Evaluating Cookery Characteristics, Consumer Acceptability, and Electronic Assessment of Attributes in Ground Beef Patties

by

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ABSTRACT

With consumers driving beef demand, attributes such as flavor, wholesome, safe, and affordability remain at the forefront of the meat industry. Three unique studies were created and conducted to evaluate quality attributes of ground beef and are presented throughout this thesis. Consumer friendly technology such as sous vide is growing in popularity and the industry application to use across the foodservice sector is eminent. Additionally, technologies such as electronic nose and electronic tongue provide researchers the ability to analyze sensory components of a meat product without the use of human subjects. The current studies will highlight fresh and cooked characteristics of ground beef patties, explore the impact of adding alternative proteins and cooking method on sensory attributes. Sous vide cookery has gained popularity among in-home and fine dining consumers, yet its application in quick-service settings remains limited. To address this gap, ground beef patties were produced to assess how sous vide cooking time affects moisture, color, and objective tenderness. Patties cooked for 30 minutes exhibited significantly greater cook loss, Allo–Kramer Shear Force (AKSF), and darker color (L*) compared to those cooked for 60 or 90 minutes ($p < 0.05$). However, internal redness, chroma, hue angle, and red-to-brown values did not vary significantly across cooking times ($p > 0.05$). This indicates that sous vide cooking duration affects moisture, color, and texture characteristics of ground beef patties prior to grilling. In the second study, ground beef patties were cooked from frozen using various cooking methods. Evaluation of cooked patties show patties cooked on the griddle (GRID) exhibited significantly longer cooking times ($p < 0.0001$) compared to those cooked in the oven (OVEN) and clam shell (GARL). Additionally, GRID-cooked patties showed the highest percentage of cook loss compared to OVEN ($p < 0.0001$) and GARL ($p = 0.0223$). GRID-cooked patties required more Allo-Kramer shear force ($p < 0.0001$), indicating less objective tenderness compared to OVEN ($p < 0.0001$) and GARL ($p = 0.0988$). These findings highlight that the choice of cooking method significantly impacts the cooked characteristics of frozen patties. The final study aimed to evaluate the textural, color, and flavor characteristics, along with volatile compounds, of ground beef patties formulated with varying levels of beef heart inclusion. Patties were prepared with 0%, 6%, 12%, or 18% beef heart, with the remaining meat derived from shoulder clod. Overall, patties with beef heart did not require additional cooking time ($p = 0.1325$) nor exhibited higher cook loss ($p = 0.0803$). However, higher beef heart inclusion led to increased hardness ($p = 0.0030$) and chewiness values ($p = 0.0316$), deeper internal redness ($p = 0.0001$), and decreased consumer preference ($p = 0.0367$). These findings indicate that the inclusion of beef heart alters both the quality characteristics of ground beef and its consumer acceptability. Overall, results from these studies provide new foundational knowledge to an extremely popular consumer meat protein in ground beef that may elicit alternative processing and manufacturing techniques to consider throughout the meat and food industry.

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"I believe in Auburn and love it!" WAR EAGLE!!

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LITERATURE REVIEW

1.0 INTRODUCTION

In a fast-paced environment, many consumers are looking for food that is quick and easy. The fast-food industry has grown significantly over the last 25 years (USDA, 2022). In the U.S., most households spend 10% of their income on fast food alone (USDA, 2022). Restaurants are constantly having to keep up with the fast-paced market and consumer preferences. One of the most popular fast-food items is the ground beef patty. Popular restaurant chain, McDonalds sells 75 hamburgers every second in the United States (Wilson, 2023). During the COVID-19 pandemic, a group of Research and Development specialists from food chain Arby's wanted to explore the idea of adding a beef hamburger patty to their menu to compete with other restaurants. With no grills currently in any of their restaurants, this was a challenge which brought on the successful pursuit of the sous vide style burger. This burger was a blend of Waygu and traditional blend beef (Cobe, 2022). After a lot of trial and error, Arby's launched their limited-edition menu item with great success (Cobe, 2022).

The low-temperature, long-time method of cooking known as sous vide (Chotigavin et al., 2023) is becoming a common method of cooking for a variety of products including red meat. Red meat contains greater amounts of myoglobin compared to other protein sources and is a great source of protein for consumers. In the early 2000s, meat seen in grocery stores and restaurants were from younger and leaner animals (McGee, 2007). Today, as the consumption of meat and meat products has increased, cattle are being finished as heavier weights resulting in a higher USDA graded carcass (Chotigavin et al., 2023; Nam et al., 2010). Since the use of traditional production has changed so has the way meat products are prepared. The sous vide cooking method allows chefs to take a variety of retail cuts that may be considered undesirable, and turn them into a dish that is moist, tender, and flavorful (Baldwin, 2012). Moreover, coking products from a frozen state can eliminate the thawing process that takes place and provide more ready-to-cook items in the ground beef sector. The well-known ground beef patty is typically ground trimmings of a beef carcass. Ground beef patties have a specific look and texture that is appealing to the eye and taste of the consumer (Taylor et al., 2020). Lastly, capitalizing on ground beef consumption is crucial in maintaining a competitive product on the grocery store shelved. Using value-added products or alternative protein sources to enhance the value of the popular ground beef item has not been thoroughly explored.

This review is aimed to determine the influence variety meats and cookery methods have on ground beef patty characteristics and consumer acceptability.

1.1 WHAT IS SOUS VIDE?

Sous vide is French for "under vacuum" and can be defined as raw materials or raw materials with intermediate foods that are cooked under controlled temperature and time conditions inside heat-stable vacuumized pouches (Schellekens, 1996). Sous vide processed food can be found as cook-hold or cook-serve and cook-chill or cook-freeze food (Stringer & Metris, 2018). Sous vide may be a new trend to the quick service restaurant industry, however, it has been studied and used since the 1970s to extend the shelf life of certain products and improve meat quality as perceived by consumers through tenderness and palatability. Consumers are starting to pay more attention to their food source as well as creating a more sustainable and healthier lifestyle. Marketing foods with clean labels of natural, fresh, and free from synthetic additives and preservatives have gradually gained attention from consumers (Zemser, 2015). This change in marketing in the food industry has motivated meat processors toward food processing using less preservatives in the final product. This has resulted in decreased use of synthetic additives and preservatives while improving natural flavors, safety, and quality of meat and meat products (Huang et al., 2017). When it comes to methods that could help improve this status, the sous vide processing technique has achieved a notable position in the modern world of meat and meat product processing (Baldwin, 2012; Roldan et al., 2015a). Sous vide has the potential to improve or maintain the quality, color, flavor, and nutritional value of the meat without using any additional synthetic additives or preservatives (Kato et al., 2016). The temperature and time combination can be adjusted based on the product at hand. The cooking medium for sous vide is either a water bath or a convection steam oven (Baldwin, 2012). The convection steam oven does not provide a uniform distribution of steam at temperatures below 100°C. In comparison to the water bath which typically heats uniformly and has temperature swings of less than -17.6°C. The pouches must be completely submerged and not overlapped to prevent undercooking (Rybka, 1999). The water bath provides an advantage as it allows the meat to be completely submerged and heat is efficiently transferred from the water to the meat (Baldwin, 2012). This one cooking method is suitable for a variety of products and cuts of meat (Thathsarani et al., 2022). Cooking with sous vide is one of the best cuisine solutions for the food industry in the production of high quality and convenient food products. In addition, sous vide has become increasingly popular in the home and specialty restaurants including Starbucks with products such as their egg white bites. Using this method for ground beef patties could prove to be just as popular in quick-service restaurants worldwide.

1.2 TEMPERATURE VARIATIONS

Meat is roughly 75% water, 20% protein, and 5% fat and other substances (Soren et a., 2020). Cooking uses heat to change (or denature) these proteins. Temperature dictates which proteins and how much are denatured during cooking (Baldwin, 2012). Sous vide is known for the low temperature and minimal time in an aerobic environment. It is a powerful technique that can provide consistency in doneness, texture, and color compared to traditional cooking methods (Baldwin, 2012; Ismail et al., 2019a). Several factors are involved when determining meat quality including color, juiciness, and tenderness. Sous vide may impact these factors. During the early 2000s, sous vide water baths were used at a temperature higher than the final core temperature of the food (Roca and Brugues, 2010). When cooking at a temperature that is higher than the desired final core temperature of the food, the food must be removed from the bath once it comes to that temperature to prevent overcooking (Baldwin, 2012). Cooking at or just above the desired final temperature allows for slower changes. When cooking tough meats, slow changes in temperature is the most important process. The lower temperature and slow change allow for the collagen to dissolve and reduction to take place resulting in a more tender product as connective tissues are broke down (Baldwin, 2012). Precise temperature control in sous vide cookery allows for a better control of desired doneness and allows for control the degradation of muscle fibers which is reflected in the tenderness of the product. The muscle fibers in beef begin to shrink at 35 to 40.5°C. The aggregation and gelation of sarcoplasmic proteins begins around 40.5°C. and finishes around 60°C. Connective tissues start shrinking around 60°C but contract more intensely over 65.5°C (Vaskoska et al., 2020). The slow changes mainly increase tenderness by dissolving collagen into gelatin and reducing inter-fiber adhesion. These changes lead to the idea that the doneness of meat is determined by the greatest temperature that it reaches (Charley and Weaver, 1998).

Ground beef hamburger patties are a mixture of ground lean and fatty beef. Without proper heat treatment, cooked hamburger can contain surviving microorganisms some of which could be a foodborne pathogen including: E. coli, Pseudomonas, Enterobacter, and Salmonella species (Tassew et al., 2010). Thus, ground beef must be cooked to 71.1℃ to eliminate any potential pathogens that were on the surface of trimmings used.

1.3 COOKERY METHODS OF GROUND BEEF PATTIES

Cookery method can often be overlooked for ground beef patties. Sixty-one percent of Americans responded in a survey that a burger is part of their ideal barbeque plate (Ballard, 2021). In today's fast-paced society, where food preparation is constrained by numerous demands and preferences, the joy of serving a completed meal remains a highlight for more than 79% of consumers. However, this hasn't deterred 51% of individuals from opting to dine out rather than cook at home (Stouffer's, 1999). As cooking increasingly becomes a task to expedite, people seek methods to streamline the process.

Dry cooking methods are ideal for meats with minimal connective tissue, as they swiftly elevate the meat's temperature without compromising tenderness (Herring & Rogers, 2003). Conversely, cuts of meat rich in connective tissue, such as shank and chuck, benefit from longer cooking times with moisture. This moist heat not only aids in breaking down collagen but also enhances tenderness (Herring & Rogers, 2003).

Convection cooking employs heat transfer from the medium surrounding the food item. The oven heats this medium directly, which in turn cooks the food. When utilizing convection heating, it's essential to allow time for the medium's temperature to gradually increase, ensuring the food temperature rises at a corresponding pace (Herring & Rogers, 2003).

1.4 SURFACE AND INTERNAL COLOR IMPLICATIONS

Color is the main visual attribute for a consumer when determining the quality of a fresh meat product (Tomasevic et al., 2021). Although two similar cuts cooked to the same internal temperature will have a similar plumpness and juiciness, their cooked color may be different (Baldwin, 2012). The internal color of meat cooked to the same temperature depends on how quickly it reaches that temperature and on how long it is held at that temperature: the faster it comes up to temperature, the redder it is; the longer it is held at a particular temperature, the paler it becomes due to the breakdown of proteins and lack of oxygen (Charley and Weaver, 1998). A negative quality of using sous vide in ground beef patties is impact on color and consumer perceived correlate of color and quality. The main concern is the lack of Maillard reaction to occur on the surface of cooked meats that are under long time low temperature (LTLT) conditions (Roldan et al., 2015a, 2015b). The known color and flavor of some meat products occur during cooking due to the Maillard reaction, lipid oxidation, and reactions from compounds (Mitra et al., 2018; Roldan et al., 2015a, 2015b; Sanchez del Pulgar et al., 2013). In sous vide cooked meat, the surface does not receive extremely high temperatures like in other cooking methods. With no surface dehydration, this leads to lower levels of a Maillard reaction development (Mitra et al., 2018; Roldan et al., 2015a, 2015b). To counteract this, chefs often roast or fry the surface of cooked meats before or after sous vide in order to achieve the browning effect of Maillard reaction on the crust while still using the LTLT method (Myhrvold et al., 2011). Whether this should be carried out before or after the sous vide treatment is undecided. In order to test this, the University of Spain and the University of Copenhagen partnered with chef Francis Refolio in Caceres, Spain to address differences in lamb meat characteristics when Maillard reactions were promoted either before or after sous vide cooking. The results of their research suggest that roasting in the oven, either before or after sous vide cooking of lamb meat, leads to a browner surface and a more intense cooked meat flavor. Specifically, oven roasting after sous vide cooking leads to a more intense Maillard reaction, leading to a browner surface and a higher proportion of compounds from Maillard reaction as compared to oven roasting before sous-vide cooking (Ruiz et al., 2019). In a Thailand study conducted by Chotogavin et al., (2023) beef muscles were used to determine the effect that sous vide pressure technique has on beef muscle using both time and pressure as variables. Measuring cooked color according to lightness (L*), yellowness (b*) and redness (a*), it was found that the lightness levels increased only a small amount with cooking time. When proteins breakdown, it can affect the surface structure of the meat. This in turn causes greater light reflectance and scattering which gives a higher L* measurement. Overall, a* decreased with cooking suggests that the beef samples become less red the longer they cook which could be attributed to the breakdown of myoglobin. Yellowness values increased with longer cook time indicating that the sous vide method of low temperature, long time cooking produces a greater saturation of yellow. This study suggests that the sous vide cooking method decreases the overall redness while the lightness levels only increase a small amount with increased cooking time.

1.5 FROZEN COOKERY

Freezing meat is often necessary in order to prolong the shelf life and keep product stable until needed (Eastridge and Bwoker, 2011). Cooking meat directly from a frozen state is not prevalent. Measurements of quality of red meat can be influenced by cooking from a thawed or frozen state (Zhuang and Savage, 2013). Beef cooked from frozen has been found as more tough than beef cooked after thawing due to the loss of water and product dehydration (James and Rhodes, 1978; Obuz and Dikeman, 2003). However, due to the time and physical changes that occur during the thawing process, cooking from frozen could be a plausible way to eliminate time and preparation of a product (Li and Sun, 2002). One concern with freezing products involves the freeze-thaw cycle that takes place when a product is thawed before cooking. Freezing and thawing are complex processes that involve a transfer of heat as well as physical changes that can affect the quality of a product (Bing et al., 2002). Thawing frozen meat items can pose a food safety issue leading to foodborne illnesses. Once a product begins to thaw and becomes warmer than 40°F bacteria that was present prior to freezing can begin to multiply (USDA, 2023).

1.6 QUALITY CHARACTERISTICS AFFECTED

1.6.1 Tenderness

Tenderness is a factor that influences the eating quality of a particular product (Bolumar & Toepfl, 2016). The degree of tenderness for a product cooked is determined by the time and temperature effect on the intramuscular connective tissue and the myofibrillar protein components (Ismail et al., 2019b; Purslow, 2018). Research in red meat has focused primarily on tenderness, as it is a major determinant in the satisfaction and likelihood of purchase for consumer (Garmyn, 2020). Consumers are increasingly demanding superior meat and food products with willingness to pay higher prices (Channon et al., 2011; Lyford et al., 2010). Tenderness is a sensory trait and is determined by several interactions of factors that occur ante- and post-mortem. These factors range from practices used throughout the animal production chain starting before breeding and with the genetics of the animal and continuing throughout its life until it reaches a consumer's plate. Some of these factors include: feed ingredients, transport, stunning and exsanguination, storage methods and cooking procedure for the final product (Warner et al., 2010; Warner et al., 2011).

1.6.2 Cook Loss

When meat is cooked, proteins become denaturated which prohibits the muscles ability to hold water which causes an inevitable issue with the water-holding capacity. However, using a slow-cooking regimen minimizes fluid loss as moisture is maintained inside the vacuum pouch. (James & Yang, 2012; Roldan et al., 2014). Cook loss is the amount of weight or water lost during cooking and is directly linked to cooking duration and temperature. Cook loss increases with an increase of cooking temperature or cooking time (Pang et al., 2021). According to Vaudagna et al. (2002), the authors hypothesized one of the reasons sous-vide cooking does not suffer high cooking losses is because of the heat-induced shrinkage intramuscular connective tissue (IMCT) and collagen which does not occur at lower temperatures. The shrinkage of myofibrils and IMCT collagen are speculated to be associated with water loss during cooking. Purslow et al. (2016) heated semitendinosus muscles at two different temperature ranges to look at the transverse shrinkage at 40 to 60°C and longitudinal shrinkage at 60 to 80°C to determine if fluid was driven out of the meat. Results found that the whole meat, muscle fibers, and myofibrils all shrunk by the same amount and had no difference in transverse shrinkage and longitudinal shrinkage. This cooking loss was driven by protein denaturation of the myosin molecules at temperatures of 50 to 65°C and the denaturation of actin at higher temperatures 70 to 75°C (Purslow et al., 2016). Water holding capacity and cook loss are important in the restaurant industry to understand product yield. In addition, changes in water-holding capacity impact sensory attributes such as taste. If a product expels most of the water content through the cooking process, a drier product if often the result.

1.7 MYOGLOBIN CONTENT

Myoglobin is the pigment responsible for giving beef it's red color and can appear in different forms. Each of these forms of pigment develop based on the environment and presence of other compounds (Govindarajan et al., 1977). The sous vide method used for cooking meat and a variety of foods is advantageous in terms of physical, chemical and quality attributes but can create a major color issue as even when meat is cooked to the proper internal temperature, a pink color of the product may appear. It occurs due to the leaching of myoglobin in the muscles (Kathuria, 2022). Although the product could be safe to consume, consumers often correlate the presence of the pink color to a defect of the meat with the either the presence of blood or uncooked meat while in other cooking methods, the result is browning of meat due to the Maillard reaction (Kieffer et al., 2000). The red or pink pigment in meat that is present during sous-vide cooking is because of oxymyoglobin or deoxymyoglobin while sarcoplasmic proteins deposit inside fibers forming gel giving the meat a swollen and compact texture (Dominguez-Hernandez et al., 2018). This is one of the detriments of sous vide cookery is the amount of myoglobin that appears once the product reaches the proper internal temperature.

1.8 ELECTRONIC ANALYSIS OF ATTRIBUTES

Electronic nose (e-nose) and electronic tongue (e-tongue) are instruments designed to mimic the human nose and tongue by using a combination of both gas or chemical sensors. The electronic nose is gas chromatography and could determine food quality, sensory attributes, microbiological properties, and processing quality (Matindoust et al., 2016). The electronic tongue is composed of sensors that react when immersed in a solution. The technology recognizes the different patterns for classes of compounds that are responsible for one of the five basic tastes (Titova & Nachev, 2020). The applications of e-nose and e-tongue have been used in food quality determination. The human nose is a tool used to evaluate the quality of a food product before consumption. In most industries, determining the quality of a product is completed by a human sensory panel. Although the human nose and tongue can rate a smell or taste, an individual could be subject to bias and humans cannot be exposed to toxic gases or adulterated products (Tan & Xu, 2020). In the meat industry, using these electronic analyses for adulterated product could be beneficial. The quality and shelf life of meat are key factors which are typically evaluated by intricate laboratory protocols. Meat is full of key nutrients but can be easily degraded if it is not properly handled or preserved. With this degradation, it can cause serious health risks to consumers and a loss of profit for producers (Wijaya et al., 2017). It is plausible that with the incorporation of these electronic technologies, the use of human sensory panels may decline. Additionally, if used in the commercial meat and food industry the technology could potentially detect adulterated product quicker.

1.9 VALUE ADDED PRODUCTS

Sustained livestock production to provide food and nutrition for a large population is dependent on the use of livestock products (Kondaiah, 2004). Value added products contribute to sustained demand for meat and efficient marketing of meat products. Global meat production has doubled since 1970 and there has been increased demand for value added meat products to help combat increased consumer demand. Millions of tons of processing waste are produced every day, some of which contain nutritive filled organs but are sometimes considered waste materials (Deogade et al., 2008). Organ meat is full of nutrients and constitutes as a delicacy in certain countries (Nollet & Toldrá, 2011). In order to compliment and supplement qualities and availability of different meats and their byproducts combination of meats is desirable to produce value added products. The use of chicken byproducts such as skin, gizzard and heart are highly acceptable in products such as nuggets, patties, or sausage (Kondaiah, 2004). Additionally, organ meats could be used to add value to a product, decrease waste and create a more affordable option of a meat product.

1.10 CONCLUSION

As restaurants evolve and to keep up with consumer demand, various cooking techniques could provide value to the industry. With a growing demand, sous vide provides the opportunity for quick service restaurants to provide this for consumers without altering the quality or sensory attributes. Additionally, cooking products from a frozen state could limit the amount of cook preparation and time but may negatively impact quality characteristics. Lastly, including variety meats in meat blocks may be another way to provide options for the meat industry and consumer during economic and production challenges. Opportunities to include ground beef in value-added products are endless.

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CHAPTER II

Influence of Sous Vide on Ground Beef Patties

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Abstract:

With rising consumer demand for fast-food options, quick-service restaurants are constantly developing new menu items to attract consumers. Sous vide cookery has become popular for the in-home and fine dining consumer but has not been considered the first cooking option for quick service applications. Therefore, ground beef patties were manufactured to measure the influence of sous vide cooking time on the patty characteristics of moisture, color, and objective tenderness. Patties were randomly assigned a sous vide cooking time of 30, 60, or 90 min and then grilled to an internal temperature of 71.1 °C. Patties sous vide cooked for 30 min exhibited the greatest ($p < 0.05$) cook loss, Allo–Kramer Shear Force (AKSF) and were darker (L^*) than patties sous vide cooked for 60 or 90 min. Additionally, neither internal redness, calculated spectral values of chroma, hue angle, or red-to-brown differed ($p > 0.05$) regardless of sous vide cooking time. Sous vide cooking duration prior to grilling the ground beef patties altered the moisture, color, and objective texture characteristics of ground beef patties.

Keywords: Allo–Kramer shear force; cooked color; ground beef; sous vide cooking

1. Introduction

Evaluating the cookery methods of meat products is necessary to understand the changes that occur in meat quality because of cooking, as differences caused by cookery may alter consumer perceptions. Very little is known about the influence of sous vide cooking on ground meat. However, within the United States, the fast-food industry is very popular, and quick-service restaurants often face challenges to providing new items for consumers using ground meat. During the pandemic, a fast-food restaurant focused on menu creativity to enhance consumer demand for dining that incorporated sous vide cooking methods [1]. Sous vide is a cooking technique using low temperatures and longer cooking times and has become popular in commercial applications [2]. It is estimated that by 2028, the sous vide market will reach USD 10.2 billion with an annualized growth rate of 5.3% [3]. Unlike traditional cooking methods, sous vide cooks the product in a controlled temperature water bath environment inside a heat-stable vacuum-sealed pouch [4]. In addition, sous vide allows professional chefs or home cooks to use cuts of meats considered undesirable and turn them into something that becomes a moist, tender, and flavorful dish [5]. In the fast-food industry, sous vide allows restaurants to hold meat at cooked temperatures, reducing cooking times. Sous vide cooking has several benefits: creating a uniform and desired texture, retaining a desirable color, preventing moisture or flavor losses, and prohibiting cross-contamination in storage [6–8]. Although sous vide can provide many desirable traits for consumers, it does have the potential to reduce consumer acceptability based on appearance [9].

As consumers remain focused on food sources and creating a sustainable and healthier lifestyle, a need for convenient foods without altering their preferred dietary restrictions is necessary. Restaurants that focus marketing attempts on food with clean labels have gained more attention from consumers and are driving greater marketing changes throughout the food industry [10]. Sous vide has garnered more attention as a meat processing tool able to maintain the quality, flavor, and nutritional value of meat that consumers prefer [11].

Raw or cooked color is a driving factor the consumer uses for determining the quality of a meat product. Sous vide cooking does not create a Maillard reaction on the surface of the meat. To counteract this cooking pitfall, chefs have roasted or fried the surface of the meat to achieve a roasted surface color while still using the long-time, low-temperature (LTLT) method [6]. In previous results using lamb meat, research concluded that roasting after sous vide cooking intensifies the Maillard reaction when compared to no additional cooking after sous vide [12].

Recommendations for using sous vide cookery are often based on variations in the objective tenderness ratings of lower-valued whole muscle cuts of beef or pork. However, little is known about the impact that sous vide has on ground meat characteristics. Undesirable cuts are not the only item used in sous vide cooking. This cooking method may provide the opportunity for quick-service restaurants to provide additional menu items without the cost of new equipment. Sous vide products can exhibit the desired palatability and have been reported to extend shelf life by inhibiting the growth of bacteria and lipid oxidation [4]. Using sous vide in a way to increase storage duration is possible. Heating fresh meat products at low temperatures for long times can reduce the quantity of vegetative cells [4]. Reducing microbial organisms in any quantity is well-documented to support the enhanced storing of meat products using a variety of aerobic or anaerobic packaging materials. Additional factors in the combination of sous vide cooking may include water activity, storage temperature, packaging materials, and irradiation to enhance the storage ability of meat and food products to obtain longer storage durations [4]. Currently, there are no specific guidelines or research practices for using sous vide as a cooking method for ground meat. Therefore, the objective of this study was to evaluate the influence of sous vide cooking time on the cooked characteristics of color, moisture, and objective texture in ground beef patties.

2. Materials and Methods

2.1. Raw Materials

Six crossbred (Brangus) cattle were harvested by the Auburn University Lambert- Powell Meat Laboratory (Auburn, AL, USA). Cattle were harvested using commercial meat processing techniques for USDA humane slaughter. Carcasses were chilled at 2 °C (±1.25 °C) for 24 h prior to fabrication. After chilling, carcasses were fabricated into wholesale subprimals using fresh beef USDA institutional meat purchase specifications (IMPS) [13]. For this study fresh beef (n = 12) shoulder clods (IMPS 114) and (n = 12) chuck eye rolls (IMPS 116D) were removed, and subcutaneous fat was trimmed to not exceed 0.635 cm thick. Combined subprimals totaling 140 kg were coarse ground once through a 9.525 mm plate (SPECO 400, Shiller Park, IL, USA) using a commercial meat grinder (Model AFMG-48, The Biro Manufacturing Company, Marblehead, OH, USA). Coarse ground beef was then ground once through a 3.18 mm plate (SPECO 400, Shiller Park, IL, USA) with a bone eliminator attached (SPECO 400, Shiller Park, IL, USA). After final grinding, the ground beef was formed into 151 g patties using a food portioning machine (Hollymatic Corporation Model 54, Countryside, IL, USA). Formed patties were placed on trays lined with freezer paper (Kold-Lok KL18, Dixie Consumer Products LLC, Atlanta, GA, USA) and crust-frozen for 45 min at −22.2 °C to facilitate packaging. Crust frozen ground beef patties were packaged individually into thermoforming vacuum packaging using a Reiser roll-stock packaging machine (Optimus OL0924, Variovac, Zarrentin, Germany). A total of 225 patties were portioned, packaged, and randomly assigned to a time interval of 30, 60, or 90 min (n = 75/sous vide duration). Patties were sealed in a forming layer with an oxygen transmission rate of 0.8 cc/sq. m/24 h, and a non-forming layer with an oxygen transmission rate of 1.0 cc/sq. m/24 h (WINPAK Ltd., Winipeg, MB, Canada). The packaged product was stored in the absence of light at −22.2 °C (±2.1 °C) until laboratory analysis could be completed.

2.2. Proximate Analysis and pH Value

Duplicate samples for proximate analysis (protein, moisture, fat, salt, and collagen) were evaluated after packaging. Analysis was conducted using a near-infrared (NIR) approved spectrophotometer (Food ScanTM, FOSS Analytical A/S, Hilleroed, Denmark), and data processing was determined using ISIscanTM Software. Ultimate pH of the ground beef was measured by weighing 2 g into a plastic centrifuge tube, adding 20 mL of deionized water and homogenizing (Kinematica CH-6010, Brinkmann Instruments, Inc., Westbury, NY, USA) for 45 s. Homogenized ground beef pH was measured using a pH meter (Model- HI99163, Hanna Instruments, Woonsocket, RI, USA) equipped with a glass electrode. The pH meter was calibrated (pH 4.0 and pH 7.0) using 2-point standard buffers (Thermo Fisher Scientific, Chelmsford, MA, USA) prior to sampling (Table 1).

2.3. Cookery Method and Cook Time

At the time of cooking, patties were thawed for 12 h at 2 °C. Using a circulating temperature-control sous vide heating element (Model AN400-US00, Anova Culinary, San

Francisco, CA, USA) in a 65-qt water bath, the water was heated until reaching 60 °C. Vacuum-packaged patties were placed into the water bath and submerged. Once the cooking time of 30, 60, or 90 min was complete, patties were removed from the water bath, packaging was removed, and the patty was blotted dry with a paper towel and weighed on a calibrated scale (Model PB3002-S, Mettler Toledo, Columbus, OH, USA). A commercial grill pre-heated to 148.8 °C was used to mimic an industry grilling method (Model XPE12, Garland Commercial Ranges, Mississauga, ON, Canada) following the use of sous vide. Each patty was cooked until reaching an internal temperature of 71 °C using a thermometer (Therma K-Plus, American Fork, UT, USA). The time each patty was grilled was recorded in seconds. After removal from the clamshell grill, patties were weighed again on the calibrated scale to obtain final cooked weights.

2.4. Cook Loss

Total cook loss percentage was calculated with the following: (sous vide cooked weight − grilled cooked weight) ÷ sous vide cooked weight × 100. Packaged patties were removed from packaging material after sous vide cooking time and weighed on an analytical scale (Model PB3002-S, Mettler Toledo, Columbus, OH, USA). Patties were transferred immediately to the clamshell grill until reaching an internal temperature of 71.1 °C. Grilled patties were cooled to room temperature and grilled cooked weights were recorded.

2.5. Instrumental Color Measurement

Once cooled, patties were sliced horizontally through the geometric center of the patty and scanned for internal cooked color using a HunterLab MiniScan EZ colorimeter (Model 45/0 LAV, Hunter Associates Laboratory Inc., Reston, WV, USA). Before data collection, the colorimeter was calibrated using a black and white tile per the manufacturer guidelines for accuracy. Instrumental color values were determined from the mean of three readings on the internal surface of each ground beef patty using illuminant A, with an aperture of 31.8 mm, and a 10° observer to measure the lightness (L*), redness (a*) and yellowness (b*) of each ground beef patty [14]. In addition, hue angle was calculated using the following: tan − 1 (b*/a*), with a greater value indicative of the surface color shifting from red to yellow. Chroma (C*) was calculated as: vivid color. Lastly, reflectance values within the spectral range 400 to 700 nm were used to capture the surface color changes from red to brown by calculating the reflectance ratio of 630 nm:580 nm.

2.6. Allo–Kramer Shear Force

Using the 5-Blade-Allo-Kramer attachment (AKSF) with a texture analyzer (Model TA-XT Icon, Texture Technologies Corp., New York, NY, USA) the objective tenderness of each patty was measured (n = 225; 75/treatment). Patties were cooked and cooled according to the procedures described above. After cooling to room temperature 23.3 $^{\circ}$C, at a load cell of 500 N and a speed of 3 mm/s, each patty was cut into a 6 × 9 cm square. Each sample was sheared once, and the maximum peak force recorded during analysis was reported in newtons (N) of shear force [14].

2.7. Statistical Analysis

Data was analyzed using the GLIMMIX model procedures of SAS (version 9.2; SAS Inst., Cary, NC, USA). Least squares means were computed for all variables. When sig- nificant ($p \leq 0.05$) F-values were observed, least squares means were separated using pair-wise t-tests

(PDIFF option). This experiment had a completely randomized design with each experimental unit (patty) assigned to treatment group times of 30, 60, and 90 min at random.

3. Results and Discussion

3.1. Cook Time

A concern with using sous vide is the lack of Maillard reaction that occurs on the surface of the meat products. To simulate a commercial cooking process after sous vide, patties were cooked to their specific treatment group time (30, 60, 90 min), then patties were transferred to a clamshell grill to reach an internal temperature of 71.1 °C. The cook time after sous vide was recorded in seconds (Table 2). Expectedly, the cook time on the clamshell grill did not decrease with the increase of time in the water bath as the patties were all cooked at the same temperature before grilling occurred (p = 0.9868).

Unfortunately, the documented literature regarding the cooking time of ground meat patties is limited. Limited results measuring cooking time are either presented as a standardized cooking time or end-point temperature. However, cooking time was recorded in the current study to capture an understanding of the differences that occur due to cooking methods and their subsequent influence on the final cooking time. The end-point cooked temperature can be considered a greater influence on cooking time. Previous results in a ground meat patty report that longer cooking times are necessary when the end-point temperature of the meat patty increases [15,16].

Overall, the grilling time of each treatment group did not change, therefore, the difference that was recorded in each characteristic may be attributed strictly to the sous vide duration and not the clamshell grilling duration.

3.2. Cook Loss

Since meat consists of 75% water, there can be a significant change in the overall weight of the product after cooking, especially when using a two-step cooking method such as sous vide. Measurements were calculated based on the total amount of weight lost after sous vide and grilling. The calculated loss of moisture in the current study does not represent the moisture lost only during water bath cooking, nor the moisture loss after only grilling, cook loss was recorded as the combined moisture loss of sous vide and grilling. The cook loss after grilling decreased with the increased initial cooking time of sous vide. The cook loss in the 30 min test group was greater than the cook loss for the 60 min and 90 min ($p = 0.0001$) test groups (Table 2). The decreasing moisture loss suggests that longer cooking times of a ground meat patty in a water bath may alter the total moisture loss that occurs during the final cooking method. It is plausible that the moisture lost during sous vide cooking will be greater than moisture losses during grilling. The initial moisture loss and muscle fiber shrinking during cooking will likely not lead to the patty absorbing additional moisture during grilling. However, additional research is needed to capture the moisture loss differences that occur within each cookery method (sous vide vs. grilling) to accurately assess the total moisture losses when using any two-step cooking method.

The characteristics of meat are often associated with cooking properties [17,18]. During the cooking process, proteins are denatured, water evaporates, and there is a loss of melted fat which leads to the reduction in cooked weight of a meat product. In previous studies, a similar weight loss to the current results was reported using conventional cooking methods in meat patties and sausages [19,20]. Likewise, the cooking loss was similar in cooked beef when using steaming after sous vide [21]. In a previous study [22], pork patties cooked for a 60 s sear time experienced greater cook loss than the control group that was strictly sous vide. Secondary cooking such as grilling creates the Maillard reaction that consumers prefer in cooked meat proteins, but additional heating and cooling can alter the moisture content, causing greater cooking losses. The current results suggest that the duration of sous vide cooking may alter the moisture retention and subsequent cooking losses that occur in either sous vide or secondary cooking such as grilling. Patties cooked for 30 min exhibited a greater total cook loss supporting the previous literature that longer cooking times using sous vide result in less cook loss.

However, the literature concludes that in long-time, low-temperature (LTLT) cooked proteins, the cook loss increases as moisture declines with greater cooking times [16,23,24]. Water in the muscle is retained by myofibrillar proteins, however, at a temperature above 60 °C these proteins shrink and can cause an influx of water loss [25]. It is plausible that sous vide cooking creates a less evaporative environment as the product is cooked within a vacuum-sealed bag. When increasing cooking temperatures, myofibrillar proteins shrink and result in greater moisture loss [16,23–25]. Using an alternative cooking method such as sous vide could potentially reduce the volume of moisture losses without altering the tenderness or flavor of the meat product.

3.3. Instrumental Color

Even after being cooked to 71.1 °C on the clamshell grill, each patty still appeared reddish/pink on the internal surface. This could pose an issue in the industry for consumers that will not eat a burger perceived to be “undercooked”. The b* values represent the change in yellowness. Samples exhibited higher values in the 60 and 90 min sous vide treatment time (p = 0.0846) when comparing the 30 min treatment time to 60 min (p = 0.0001) and 90 min (p = 0.0006). Overall, L* values were significant for this study (p = 0.0001). The L* values represent the amount of light detected and values displayed; the 60 min treatment group had the highest value compared to the 30 min (p = 0.0001) and the 90 min treatment groups (p = 0.3510). The a* values indicate the amount of redness with a larger value indicating a redder color. This often has a greater appeal to consumers when purchasing fresh beef but not necessarily for cooked beef. With the increase in sous vide cooking time, numerically, the a* values of the internal surface of the cooked patties increased. Regardless, the objective color measurement of redness (a*) was not different across the sous vide cooking times suggesting that the degree of doneness as perceived by consumers would not be altered for sous vide patties (Table 3). Based on objective color measurements, the internal cooked color does not differ after 30 min of sous vide cookery. Cooking ground beef patties for longer than 30 min does not improve the degree of doneness after reaching a final end-point temperature of 71°C.

When the cooking of a product takes place, there are several physical changes that take place as well [26]. The change in the color of a meat product is one of the most noticeable to a consumer’s eye. Much of the research and the literature relating to cooked color provides information on the surface color of a product instead of the internal color. Notably, the surface color values of a protein product cooked using sous vide can be altered and subsequently increase the browning index values as stated by previous research [27].

Unfortunately, the documented literature describing the sous vide implications on meat product characteristics is primarily focused on whole-muscle cuts such as steaks. The current results provide a limited understanding of the changes sous vide causes in minced meat products, but additional research is needed to elicit more information regarding cooking techniques such as sous vide. In a similar study comparing the effect of high- pressure processing (HPP) on beef steaks that were intended for sous vide, it was reported that sous vide cooking did not significantly alter the color of post-HPP beef samples except for those that were processed the longest and with the highest amount of pressure. Whole- muscle beef steaks cooked using sous vide resulted in higher a* and b* values than those in atmospheric pressure conditions [26,28]. These previous studies contrast with the current results; the longer the ground meat product is cooked using sous vide, the more the cooked color values decrease indicating a less vivid color. In reference to a previous study, it was found that meat cooked using sous vide had a more intense red color [26]. Similar results in the current study on ground meat patties resulted in higher a* values for patties cooked for the longer time increments. Due to myoglobin degradation, it is possible that the sous vide cookery in combination with packaging provides a protective mechanism for the minced meat patty which may limit the amount of myoglobin breakdown [26]. It has been suggested by previous authors that an additional cooking method should be incorporated when considering the use of sous vide to improve on the potential drawbacks of the method that may alter color, texture, or moisture [4,13]. Using sous vide as the only cooking method could decrease the consumer acceptability of a product [9]. Using additional cooking methods in combination with sous vide cooking allows for a Maillard reaction on the meat surface which plausibly could provide a more common and appealing appearance that consumers are seeking in cooked meat products.

There was no difference observed (p = 0.9869) for hue angle value which indicates the shift in color from red to yellow. There was no difference observed (p = 0.7885) in the chroma (C*) values that represent a total measure of color (Table 4).

In addition, spectral values were calculated from the CIE measurement of L*, a*, and b*. Color measurements were taken from cooked meat patties at three different locations after slicing patties through the geometric center. There was no interaction between any of the cooking test times and hue angle or chroma ($p > 0.05$) suggesting that sous vide does not enhance or negatively affect the internal cooked color of the patties. However, there was a significant difference in the reflectance ratio of 630 nm:580 nm and this value represents a change in color from red to brown. The 60 min patties were found to have a higher RTB value indicating that the 60 min test group had the largest amount of change from red to brown. This is evidence that the sous vide cook time does not influence the vividness or the change in color of the ground beef patties. It does, however, exhibit the change in color from red to brown. The 90 min cooking duration of ground beef patties displayed the least amount of cooked color change in red-to-brown appearance. It is plausible that the changes in red-to-brown are influenced by the grilling cook time as this treatment group required less time to reach the end-point temperature of 71 °C.

3.4. Allo–Kramer Shear Force

One of the perceived benefits to the sous vide cooking method is the potential for improving the overall tenderness of a cooked product. Objective tenderness was measured via Allo–Kramer Shear Force (AKSF) and reported in newtons (N) of force. Sheaf force values were greatest in patties sous vide cooked for 30 min compared to patties cooked for 60 min (p =

0.0081) or patties cooked for 90 min ($p < 0.0001$). The least amount of shear force was recorded on the patties sous vide cooked for 90 min (Table 2). As sous vide cooking time increased, the amount of Allo–Kramer force required to shear through the patty declined.

Limitations in the literature on the objective tenderness results of meat patties cooked using a sous vide method hinders support of the current results. Interestingly, in a study using sous vide on whole-muscle pork loins cooking for varying allotments of time, re- ported pork loins cooked longer than 60 min resulted in a notable increase in objective firmness [16]. Obviously, whole-muscle cooked characteristics would contrast the current results reported in ground meat patties. It is likely that mincing, grinding, and forming meat patties may also contribute to altering the objective tenderness values, in addition to cooking in sous vide. Additionally, the literature states that the increase of firmness with a longer sous vide cooking time can be related to the temperature associated with the denaturation of tropocollagen at 68 °C. Cooking sous vide at anything greater than 70 °C can cause an increased cook loss [23]. Moreover, the denaturation of myofibrillar proteins and water loss has been well documented to cause variation in meat toughness [4,23]. Reported differences in these pork loins could likely be linked to the increase of cook loss. Similarly, the results of this current study show that the patties cooked the longest experienced the least amount of cook loss and had the lowest shear force values indicating that the loss of moisture in a product has a direct link to the tenderness. In previous research, beef muscles were ranked according to the objective tenderness values of Warner–Bratzler Shear Force (WBSF). It was found that the *triceps brachii* from the shoulder clod was considered intermediate in terms of WBSF with values of force ranging from 38.2 to 45.1 N [29]. In this current study, shoulder clods were used as part of the trimmings to form the patties. A muscle such as the *triceps brachii* may have contributed to the increases in AKSF required to shear the patties. Contrastingly, it is recognized that through the process of grinding, forming, and freezing the disadvantages associated with a tougher muscle from the beef chuck may have been eliminated.

Previous literature suggests that sous vide-processed beef has more space between the muscle fibers in comparison to raw beef or boiled beef [2]. As the internal muscle temperature increases the internal space within meat becomes thinner causing connective tissue to dissolve allowing for more space between the muscle fibers. In summary of this previous study, sous vide samples had an increase of shrinkage which coincides with the greater loss of water previously reported [2,30].

4. Conclusions

Sous vide cooking time does alter the quality attributes of ground beef patties that include objective texture and internal cooked color. Patties with a longer cooking time exhibited less change in cooked color as the 90 min treatment group exhibited the highest redness value. However, cooking patties in sous vide for longer than 30 min had no effect on the internal cooked color. Additional research is needed to further identify the sensory taste impacts on ground beef using sous vide as the primary cooking method compared to other cookery methods. Furthermore, the evaluation of moisture losses using a two- step cooking method, such as sous vide and grilling ground meat patties, is necessary to improve our foundational knowledge of meat cookery.

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TABLES

Table 1. Proximate analysis and ultimate pH level of raw ground beef trimmings.

pH	MOISTURE	PROTEIN	FAT	COLLAGEN
5.712	66.81	22.04	18.13	3.742

Table 2. Influence of sous vide cook time on cook loss, grill time, and Allo–Kramer shear force.

TRAIT	30 MIN	60 MIN	90 MIN	SEM*	*p*-Value
COOK LOSS (%)	21.23 [a]	17.33 [b]	15.35 [c]	0.469	0.0001
GRILL TIME (s)	38.00	37.50	37.50	2.511	0.9868
AKSF (N)	212.6 [a]	199.6 [b]	183.6 [c]	3.372	0.0001

[a–c] Mean values within a row lacking common superscripts differ ($p < 0.05$). * SEM, standard error of the mean.

Table 3. Influence of duration of sous vide on the internal cooked color (L*, a*, b*) values of ground beef patties.

TRAIT	30 MIN	60 MIN	90 MIN	SEM*	*p*-Value
L*[1]	58.08 [b]	60.41 [a]	59.98 [a]	0.327	0.0001
a*[2]	15.93	16.71	16.77	0.417	0.2878
b*[3]	18.97 [b]	20.08 [a]	19.97 [a]	0.201	0.0001

[1] L* Values are a measure of darkness to lightness (larger value indicates a lighter color); [2] a* values are a measure of redness (larger value indicates a redder color); and [3] b* values are a measure of yellowness (larger value indicates a more yellow color). [a–b] Mean values within a row lacking common superscripts differ ($p < 0.05$). * SEM, standard error of the mean.

Table 4. Calculated spectral values of the influence sous vide has on ground beef patties.

TRAIT	30 MIN	60 MIN	90 MIN	SEM*	*p*-Value
CHROMA	50.88	38.00	24.96	0.792	0.7885
HUE ANGLE (°)	50.71	38.00	26.21	3.567	0.9869
RTB	50.35[b]	38.50[a]	26.14[a]	0.548	0.0414

[1] C* (Chroma) is a measure of total color (larger number indicates a more vivid color). [2] Hue angle (°) represents the change in color from the true red axis (larger number indicates a greater shift from red to yellow). [3] RTB is the reflectance ratio of 630 nm ÷ 580 nm and represents a change in the color of red to brown (larger value indicates a redder color). [a–b] Mean values within a row lacking common superscripts differ ($p < 0.05$). * SEM, standard error of the mean.

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CHAPTER III

Influence of Cookery Method on Frozen Ground Beef Patties

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Abstract:

Ground beef patties commonly known as hamburgers are a popular food item throughout the United States among meat consumers. Technologies for measuring changes in cooked and fresh characteristics of ground beef patties have improved, and the need for evaluating cooked meat patty characteristics are necessary. In the current study, ground beef patties were cooked from frozen using a griddle (GRID), convection oven (OVEN), or clam shell (GARL) to 71.1 °C. Cooked patties were evaluated for cook loss, cooking time, and objective tenderness (Allo-Kramer Shear Force). Patties cooked using the direct heat method GRID had the longest cooking time ($p < 0.0001$) compared to OVEN ($p < 0.0001$) and GARL ($p < 0.0001$) to reach 71.1 °C and the greatest percentage of cook loss versus OVEN ($p < 0.0001$) and GARL ($p = 0.0223$). In addition, patties cooked using the GRID required more Allo-Kramer shear force ($p < 0.0001$) and thus less objective tenderness compared to either OVEN ($p < 0.0001$) or GARL ($p = 0.0988$). Current results suggest that if frozen patties are cooked using various cookery methods, then the cooked characteristics are altered.

Keywords: Allo-kramer shear force; Cook loss; Cook time; Ground beef

1.0 Introduction

The popular meat patty is manufactured from a combination of lean trimmings followed by grinding, blending, and forming ground beef. Most meat patties are comprised of ground beef and can be produced through grinding methods by manufacturers in a variety of textures that may affect consumer mouthfeel [1]. More importantly, ground beef patties remain a common staple in most diets; nearly 60% of consumers use ground beef as an ingredient and 50% consume ground beef patties weekly [2]. In 2021, it was reported that ground beef products comprised 48% of consumer sales and 37% of spent consumer dollars in the United States [2]. Of this, 38% of patties are consumed from fast-food restaurants and 33% are consumed at home [1].

Selecting a cooking method can alter the amount of water and fat lost during cooking and affect the tenderness of the cooked product. Tenderness is a trait that has been measured extensively for many decades and has been correlated to the eating quality of a particular product, especially red meat [4]. Tenderness can be a major determinant for consumers in their satisfaction of a product or likelihood of repeat purchases [5]. Furthermore, it has been well demonstrated throughout the literature that ground beef patties are recognized for palatability traits of juiciness, beef flavor, and even tenderness. When meat is cooked, proteins become weaker, which expels fluid from the muscle. Inevitably, this causes an issue with the water holding capacity which is also linked to the cook loss, or the amount of weight lost once a product has been cooked [6].

Cooking methods are instrumental in preserving the characteristics of quality within a meat product before eating occurs. In a previous study [7], cooking leads to a weight reduction of hamburger patties largely due to water loss during the cooking process. Greater moisture loss in ground beef patties has been reported to occur when indirect cookery methods such as roasting or microwaving are used [7]. This supports the idea that cooking methods influence the water holding capacity and cook loss which can then in turn impact the consumers perception of tenderness.

Undercooked ground beef has been linked to foodborne illnesses, specifically Escherichia coli O157:H7 [8,9]. To prevent such illnesses, it is recommended to cook ground beef to an internal temperature of 71 °C [10]. Various cookery methods can be used to prepare hamburger patties such as deep frying, infrared radiation, convection heating, and double-sided contact cooking are common in restaurants within the United States [11]. Each cookery method can change the overall quality attributes of texture, juiciness, color and palatability of the ground beef patty.

For the last two decades, it has been communicated that the internal color of a ground beef patty is not a reliable indication of determining safety and product temperature of ground beef patties [12]. In addition to the internal cooked color, thawing for an increased amount of time can lead to food safety concerns [16]. Some beef patties may have persistent pinking even after reaching an internal temperature of 71.1°C [13-15]. Persistent pinking may be a result of post-mortem muscle pH, storage temperatures, or cooking method. Consumers have been advised against consuming meat patties that remain pink after cooking [16]. Previously, it has been shown that thawing prior to cooking meat patties can eliminate the issue of a red or pink color internal color. More specifically, literature reports that thawed patties require less cook time, and have an increased brown appearance due to the conversion of myoglobin to metmyoglobin [16,17]. Additionally, frozen patties had a higher peak load for shear force testing compared to thawed patties resulting in less objective tenderness [16]. Cooking ground beef patties from a frozen state can be more convenient to a consumer such as those in a restaurant or a school food service setting [18]. As most research on ground beef patties dates back several decades, it is important to continue research on an important meat product, such as ground beef patties. Therefore, the objective of this study was to analyze the impacts of direct and indirect cooking methods on the objective texture, cook loss and cooking time of frozen ground beef patties.

2.0 Materials and Methods

2.1 Raw materials

Commercial crossbred cattle (N = 6) were procured from the Auburn University's Beef Teaching Unit and harvested at the Auburn University's Lambert-Powell Meats Laboratory (Alabama Establishment Number: 43-ME-4) using commercial meat processing standards under USDA humane slaughter standards. Carcasses were chilled at 2.0°C (± 1.0°C) for 24 hours. After chilling, carcasses were fabricated into wholesale subprimals using fresh beef USDA institutional meat purchase specifications (IMPS) [19]. For this study, fresh beef (n = 12) shoulder clods (IMPS 114) and (n = 12) chuck eye rolls (IMPS 116D) were removed, and subcutaneous fat was trimmed to not exceed 0.635 cm thick. The subprimals were combined as one block of meat totaling 140 kg. Trimmings were coarse ground once through a 9.525 mm plate (SPECO 400, Shiller Park, IL, USA) using a commercial meat grinder (Model AFMG-48, The Biro Manufacturing Company, Marblehead, OH, USA). Coarse ground beef was then ground once through a 3.18 mm plate (SPECO 400, Shiller Park, IL, USA) with a bone eliminator attached (SPECO 400, Shiller Park, IL, USA). After final grinding, ground beef was formed into 151 g patties using a food portioning machine (Hollymatic Corporation Model 54, Countryside, IL, USA). Formed patties were placed on trays lined with freezer paper (Kold-Lok KL18, Dixie Consumer Products LLC, Atlanta, GA, USA) and crust- frozen for 45 minutes at -22.2°C to facilitate packaging. Crust frozen ground beef patties were packaged individually into thermoforming vacuum packaging using a Reiser roll-stock packaging machine (Optimus OL0924, Variovac, Zarrentin, Germany). A total of 225 patties were portioned, packaged and randomly assigned to a cookery method (n = 75/method). Patties were sealed in a forming layer with an oxygen transmission rate of 0.8cc/sq. m/24hr, and a non-forming layer with an oxygen transmission rate of 1.0 cc/sq. m/24hr (WINPAK Ltd, Winipeg, Canada). The packaged product was stored in boxes in the absence of light at -22.2°C until laboratory analysis could be completed.

2.2 Proximate analysis & pH value

Ground beef used in manufacturing patties was measured for proximate analysis using a near-infrared (NIR) approved spectrophotometer (Food ScanTM, FOSS Analytical A/S, Hilleroed, Denmark), and data processing was determined using ISIscanTM Software (Santa Clara, CA, USA). Ultimate pH of ground beef was measured by weighing 2g into a plastic centrifuged tube, adding 20mL of deionized water and homogenizing (Kinematica CH-6010, Brinkmann Instruments, Inc., Westbury, NY, USA) for 45 seconds. Homogenized ground beef pH was measured using a pH meter (Model-HI99163, Hanna Instruments, Woonsocket, RI, USA) equipped with a glass electrode. The pH meter was calibrated (pH 4.0 and pH 7.0) using 2-

point standard buffers (Thermo Fisher Scientific, Chelmsford, MA, USA) prior to sampling (Table 1).

2.3 Cookery method and cook time

Patties (n = 225; 75/treatment) were assigned randomly to one of three cookery methods that included a commercial cooking griddle (GRID; Model HEG36E-1, Vulcan, Baltimore, MD, USA), commercial convection oven (OVEN; Model VC3ED, Vulcan, Baltimore, MD, USA), or clamshell grill (GARL; Model XPE12, Garland Commercial Ranges, Ontario, Canada). Prior to cooking patties, each cookery method was pre-heated to 148.8°C. Internal temperature of each patty was monitored using a thermocouple placed into the geometric center of the patty until an internal temperature of 71.1 °C (Therma K-Plus, American Fork, Utah, USA) was reached. Patties cooked using the GRID and OVEN method, were flipped once reaching an internal temperature of 27°C. Cooking time of each patty was recorded, and cooked patties were removed, placed onto a wire-rack and cooled to room temperature 24.4 C.

2.4 Cook loss

Prior to cooking, patties (n = 225; 75/treatment) were removed from packaging and weighed on a calibrated scale (Model PB3002-S, Mettler Toledo, Columbus, OH, USA) to determine raw product weight. Once cooked as previously described, patties were cooled to room temperature and cooked weights were recorded. Cook loss percentage was calculated with the following formula: [(weight of raw sample – weight of cooked sample) ÷ weight of raw sample × 100)].

2.5 Allo-Kramer shear force

Patties (n = 225; 75/treatment) were measured for objective tenderness using a 5-Blade-Allo-Kramer attachment Shear Force (AKSF) attached to a texture analyzer (Model TA-XT Icon, Texture Technologies Corp., New York). Patties were cooked and cooled to room temperatures as described above. From each patty a 6 × 9 sq. cm (l × w) cube was cut from the center and the tenderness of each patty (n = 75/cookery methods) was measured. A load cell of 30 kg and a speed of 3 mm/sec, sheared each sample once, and the maximum peak force recorded during analysis was reported as Newton (N) of shear force.

2.6 Statistical analysis

Data were analyzed using the GLIMMIX model procedures of SAS (version 9.2; SAS Inst., Cary, NC, USA). Least squares means were computed for all variables. When significant ($p \leq 0.05$) F-values were observed, least-squares means were separated using pair-wise t-tests (PDIFF option). This experiment was a completely randomized design, the treatments (GRID, GARL, OVEN) were assigned to experimental units (patty) at random.

3.0 Results and Discussion

3.1 Cooking time

Analysis of cook time for the various cooking methods on frozen ground beef patties is presented in figure 1. Cooking time was impacted ($p = 0.0001$) by cooking method with GARL requiring the least amount of cook time (168 s) to reach an internal temperature of 71.1°C compared to GRID (1002 s) or OVEN (780 s) which proved to be significant ($p < 0.0001$). This was not surprising as the GARL method ($p < 0.0001$), which provides double-sided contact cooking and is commonly used in quick-service restaurants. The reduced cook time the GARL method provides can be beneficial in a quick-service restaurant where on average they are selling 4,500 burgers every minute [20]. Literature reports that mathematical models can be used to predict the change in temperature for cooking methods such as the clamshell grill as it has proven to be difficult to monitor temperature with the double-side cooking platens [21]. Additionally, it has been reported that ground beef patties containing an extra protein source require more cook time than those without [22]. Moreover, the fat percentage of the product can affect the cooking time. Beef patties containing more fat and less lean will require more time to reach an internal temperature of 71.1°C [23]. Great cooking times maybe the result of greater fat content in the patty. During cooking animal fat melts and dissolves at an increasing rate thus requiring less time to cook and reach an internal temperature of 71.1°C. Previous research on cooking times for the cooking methods used in the current study are limited. Therefore, more research is needed to identify the duration of cooking frozen beef patties to achieve an internal temperature of 71.1°C.

3.2 Cooking loss

Fresh meat can be comprised of almost 75% water and cooking greatly impacts the available moisture of a meat product. Analysis of the cook loss from each cooking method on frozen beef patties is presented in figure 2. Cook loss was greatest ($p = 0.0001$) in patties cooked using the GRID. However, both OVEN and GARL ($p = 0.0107$) both resulted in moisture loss after cooking greater than 30%. GARL cooking method compared to GRID had 2% less cook loss ($p = 0.0223$). Furthermore, comparing GRID which had the most cook loss at 37% to OVEN ($p < 0.0001$) it is evident the OVEN cooking method has the most moisture retention. During the cooking process, proteins are denatured, water evaporates, and there is a loss of melted fat which leads to the reduction in cooked meat weight. Changes in moisture can be accredited to the cookery method and duration of cooking [8]. In contrast to the current results, a variety of protein patties were cooked using a microwave and a conventional oven. Results indicate that beef and chicken patties cooked in an oven had greater cook loss than those patties cooked in the microwave [24]. Additional research suggests that the cook loss of camel whole-muscle steaks in comparison with veal, was much greater when cooking with a microwave than conventional methods such as roasting and braising [25]. Furthermore, cooking frozen chicken breast fillets concluded that cooking from frozen without thawing increased the amount of cook loss [26]. It is plausible that due to direct heat from GRID and GARL caused greater amounts of evaporation and increased cook loss. Whereas cooking frozen patties in the OVEN had the least amount of cook loss but required longer cooking times. Regardless, it appears cook loss is negatively associated with water-holding capacity, and cooking directly from a frozen state can result in a reduced water holding capacity when compared to cooking from a thawed state [25,26].

3.4 Allo-Kramer shear force

Objective tenderness of cooked patties was measured to identify variations in cookery method of frozen ground beef patties (Figure 3). Average value of force required to shear the sample was calculated. GRID = 265 N, GARL = 252 N, and OVEN = 201 N. Tenderness values were greater ($p = 0.0001$) in patties cooked using direct heat GRID and GARL. The lowest amount of force required to shear through the patty was from the OVEN cooking method compared to GARL and GRID ($p < 0.0001$). Previous literature on cookery method from fresh or frozen status is quite limited. More importantly, literature focused on ground beef patties centers on historical data nearly four decades ago. Improvements in technology and methods for measuring objective tenderness of meat products have been adopted throughout the industry and the need for identifying variations in cooking are warranted. Previous results suggest that lean trimming sources (young vs. old beef) or even mechanical obtained trimmings will alter objective tenderness of ground beef patties using a single blunt blade shear attachment [27]. Ground beef patty are a common consumer item, it is important to identify variation that can occur due to cooking to avoid consumer dissatisfaction. It is plausible that direct heat cooking of the patty resulted in greater moisture loss whereby causing objective tenderness values to increase. Previous literature on beef steaks cooked to varying end-points temperature or with varying methods have resulted in greater objective tenderness values [28]. Similar cooking methodologies using forced air (oven) or conduction (griddle) heat for steaks have been widely inconsistent for objective tenderness in either increasing or causing no differences in objective tenderness of longissimus steaks [29-32]. The reported differences in whole-muscle tenderness when using different cookery methods appear to be linked to the cooking duration of the selected method. Steaks cooked for a longer time have been reported to be more tender (objectively) than rapid cooking times [33]. Interestingly, cooking frozen patties has been reported to cause increases in objective tenderness [12]. This same trend was not identified in the current study which indicates that factors other than cook time are more important in ground beef in comparison to whole-muscle cuts. Cooking on the GRID or GARL from frozen likely caused a crust to form on the surface of the patty increasing the required force to shear through the patty.

4.0 Conclusions

Cookery method of frozen ground beef patties does directly influence cooking time, cook loss, and objective texture measurements. These results suggest that indirect heat (OVEN) cooking is the best of the evaluated cookery method for improved tenderness, minimizing cook loss and improving cooking yield. However, OVEN cooking required greater cooking times and may not be suitable for quick- service restaurant applications where GRID or GARL may be beneficial. However, more information is needed to fully capture the influence of cookery method on frozen and fresh ground beef patties. This preliminary study provided a brief snapshot of the influence cookery method elicits on meat quality, but future efforts are needed to determine the impact cookery method incurs on sensory attributes.

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TABLES & FIGURES

Table 1. Proximate analysis and ultimate pH level of raw ground beef trimmings.

pH	MOISTURE [1]	PROTEIN [2]	FAT [3]	COLLAGEN [4]
5.712	66.81	22.04	18.13	3.742

[1]Moisuture percentage (g/100g). [2] Protein percentage (g/100 g). [3] Fat percentage (g/100 g). [4] Collagen percentage (g/100 g).

Figure 1. Average cook time of various cookery methods of frozen ground beef patties. Bars lacking common letters differ ($p < 0.05$).

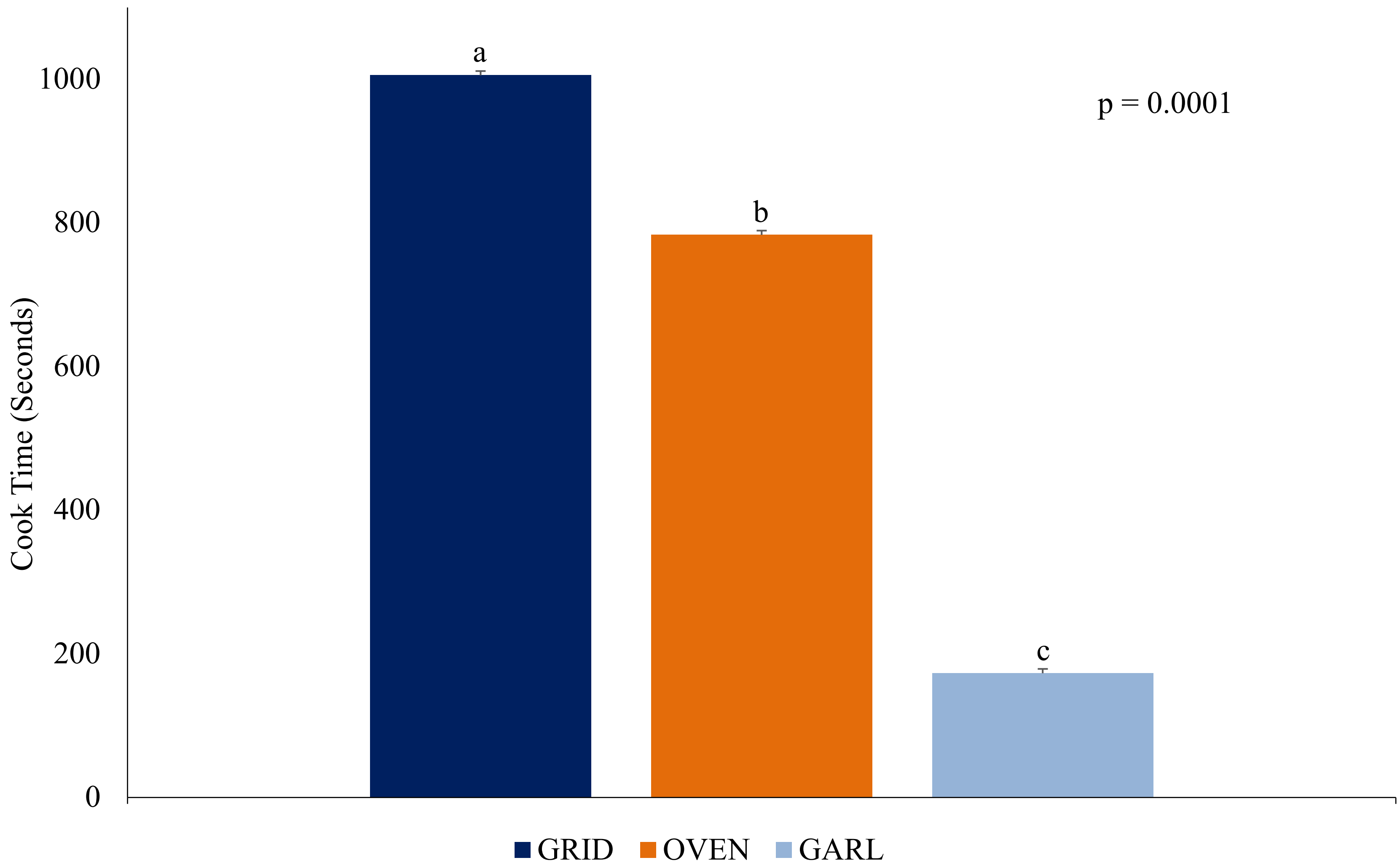


Figure 2. Influence of cooking method on cook loss of frozen beef patties. Bars lacking common letters differ ($p < 0.05$).

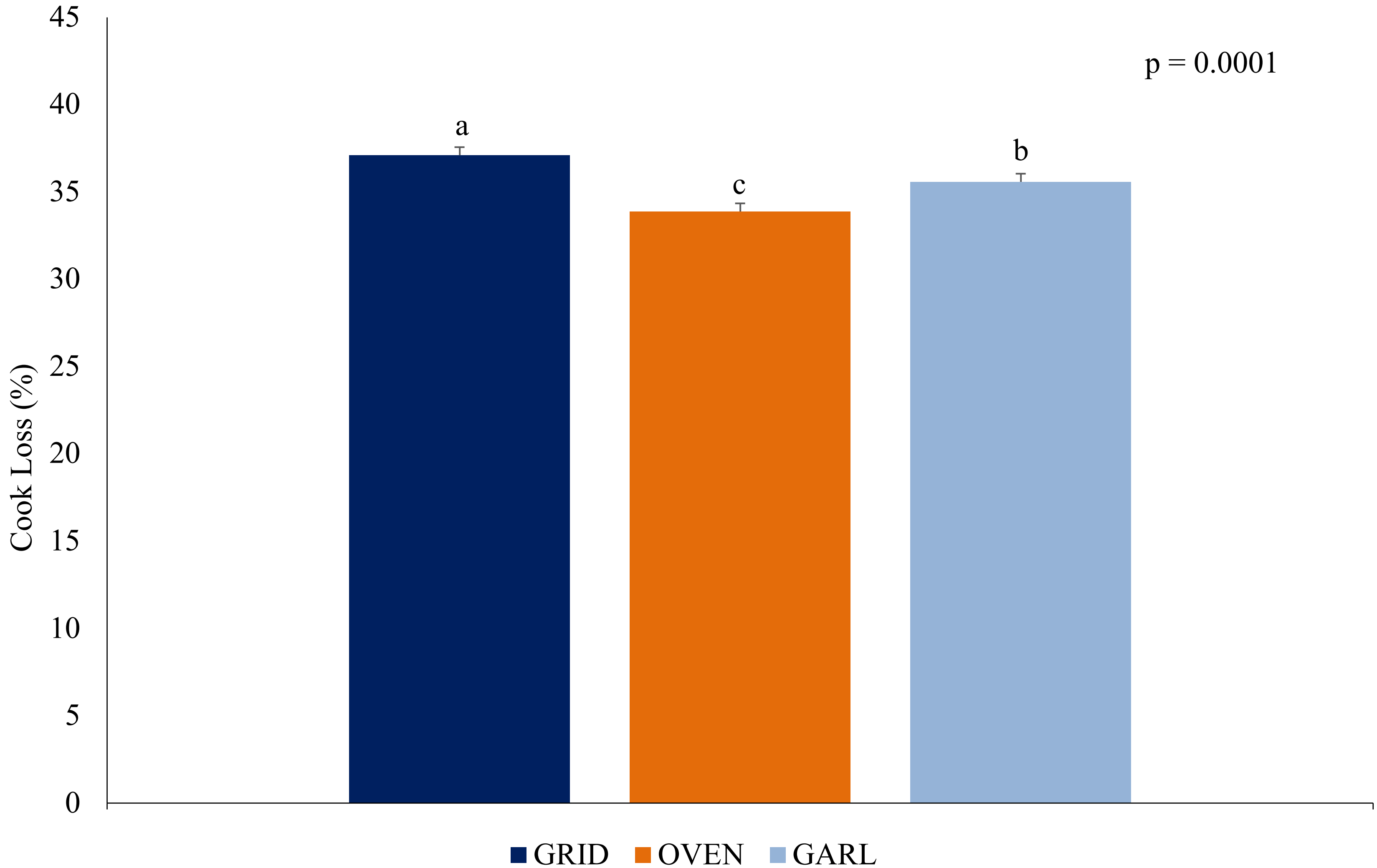
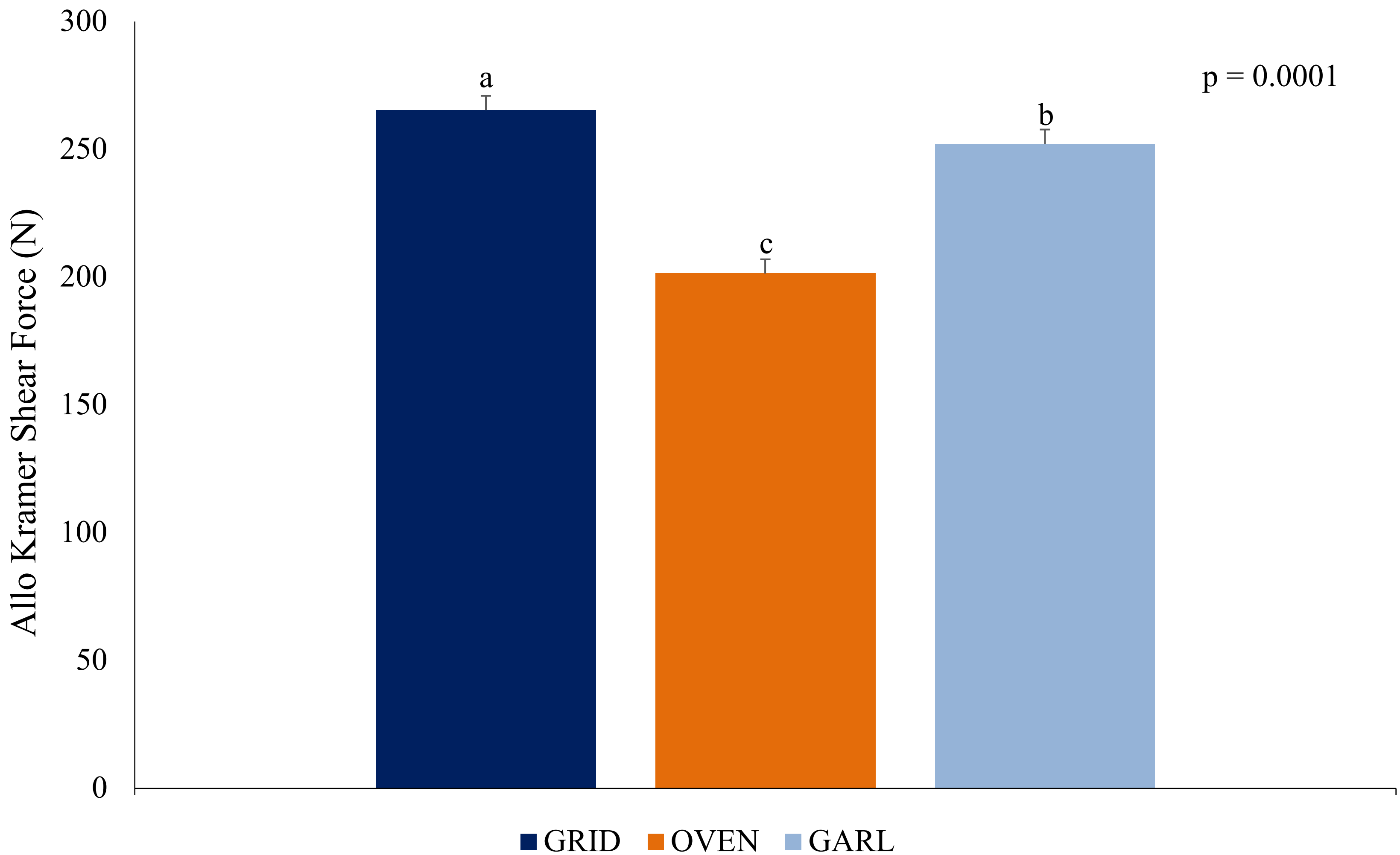


Figure 3. Average influence of cooking method of Allo-Kramer Shear Force on ground beef patties. Bars lacking common letters differ ($p < 0.05$).



This Chapter is formatted to fit the style and guidelines for the MDPI Publisher Journal of Foods.

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CHAPTER IV

Inclusion of Beef Heart in Ground Beef Patties Alters Quality Characteristics and Consumer Acceptability as Assessed by the Application of Electronic Nose and Tongue Technology

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Abstract:

Consumer purchasing of beef is often driven by the trinity of flavor, palatability, and convenience. Currently, beef patties in the United States are manufactured with fat and lean trimmings de- rived from skeletal muscles. A reduction in total beef supply may require the use of animal by-product utilization such as variety meats to achieve patty formulations. The current study aimed to assess textural, color, and flavor characteristics in addition to volatile compounds through electronic technology, e-nose and e-tongue, of ground beef patties formulated with beef heart. Ground beef patties were manufactured with 0%, 6%, 12%, or 18% beef heart, with the remainder of the meat block being shoulder clod-derived ground beef. Patties (n = 65/batch/treatment) within each batch (n = 3) with each treatment were randomly allocated to cooked color (n = 17/batch/treatment), Allo–Kramer shear force (AKSF; n = 17/batch/treatment), texture profile analysis (TPA; n = 6/batch/treatment), cooking loss (n = 17/batch/treatment), consumer panel (n = 3/batch/treatment), e-nose (n = 1/batch/treatment), and e-tongue (n = 1/batch/treatment) analysis groups. Patties containing beef heart did not require additional cooking time ($p = 0.1325$) nor exhibit greater cooking loss ($p = 0.0803$). Additionally, inclusion rates of beef heart increased hardness ($p = 0.0030$) and chewiness values ($p = 0.0316$) in TPA, were internally redder ($p = 0.0001$), and reduced overall liking by consumer panelists ($p = 0.0367$). Lastly, patties containing beef heart exhibited greater red-to-brown ($p = 0.0003$) and hue angle ($p = 0.0001$) values than control patties. The results suggest that beef heart inclusion does alter ground beef quality characteristics and consumer acceptability.

Keywords: beef heart, cooked color, electronic nose, electronic tongue, ground beef patties, sensory analysis

1. Introduction:

Ground beef is a popular product purchased by meat consumers because of the meal versatility and affordability. Consumption patterns of ground beef in the United States from 2001 to 2018 comprised a minimum of 20 g daily for respondents ranging in age from 2 to 60 years old [1]. Beef is often the preferred red meat of consumers throughout the world and ranks third in per capita consumption of all meats globally [2]. It is well documented that consumer spending on meat proteins throughout the retail sector is price-driven as consumers are opting for less expensive cuts at the retail meat level [3]. Moreover, as economic conditions fluctuate each year, types of beef products purchased shift based on supply and demand [4]. Retailers have marketed ground beef as a product that can be selected for a lower purchase price than a whole muscle product such as a steak or a roast [5]. However, over the last decade, consumer demand has driven the need to improve the marketability of ground beef [5].

Advances in technology through applications of electronic multisensory instruments have been utilized in the food industry to assess sensory profiles like human senses of taste and smell [6–8]. However, limited efforts using e-tongue or e-nose technology have been focused on fresh or cooked ground meat samples such as beef. Previous efforts using rapid and non-destructive technologies have been focused on evaluating food spoilage and identifying toxic substances [9]. An electronic nose (e-nose) can be constructed with chemical gas sensors that measure volatile compounds or based on flash gas chromatography [10]. Technology such as the Alpha MOS e-nose uses ultra-fast gas chromatography, giving rapid and high throughput results [11]. The sensor array of an electronic nose can detect many components within a specified time frame and produce a specific response pat- tern [12]. Electronic nose techniques have been used sparingly to classify meat samples [13]. Using principal component analysis, reduced data sets have been able to discriminate between fresh and cooked characteristics of meat [12]. Technology such as the e-nose may be particularly useful in identifying potential pathogens that are harmful to human health and considered a food safety hazard without delays caused by conventional quantitative laboratory methods [12].

In addition, the electronic tongue (e-tongue) has been investigated as a method to discriminate and analyze sensory taste characteristics such as the five basic tastes of sweet, salty, sour, bitter, and umami [14]. A common method for taste detection in foods is to recruit and evaluate responses from trained descriptive or consumer sensory panels, but human sensory panelists cannot be used to evaluate food or drugs that are deemed harmful [14]. Moreover, human panelists often experience sensory taste fatigue or become difficult to recruit, which can alter study results. Therefore, the development of a sensor such as the e-tongue has proven capable in detecting basic taste properties correlated with chemical components, acids, and hydrogen ions [14]. Like the e-nose, analyzing samples with an e-tongue can aid in detecting freshness within foods and identifying many additives or adulterations of the product [14]. Using electronic technology in cooperation with human sensory panelists may provide a more wholistic interpretation of quality parameters for food products that have been previously limited.

Investigative efforts throughout the literature assessing the use of the electronic nose and tongue in beef, specifically ground beef, are limited. Early adoption of technology such as the e-nose was introduced as a method to evaluate the quality of fresh chicken meat [15]. Additionally, electronic analysis was used to identify meat sources from different breeds of beef cattle and domesticated buffalo [16,17]. It has been reported that the electronic tongue could identify the meat of different breeds with 100% accuracy [15]. However limited, the results published suggest that the methods of electronic analysis can be a successful monitoring step in the identification of meat and meat quality [15].

Consumers may not find the use of organ meats appealing; however, the use of animal by-product proteins such as beef heart in manufacturing ground beef may provide a nutritional benefit to consumers when beef inventories decline. Organ meats are some of the most nutrient-dense foods available and are naturally enriched with nutrients that are required for human survival [18]. Specifically, the heart is a source of copper, selenium, and iron, and it contains B12, but may contain excessive amounts of collagen [18]. The inclusion of variety meats in ground beef products could lower consumer product retail costs, provide an affordable value-added product, and improve environmental impacts by increasing the sustainable use of animal proteins for beef consumers. Adding organ meat can reduce lean trimming demands for the manufacturer and consumer cost [19].

Nevertheless, the use of beef organs such as the heart in ground beef has not been thoroughly studied; therefore, the objective of this study was to measure quality characteristics of ground beef patties with different inclusion rates of beef heart.

2. Materials and Methods:

2.1 Raw Materials:

Beef chuck eye rolls (USDA Institutional Meat Purchasing Specification #116A) and beef heart (USDA Institutional Meat Purchasing Specifications #1723) were purchased from a commercial meat distributor (Sherwood Foods, Atlanta, GA, USA) and transported to the

Lambert Powell Meat Laboratory (Auburn, AL, USA) under refrigerated conditions (1.5 ◦C, ±1.0 ◦C). Raw materials were allocated to one of four treatments containing 0%, 6%, 12%, or 18% beef heart in 14.97 kg batches (three batches/treatment). Allocated raw materials were trimmed and coarsely ground once through a 9.525 mm plate (SPECO 400, Shiller Park, IL, USA) using a commercial meat grinder (Model AFMG-48, Biro Manufacturing Company, Marblehead, OH, USA). Each batch was mixed for 3 min, then ground once through a 3.18 mm plate (SPECO 400, Shiller Park, AL, USA) with a bone eliminator attached (SPECO 400, Shiller Park, IL, USA). Batches of ground beef were formed into 226.8 g patties (n = 65/batch/treatment) using an automated forming machine (Super 54, Hollymatic Corporation, Countryside, IL, USA). Formed patties were individually identified and vacuum packaged using 25.40 cm × 20.32 cm (l × w) 3 Mil vacuum pouches. A total of 780 patties were portioned, packaged, and frozen at −22.2 ◦C (±2.1 ◦C). Within each batch (n = 3), patties were assigned randomly to groups for laboratory anal- ysis of cooked color (n = 17/treatment/batch), cooking loss (n = 17/treatment/batch), texture (n = 17/treatment/batch), electronic (e-nose/e-tongue) technology (n = 6/treat- ment/batch), and a consumer taste panel (n = 9/treatment/batch; Table 1). Packaged patties were stored at −22.2 ◦C (±2.1 ◦C) until laboratory analysis could be completed.

2.2 Proximate Analysis & pH Value:

Beef patties (*n* = 1/batch/treatment) for determining relative proximate analysis (protein, moisture, and fat) were evaluated after packaging. Analysis was conducted using a near-infrared (NIR) spectrophotometer (Food ScanTM, FOSS Analytical A/S, Hilleroed, Denmark), and data processing was determined using ISIscanTM Software (version 4.8, Höganäs, Sweden). Ultimate pH of ground beef was measured by weighing 2.00 g into a plastic centrifuge tube, adding 20 mL of deionized water, and homogenizing (Kinematica CH-6010, Brinkmann Instruments, Inc., Westbury, NY, USA) for 45 s. Homogenized ground beef pH was measured using a pH meter (Model-HI99163, Hanna Instruments, Woonsocket, RI, USA) equipped with a glass electrode. Calibration of the pH meter was completed (pH 4.0 and pH 7.0) using 2-point standard buffers (Thermo Fisher Scientific, Chelmsford, MA, USA) prior to sampling (Table 2).

2.3 Cookery Method, Cook Time & Cook Loss

Before cooking, patties (n = 17/batch/treatment) were thawed for 12 h at 2.0 ◦C (±1.5 ◦C). A commercial cooking griddle (Model HEG36E-1, Vulcan, Baltimore, MD, USA) was pre-heated to 176.7 ◦C and each patty was cooked until reaching an internal temperature of 71.1 ◦C using a thermometer (Therma K-Plus, American Fork, UT, USA). Packaged patties were removed from packaging material after thawing and weighed on an analytical scale (Model PB3002-S, Mettler Toledo, Columbus, OH, USA). Throughout the cooking process, patties were turned every two minutes to minimize cooking variation, as described by the American Meat Science Association Meat Cookery Guidelines [20]. Cooking time was recorded as the time required to reach an internal temperature of 71.1 ◦C. After cooking, patties were cooled to room temperature and re-weighed on the calibrated scale to obtain final cooked patty weight. Cooking loss percentage was calculated by the following formula: [(cooked weight − raw weight) ÷ cooked weight × 100)].

2.4 Instrumental Color Measurement:

Cooled, cooked patties (n = 17/batch/treatment) were sliced horizontally through the geometric center of the patty and scanned for internal cooked color using a HunterLab MiniScan

EZ colorimeter (Model 45/0 LAV, Hunter Associates Laboratory Inc., Reston, WV, USA). Before the color measurement, the colorimeter was calibrated using a black and white tile per the manufacturer's guidelines to ensure instrument accuracy. Instrumental color values were determined from the mean of three readings on the cooked internal surface of each ground beef patty using illuminant A, an aperture of 31.8 mm, and a 10◦ observer measuring lightness (L*), redness (a*), and yellowness (b*) of each ground beef sample [20]. In addition, relative values for hue angle were calculated using the following equation: tan−1 (b*/a*), with a greater value indicative of color shifting from red to yellow. Chroma (C*) was calculated as √a*2 + b*2, where a larger value indicates a more vivid color. Lastly, reflectance values from spectral range 400 to 700 nm were used to calculate color changes from red to brown (630 nm/580 nm).

2.5 Texture Analysis:

Using a 5-blade Allo–Kramer attachment (AKSF) with a texture analyzer (Model TA-XT Icon, Texture Technologies Corp., New York, NY, USA), the objective tenderness of each patty was measured (*n* = 17/batch/treatment). Patties were cooked and cooled according to the same procedures described for measuring the cooked color. After cooling to room temperature (23.3 ◦C), with a load cell of 294.2 N and a speed of 3 mm/s, each patty was cut into a 6 × 9 cm2 sample. Each sample was sheared once, and the maximum peak force recorded during analysis was recorded as Newton (N) of shear force.

Texture profile analysis (TPA) was performed on each patty (*n* = 6/batch/treatment) at room temperature using a texture analyzer (Model TA-XT Icon, Texture Technologies Corp., New York, NY, USA). Six 1 × 1 cm2 samples from each patty were removed and subjected to a two-cycle compression test using a load cell of 294.2 N. Samples were compressed to 60% of their original height with a cylindrical probe (TA-25A) 50 mm in diameter with a cross-head speed of 6.00 cm/min. Texture profile parameters were calculated as hardness (kg), which is the force required to compress a sample; cohesiveness, which is the extent of sample deformation prior to rupture; springiness, which is the ability of a sample to return to its original shape after force is removed; and chewiness (kg × cm), which is the force needed to masticate a sample for swallowing (hardness × cohesiveness × springiness) according to previously described procedures [21–23].

2.6 Electronic Testing

Objective sensory values were measured (n = 1/batch/treatment) with an electronic tongue (α-Astree II Electronic Tongue, Alpha MOS, Toulouse, France) designed to mimic human taste responses and record taste profiles. An electronic tongue contains seven sensors representing subjective values for sour, salty, umami, sweet, and bitter, and two sensors working as general purpose sensors according to previously described methods [23]. Water-soluble extraction (WSE) of the ground beef patty was obtained by mixing 20.00 g from each treatment with 100 mL distilled water, and homogenizing the mixture (Model 38BL54, Waring Products, Torrington, CT, USA) for 30 s. Homogenized mixture was centrifuged at 1500× g (Model D-37520 Osterode, Thermo Electron Corporation, Karlsrube, Germany) for 5 min at room temperature. Supernatant was removed and filtered by a 500 mL 0.45 µm PES filter unit (VWR International, LLC, Radnor, PA, USA) under vacuum (Welch Vacuum Technology, East Hanover, NJ, USA) to remove any excess solids. E-tongue sensors were placed into each sample for 120 s to record taste values. After each sample, deionized water was used as a cleaning solution for the e-tongue sensor for 10 s. Using the AlphaSoft (version 7.2.8, Toulouse, France) software, relevance indexes for captured volatiles were sorted from largest to smallest for statistical analysis.

Volatile compounds of raw patties (n = 1/batch/treatment) were analyzed by using an electronic nose (Heracles Neo e-nose, Alpha MOS, Toulouse, France) containing an autosampler. Compounds were tested using flash gas chromatography throughout the e-nose evaluation. Under a laboratory fume hood, 2.00 g of each patty was weighed and transferred into 20 mL e-nose vials. Vials were agitated at 500 rpm with a 50.0 ◦C incubation temperature for 20 min in the autosampler incubator to generate volatiles for headspace analysis. After incubation, the autosampler injector inserted 5000 mL of the headspace gas at 125 mL/s to concentrate the odor inside the trap. Trapping condition was maintained at 40.0 ◦C for 50 s. Hydrogen gas was used at a 1 mL/min flow rate to carry the volatile components into the non-polar (MXT-5) and polar (MXT-1701) capillary columns for chromatographic analysis using a parallel, two-flame ionization detector (FID1 and FID2). Both columns were 180 mm in diameter and 10 m long. Final temperature of the analysis sequence was increased to 250 ◦C at 1 ◦C/s temperature increments from the initial 40.0 ◦C temperature according to described methods [24]. Peaks of the chromatogram were identified by comparing the retention time of each compound with their corresponding retention indices.

2.7 Consumer Testing for Ground Beef Patties

Consumer panelists older than 18 years with a preference for consuming ground beef at least 3 to 4 times per month were recruited from the faculty, staff, and student body at Auburn University (Table 3). Prior to conducting consumer panel activities, Auburn University Institutional Review Board (IRB) approved the exempt use of human panelists for this study

(Exempt Protocol Number 23-524 EX 2310). Treated ground beef patties with different inclusion rates of beef heart were evaluated by consumers (*n* = 96). Panelist serving order was computed using RedJade software (version 6.1, Pleasant Hill, CA, USA) so that panelists would evaluate random samples masked with 3-digit codes. Ground beef patties (*n* = 3/batch/treatment) were cooked to an internal temperature of 71.1 ◦C and cut into triangular samples (*n* = 4/patty) according to American Meat Science Association guidelines [20]. Cooked samples were presented randomly to the panelists in the isolated sensory booths under normal color-masked lighting. Panelists were instructed to use saltine crackers (Great Value Unsalted Tops, Walmart Inc., Bentonville, AR, USA) and room temperature water as a palate cleanser between each sample. Consumer panelists evaluated their first impression of "overall liking" of the samples on a 9-point hedonic scale (1 = dislike extremely; 9 = like extremely).

2.8 Statistical Analysis

Data were analyzed using the MIXED model procedures of SAS (version 9.2; SAS Inst., Cary, NC, USA) as a randomized complete block design. Random effects included batch and error, while treatment was the lone fixed effect. Least squares means were computed for all variables. Orthogonal contrasts were used to compare beef heart inclusion at any rate to the control (beef heart vs. no beef heart) in ground beef patties. When significant ($p \leq 0.05$) F-values were observed, least squares means were separated using pairwise *t*-tests (PDIFF option).

3. Results & Discussion:

3.1. Cook Time

The cooking time of a product can be affected based on its size, water content, and cooking method [25]. The mean values for chemical composition presented in Table 2 are presented for reference only and for treatment definition. Rapid detection using NIR technology for chemical components suggests that the treatment formulations lacked wide ranges of variability among components of water, fat, and protein. Furthermore, the pH of patty formulations and cooking time for each treatment are presented in Table 4. There was a main effect of treatment on cooking time ($p = 0.0017$), with patties containing 6% or 18% added beef heart taking longer ($p \leq 0.0941$) to reach an internal cooked temperature of 71.1 ◦C compared to patties containing 0 and 12% inclusion of beef heart. Griddle temperature, the moisture content of meat, and the thickness of the meat product may alter thermal properties when cooking meat proteins. It has been previously reported that ground beef patties containing an additional source of protein require longer cooking times than patties without added protein sources [26]. It is plausible that the added protein within the ground beef patties resulted in a greater concentration of moisture content within the protein fraction of the beef patty, therefore resulting in a greater need for heat for denaturation during the cooking period. However, the reduction in cooking time and cooking loss for beef patties containing 12% beef heart is unknown, but possibly linked to a slight increase in moisture and a reduced quantity of fat, as measured by NIR compositional analysis. Surprisingly, orthogonal contrast analysis of beef patties containing heart inclusion indicated that the cooking parameters of beef heart patties did not differ in terms of cooking time from control patties ($p = 0.1325$). Unfortunately, previous studies describing beef patty formulations with by-products such as beef heart are limited.

3.2. Cook Loss

Cooking loss, which can often be overlooked, identifies the loss of product through the cooking process of thawing, dripping, or evaporative losses [27]. Greater cooking losses can result in large financial impacts on the food service industry [27]. Differences in cooking loss among patties are presented in Table 4. The main effect of treatment on cooking loss was impacted ($p = 0.0001$) by the inclusion of beef heart in ground beef patties. Ground beef patties formulated with 6% heart had greater cooking losses ($p \leq 0.0005$) compared to patties formulated with 12 and 18%, but did not differ ($p = 0.0725$) from 0% control patties. Contrastingly, patties formulated with 18% beef heart exhibited similar cooking losses to the control ($p = 0.0782$) patties. Beef patties formulated with 12% beef heart had the least amount of cooking loss ($p \leq 0.0110$) in comparison to the control and other inclusion rates. Orthogonal contrasts pooling all treatments with the inclusion of beef heart within patties exhibited no overall difference ($p = 0.0803$) in cooking loss when compared to control patties. It is well known that cooking losses can be attributed to several factors such as cooking duration, the thickness of the patties, moisture content, and even fat quantity. Cooking losses for beef patties in the current study align with foundational results for cooking losses associated with whole-muscle and ground beef products from the previous literature [28].

3.3 Texture Analysis

There was a main effect of treatment ($p = 0.0001$) on the objective tenderness of patties with varying inclusion rates of beef heart. Patties formulated with 6% beef heart had the greatest ($p < 0.0001$) AKSF compared to all other patty treatments (Table 5). Variations in objective tenderness suggest that tenderness may have been driven by cooking and moisture losses rather than beef heart inclusion. The current results for objective tenderness coincide with the increase in moisture loss and cooking time across treatments, as reported in formulation means (Table 2). Patties containing 18% beef heart had lower AKSF values in comparison to either control ($p = 0.0055$) patties or patties containing 6% ($p < 0.0001$) added beef heart. AKSF values for patties containing 12% and 18% beef heart were similar ($p = 0.2955$). Evaluating tenderness using an orthogonal contrast across all treatments indicates that there was no difference in objective tenderness values between patties with beef heart inclusion and control ($p = 0.1801$) patties. Object tenderness values can be correlated to sensory taste anchors of texture, and surprisingly, objective values tend to align with consumer panel ratings for texture. Consumer panelist ratings did not differ but numerically were greater for patties formulated with 6% beef heart. Changes in objective and subjective tenderness can be a result of greater connective tissue, increased moisture losses, a reduction in fat quantity, and even the cooking method. Previously, a study evaluating varying fat levels of ground beef reported that objective tenderness values did not differ between regular and lean samples; however, extra-lean (less fat) ground beef required more force to shear [29]. Retailer offerings of ground beef are often presented as regular, lean, and extra-lean based on the actual fat percentage. It is well documented that the quantity of fat within a meat product, especially ground beef, can have an indirect relationship with the tenderness of a product. As a meat product is cooked and the fat within the meat reaches a melting point, cooking losses will alter cooked yields and subsequently objective tenderness [30]. In addition, a greater shear force is correlated with a reduced fat content in a meat product [31]. Dissimilar to the current study, beef heart was used to create surimi and used in the formulation of frankfurters [32]. Frankfurters containing greater percentages of beef heart surimi were characterized as more tender by sensory taste panelists [32]. Additionally, this same study reported lower values of AKSF, and TPA hardness and cohesiveness for the frankfurters containing the greatest amount of heart surimi. Previous studies suggest that using heart as a source of raw materials can reduce objective tenderness values, which is supported by the current results [32].

Texture profile analysis (TPA) was conducted to measure the textural values of the beef patties (Table 5). Springiness did not differ regardless of treatment ($p = 0.5974$). Hardness of the beef patties is represented as the force necessary to achieve sample deformation [33]. Orthogonal contrasting reported that patties containing beef heart (6, 12, and 18%) were harder ($p = 0.0030$) compared to control beef patties (0%). Moreover, patties containing beef heart had a greater hardness value ($p \leq 0.0478$) compared to the control. The previous liter- ature evaluating texture profile analysis and Warner–Bratzler shear force suggests that both TPA and Warner–Bratzler tests provide different parameters for measuring objective ten- derness [34]. TPA can be considered more useful in measuring the sensory texture of meat than the Warner–Bratzler method, but both objective measures provide a similar result [34]. Chewiness was numerically greater for patties containing 6% beef heart ($p = 0.0408$); how- ever, there was no treatment main effect difference ($p = 0.1721$). Additionally, using an orthogonal contrast for beef heart treatments versus the control, chewiness increased with beef heart inclusion ($p = 0.0316$). A main effect of treatment was detected for cohesiveness ($p = 0.0002$), with 6% inclusion of beef heart having greater cohesiveness compared to all treatments ($p \leq 0.0234$). Springiness is related to the recovery of the sample after the first cycle and in between the second cycle, as well as the viscoelastic properties [35]. The current results indicate no significant change throughout each treatment, summarizing that beef heart inclusion does not affect the springiness ($p = 0.5974$) of a sample, but it does provide better resilience of the product ($p = 0.0002$). Lastly, orthogonal contrasts pooling all three treatments for beef heart compared to control patties indicate no difference in springiness ($p = 0.5291$) or cohesiveness ($p = 0.6379$). These results suggest that heart inclusion can impact certain textural profile traits. Objective measures for beef patties provide further support that adding protein by-products may alter textural properties that can be detected by consumers.

3.4 Instrumental Color and Spectral Values:

Cooked meat color is dependent on the denaturation stage of the myoglobin protein [36]. Denaturation of myoglobin occurs through heat, and the endpoint cooking temperature can alter the amount of denaturation along with the internal color of cooked patties. The previous literature suggests that raw material formulation used in the manufacturing phases of ground beef may contribute to altering the internal cooked color regardless of the endpoint temperature [26,36,37]. The current results (Table 6) suggest that patties containing beef heart were redder internally than control (0%) patties when looking at the treatment main effect ($p = 0.0003$). Meanwhile, an exploration involving the incorporation of value-added vegetable proteins in ground beef patties reported that the inclusion of vegetable proteins did not affect the cooked CIE L* values of ground beef patties [26]. In agreement with previous results, there was no significant difference ($p = 0.2088$), regardless of treatment, for lightness (L*) among beef patties. However, beef patties containing 6% and 12% beef heart had greater ($p \leq 0.0378$) yellowness (b*) values than control patties or patties containing 18% beef heart. Nonetheless, lightness and yellowness values did not significantly differ in an orthogonal contrast of beef heart samples versus the control. However, indications of internal redness such as a*, red-to-brown color change, hue angle, and vividness were greater ($p = 0.0014$) for all patties containing beef heart compared to control patties, illustrating the impact beef heart inclusion has on cooked color values. Adding beef heart to the formulation of ground beef may have increased the total quantity of myoglobin, hence the greater objective results for redness values of a*, hue angle, and red-to-brown color change. Unfortunately, the total myoglobin of fresh and cooked patties was not measured. Additional research should elicit results confirming that the inclusion of beef heart may alter total myoglobin quantity when incorporated into a ground beef formulation.

3.4 Electronic Sensory Testing:

Electronic instruments such as the e-nose and e-tongue are used to evaluate the quality and sensory attributes of food. Rapid analysis instruments such as the e-tongue and e-nose have been designed to measure and mimic the sense of smell, taste, and vision [38]. Applications have included evaluating the wholistic quality and shelf-life of fresh meat in addition to adulteration detection [38]. The literature has reported that the electronic tongue can aid in determining shelf life, the wholesome quality of a product, and the detection of adulterated products [38,39]. Using various levels of chicken and pork mixed with mutton, the electronic tongue correctly identified samples containing various levels of adulterated chicken or pork [39]. The current results concluded that the e-tongue was able to detect differences among beef patties with or without beef heart within the formulation (Table 7). The e-tongue results represent the mean percent of relative standard deviation (%RSD) for each sensor. The mean values for the sensors within the current study ranged from 0.31% to 4.00%, and based on previous results, the document literature suggests that lower %RSD values are indicative of greater analytical precision [40]. Electronic tongue values for sourness increased ($p = 0.0001$) and were greatest for patties containing 12% and 18% beef heart, whereas saltiness was greater ($p = 0.0086$) for beef patties containing 12% and 18% beef heart. It is plausible that a greater concentration of beef heart inclusion may impart greater quantities of measured sodium within the beef patties when using electronic detection methods such as the e-tongue. The current results for sourness and saltiness are similar to a study where electronic tongue measurements of vegetable protein in ground beef patties increased [41]. Umami is often the one sensory anchor associated with beef products but difficult to detect using subjective measures. Umami values measured with the e-tongue were greater in patties containing 12% and 18% added beef heart ($p = 0.0001$) when compared to 6% and control beef patties. Moreover, treatment main effect values show significance in saltiness ($p = 0.0086$) and umami ($p = 0.0001$), suggesting the effect that beef heart inclusion has on samples. However, using orthogonal contrasts suggests that beef heart patties did not differ in saltiness ($p = 0.4472$), bitterness ($p = 0.4932$), or umami ($p = 0.0748$) compared to control patties. The e-tongue values suggest that the technology can distinguish differences among samples. However, the technology remains relatively new and iterations through development may lead to improved and quicker detection of meat quality parameters linked to subjective measures such as consumer and trained sensory evaluation. Additional research is needed to quantify the use of rapid analysis methods such as the e-tongue and the subsequent correlation with consumer taste panel responses.

Additionally, the electronic nose was explored to identify meat volatiles that are present within the beef patty treatments (Table 8). Electronic nose instruments are con- structed to differentiate samples by measuring headspace volatiles. It has been documented that aldehydes and alcohols can be used to assess the oxidative state of a meat or food product or to identify the presence of microbes [42]. In the current study, 24 volatiles were repeated at least two times among sample replicates of beef patties. Volatile compounds have been reported within the literature to contribute to the aroma profile of meat and to ultimately influence flavor perceptions by sensory panelists [43]. Volatiles that are commonly related to meat include tridecanal, a distinctly beef-like aroma compound and constituent of species flavor, and 2,3-Octanedione, which is a result of lipid oxidation and creates a warmed-over flavor [44]. It has also been reported that another key volatile of cooked beef includes N-nonanal [45]. N-nonanal was present in all beef patties among all treatments within the current study, as expected for cooked beef. Additionally, volatiles butanol and propanal have been linked to dry-cured hams and subsequent lipid oxidation [46,47]. Overall, there was a variety of volatile compounds identified within the beef patties, confirming that the use of electronic technology such as the e-nose can be applied to measure compositional characteristics in beef products. Recorded volatiles within the patties that differed significantly represent volatiles that have been successfully measured within the documented literature [44–47]. The use of the electronic nose is promising for the meat and food industry as a rapid technique to evaluate food products. In a preliminary study, the electronic nose detected meat adulteration of uncooked and cooked ground beef with the inclusion of pork at various percentages [48]. It appears that technological developments such as the electronic nose may be used to separate or identify adulterated meat or food samples. However, additional testing of electronic and rapid methods for determining quality differences linked to sensory anchors should be conducted.

3.5 Consumer Panel:

Subjective evaluation of sensory characteristics by consumer panelists was conducted to highlight hedonic ratings of beef patties formulated with added beef heart (Table 9). A main effect of treatment was detected ($p = 0.0002$) on overall liking by the consumer panelists. Consumer panelist ratings for overall liking were greater ($p \leq 0.0196$) for beef patties with either

0% or 6% added beef heart compared to either 12% or 18% beef heart inclusion. Interestingly, consumer panelists identified that there were no differences ($p = 0.0955$) in the overall texture among patties across all treatments. Overall, there was not a significant difference in orthogonal contrasts for appearance ($p = 0.4605$), aroma ($p = 0.4679$), flavor ($p = 0.2184$), or texture ($p = 0.3829$), regardless of treatment. It appears that using orthogonal contrasts improved our understanding of the effects on inclusion of beef heart as consumer panelist ratings based on overall liking differed when patties contained beef heart. Consumer ratings and orthogonal contrasts suggest that consumer panelists could not accurately identify patties containing beef heart for anchors of appearance, aroma, flavor, or texture. Sensory taste and objective tenderness results suggest differences in beef patty formulations, but the detectable ranges vary. A previous study evaluating rice by-product as an ingredient in the formulation of chicken patties reported no difference in consumer preference between the control sample and the treatment that contained the least amount of rice bran [49]. Adding ingredients to a meat block may have limits that are easily detectable when the inclusion rate exceeds flavor and textural preferences of consumer panelists. Notably, there was a distinguishable difference in the characteristics of meat patties that had greater inclusion rates, as the values for consumer acceptance declined [49]. Furthermore, the current results agree with previous findings that consumer testing of taste and visual characteristics can be a determining factor in the success and acceptance of a new product [50].

4. Conclusion:

Creating value-added beef patties using alternative proteins such as beef heart appears to show promise based on the current findings. The characteristics of meat quality are altered; it is estimated that 18% beef heart would reduce beef patty manufacturing costs by 10% per pound. Although the results suggest that consumer panelists can detect differences in sensory attributes, the patties containing 6% beef heart had the greatest numerical values in all sensory areas, suggesting that adding 6% or less of beef heart might be a viable option. The inclusion of beef heart exceeding 6% does alter the texture, cooked color, and sensory attributes of the beef patty, but this study could be a starting point for new product development. Technology such as the e-nose and e-tongue may provide new information regarding meat quality measurements, but additional testing and correlation with sensory taste and objective texture measurements are needed. Overall, with further research incorporating a variety of meats at a low inclusion percentage, this option could continue to prove viable as an alternative protein source for red meat consumers.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

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TABLES & FIGURES

Table 1. Treatment and patty allocation for ground beef patties with or without heart inclusion.

Treatment	Lean Trimmings	Beef Heart	Batch[1] (kg)	Patties/Batch[1]	Total/Treatment
1	100% Ground Chuck	0.00%	14.97	65	195
2	94% Ground Chuck	6.00%	14.97	65	195
3	88% Ground Chuck	12.00%	14.97	65	195
4	82% Ground Chuck	18.00%	14.97	65	195

[1]Three batches per treatment were manufactured and patties allocated randomly within each batch for analysis.

Table 2. Relative mean values for proximate analysis and ultimate pH of beef patties with or without heart inclusion

TRAIT	0%	6%	12%	18%
pH	5.76	5.80	5.81	5.95
MOISTURE (%)	65.52 ± 1.52	65.49 ± 1.02	66.86 ± 0.69	65.04 ± 1.12
PROTEIN (%)	23.80 ± 0.56	24.14 ± 0.85	24.47 ± 0.26	24.04 ± 0.68
FAT (%)	17.86 ± 2.06	17.52 ± 1.60	15.74 ± 0.68	18.61 ± 1.65

Table 3. Consumer sensory panel frequency demographics

	Respondents	Percentage
Sex		
Male	54	58
Female	43	41.9
Age		
Less than 20 y	6	6.5
21 to 29 y	56	60.2
30 to 39 y	19	20.4
40 to 49 y	6	6.5
50 to 59 y	3	3.2
60 to 69 y	2	2.2
Ethnicity		
Caucasian	51	54.8
Latino/Hispanic	18	19.3
Asian or Pacific Islander	13	13.9
African American	7	7.5
Prefer not to respond	2	2.1
Other	2	2.1
Income		
Less than $30,000	70	75.2
$30,000 to $49,999	6	6.5
$50,000 to $70,999	5	5.4
Greater than $80,000	9	9.7
Consume Beef Patties		
Once a day or more	2	2.2

More than 3 times per week	8	8.6
2 to 3 times per week	22	23.7
Once a week	22	23.7
2 to 3 times per month	24	25.8
Once a month	14	15.1
Less than once a month	1	1.1
Purchase Beef Patties		
Once a week	14	15.1
Once every 2 or 3 weeks	28	30.1
Once a month	26	27.9
Once every 2 or 3 months	14	15.1
Once every 4 to 6 months	4	4.3
Once or twice a year	2	2.15
Less than once a year	2	2.15

Table 4. Evaluation of cooking loss and cooking time of ground beef patties with or without beef heart inclusion.

	TREATMENT						
	0%	**6%**	**12%**	**18%**	SEM*	p Value	Contrast[1]
COOKING TIME (s)	713.58[b]	752.24[a]	702.69[b]	736.74[a]	10.122	0.0017	0.1325
COOKING LOSS (%)	34.36[ab]	35.06[a]	32.65[c]	33.66[b]	0.381	0.0001	0.0803

[a–c] Mean values within a row lacking common superscripts differ ($p < 0.05$). *SEM, Standard error of the mean. [1]Orthogonal contrast: beef heart vs. control.

Table 5. Objective tenderness values for beef patties with or without heart inclusion.

TRAIT	0%	6%	12%	18%	SEM*	p Value	Contrast[1]
AKSF (N)	261.88^{b}	312.75^{a}	250.46^{bc}	243.68^{c}	4.934	0.0001	0.1801
HARDNESS (kg)	4.45^{a}	5.04^{b}	5.44^{b}	5.02^{b}	0.216	0.0102	0.0030
SPRINGINESS[2]	1.63	1.69	1.63	1.85	0.132	0.5974	0.5291
COHESIVENESS[3]	0.44^{b}	0.48^{a}	0.42^{bc}	0.41^{c}	0.0100	0.0002	0.6379
CHEWINESS[4]	3.10	4.04	3.79	3.89	0.3338	0.1721	0.0316
RESILIENCE[5]	0.208^{a}	0.216^{a}	0.187^{b}	0.180^{b}	0.0060	0.0002	0.0467

$^{a\text{–}c}$ Mean values within a row lacking common superscripts differ ($p < 0.05$). * SEM, Standard error of the mean. [1] Orthogonal contrast: beef heart vs. control. [2]Values for springiness (ratio of the time duration of force input during the second compression to that during the first compression or Length 2/Length 1) [3] Values for cohesiveness (ratio of the positive force area during the second compression to that during the first compression Area 2/Area 1). [4]Chewiness = hardness x cohesiveness x springiness. [5]Values for resilience (ratio of the time duration of force input to positive force input during the first compression or Area 5/Area 4)

Table 6. Instrumental cooked color of beef patties with or without heart inclusion

	TREATMENT						
	0%	**6%**	**12%**	**18%**	SEM*	p Value	Contrast[1]
L*[2]	55.02	55.11	54.78	54.18	0.403	0.2088	0.3951
a*[3]	15.86[b]	17.54[a]	18.59[a]	17.92[a]	0.478	0.0003	0.0001
b*[4]	18.93[b]	19.55[a]	19.49[a]	18.95[b]	0.215	0.0217	0.0642
CHROMA[5]	50.41[a]	48.55[b]	46.85[c]	46.88[c]	0.651	0.0001	0.0001
HUE ANGLE (°)[6]	24.61[b]	26.38[a]	27.04[a]	26.15[a]	0.438	0.0006	0.0001
RTB[7]	1.84[b]	2.06[a]	2.22[a]	2.15[a]	0.077	0.0014	0.0003

[a-c] Mean values within a row lacking common superscripts differ ($p < 0.05$). *SEM, Standard error of the mean. [1]Beef heart vs. control. [2]L* Values are a measure of darkness to lightness (larger value indicates a lighter color); [3]a* values area measure of redness (larger value indicates a redder color); and [4]b* values are a measure of yellowness (larger value indicates a more yellow color). [5]C* (Chroma) is a measure of total color (larger number indicates a more vivid color). [6]Hue angle (°) represents the change in color from the true red axis (larger number indicates a greater shift from red to yellow). [7]RTB is the reflectance ratio of 630 nm ÷ 580 nm and represents a change in the color of red to brown (larger value indicates a redder color).

Table 7. Mean relative standard deviation (%RSD) of ground beef patties with or without heart inclusion measured by Alpha MOS e-tongue.

SENSORS	TREATMENT						
	0%	**6%**	**12%**	**18%**	SEM*	p Value	Contrast[1]
Sourness	0.59[c]	0.76[b]	1.03[a]	0.92[a]	0.455	0.0001	0.0001
General	1.78	1.78	1.92	1.93	0.093	0.4844	0.3552
Saltiness	1.63[bc]	1.11[c]	2.32[a]	2.08[ab]	0.234	0.0086	0.4472
Umami	1.85[b]	1.11[c]	3.28[a]	2.73[a]	0.239	0.0001	0.0748
Bitterness	0.32	0.47	0.28	0.44	0.083	0.3626	0.4932

[a-c] Mean values within a row lacking common superscripts differ ($p < 0.05$). %RSD = (standard deviation ÷ χ) × 100. *SEM, Standard error of the mean. [1] Orthogonal contrast: beef heart vs. control.

Table 8. Volatile compounds (relative area) measured using an electronic nose (e-nose).

Group/compound	Treatment 0%	6%	12%	18%	Sensory Descriptors[1]	SEM*	p Value	Contrast[2]
Alcohol								
ethanol	2.17	2.17	2.30	2.68	Alcoholic	0.160	0.1017	0.4611
n-butanol	1.55	0.85	0.64	0.88	Fermented	0.224	0.0681	0.0681
heptan-2-ol	0.55	0.85	1.32	0.94	Fatty	0.134	0.2774	0.0131
2,3-Octanedione	1.37[ab]	1.24[b]	1.57[a]	1.59[a]	Aldehydic	0.085	0.0165	0.3332
Glycerol	0.25	0.18	0.23	0.19	Almond	0.036	0.5654	0.3875
Butanethiol	0.27[a]	0.19[b]	0.14[c]	0.18[d]	Sulfurous	0.009	0.0005	0.0024
Aldehyde								
propanal	7.8	6.31	6.15	6.02	Etheral	0.911	0.4502	0.1171
n-nonanal	0.52[ab]	0.48[ab]	0.52[b]	0.54[a]	Tallowy	0.066	0.0103	0.9620
tridecanal	0.22[a]	0.19[ab]	0.12[a]	0.21[ab]	Aldehydic	0.181	0.0056	0.3308
3-Methlybutanal	2.23	2.09	1.64	1.11	Green	0.259	0.0631	0.1030
Alkane								
Hexane	4.37	2.70	2.50	2.03	Alkane	0.522	0.1946	0.0497
4-Methylheptane	0.4[a]	0.36[ab]	0.28[a]	0.28[a]	-	0.082	0.0057	0.37103
Ketone								
Butane-2, 3-dione	31.10[a]	18.46[b]	16.02[b]	32.21[a]	Butter	3.435	0.0294	0.0569

Acetoin	0.64	1.65	4.07	2.86	Sweet	1.003	0.1971	0.1902
Butan-2-1	28.16[a]	23.53[ab]	21.34[ab]	17.44[b]	Pungent	2.456	0.0195	0.0188
Other								
Carbon disulfide	76.31	85.56	87.7	148.82	Aromatic	18.565	0.0924	0.2025
Methyl butanoate	664.31	1327.87	1592.42	1590.85	Ester	177.055	0.0708	0.0708
Dibromochloromethane	26.66[b]	34.13[a]	42.49[a]	36.11[a]	Sweet	2.931	0.0326	0.0010
1,2 - Benzenediol	0.25	0.21	0.17	0.18	Faint	0.032	0.4632	0.1202
1-Chloropentan	1.53	4.74	5.06	5.16	Green plant	0.460	0.0726	0.0343
E-2-Pentenal	0.48	0.37	0.34	0.39	Apple	0.036	0.0813	0.0126
1-Penten-3-1	0.62[abc]	0.21[d]	0.65[b]	0.71[a]	Fishy	0.546	0.0013	0.2416
P-menthatriene	0.41	0.42	0.54	0.51	Woody	0.118	0.7902	0.5060
p-mentha-dien-hydroperoxide	83.23	82.96	82.95	83.18	Turpentine	0.128	0.3686	0.0001

[a–d] Mean values within a row lacking common superscripts differ ($p < 0.05$). * SEM, standard error of the mean. [1] Sensory descriptor from AlphaSoft (version 7.2.8, Toulouse, France) Software Library. [2] Orthogonal contrast: beef heart vs. control.

Table 9. Consumer panel rating of ground beef patties

	TREATMENT					
Sensory Anchor[1]	**0%**	**6%**	**12%**	**18%**	p Value	Contrast[2]
OVERALL LIKING	6.79[a]	6.89[a]	6.15[b]	6.37[b]	0.0002	0.0367
APPEARANCE	7.04[a]	7.28[a]	6.59[b]	6.90[ab]	0.0055	0.4605
AROMA	7.01[a]	7.19[a]	6.62[b]	6.89[ab]	0.0254	0.4679
FLAVOR	6.47[ab]	6.73[a]	5.86[c]	6.12[bc]	0.0011	0.2184
TEXTURE	6.78	6.96	6.4	6.42	0.0955	0.3829

APPENDICES

APPENDIX A

DEMOGRAPHIC QUESTIONNAIRE

Q1- Please enter your age below:
Q2-Please select your gender below:

- Male
- Female
- Other

Q3- Please enter your email address below:
Q4- What is your highest level of education achieved

- Less than high School
- High School diploma or GED
- 2-year college degree
- 4-year college degree
- Graduate degree (Master's, Doctorate, etc.)

Q5- What is your ethnicity?

- White or Caucasian
- Hispanic or Latino
- Black or African-American
- Native American or American Indian
- Asian or Pacific Islander
- Other (please specify):
- Prefer not to respond

Q6-What is your income?

- Under $30,000
- $30,000 to $49,999
- $50,000 to $70,999
- Over $80,000

Q7- How often do you consume ground beef patties?

- once a day or more
- more than 3 times per week
- 2-3 times per week
- once a week
- 2-3 times per month
- once a month
- less than once a month

Q8- How often do you purchase ground beef patties?

- once a week or more often
- once every 2 or 3 weeks
- once a month/every four weeks
- once every 2 or 3 months
- once every 4 to 6 months
- once or twice a year
- Less often than once a year

APPENDIX B

SAMPLE QUESTIONNAIRE

Q1- How would you rate the **Overall Liking** of this sample?

- Dislike extremely
- Dislike very much
- Dislike moderately
- Dislike slightly
- Neither like nor dislike
- Like slightly
- Like moderately
- Like very much
- Like extremely

Q1-1-What, if anything, did you **like** about this product?

Q1-2-What, if anything, did you **dislike** about this product?

Q2-For each question below, please mark the box which best describes your opinion of the sample you just tasted.

	Dislike Extremely	Dislike Very Much	Dislike Moderately	Dislike Slightly	Neither Like nor Dislike	Like Slightly	Like Moderately	Like Very Much	Like Extremely
OVERALL APPEARANCE	@	@	@	@	@	@	@	@	@
OVERALL AROMA	@	@	@	@	@	@	@	@	@
OVERALL FLAVOR	@	@	@	@	@	@	@	@	@
OVERALL TEXTURE	@	@	@	@	@	@	@	@	@

APPENDIX C

ELECTRONIC NOSE ANALYSIS (E-Nose)

General notes: Prepare Alpha MOS Software by developing a test and naming each sample slot on the Heracles Neo e-nose.

For sample preparation:

1. Under a laboratory hood, weigh out 2.00g of sample into a 20mL e-nose vial.

2. Seal vials with airtight aluminum caps containing PTFE/silicon septum.

For analysis:

1. Place each vial into the holding tray of the e-nose device.

2. Wait for completion of analysis and gather results.

APPENDIX D

ELECTRONIC TONGUE ANALYSIS (E-Tongue)

General notes: Prepare Alpha MOS Software by developing a test and naming each sample slot on device. It is important to remember to add the cleaning steps into the autosampler configuration.

For sample preparation:

1. Gather samples for analysis.
    a. Samples can be raw or cooked.
2. Weigh 20.00g of each sample/treatment and set aside.
3. Combine previously weighed samples with 100ml of distilled water and homogenize for 30 seconds.
4. Place homogenized mixture into a centrifuge tube.
5. Centrifuge samples at 1500 x g for 5 minutes at room temperature.
6. Slowly pour centrifuged samples into a 500ml 0.45 µm PES filter.
7. Samples should be filtered with a vacuum to remove any excess solids.
8. Once filtered, samples should be poured into an e-tongue beaker.

For analysis:

1. Place samples into autosampler for analysis.
2. Prior to analysis, each sensor should be submerged into deionized water for 30 minutes.
3. The e-tongue system is equipped with #6 sensory array.
4. E-tongue analysis is repeated six times throughout the acquisition time for each sample.
5. In between samples, the sensors are submerged into beakers of distilled water for 10 seconds of cleaning to prevent cross-contamination between samples.