural/organic claims", "packaging", "preformed patty", and "brand of product". Within this group, "packaging", "pre-formed patty", and "brand of product" were found to be least ($P < 0.05$) important.

Consumer palatability ratings

Consumer palatability ratings are presented in Table (2-2). Few differences existed among the three ground beef treatments for the palatability traits evaluated. There were no differences ($P > 0.05$) among ground beef treatments for appearance liking, juiciness, overall flavor liking, beef flavor liking, and overall liking. Furthermore, all three ground beef treatments were rated higher ($P < 0.05$) than all three plant-based ground beef alternatives for appearance liking, overall flavor liking, beef flavor liking, and overall liking. Retail GBA rated lowest ($P < 0.05$) for appearance, overall flavor, texture, and overall liking. Of the GBA samples, FGBA rated highest ($P < 0.05$) for juiciness, beef flavor, and texture liking, and TGBA rated lowest ($P < 0.05$) for juiciness. However, FGBA rated higher ($P < 0.05$) for tenderness than the 20% fat GB samples. Moreover, among the GBA samples, FGBA and TGBA rated similar ($P > 0.05$) for appearance liking, tenderness, overall flavor liking, and overall liking.

The percentage of samples rated acceptable by consumers mirror the consumer palatability ratings (Table 2-3). All three ground beef treatments had a similar ($P > 0.05$) percentage of samples rated acceptable for appearance liking, juiciness, overall flavor liking, beef flavor liking, texture liking, and overall liking, with all of these values above 70% on the scale. All three ground beef treatments had a higher ($P < 0.05$) percentage of samples rated acceptable for appearance liking, overall flavor liking, beef flavor liking, texture liking, and overall liking than the three GBAs. Retail GBA had the lowest ($P < 0.05$) percentage of samples rated acceptable for appearance liking, overall flavor, texture, and overall liking. Traditional GBA had the lowest ($P < 0.05$) percentage of samples rated acceptable for juiciness. Among the GBA samples, FGBA had the highest ($P < 0.05$) percentage of samples rated acceptable for juiciness and beef flavor liking. Furthermore, among the GBA treatments, FGBA and TGBA had a similar ($P > 0.05$) percentage of samples rated acceptable for appearance liking, overall flavor liking, texture liking, and overall liking.

Consumers also rated the samples on likelihood of purchasing each sample if price were not a factor (Table 2-2). Consumers were more likely to purchase ($P < 0.05$) all three GB samples over all three of the GBA samples. Of the GBA samples, consumers were less likely ($P < 0.05$) to purchase RGBA than FGBA. Consumers indicated they would purchase TGBA a similar ($P > 0.05$) amount to compared to both RGBA and FGBA.

Perceived quality of GB and GBA samples

The results for the perceived quality levels of GB and GBA samples are presented in Table 2-5. There were no differences ($P > 0.05$) among the GB samples for the percentage of samples classified as each quality level. Close to half (42.5 – 50.8%) of the GB samples were considered "everyday quality". More than half (50.0 – 81.7%) of GBA samples were rated "unsatisfactory", with only 20.8 – 27.5% of GB samples receiving the "unsatisfactory" rating. Of the GBA samples, RGBA had the highest ($P < 0.05$) percentage of samples rated "unsatisfactory" at 81.7%. Furthermore, TGBA had the second highest ($P < 0.05$) percentage rated "unsatisfactory" with 63.3%. All GB and GBA samples were rated "premium quality" at a rate of 5.0% or less. Of note, RGBA and TGBA were rated 0.8 and 0.0% for premium quality, respectively, with the GB samples ranging from 4.2 to 5.0% for premium quality. Of the GBA samples, FGBA was the only sample to be rated similar ($P > 0.05$) to any of the GB samples. This occurred within the "better than everyday quality" rating, where FGBA and 90/10 GB had a similar ($P > 0.05$) percentage of samples that received this rating; and within the "everyday quality" rating, where FGBA, 80/20 GB, and 70/30 GB all had a similar ($P > 0.05$) percentage of samples classified.

Trained sensory analysis of GB and GBA samples

The results for trained sensory analysis of GB and GBA samples are presented in Table (2-4). For all palatability characteristics evaluated by the panel, GB samples rated different ($P < 0.05$) than all GBA samples. For juiciness, all GB samples were rated juicier ($P < 0.05$) than all GBA samples. Of the GB samples, 90/10 GB rated less juicy ($P < 0.05$) than the other two GB samples. Of the GBA samples, TGBA was rated the least juicy ($P < 0.05$). For tenderness, all GBA samples were rated more tender ($P < 0.05$) than all GB samples. There was no ($P > 0.05$) tenderness difference among the GBA samples. Of the GB samples, 90/10 GB was rated less tender ($P < 0.05$) than 70/30 GB.

For flavor characteristics, two different traits were evaluated. The first was beef flavor identity, intended to measure the closeness of the sample's flavor to the characteristic flavor associated with beef. The second was beef flavor intensity, intended to quantify the level at which the characteristic beef flavor was present.. For beef flavor identity, all GB samples rated higher ($P < 0.05$) than all GBA samples. The GBA samples were all rated similar ($P > 0.05$), with extremely low ratings (1.6 – 2.9). Among the GB samples, 90/10 GB had the least ($P < 0.05$) beef flavor identity. For beef flavor intensity, results were similar to the beef flavor characteristic. All GB samples rated higher ($P < 0.05$) than all GBA samples, with the GBA samples all rated similar ($P > 0.05$). Moreover, among the GB samples, 90/10 GB had the least intense ($P < 0.05$) beef flavor. For off-flavor intensity, all GB samples had much less ($P < 0.05$) off-flavor intensity than all GBA samples. There were no differences ($P > 0.05$) among GB samples for off-flavor intensity. Among the GBA samples, FGBA had a higher ($P < 0.05$) off-flavor intensity than RGBA, with TGBA having a similar ($P > 0.05$) off-flavor intensity rating to both. Panelists described the off-flavors of the RGBA as "fermented bean" and "musty bean" most frequently. The descriptors most associated with FGBA were “sour”, “sour bean”, and “fermented bean”. The descriptors most associated by panelists with TGBA were “starchy” and “fried-food”. For texture, all GB samples were firmer ($P < 0.05$) than the three GBA samples. There were no differences ($P > 0.05$) among the GB samples for texture and RGBA and TGBA were the softest of all GB and GBA samples ($P < 0.05$).

Color was evaluated using the Ground Beef Patty Cooked Color Guide (Marksberry et al, 1990). For color, all three GB samples were rated closer to the 68°C (or 2 rating) mark than all GBA samples. Among the GB samples, 90/10 GB was rated the closest to the 68° C reference. There were no differences ($P > 0.05$) among the GBA samples. All GBA samples rated closer to the well-done appearing end of the scale than all GB samples, indicating less red was visible in the internal center of the cooked patty.

All GB samples rated substantially higher ($P < 0.05$) than all GBA samples for beef odor. Among the GB samples, 70/30 GB had the greatest ($P < 0.05$) amount of beef odor. There were no differences ($P > 0.05$) among the GBA samples, with very low mean ratings (2.2 – 3.4). For non-characteristic beef odor, all GB samples were rated substantially lower ($P < 0.05$) than all GBA samples. All GB samples were rated between 2.1 and 7.8, while all GBA samples were rated between 67.7 and 73.0.

Cook loss and cook time

The results for physical changes resulting from cooking, cook loss, and cook time are found in Table (2-7). Diameter and thickness changes are expressed as a percentage of the patty shrink. Diameter change results show all GB samples shrank in diameter more ($P < 0.05$) than all GBA samples. Of the GB samples, 90/10 GB shrank the least ($P < 0.05$). All GB samples yielded diameter shrink percentages of 11.2 to 16.2%. However, the GBA samples did not shrink in diameter to the extent of the GB samples, with FGBA actually increasing in diameter following cooking, as indicated by a negative value.

Again, thickness changes are expressed as a percentage of patty shrink. Aside from TGBA, both GBA samples increased in thickness compared to the GB samples ($P < 0.05$). The TGBA sample shrunk the equivalent ($P > 0.05$) of 70/30 GB. Among the GB samples, 90/10 shrank more ($P < 0.05$) than 70/30, with 80/20 between the other two treatments.

For cooking loss percentage, all GB samples had greater ($P < 0.05$) cooking loss than all GBA samples. Of the GB samples, 80/20 GB and 70/30 GB had a greater ($P < 0.05$) cooking loss percentage than 90/10 GB. Of the GBA samples, RGBA had the greatest ($P < 0.05$) cooking loss percentage and TGBA had the least ($P < 0.05$).

Cooking time is expressed as the total seconds the patties spent on the griddle. Cook time began with the patty being placed on the griddle, and ended when the patty reached 67.2° C. This allowed for post-cooking temperature rise to the targeted 71° C final endpoint cooked temperature. Total time to peak temperature takes into account both cook time and post-cooking temperature rise time. Apart from TGBA, GBA samples took more ($P < 0.05$) time to reach 67.2° C than the higher fat GB samples. Apart from FGBA, GBA samples took less ($P < 0.05$) time to reach peak temperature post-cooking than all GB samples. As fat level decreased in GB samples, total time to peak temperature decreased, with 70/30 taking 19.2 seconds longer ($P < 0.05$) than 90/10 GB to reach peak temperature. The GBA samples total times to peak temperature varied from the GB samples, with TGBA taking a similar ($P > 0.05$) amount of time as 70/30 and 80/20 GB. However, RGBA and FGBA took less ($P < 0.05$) time compared to the higher fat level GB samples, with FGBA taking the least ($P < 0.05$) time overall to reach peak temperature

Fat and moisture percentage

Results for fat and moisture percentage can be found in Table 2-7. Fat percentages are close to the fat percentages used to market each of the GB samples. Comparing the GB and GBA fat levels, TGBA has a similar ($P > 0.05$) fat percentage to 90/10 GB. Both RGBA and FGBA had similar ($P > 0.05$) fat percentages, with percentages of 16.6 and 15.5%, respectively. Moisture percentages indicate distinct differences between GB and GBA samples. Moisture percentages for GB samples decreased ($P < 0.05$) as fat level increased. Comparing the GBA samples to the GB samples, RGBA and FGBA moisture percentages fell between 80/20 and 70/30 GB. The TGBA sample had the lowest ($P < 0.05$) moisture percentage of all samples.

Texture profile analysis, shear force, and pressed juice percentage

Results for texture profile analysis, shear force, and pressed juice percentage are found in Table (2-8). Texture profile analysis yielded five different values - hardness, cohesiveness, springiness, gumminess, and chewiness. In general, GB samples had higher values for each texture factor. The 80/20 GB was rated highest ($P < 0.05$) for hardness, cohesiveness, gumminess, and chewiness. The TGBA sample was the GBA most similar to the GB samples. For example, TGBA was similar ($P > 0.05$) to 90/10 GB for hardness, cohesiveness, springiness, gumminess, and chewiness. The other two GBA samples, RGBA and FGBA, had the lowest ($P < 0.05$) values for all five TPA factors compared to TGBA and all GB samples.

All GBA samples had lower ($P < 0.05$) shear force values compared to all GB samples. Among the GBA samples, TGBA had a higher ($P < 0.05$) shear force value than RGBA and FGBA. These two GBA samples had the lowest ($P < 0.05$) shear force values out of all the treatments.

Pressed juice percentage indicates how much juice is present in the sample and is a measure of juiciness. All three GB samples yielded more ($P < 0.05$) juice than all three GBA samples. Of the GB samples, 90/10 was the least ($P < 0.05$) juicy. The FGBA sample had the most ($P < 0.05$) expressible juice compared to the other GBA..

Raw, cooked external and cooked internal color

Results for color analysis can be found in Table 2-6. Raw L* results show 90/10 GB, 80/20 GB, and RGBA were lighter ($P < 0.05$) than FGBA, 70/30 GB, and TGBA. Of the GBA samples, TGBA was the darkest ($P < 0.05$). Of the GB samples, 70/30 GB was darker ($P < 0.05$) than 80/20, and 90/10 GB. Raw a* values were vastly different among the GBA samples. The TGBA sample was the reddest ($P < 0.05$) out of all GB and GBA samples. The RGBA sample had the lowest a* value ($P < 0.05$) out of all GB and GBA samples. The FGBA sample had a lower a* value ($P < 0.05$) than the GB samples. For raw b*, GB and GBA sample results are mixed among each other. The 70/30 GB sample was the most yellow ($P < 0.05$), while RGBA was the lowest b* value$P < 0.05$).

For cooked surface L*, the TGBA sample was the darkest ($P < 0.05$). The 90/10 GB, 80/20 GB, and FGBA samples were all similar in lightness ($P > 0.05$). For cooked surface a*, TGBA and RGBA were redder ($P < 0.05$) than all other GB and GBA samples. The 90/10 GB, 70/30 GB, and FGBA samples were the greenest samples ($P < 0.05$). For cooked surface b*, TBA was the yellowest sample out of all GB and GBA samples ($P < 0.05$).

For cooked internal L*, all GB samples were lighter than all GBA samples ($P < 0.05$). Among the GB samples, 90/10 GB was darker ($P < 0.05$) than 80/20 and 70/30 GB. All GBA samples were the same lightness ($P > 0.05$). For cooked internal a*, 70/30 GB was the greenest sample ($P < 0.05$). For cooked internal b*, TGBA was the yellowest sample ($P < 0.05$). Another GBA samples, RGBA, was the bluest sample ($P < 0.05$).

Discussion

Demographics and purchasing motivators

The ratio of male to female panel participants was split almost exactly in half. For this study, it was important to target a demographic of people who would be frequent users of ground beef. This goal was accomplished, with over 80% of participants consuming ground beef at least once a week. Another goal for participants was to target potential purchasers of plant-based ground beef alternatives, or at least have the means to. A large percentage of consumers fit the age and income brackets for this to make sense. The preferred degree of doneness for ground beef resulted in interesting results. The largest bracket consumers fell in was the medium and medium-well categories. Medium degree of doneness corresponds with 63°C, and medium well corresponds with 66°C (Certified Angus Beef, 2020) This is problematic because USDA recommends ground beef to be cooked to a minimum of 71°C, or well done (FoodSafety.gov. 2021). Undercooking ground beef can cause foodborne illnesses, with the most relevant foodborne pathogen being shiga-toxin producing *E. coli* species (National Research Council, 2010).

Purchasing motivators are often evaluated to obtain a view of how consumers select and choose meat when shopping in a retail environment. There is a pretty clear break between the first six purchasing motivators and the next five. Similar to what Wilfong et al., (2016) found, price is one of the most important traits for consumers purchasing beef. The other factors in the top half of purchasing motivators were largely intrinsic factors such as lean to fat ratio, color, and fat content.

Consumer palatability ratings

There were vast differences between the GB and GBA treatments. For appearance liking, it is logical consumers would rate the GBA samples lower. Cooked surface and cooked internal color results indicate color differences seen by the naked eye. Consumers were aware of appearance differences, and color likely played a role in this. Based on the consumers preferred degree of doneness for ground beef (medium or medium-well), they are expecting to see a small amount of red color remaining in the patty. However, based on the trained panel color scores, there was no red remaining in the GBA patties.

Consumer juiciness ratings indicate FGBA is the only GBA similar in juiciness level to the GB samples. Pressed juice percentage backed this up, with results mirroring very closely the consumer ratings. Due to the patty being precooked, it is no surprise TGBA was rated the least juiciness rating results. However, trained panel results show a clear break between GB and GBA samples for juiciness. Due to being a precooked patty, TGBA resulted in the lowest juiciness rating by consumers. It also had the lowest pressed juice percentage. Along these lines, TGBA also had the lowest moisture percentage with 52.5%. Again, TGBA was preformed and precooked, explaining much of why it generated different results from the other two GBA samples.

Tenderness is a palatability category with different results than the other categories. Consumer ratings ranged from 56.4 to 64.9. Compared to the other palatability traits, this spread is minimal. Warner-Bratzler shear force values may be able to explain the inconsistency of the consumer ratings. All WBS values were less than 3.5 kg. While WBS has been well-documented in whole muscle research, few studies have evaluated ground beef patties. Consumers may have struggled distinguishing tenderness difference between GB and GBA samples because they were all very tender. Trained sensory panel results indicate GBA samples were more tender than GB samples. This may be due to how muscle protein reacts when cooked versus plant proteins. Actin begins to denature around 66°C. At this temperature, the protein becomes firmer, shorter, and releases liquid (Allison, 2020). The higher trained panel tenderness ratings and lower WBS values for the GBA samples indicate they do not result in the same eating experience. More tender would not yield the same eating experience as ground beef and may turn consumers away due to the incredibly soft texture of the GBA samples.

Flavor results across all aspects of the study tell the same story; GBA samples do not taste like the GB samples or beef in general. Consumer palatability ratings for overall flavor liking and beef flavor liking are very similar, with all GB samples rating higher than all GBA samples. Consumer acceptability percentages also back this up, with identical results. Trained sensory analysis found even bigger differences. Beef flavor for GB samples was rated in the mid to upper 80 %, while GBA samples were rated less than three for beef flavor. Beef flavor intensity matches these results as well. Between the consumer and trained sensory analysis, several conclusions can be made. First, the GBA samples do not taste like the GB samples. Second, the flavor of the GBA samples was not as acceptable as the GB samples. Based on the off-flavor ratings and descriptions by the trained sensory analysis group, the GBA samples do not give flavors characteristic of beef. The flavors characterized from the GBA samples more than likely are derived from the actual protein sources used, along with natural flavors added. The fat and oil sources found in the GBA products were highly refined, ensuring they would not have a flavor or odor.

Juiciness results vary between consumer panel data and trained panel data. Both panel sets found TGBA to be least juicy. This makes sense because the TGBA was a precooked, preformed patty. Pressed juice percentage backs this up, along with moisture percentage as well. Among the GBA samples, FGBA was rated by consumer panelists the same for juiciness as the GB samples. However, trained panelists found FGBA and RGBA to be considerably less juicy than GB samples. Pressed juice percentage tells a similar story, with all GBA samples having less juice than all GB samples. For moisture percentage, FGBA and RGBA had less moisture than two of the GB samples. Juiciness ratings for all GB samples were similar for consumer panelists. Trained panelists only distinguished one difference with 90/10 being rated less juicy than the other two GB samples. Pressed juice percentage backs this up, with 90/10 yielding less juice than the other two GB samples. However, moisture percentage is opposite, with 90/10 yielding the highest moisture percentage, followed by 80/20 and 70/30, respectively. This could be due to moisture percentage being inverse of fat percentage. As the fat level increased among GB samples, moisture level decreased.

Color was ranked third by consumers for purchasing motivators when buying fresh ground beef. Multiple studies (Wilfong et al., 2016) indicate color is consistantly one of the most important purchasing motivators for consumers. However, consumer panelists rated all GB samples higher for appearance liking than all GBA samples. This could be problematic for the marketing of the GBA products. With the push to include the GBA products in the same retail space as GB products (Nelson, 2021), consumers could see the color differences and make the decision to not purchase the non-typical meat colored GBA products. In a raw state, objective color varied amongst all GBA samples. This makes sense because the ingredients in the three GBA's were different, and TGBA was precooked. Trained panelists rated all GBA samples as appearing more 'well done' than all GB samples. FGBA contained leghemoglobin, meant to give the GBA patty a ‘bloody’ appearance (Wolf, 2019). However, according to trained panelist color results, the bloody red color was not present upon inspection of the cooked GBA patty.

Leghemoglobin is cited as not only assisting with the appearance of the FGBA sample but allowing it to taste like beef (Wolf, 2019). However, for all palatability traits relating to beef flavor between both consumer panelists and trained panelists, none of the GBA samples were rated close to the GB samples. Rather than yielding beef-like flavors, all GBA samples had distinct off-flavors associated with each. Off-flavor ratings ranged from 69.1 to 75.0 among the GBA samples. Aside from off-flavors, odors were another key difference between GB and GBA samples. Beef odor and non-beef odor were analyzed by trained panelists. None of the GBA samples rated near the GB samples for beef odor, and all GBA samples were associated with strong non-beef odors compared to the GB samples. The non-beef odor ratings for GBA samples ranged from 67.7 to 73.0. It is unknown exactly what caused the GBA samples to give off such strong off flavors and non-beef odors. Protein source could be a leading cause, as some of the protein ingredients in the GBA’s have undergone a fermentation process.

Texture differences were seen across multiple assays. The results tell a similar story across multiple assays. The GBA samples are more tender and softer than the GB samples. The trained panel indicated this by rating all GB samples tougher and firmer than all GBA samples. Objective measurements follow this trend as well, with less shear force for the GBA samples than the GB. (Wilfong et al., 2016) found very similar TPA results for GB to this study. This indicates consitancy of GB, regardless of fat percentage.

Proximate analysis results back up panel findings, as well as support other objective measurements. Fat percentage is as expected for the GB samples, except for 80/20. Presumably, 80/20 GB should have less than 20% fat; however, the fat percentage for 80/20 was 21.2%.

While this higher-than-expected percentage did not seemingly have an impact on this study, it would have a regulatory/ marketing impact for the production facility. Wilfong et al., (2016) found a similar issue with 90/10 commodity ground beef. The fat percentage was measured at 10.1%, also exceeding the expected limit. The TGBA sample had a fat percentage comparable to 90/10 GB. However, the other two GBA samples had significantly higher fat levels, closer to the 80/20 GB sample. This could be due to the multiple fat and oil sources found in both RGBA and FGBA's ingredients. With multiple inclusions of oils in both samples, it can be presumed these fat sources are what is causing their fat percentages to be higher than expected.

Cooking between the GB and GBA samples varied considerably. The GB samples decreased consistently in diameter and thickness, while the GBA samples cooked very differently. Compared to the GB samples, the GBA samples did not shrink in diameter- in fact, FGBA increased in diameter. Little change occurred in the TGBA sample, probably due to it being a precooked, preformed patty. The RGBA and FGBA samples increased in thickness when cooked by an average of 10.3 and 15.3%, respectively. This difference between the GB and GBA samples could be due to the cooking behaviors of the different proteins found in each.

In general, the GB samples took longer to cook than the GBA samples. The exception was the TGBA sample, which took the longest to reach temperature. However, the TGBA sample had the shortest post-cooking temperature rise period. This may be due to the patty being thinner and smaller in diameter. The smaller patty would trap less heat, resulting in more rapid cooling than with the thicker patties of the other samples. An interesting observation during cooking was the reaction of the leghemoglobin in the FGBA sample. Visually inspecting patties only cooked to approximately 60°C, the red color of the leghemoglobin could still be seen, primarily in the center of the patty. However, as the trained panel color ratings indicate, this leghemoglobin can no longer be seen in its red state when the patties are cooked to a peak temperature of 71°C.

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Table 2-1. Definitions and selected references for ground beef palatability traits evaluated by trained sensory panelists

	Definition	Reference
Juiciness	Amount of moisture released when chewing the sample	80% lean ground beef = 65
Tenderness	Level of tenderness of the sample throughout the chewing process	80% lean ground beef = 65
Beef Flavor	How closely the flavor of the samples resembles beef flavor	80% lean ground beef = 90
Beef Flavor Intensity[1]	Amount of beef flavor identity within the sample	Swanson's beef broth = 31 80% lean ground beef = 44
Off Flavor	Amount of flavors not normally associated with beef flavor within the sample	Plant-based ground beef alternative patty = 70
Texture	How soft or firm the sample is when chewing	80% lean ground beef = 70
Color[2]	The degree of doneness internally to which the sample appears to be cooked to	Marksberry et al., 1990
Beef Odor	How closely do the odors of the sample resemble beef odor	80% lean ground beef = 65
Non-Beef Odor	Amount of odors not normally associated with beef odor within the sample	Plant-based ground beef alternative patty = 70

[1]Adapted from beef identity described by Adhikari et al. (2011)
[2]Internal cooked color ratings scale adapted from Marksberry et al (1990)

Table 2-2. Demographic characteristics of consumers (n = 120) who participated in sensory panels

Characteristic	Response	Percentage of Consumers
Gender	Male	50.8
	Female	49.2
Household size	1 people	15.0
	2 people	41.7
	3 people	17.5
	4 people	19.2
	5 people	3.3
	6 people	2.5
	> 6 people	0.8
Marital status	Married	66.4
	Single	33.6
Age, year	Under 20	6.7
	20 to 29	20.0
	30 to 39	21.7
	40 to 49	17.5
	50 to 59	23.3
	Over 60	10.8
Ethnicity	African-American	4.2
	Asian	8.4
	Caucasian/White	84.0
	Hispanic	0.8
	Native American	0.8
	Mixed Race	1.7
Annual household income, $	< 25,000	10.9
	25,000 – 34,999	4.2
	35,000 – 49,999	5.9
	50,000 – 74,999	19.3
	75,000 – 99,000	17.7
	100,000 – 149,999	26.9
	150,000 – 199,999	10.1
	> 199,999	5.0
Highest level of education completed	Non – high school graduate	3.4
	High school graduate	6.7
	Some college/technical school	20.2
	College graduate	31.9
	Post – college graduate	37.8
Most important palatability trait when consuming ground beef	Flavor	71.4
	Juiciness	23.5
	Tenderness	5.0
Preferred degree of doneness for ground beef	Medium-rare	24.4
	Medium	26.7
	Medium-well	29.4
	Well-done	17.7
	Very well-done	1.7
Ground Beef consumption, times per week	1 to 3	84.2
	4 to 6	12.3
	7 to 9	1.8
	> 9	1.8

Table 2-3. Least squares means for consumer (n = 120) ratings[1] of the palatability traits of ground beef and plant-based ground beef alternatives

Treatment[2]	Appearance Liking	Juiciness	Tenderness	Overall Flavor Liking	Beef Flavor Liking	Texture Liking	Overall Liking	Purchase Intent[3]
90/10	56.9[a]	65.8[a]	64.5[a]	57.2[a]	65.9[a]	62.5[a]	58.5[a]	51.7[a]
80/20	59.4[a]	63.8[a]	57.3[bc]	58.6[a]	64.3[a]	59.8[b]	56.5[a]	50.6[a]
70/30	63.2[a]	68.3[a]	63.5[ab]	59.0[a]	67.5[a]	64.3[a]	59.6[a]	56.2[a]
Retail GBA[4]	26.7[c]	47.0[b]	56.4[c]	27.5[c]	28.7[c]	28.0[d]	23.8[c]	17.9[c]
Food Service GBA[5]	46.9[b]	68.0[a]	64.9[a]	44.6[b]	37.0[b]	46.6[b]	41.2[b]	34.1[b]
Traditional GBA[6]	41.0[b]	32.7[c]	62.3[abc]	40.0[b]	27.2[c]	37.7[c]	34.7[b]	26.2[bc]
SEM[7]	2.93	3.01	2.52	2.87	2.59	2.57	2.95	3.03
P – value	< 0.01	< 0.01	0.04	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

[abcd]Least squares means in the same column without a common superscript differ (P < 0.05).

[1]Sensory scores: 0 = dislike appearance/overall flavor/texture/beef flavor/overall extremely, not juicy/tender; 50 = neither tough nor tender, dry nor juicy, or neither like nor dislike appearance/overall flavor/texture/beef flavor/overall; 100 = extremely juicy/tender, like appearance/overall flavor/texture/beef flavor/overall extremely.

[2]Ground beef treatment lean content presented as: percent lean / percent fat

[3]If price were not a factor, how likely would you be to purchase each treatment (1 = not likely, 100 = extremely likely)

[4]Retail GBA = Plant-based ground beef alternative most notably present in retail markets (grocery stores, supermarkets)

[5]Food Service GBA = Plant-based ground beef alternative most notably present in food service establishments (restaurants)

[6]Traditional GBA = Plant-based ground beef alternative most indicative of a traditional soy-based frozen patty (pre-formed, fully cooked)

[7]SE (largest) of the least squares means.

Table 2-4. Least squares means for the percentage of ground beef and plant-based ground beef alternative samples rated acceptable for each palatability trait by consumers (n = 120)

Treatment[1]	Appearance Liking	Juiciness	Tenderness	Overall Flavor Liking	Beef Flavor Liking	Texture Liking	Overall Liking
90/10	83.9^{a}	88.2^{a}	92.8^{a}	77.5^{a}	83.6^{a}	89.0^{a}	77.5^{a}
80/20	83.9^{a}	84.9^{a}	82.1^{bc}	70.8^{a}	77.0^{a}	81.7^{a}	73.3^{a}
70/30	90.4^{a}	84.1^{a}	84.6^{ab}	78.3^{a}	84.5^{a}	86.6^{a}	79.2^{a}
Retail GBA[2]	28.7^{c}	61.3^{b}	71.3^{c}	30.8^{c}	28.9^{c}	34.4^{c}	22.5^{c}
Food Service GBA[3]	67.9^{b}	88.2^{a}	84.6^{ab}	51.7^{b}	41.5^{b}	63.1^{b}	51.7^{b}
Traditional GBA[4]	59.4^{c}	38.8^{c}	81.3^{bc}	50.8^{c}	28.9^{c}	50.9^{b}	45.8^{b}
SEM[5]	5.01	5.18	4.49	4.56	4.38	5.42	4.56
P – value	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

^{abc}Least squares means in the same column without a common superscript differ ($P < 0.05$).

[1]Ground beef treatment lean content presented as: percent lean / percent fat

[2]Retail GBA = Plant-based ground beef alternative most notably present in retail markets (grocery stores, supermarkets)

[3]Food Service GBA = Plant-based ground beef alternative most notably present in food service establishments (restaurants)

[4]Traditional GBA = Plant-based ground beef alternative most indicative of a common soy-based frozen patty (pre-formed, fully cooked)

[5]SE (largest) of the least squares means.

Table 2-5. Least squares means for the palatability characteristics[1] rated by trained sensory panelists for ground beef and plant-based ground beef alternatives

Treatment[2]	Juiciness	Tenderness	Beef Flavor	Beef Flavor Intensity	Off Flavor	Texture	Color[3]	Beef Odor	Non-Beef Odor
90/10	52.8^{b}	62.5^{c}	85.2^{b}	60.3^{b}	2.5^{c}	71.6^{a}	2.5^{c}	60.9^{b}	7.8^{b}
80/20	65.1^{a}	66.0^{bc}	87.7^{a}	67.3^{a}	6.4^{c}	68.3^{a}	3.0^{b}	62.1^{b}	3.5^{b}
70/30	69.0^{a}	67.6^{b}	89.0^{a}	68.6^{a}	1.6^{c}	68.2^{a}	3.2^{b}	66.7^{a}	2.1^{b}
Retail GBA[4]	21.1^{c}	83.0^{a}	2.9^{c}	2.1^{c}	69.1^{b}	18.8^{c}	4.2^{a}	3.4^{c}	72.3^{a}
Food Service GBA[5]	17.1^{c}	79.8^{a}	2.6^{c}	2.1^{c}	75.0^{a}	23.1^{b}	4.2^{a}	3.1^{c}	67.7^{a}
Traditional GBA[6]	5.4^{d}	81.2^{a}	1.6^{c}	2.2^{c}	71.1^{ab}	16.9^{c}	4.5^{a}	2.2^{c}	73.0^{a}
SEM[7]	2.01	1.36	1.16	1.24	2.55	2.04	0.18	1.77	4.51
P – value	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

[abc]Least squares means in the same column without a common superscript differ ($P < 0.05$).

[1]Sensory scores: 0 = extremely dry/tough/soft/unbeef-like, bland; 50 = neither dry nor juicy, tough nor tender, soft nor firm, beef-like or unbeef-like; 100 = extremely juicy/tender/firm/beef-like/intense

[2]Ground beef treatment lean content presented as: percent lean / percent fat

[3]Internal cooked color rating scale adapted from Marksberry et al (1990); 1 = 65°C, 2 = 68°C, 3 = 71°C, 4 = 74°C, 5 = 77°C

[4]Retail GBA = Plant-based ground beef alternative most notably present in retail markets (grocery stores, supermarkets)

[5]Food Service GBA = Plant-based ground beef alternative most notably present in food service establishments (restaurants)

[6]Traditional GBA = Plant-based ground beef alternative most indicative of a common soy-based frozen patty (pre-formed, fully cooked)

[7]SE (largest) of the least squares means.

Table 2-6. Fresh ground beef purchasing motivators[1] of consumers (n = 120) who participated in consumer sensory panels

Purchasing motivator	Importance of each trait
Price	72.1[a]
Lean to fat ratio	71.7[a]
Color	69.4[ab]
Fat content	68.9[ab]
Healthfulness	65.7[ab]
Proteins	63.1[b]
Environmental impact	48.0[c]
Natural/ organic claims	42.0[cd]
Packaging	39.3[de]
Pre-formed patty	34.9[e]
Brand of product	33.4[e]
SEM[2]	3.32
P - value	< 0.01

[abcde]Least squares means without a common superscript differ ($P < 0.05$).
[1]Specific factors consumers place on when purchasing ground beef (0 = not important); (100 = very important)
[2]SE (largest) of the least squares means.

Table 2-7. Raw, cooked surface, and cooked (71°C) internal color values for ground beef and plant-based ground beef alternatives (n = 90)

Treatment[1]	Raw color			Cooked surface color			Cooked internal color		
	L*[2]	a*[3]	b*[4]	L*	a*	b*	L*	a*	b*
90/10	53.6^{a}	22.4^{bc}	22.6^{d}	37.3^{bc}	8.4^{c}	17.1^{e}	51.7^{b}	11.3^{ab}	19.3^{bc}
80/20	53.4^{a}	24.0^{b}	25.5^{c}	38.9^{ab}	9.1^{b}	19.7^{bc}	56.1^{a}	9.2^{c}	18.7^{c}
70/30	29.4^{d}	21.3^{c}	46.7^{a}	40.4^{a}	8.2^{c}	18.0^{de}	57.2^{a}	7.6^{d}	17.5^{d}
Retail GBA[5]	52.4^{a}	11.6^{e}	14.0^{f}	36.0^{c}	12.7^{a}	18.7^{cd}	42.3^{c}	11.6^{a}	16.6^{e}
Food Service GBA[6]	49.4^{b}	17.8^{d}	20.6^{e}	37.3^{bc}	8.1^{c}	20.8^{b}	41.5^{c}	12.7^{a}	19.9^{b}
Traditional GBA[7]	42.7^{c}	31.4^{a}	29.7^{b}	34.0^{d}	12.6^{a}	24.4^{a}	42.7^{c}	10.0^{bc}	28.0^{a}
SEM[8]	0.72	0.60	0.62	0.66	0.24	0.47	0.54	0.53	0.25
P – value	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

[abcdef]Least squares means in the same column without a common superscript differ ($P < 0.05$).
[1]Ground beef treatment lean content presented as: percent lean / percent fat
[2]L* = lightness (0 = black and 100 = white)
[3]a* = redness (-60 = green and 60 = red)
[4]b* = blueness (-60 = blue and 60 = yellow)
[5]Retail GBA = Plant-based ground beef alternative most notably present in retail markets (grocery stores, supermarkets)
[6]Food Service GBA = Plant-based ground beef alternative most notably present in food service establishments (restaurants)
[7]Traditional GBA = Plant-based ground beef alternative most indicative of a common soy-based frozen patty (pre-formed, fully cooked)
[8]SE (largest) of the least squares means.

Table 2-8. Physical changes in shape of ground beef and ground beef alternative patties (n = 90) as a result of cooking, and fat and moisture percentages

Treatment[1]	Diameter[2]	Thickness[2]	Cook loss[3]	Cook time[4] (s)	Total time to peak temp (s)	Post-cook temp rise time (s)	Fat %	Moisture %
90/10	11.2^{b}	12.2^{a}	17.6^{b}	125.9^{cd}	169.3^{bc}	43.4^{ab}	8.5^{d}	70.9^{a}
80/20	16.2^{a}	5.8^{ab}	25.9^{a}	134.8^{bc}	178.9^{ab}	44.1^{ab}	21.2^{b}	60.9^{b}
70/30	15.5^{a}	3.2^{b}	27.5^{a}	142.7^{b}	188.5^{a}	45.7^{a}	25.7^{a}	56.8^{d}
Retail GBA[5]	1.0^{c}	-10.3^{c}	12.9^{c}	119.3^{de}	156.2^{cd}	36.9^{c}	16.6^{c}	59.0^{c}
Food Service GBA[6]	-1.5^{d}	-15.3^{c}	8.5^{d}	107.9^{e}	148.0^{d}	40.1^{bc}	15.5^{c}	59.5^{c}
Traditional GBA[7]	0.4^{c}	3.1^{b}	1.3^{e}	171.1^{a}	190.9^{a}	19.8^{d}	9.7^{d}	52.5^{e}
SEM[8]	0.64	2.55	0.65	5.00	5.44	1.89	0.90	0.64
P – value	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

^{abcde}Least squares means without a common superscript differ (P < 0.05).
[1]Ground beef treatment lean content presented as: percent lean / percent fat
[2]Values expressed as % shrink [(Raw Patty Measurement - Cooked Patty Measurement) / Raw Patty Measurement] * 100
Negative values indicate patty expansion for both diameter and/or thickness
[3]Cook loss = [(raw mass – cooked mass) / raw mass] * 100
[4]Cook time = total seconds patty spent on griddle; patties were removed at 67.2°C to account for post-cooking temperature rise
[5]Retail GBA = Plant-based ground beef alternative most notably present in retail markets (grocery stores, supermarkets)
[6]Food Service GBA = Plant-based ground beef alternative most notably present in food service establishments (restaurants)
[7]Traditional GBA = Plant-based ground beef alternative most indicative of a common soy-based frozen patty (pre-formed, fully cooked)
[8]SE (largest) of the least squares means.

Table 2-9. Texture profile analysis[1], shear force, and percent juice press results for ground beef and plant-based ground beef alternatives (n = 90)

Treatment[2]	Hardness	Cohesiveness	Springiness	Gumminess	Chewiness	Shear force (kg)	Pressed juice percentage[3]
90/10	17.2[b]	31.4[b]	65.6[a]	5.4[b]	3.5[b]	3.4[a]	12.7[b]
80/20	21.9[a]	34.5[a]	68.6[a]	7.7[a]	5.2[a]	3.5[a]	14.7[a]
70/30	14.5[c]	31.4[b]	55.3[b]	4.6[b]	2.6[c]	3.1[a]	15.5[a]
Retail GBA[4]	3.6[e]	21.5[c]	39.8[c]	0.8[c]	0.3[d]	1.8[c]	8.7[d]
Food Service GBA[5]	8.0[d]	19.8[c]	42.8[c]	1.6[c]	0.7[d]	2.0[c]	11.4[c]
Traditional GBA[6]	17.1[b]	31.5[b]	65.3[a]	5.4[b]	3.6[b]	2.5[b]	3.0[e]
SEM[7]	0.8	0.7	1.2	0.4	0.2	0.2	0.4
P - value	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

[abc]Least squares means in the same column lacking a common superscript differ ($P < 0.05$).
[1]Texture profile methods as described by Bourne (1978).
[2]Ground beef treatment lean content presented as: percent lean / percent fat
[3]Percentage of juice pressed = [(dry filter paper – wet filter paper) / wet filter paper] * 100
[4]Retail GBA = Plant-based ground beef alternative most notably present in retail markets (grocery stores, supermarkets)
[5]Food Service GBA = Plant-based ground beef alternative most notably present in food service establishments (restaurants)
[6]Traditional GBA = Plant-based ground beef alternative most indicative of a common soy-based frozen patty (pre-formed, fully cooked)
[7]SE (largest) of the least square means.

Appendix

Trained Panel Ballot

Start of Block: Color

Q4 Panelist:

____

Q1 **Cooked Color**

Q2 A

	0	1	2	3	4	5
1 ()						

Q3 B

	0	1	2	3	4	5
1 ()						

Q5 C

	0	1	2	3	4	5
1 ()						

Q6 D

	0	1	2	3	4	5
1 ()						

Q7 E

	0	1	2	3	4	5

1 ()	

Q8 F

	0	1	2	3	4	5
1 ()						

End of Block: Color

Start of Block: Warm Up

Q17 Sample Number

____

Q89 Beef Odor

	None	Extremely Intense
	0	100
. ()		

Q90 Non-Beef Characteristic Odor

	None	Extremely Intense	Not Applicable
	0		100
Click to write Choice 1 ()			

Q91 Off Odor Descriptor

____

Q18 Juiciness

	Extremely Dry	Neither Juicy nor Dry	Extremely Juicy
	0	50	100

1 ()	

Q25 Tenderness

Extremely Tough	Neither Tough nor Tender	Extremely Tender
0	50	100

1 ()	

Q26 Texture

Extremely Soft	Neither Soft nor Firm	Extremely Firm
0	50	100

1 ()	

Q33 Beef Flavor ID

Extremely Unbeef-Like	Neither Unbeef-Like nor Beef-Like	Extremely Beef-Like
0	50	100

1 ()	

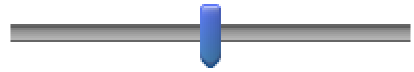
Q34 Beef Flavor Intensity

Extremely Bland	Extremely Intense
0	100

1 ()	

Q35 Off Flavor

Extremely Bland	Extremely Intense	Not Applicable
0		100

1 ()	

Consumer Panel Ballot

Start of Block: Demographics

Q10 Big Panel 1 - Red

Q1 Please tell us a little about yourself.

*

Q2 Panelist Number

____

Q3 Gender

○ Male (1)

○ Female (2)

Q4 Age

○ Under 20 (1)

○ 20 to 29 years old (2)

○ 30 to 39 years old (4)

○ 40 to 49 years old (7)

○ 50 to 59 years old (8)

○ over 60 (9)

Q5 Ethnic Origin

- African American (1)
- Asian (2)
- Caucasian/White (3)
- Hispanic (4)
- Native American (5)
- Other (6)
- Mixed Race (7)

Q6 Marital Status

- Single (1)
- Married (2)

Q7 Household Size

- 1 person (1)
- 2 People (2)
- 3 People (3)
- 4 People (4)
- 5 People (5)
- 6 People (6)
- > 6 People (7)

Q8 Annual Household Income

- ◯ < $25,000 (1)
- ◯ $25,000 - $34,999 (2)
- ◯ $35,000 - $49,999 (3)
- ◯ $50,000 - $74,999 (4)
- ◯ $75,000 - $99,999 (5)
- ◯ $100,000 - $149,999 (6)
- ◯ $150,000 - $199,999 (7)
- ◯ > $199,999 (8)

Q9 Highest Level of Education Completed

- ◯ Non-High School Graduate (1)
- ◯ High School Graduate (2)
- ◯ Some College / Technical School (3)
- ◯ College Graduate (4)
- ◯ Post-College Graduate (5)

Q12 When eating hamburger, what palatability trait is the most important to you?

- ◯ Flavor (1)
- ◯ Juiciness (2)
- ◯ Tenderness (3)

Q14 When eating hamburger, what degree of doneness do you prefer?

○ Very Rare (1)

○ Rare (2)

○ Medium-Rare (3)

○ Medium (4)

○ Medium-Well (5)

○ Well-Done (6)

○ Very Well-Done (7)

Q16 How many times a week do you consume hamburger?

	0	3	6	9	12	15	18	21
None ()								

End of Block: Demographics

Start of Block: Purchasing Motivators

Q88 Please indicate the importance of each trait when purchasing ground beef (hamburger).
Q89 Appearance - Lean to Fat Ratio

	Extremely Unimportant	Extremely Important
	0	100
1 ()		

Q91 Brand of Product

	Extremely Unimportant	Extremely Important
	0	100

1 ()	

Q90 Color

	Extremely Unimportant	Extremely Important
	0	100
1 ()		

Q92 Environmental Impact

	Extremely Unimportant	Extremely Important
	0	100
1 ()		

Q93 Fat Content

	Extremely Unimportant	Extremely Important
	0	100
1 ()		

Q94 Healthfulness

	Extremely Unimportant	Extremely Important
	0	100
1 ()		

Q95 Natural or Organic Claims

	Extremely Unimportant	Extremely Important
	0	100
1 ()		

Q96 Packaging Type

	Extremely Unimportant	Extremely Important
	0	100
1 ()		

Q97 Preformed Patty or Not

	Extremely Unimportant	Extremely Important
	0	100
1 ()		

Q98 Price

	Extremely Unimportant	Extremely Important
	0	100
1 ()		

Q99 Protein Source

	Extremely Unimportant	Extremely Important
	0	100
1 ()		

End of Block: Purchasing Motivators

Start of Block: Sample 1

Q18 Sample Number

○ 9957 (1)

Q19 Appearance

	Extremely Undesirable	Neither Desirable nor Undesirable	Extremely Desirable
	0	50	100
3 ()			

Q22 Was the sample acceptable for overall appearance?

- ◯ Acceptable (1)
- ◯ Unacceptable (2)

Q21 Juiciness

	Extremely Dry	Neither Juicy nor Dry	Extremely Juicy
	0	50	100
1 ()			

Q24 Was the sample acceptable for juiciness?

- ◯ Acceptable (1)
- ◯ Unacceptable (2)

Q25 Tenderness

	Extremely Tough	Neither Tender nor Tough	Extremely Tender
	0	50	100
1 ()			

Q27 Was the sample acceptable for tenderness?

- Acceptable (1)
- Unacceptable (2)

Q106 Overall Flavor

	Dislike Extremely	Neither Like nor Dislike	Like Extremely
	0	50	100
6 ()			

Q107 Was the sample acceptable for overall flavor?

- Acceptable (1)
- Unacceptable (2)

Q108 Beef Flavor

	Extremely Unbeef-Like	Neither Beef-Like nor Unbeef-Like	Extremely Beef-Like
	0	50	100
4 ()			

Q109 Was the sample acceptable for Beef Flavor?

- Acceptable (1)
- Unacceptable (2)

Q110 Texture

	Dislike Extremely	Neither Like nor Dislike	Like Extremely
	0	50	100
1 ()			

Q111 Was the sample acceptable for texture?

- ◯ Acceptable (1)
- ◯ Unacceptable (2)

Q28 Overall Liking

	Dislike Extremely	Neither Like nor Dislike	Like Extremely
	0	50	100
2 ()			

Q30 Was the sample acceptable overall?

- ◯ Acceptable (1)
- ◯ Unacceptable (2)

Q112 If price was not a factor, how likely would you be to purchase this product?

	Extremely Unlikely	Neither Likely nor Unlikely	Extremely Likely
	0	50	100
4 ()			

Q31 Please choose one of the following to rate the quality of the hamburger sample you have eaten.

- ◯ Unsatisfactory (1)
- ◯ Everyday Quality (2)
- ◯ Better than everyday quality (3)
- ◯ Premium Quality (4)

End of Block: Sample 1

Start of Block: Sample 2

Ground Beef Patty Cooked Internal Color Guide