EFFECTS OF SODIUM AND POTASSIUM BICARBONATES ON THE PHYSIOCHEMICAL AND SENSORY PROPERTIES OF GROUND BEEF

by

TRACY LAUREN JAICO

(Under the Direction of Anand Mohan and Rakesh Singh)

ABSTRACT

This study examined the effects of sodium bicarbonate ($NaHCO_3$), potassium bicarbonate ($KHCO_3$) and NaCl in ground beef. The raw ground beef was mixed with $NaHCO_3$ (0.5%; 1.0%), $KHCO_3$ (0.5%; 1.0%) and/or NaCl (0.5%). The treatments were compared with modified food starch (2.0%) and potato starch (2.0%) in ground beef. The addition of the bicarbonates in the ground beef increased ($p<0.05$) its pH. The bicarbonates application increased the water holding capacity and produced a more adhesive and tender ground beef. The applications of bicarbonates influenced the raw ground beef retail display color causing a darker surface color over a seven-day period. Cooked ground beef with 0.5% salt was the hardest and chewiest according to texture analysis and Warner-Bratzler shear force tests. All the more, according to texture and sensory data, cooked ground beef with salt (0.5%) and $NaHCO_3$ (0.5%) was the least chewy and most tender product.

INDEX WORDS: Ground Beef, Sodium Bicarbonate; Potassium Bicarbonate, Texture Analysis, Warner-Bratzler Shear Force, Color Evaluation, Sensory Evaluation

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DEDICATION

I dedicate this master’s thesis to the entire Jaico family.

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CHAPTER 1

INTRODUCTION

Within the United States, ground beef is the most frequently consumed beef (USDA 2009). Globally ranks third in per capita consumption behind chicken and pork (Davis and others 2005). Ground beef is remarkably profitable because in 2002 the equivalent retail value of the U.S. beef industry was $60 billion. The value in 2011 then grew to $79 billion (Matthews and others 2010). Worldwide, approximately 20% of consumers use beef as their meat protein source (Davis and others 2005). Ground beef is an exceptional source of protein and provides copious amounts of vitamins and minerals, such as Vitamin B6, iron, zinc, and niacin (Brewer 2012). The ground beef can be transformed into different products such as hamburgers, meatballs, meat loaf, and beef stew cubes. Due to today's economic decline and rising food costs this versatility has become beneficial to the meat industry. It has influenced consumers to purchase inexpensive ground beef instead of steaks and roasts (Griffing and others 2012).

Salt and phosphate are common non-meat ingredients used in meat (Boles and others 1999) to create reconstructed meat products. However, applications of salt in reconstructed beef products may induce quality defects such as discoloration (Trout 1983). Non-meat ingredients tend to extract myofibrillar proteins, which are used to bind the restructured beef into desired meat products. Phosphates and bicarbonates tend to extract myofibrillar proteins from the muscle with NaCl and mechanical force to create a heat-set protein during cooking (Boles and and Shand 1998).

Some non-meat ingredients in ground beef are sodium bicarbonate ($NaHCO_3$) and potassium bicarbonate ($KHCO_3$). $NaHCO_3$ is a generally recognized as safe (GRAS) food ingredient and can be incorporated into any meat product. According to the USDA (2013), there is a limit of 0.5% of $NaHCO_3$ allowed in an injected solution for product formulation. The common name of $NaHCO_3$ is "baking soda" as its largest application is in baked goods for its ability to release carbon dioxide (CO_2) and utilization as a leavening agent. In many Asian cuisines, $NaHCO_3$ tenderizes meats as it is often mixed in with liquid marinades (Sultana and others 2009). It is popular in food products at levels of up to 2% for leavening, pH control, and taste or texture development (Corral and others 1988; Curran and others 1989).

Typically, $KHCO_3$ is used include being a leavening agent in baked goods, potassium supplement, the ability to control pH in food, and being a color preservative in food (Armand Products Company). Due to the beneficial nutritional attributes of $KHCO_3$ is commonly used in ruminant feed to act as a dietary supplement for the cattle. It has also acted as an antimicrobial and fungicide in fruits and vegetables (Mitre and others 2009). According to the FSIS direct list of safe and suitable ingredients used in the production of meat and poultry products, it is also used to remove feathers from poultry carcasses (USDA 2013). However, few studies have focused on the direct application of $KHCO_3$ in ground beef as a non-meat ingredient and texture enhancer.

NaCl, $NaHCO_3$, and $KHCO_3$ provide the ability to extract myofibrillar proteins. Within the myofibrillar proteins are actin and myosin and when extracted they create a sticky exudate. The sticky exudate allows for an increased binding ability and softer texture. This will permit for the creation of the various meat products such as hamburgers, meatballs, meat loaves, and beef soup cubes.

There has been limited research documenting the detailed physiochemical properties of $NaHCO_3$ and $KHCO_3$ as non-meat ingredients in ground beef and its function. Many other studies have utilized $NaHCO_3$ and $KHCO_3$ on various other types of meats such as sow loins and broilers. Therefore, the objectives of this research were to:

1). Investigate the pH, surface color, water holding capacity, metmyoglobin content, and instrumental textural properties of the bicarbonates in raw ground beef.

2). Evaluate the surface color, expressible moisture, cooked loss, and instrumental textural properties of cooked ground beef with sodium bicarbonate, potassium bicarbonate.

3). Analyze the sensory properties of the cooked ground beef incorporated with the bicarbonates and correlate it to the instrumental texture attributes.

4). Examine the effects of the bicarbonates in ground beef in comparison to common food industry non-meat ingredients, modified food starch and potato starch.

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CHAPTER 2

LITERATURE REVIEW

Ground Beef

Beef is a popular meat product eaten all over the world, ranking third in the world in consumption per capita compared to chicken and pork (Davis and others 2005). It is an excellent source of protein and provides copious amounts of vitamins and minerals such as Vitamin B6, iron, zinc, and niacin (Brewer 2012). Beef is a versatile food product as many Americans consume it in several forms such as steaks, ribs, hamburgers, beef stew cubes, and countless others as it can be added to any dish. Ground beef, sourced from beef trimmings, is taken from different locations on the carcass. It is placed through a grinder to mix the muscle and fat together (Mohan and others 2012). According to the Code of Federal Regulations (CFR sec. 319.15) (USDA 2013) ground beef must be made with frozen or fresh beef with or without seasoning, and must not contain more than a total of 30% fat. The best ratio of lean to fat ground beef is 80% to 20% and has been found that 80% lean to 20% fat ratio yields the optimal juiciness and flavor levels (Romas and others 2001). Ground beef is exceptionally profitable because in 2002 the equivalent retail value of the U.S. beef industry was $60 billion, which grew to $79 billion in 2011 (Matthews and others 2010). According to Davis and others, globally more than 20 percent of consumers utilize beef as their protein source (2005). Today's economic decline has directed meat buyers to purchase more ground beef instead of steaks and roasts**.** Customarily, ground beef has been used in replacement because of the flexibility in generating delectable and inexpensive meals. The low prices are definitely an essential factor to these positive attributes (Griffing and others 2012).

pH and Water Holding Capacity

pH and water holding capacity (WHC) are important factors for meat quality characterization. The pH of meat is important as it influences numerous quality factors including color, texture, cooking loss, and binding properties of comminuted and structured meats products (Dutson 1984). After slaughter, the pH of meat can differ due to the muscle's glycolytic potential. The ultimate overall pH in the meat ranges from 5.6-5.8 (Aberle and others 2001). During the postmortem period of meat, the pH drops because the lactic acid formation (Aberle and others 2001).

WHC is the ability of the inherent fluids within post rigor muscles to be chemically or physically held. It is an essential meat quality trait as it affects the yield during processing, retail display, nutrient retention, and the juiciness of cooked products (Kauffman and others 1994). It also impacts the texture, tenderness of cooked meat, and firmness of the raw meat (Aberle and others 2001). WHC is also used as a way to determine microbial quality (Jay 1967) and palatability (Miller and Harrison 1965) within muscle foods. In fresh raw meat poor, WHC results in a loss of moisture and product shrinkage or a decrease in weight (Aberle and others 2001). In packaged meat, accumulated moisture/purge is prevalent when its water capacity is low. High amounts of purge can lead to a dry product when cooked. Natural juices are lost while cooking due to drip and evaporation (Aberle and others 2001). There are diverse methods to measure the WHC of muscle foods. One method is the filter paper press method in which pressure at 10,000 psi is applied and afterwards the area of moisture emitted on the filter paper is measured (Dagbjartsson and Solberg 1972). Other WHC methods include electrical processes utilizing conductivity and resistance, optical methods utilizing reflectance and light scattering, and chemical methods utilizing protein solubility and NMR (Kauffman and others 1994). One of the most common methods used today is a centrifugal method in which high pressure (12,000 x g) is applied to the homogenized muscle product (Dagbjartsson and Solberg 1972).

The relationship between pH and WHC is significant as they affect the quality of the raw and cooked meat product. When the pH of the meat increases, it tends to impact the WHC. As the pH rises from 5.0 to 9.0, the WHC increases even more so. When the myofibrillar proteins within the meat reach its isoelectric point, the charges equalize, decreasing the WHC. As the pH rises, or the net charge becomes more negative, the filaments within the meat extend and provide more space for the water to be held. With the addition of phosphates, sodium and potassium bicarbonates, the meat pH will increase due to the alkaline nature in those non-meat binding ingredients (Puolanne and others 2001, Aberle and others 2001).

Alternative Non-Meat Ingredients

Sodium and Potassium Bicarbonate

Sodium bicarbonate ($NaHCO_3$) is a white, solid powder widely used in food. It is commonly known as baking soda and is used frequently in baked goods and as a leavening agent. However, it is not a common non-meat ingredient to use within ground beef. $NaHCO_3$ is added into ruminant feeds as a supplement and for buffering capabilities (Rauch and others 2012). In raw meat, it reduces shear forces, drip loss, and increases the yield of meat products because of its ability to retrain water at a high pH (Sultana and others 2008). $NaHCO_3$ is utilized at 2% in foods as a leavening agent, texture enhancer, and to control pH (Corral and others

1998). $NaHCO_3$ can be applied to an array of meat products. $NaHCO_3$ is a popular ingredient in Chinese food marinades (Sheard and Tali 2004). Another example included $NaHCO_3$ into broiler feed to maintain its diet. $NaHCO_3$ and $KHCO_3$ were added to the heat stressed broiler's diet to determine the optimum and practical range of bicarbonate supplementation (Hooge and others 1999). In beef *biceps femoris* muscle $NaHCO_3$ was added to determine its quality characteristics (Sultana and others 2008). Ham was injected with a $NaHCO_3$ solution to inhibit pale, soft, and exudative characteristics of pork (Wynveen and 2001). It was utilized in pork in conjunction with salt and phosphates to determine its effects on pH, yield, and texture (Sheard and Tali 2004). Sow loins were marinated with salt, sodium tripolyphosphate (0.50%), and $NaHCO_3$ (0.70%) and found as acceptable pork to consumers as it reduced atypical aromas and flavors (Sindelar and others 2003). $NaHCO_3$ was used as an antimicrobial to inhibit the growth of bacteria and yeast in agar media (Corral and others 1988). Since $NaHCO_3$ has been widely used within the past, the USDA has deemed it a GRAS (Generally Recognized as Safe) food additive. According to the USDA (2008), it can also be used in fresh pork and beef cuts to maintain the pH.

Due to the nutritional attributes of $KHCO_3$, especially potassium, it has often times been used in ruminant feed to act as a dietary supplement for the cattle (Schonewille and others 1999). It has also acted as an antimicrobial and fungicide in fruits and vegetables (Mitre and others 2009). $KHCO_3$ has been used in the past for plant protection within organic farming such as on apples to control Apple Scab a fungal disease (Mitre 2009). $KHCO_3$ is a safe product as it is a GRAS product (USDA 2013), and is safe by European Regulation (EEC 2091/92) (Mitre 2009). Some other applications of $KHCO_3$ include being a leavening agent in baked goods, a potassium supplement, a color preservative in food (Armand Products Company), and control pH in food.

The USDA has deemed it safe in order to adjust the pH in egg products and remove feathers from poultry carcasses (USDA 2013). Very limited to no studies have been performed to investigate the effects of $KHCO_3$ in slaughtered ground beef.

Both $NaHCO_3$ and $KHCO_3$ have been used in raw meat products because of their antimicrobial activity and buffering capacity. The meat pH will increase due to the alkaline nature in $NaHCO_3$ and $KHCO_3$. Few drawbacks do occur with these two bicarbonates. Unfortunately, an excessive amount of both can create a gritty texture and alkaline taste in the food products.

Salt

Generally sodium chloride (NaCl) is used as the salt component in meats. Salt is extremely popular in beef as it is one of the oldest forms of preservation dating back to 3000 B.C. (Romas and others 2001). Salt brings out the distinct taste of meat and enhances the flavor (Lemos and others 1999). Likewise it is an important factor in decreasing the cooking loss and to improve beef texture. When sprinkling on raw meat before cooking it will have a more concentrated taste (Ruusenen 2005). As the salt levels increase, saltiness is perceived more in fatty products than in lean. This is more obvious in the meat patties because, the one with a higher lean meat content required more salt to achieve the same salty perception than those of a low lean meat content. It is very effective at releasing volatile aroma compounds from food matrices especially steak as it alters the osmotic pressure and allows for the volatile compounds to be less soluble within that food matrix (Lawrie 2006). Salt also has the ability to extract the myofibrillar proteins within the meat, which binds to the fat and water and creates a sticky exudate. The salt aids in the ability for the fat and water to retain within the meat and therefore enhances flavor quality. Salt binds to the water molecules during the solubility process with the meat proteins (Lemos and others 1999). In that process, there is an increase in the release of flavor compounds. This is caused by a decrease in the availability of the water molecules to solubilize with the flavor compounds. Researchers have also changed the shape or form of salts in order to enhance the flavor in beef. Flaked or agglomerated forms of salt increase the meat protein functionality and taste when compared to the common granular shaped salt. The flaked or agglomerated forms of salt provided a sponge-like texture, larger surface area, and enhanced flavor (Aberle and others 2001). The aroma volatiles released in the air from the meat system increased and improved the ability of the protein in the tongue to perceive salt (Schilling and others 2008; Puolanne and others 2001). Other types of salt such as potassium chloride (KCl) are used but KCl is not as common due to its bitter notes. NaCl is used to tenderize the meat and improve the flavor. It increases the solubility of salt soluble proteins; therefore it improves water binding and water holding capacity of the meat tissue. This shows that salt has the great ability to bind beef together and create various meat products such as hamburgers, soup beef cubes, and meat loafs. It might also help in meat preservation by decreasing its water activity.

Phosphates

Phosphates are used to control pH, increase the water holding capacity, enhance the cook yield, and tenderness of the cooked meat. There are different types of phosphates used in meat products. Some examples include sodium acid pyrophosphate (SAPP), sodium tripolyphosphate (STPP) and sodium hexametaphosphate (SHMP). STPP is a very popular phosphate used in meat, as it is cost effective and soluble in water (Alvarado and McKee 2007). Phosphates increase the pH, which increases the negative net charge within the meat proteins and therefore increases its water holding capacity (Trout and Schmidt 1983). At high phosphate concentrations of approximately 0.4%- 0.5%, a strong metallic flavor can be detected.

Flour and Starches

Flour and starches can be applied to various sausage and meat loaf products to improve the food product's water binding capacity, moisture retention ability, texture and flavor, and decreases its formulation costs. Flour and starches are commonly used non-meat ingredients within the food industry. Popular sources of flour and starches are wheat, barley, corn and potato starch and modified food starch. The flour helps bind large quantities of water and starches to aid in improving its taste and textural characteristics (Aberle and others 2001; Shewry and Tatham 2000). Flours are shown to increase the yield and decrease product shrinkage in beef. However, they can provide undesirable flavors and even vary the beefs texture (Brewer 2012). Cereal fours, which are mainly comprised of starch, have been used as a binder to improve the cook yield and slicing capabilities. Few have incorporated cereal flours to help minimize the costs (Romas and others 2001). The addition of modified food starch to ground beef increased the juiciness and tenderness in low-fat patties without impacting flavor scores (Khalil 2000). It aids in reducing moisture loss in vacuum packaged meats, increases shelf-life, and consistency in meat products (Ingredion 2012). Potato starch at 2% in sausages with 15% fat had hardness scores comparable to sausages with 30% fat (Brewer 2012).

Meat Proteins

Meat is an excellent source of protein for the human diet. The proteins in the meat can be categorized into three different groups. They are sarcoplasmic, myofibrillar, and connective tissue proteins (Tornberg 2005, Verbeken and others 2005). Sarcoplasmic proteins are composed of myoglobin, albumin, haemoglobin, and enzymes. Myofibrillar proteins contain actin, myosin, titin, tropomyosin, troponin, and nebulin. Myosin and actin are the two must abundant proteins within the myofibrillar proteins (Aberle and others 2001). The two most abundant proteins are frequently extracted in high ionic strength buffers and therefore are soluble in salt solutions (Sun and Holley 2011). The extraction creates a sticky exudate allowing for an increased binding ability and softer texture. The myofibrillar proteins account for approximately 50%-60% of the total muscle protein content (Tornberg 2005; Wang and others 2005). The actin and myosin composition is approximately 20% and 45%, respectively, within the myofibrillar proteins (Aberle and others 2001). Gelation of the myofibrillar proteins normally occurs during the heating process, yet proteins can form gels at a lower pH in the absence of heat (Sun and Holley 2011). The third group, connective tissue proteins, consists of collagen, reticulin, sarcolemma and elastic fibers (Lawrie 2006; Aberle and others 2001;).

Meat Color

Color is an important factor in determining the quality of meat, especially in ground beef. It is essential to measure the surface color of raw meat and the internal color of cooked ground beef. The surface color of raw meat is important as many consumers utilize it as the deciding factor before purchasing it at supermarkets. More so, meat-purchasing choices are highly influenced by product appearance than any other quality factor as it denotes freshness (Tapp and others 2011).

Meat color is commonly measured spectrophotometrically using a colorimeter. The CIE $L^*a^*b^*$ scale is utilized to determine the color characteristics of meat color. L^*- values determines the lightness and darkness of the meat with a scale from 0 to 100. Zero yields black and 100 yields white tones. Positive *a**-values indicate red and negative values indicate green. Positive *b**- values indicate yellow and negative values indicate blue. Other color information can be calculated form *a** and *b** -values which are important for meat color evaluation, such as hue angle and Chroma (Tapp and others, 2011; AMSA 2012). Hue angle is calculated by the following equation: $\tan^{-1}(b^*/a^*)$ and is the progression of red color to yellow color. Larger hue angle values denote a lesser red meat product (AMSA 2012). Chroma is calculated by the following equation: $\sqrt{a^{*2} + b^{*2}}$ and denotes the saturation of color.

While placed in the display case, consumers prefer a bright cherry red color, in ground beef. The bright red surface color is caused by the myoglobin protein that is naturally found within the muscle. Myoglobin is a water soluble, monomeric globular heme protein with 150 amino acid residues (Livingston an Brown, 1981). Oxymyoglobin (OMb), Deoxymyoglobin (DMb), and metmyoglobin (MMb) are the three forms of myoglobin and frequently interchanges with each other (Zhu and Brewer, 2002). Those three forms of myoglobin are interchanged with each other through oxygenation and oxidation. Through these processes, different colors are generated (Figure 2). Once myoglobin is oxygenated or converted to OMb the meat color becomes a deep rich, cherry, bright, red color. This is deemed desirable to consumers. If the myoglobin in the meat loses oxygen or becomes DMb it becomes into a purple red color. When converted to MMb, the meat color becomes a brown color as myoglobin is oxidized and contains ferric iron (Fe^{3+}). This is commonly seen when the meat is heated and cooked. The proteins have denatured therefore exhibiting the cooked brown color. (AMSA, 2012; Zhu and Brewer 2012)

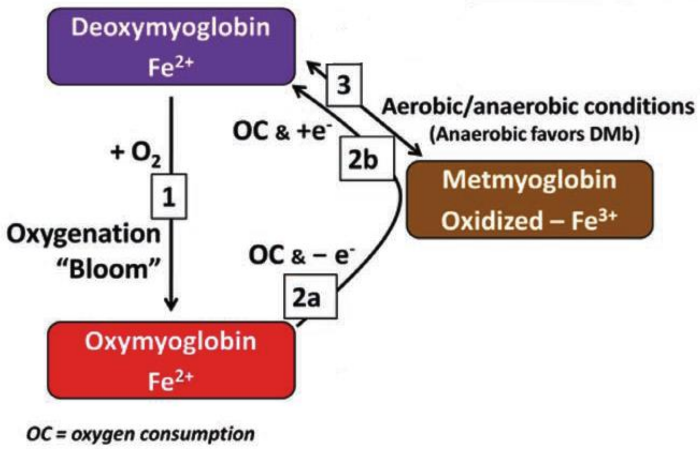

Figure 2.1: "Fresh Meat Color Triangle. Flow diagram of converted myoglobin forms in fresh meat (AMSA 2012).

For cooked beef, different internal colors can portray its doneness. At 130°F the meat is rare and the color is red throughout except for a small reddish pink layer under the surface. At 140 °F, the beef is rare with a red center and reddish to pink outer surface. A medium rare doneness produces a red to pink center, with a pink to light brown outer surface and heated to an internal temperature of 150 °F. A light pink center with a light brown outer surface has a medium doneness and heated to 160 °F. Well-done beef is cooked to 170 °F with a light brown center and contains a dark brown outer surface. Finally, at 180 °F, the beef is very well done, dry in texture with a charred outer surface and very dark brown throughout (Romas and others 2001; Tapp and others 2011). When myoglobin is cooked it will turn the meat color to brown as heat denatures myoglobin. Although evaluating the internal color of a ground beef patty is not a reliable method to determine if a patty is properly cooked to assure that a safe product is consumed, consumers are still influenced by the internal color of the cooked patty (van Laack and others 1996) Rather it is best to check the doneness of the meat product by measuring the internal temperature.

Texture Analysis

Texture is an essential aspect for meat products as consumers desire specific types of mouth feel when eating various meat products. It also provides a quantifiable and instrumental measurement of all foods. A compression probe is utilized to press down on the product twice to a specific product deformation percent strain. Texture profile analysis (TPA) is often used in ground beef as it is an overall texture analysis of the product and it shows how food is processed within the mouth. TPA measures an abundance of attributes but popular for meat characterization are hardness, springiness, adhesiveness, cohesiveness, gumminess, and chewiness of the ground beef (Bourne 2002). Figure 4.1 provides a typical force by time texture profile analysis of food products and a graphical representation of the texture attributes (Food Tech Corp). Hardness is the highest force during the first compression cycle or is the force required to deform the product between the molars and commonly done on the first bite (Food Tech Corp; AMSA 1983, AMSA 1995). Adhesiveness can be calculated by the negative area in the TPA graph for the first bite, representing the work necessary to pull the compression plate away from the meat sample (Food Tech Corp). Cohesiveness is the ratio of the first compression cycle area to the second compression cycle area. It is also the amount of food sample deforms instead of shearing (Meilgaard and others 2007). Springiness is the height that food recovers during the end of the first bite to the beginning of the second bite. Gumminess is calculated as the product of hardness and cohesiveness. (Meilgaard and others 2007, AMSA 1995, Food Technology Corporation) Chewiness is then calculated through the product of gumminess and springiness. In addition, chewiness is known for the number of required chews before swallowing (AMSA 1983) and the amount of work needed to chew the sample 15-25 times (USDA; AMSA 1995).

Shear Force is another aspect of texture analysis that is commonly performed on ground beef products. Shear force is the ability to cut through a food product and the action is normally done perpendicular to the longitudinal orientation of the muscle fibers. For ground beef or intact steaks, it is important to prepare the samples by coring the meat into small consistent cylinders. Warner-Bratzler Shear Force (WBSF) is a popular test performed on ground beef to measure tenderness and can be compared to sensory tenderness rating. A V-shaped blade is utilized to simulate the shearing motion on the ground beef. There are certain specifications for each food product but for ground beef products a crosshead speed of 250 mm per minute is the common speed on an Instron Universal Testing Machine (AMSA 1995). For WBSF, the shear force and work of shear is measured (AMSA 1995). This has become one of the most common procedures to objectively measure beef tenderness (Caine 2003). During testing, meat samples should uniform in size, weight and temperature. Room temperature is the optimal temperature to shear meat, as heated samples are not feasible. Cold meat samples are a little tougher (5%) than hot meat samples (Warriss 2000). Similar to TPA, a force over distance curve is created to measure the work of shear and shear force. Shear force is measured by the maximum force or peak in the curvature in which the meat is thoroughly cut (Miranda and Aguilera 2006). Work of shear or total shear work is the amount of force with a certain distance to shear the product, which is the area under the curve (Rothschild and Ruvinsky 2011). With meat products, high work of shear and shear force values, indicate it is more difficult it is to cut through the product. As the fat levels decrease in beef, it usually becomes less acceptable and appetizing (Berry and Leddy 1984; Cross and others 1980; Kregal and others 1986). This is especially true when it is reduced to 5-10%. As the fat in ground beef patties increase, researchers have discovered an increase in patty firmness, cohesiveness, crumbliness (Troutt and others 1992), and tenderness (Berry 1992;

Cross and others 1980). The shear force and total energy values declined (Berry and Leddy 1984; Troutt and others 1992) while texture profile analysis indicated lower peak forces, and less springiness and cohesiveness values (Berry and Leddy 1984; Troutt and others 1992).

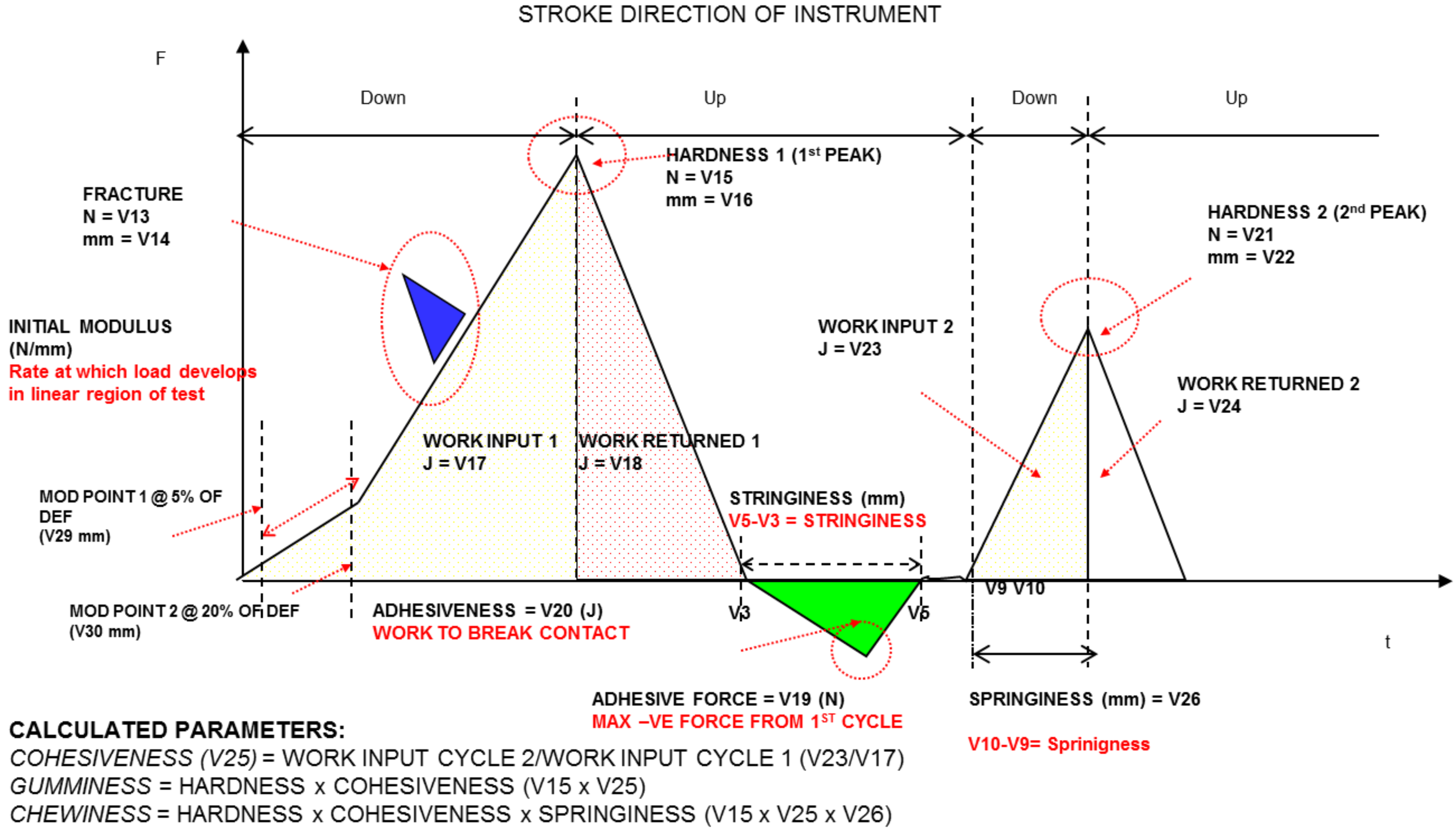

Figure 2.2: Typical Force by time texture profile analysis plot through two cycles of a tested product. Displayed is the description of the texture profile analysis attributes and the calculation of those characteristics (Food Technology Corporation).

Metmyoglobin Reducing Activity

Metmyoglobin reducing activity (MRA) is essential in meat quality characterization as it is a major factor impacting meat color. It is also a key test in fresh meat research studies, as higher amounts of metmyoglobin (MMb) often discolors the meat surface (Mancini and Hunt 2005), exhibiting a brown color that is not attractive to consumers. Therefore, it is important to test for and reduce MMb in order to lessen the undesirable appearance during retail display. The higher the MRA is within the meat, the greater its color stability (AMSA 2012). The metmyoglobin reducing activity is an intrinsic property in meat where a sequence of reactions help reduce MMb. The increase in MMb is due to the oxidation of myoglobin and ferric iron (Fe^{3+}) present in the meat. According to King and others (2011), MRA and oxygen consumption aid in color stability. Changes in these traits correspond to the degradation of lean muscle color. MRA is also an enzymatic pathway where Fe^{3+} in MMb reduced back to the Fe^{2+} state in the presence of the NADH (Renerre 1990). A few of the inherent factors within the meat muscle include oxygen scavenging enzymes, reducing enzyme systems, and the NADH pool. These inherent factors help give the muscle the ability to reduce from the MMb form and return to deoxymyoglobin (DMb) (Mancini and Hunt 2005). Bekhit and others (2003) reported that the reduction in the chemical state of iron in MMb is more dependent on the availability of NADH than MRA.

Figure 2 shows the visual forms of myoglobin and the conversions it undergoes. The initial and final % MMb to determine the MRA in ground beef, can be calculated through the following equation (AMSA 2012):

The % MMb and MRA (% of MMb reduced) was calculated using the following equation:

%MMb = *[K/S572 / K/S525* (for 100% DMb)]- [K/S572 / K/S525 (sample)]/ [K/S572 / *K/S525* (for 100% DMb)] - *[K/S572*/ K/S525 (for 100% MMb)] [x 100]

K/S= Absorbance and Scattering coefficient values for meat, respectively (Table C.2)

MRA (% of MMb reduced) = [(Initial %MMb - Final %MMb) -Initial %MMb] x 100

Sensory Perception

Sensory analysis is essential to meat science in order to evaluate the taste, texture, and quality of different meats. It is especially vital within the food industry, as numerous meat sensory properties are evaluated in order to determine the acceptability and preference of meats. These properties include the flavor, aroma, appearance and mouth feel and according to the guidelines for sensory, physical and chemical measurements in ground beef, these are essential for ground beef sensory analysis (AMSA 1983). The flavor and aroma is important, as consumers expect the raw and cooked meat to be fresh and meaty. Once cooked some off flavors include rancid, putrid, or warmed over flavor. Warmed over flavor is often attributed to lipid oxidation in beef producing an oxidized taste (Maughan and Martini 2012). It is often an off flavor found in refrigerated cooked meat (Cheng and Ockerman 2006). Appearance is important to meat consumers as they prefer the meat to be bright cherry red when purchasing in the grocery stores and when cooked it must be to their own liking. Fat, additives, and lean to fat ratio are other color appearance factors that must be considered (AMSA 1983). The visual texture appearance is measured in order to investigate particle size, the amount of connective tissue, and the condition of the surface such as marbling. Finally, mouth feel or texture is evaluated to determine the meat’s qualities of juiciness, tenderness, chewiness, cohesiveness, adhesiveness, and more. Testing the mouth feel allows food companies to mimic the way the consumer eats or chews the product. According to the American Meat Science Association (1995), juiciness is the amount of perceived juice released from the product during mastication and as fat is cooked and melted, it lubricates the muscle fibers. The optimal ratio of lean and fat percentages in ground beef and fat is 80% to 20%, respectively. Based on previous studies performed by researches, it was found that a fat content of 20% yields the optimal juiciness and flavor levels (Romas and others 2001).

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CHAPTER 3

EFFECTS OF SODIUM AND POTASSIUM BICARBONATES ON THE PHYSICOCHEMICAL PROPERTIES OF RAW GROUND BEEF [1]

[1]Jaico T, Mohan A. To be submitted to Journal of Food Science

Abstract

This study was designed to investigate the effects of sodium bicarbonate ($NaHCO_3$), potassium bicarbonate ($KHCO_3$) and NaCl alone or in combination, in raw ground beef. The raw ground beef was mixed with $NaHCO_3$ (0.5%; 1.0%), $KHCO_3$ (0.5%; 1.0%) and/or NaCl (0.5%) and the resulting treatment(s) were compared with modified food starch (2.0%) and potato starch (2.0%). The addition of the bicarbonates significantly increased ($p<0.05$) the pH of the raw ground beef and water holding capacity. The ability to hold water was greater with both starches ($p<0.05$). Metmyoglobin reducing activity decreased ($p<0.05$) with the application of salt, bicarbonates, and starches. The salt, bicarbonates, and combination of NaCl and bicarbonates ground beef impacted the *L**- values of the ground beef during retail display storage. The *a**- values decreased over seven days on display. The inclusion of bicarbonates, slightly decreased the *a**- values which displayed a lesser red product. Mixing the raw ground beef with bicarbonates increased the adhesiveness and decreased the hardness. Overall, this study suggests that the use of bicarbonates should increase the WHC due to the increased pH. The bicarbonates will produce raw ground beef that is more adhesive and softer in texture.

Keywords: Ground Beef, Sodium Bicarbonate, Potassium Bicarbonate, Sodium Chloride, Texture Analysis, Color Analysis, pH, Water Holding Capacity

Introduction

Beef is one of the most popular meat products in today's food market. In 2009, about 26.9 billion pounds of beef was consumed in the United States (Brewer 2012). The retail equivalent value of the U.S. beef industry in 2002 was $60 billion. The value then rose to $79 billion in 2011 (Matthews and others 2010). Beef is an excellent source of protein and provides numerous vitamins (B6 and B12), and minerals (iron, zinc, and niacin) to the consumer (Brewer 2012). Compared to other protein sources such as chicken and pork, beef ranks third in the world in per capita consumption (Davis and others 2005). Today's economic decline has led consumers to turn to ground beef instead of steaks and roasts. Traditionally, ground beef has been used in creating delicious and affordable meals in the United States and around the world. Its low cost is another additional factor to its positive attributes (Griffing and others 2012). Ground beef is produced from the trimmings that are commonly sourced from different cattle, makes the ground beef vulnerable of quality defects including microbial contamination (Mohan and others 2012). In order to maintain the interest and wide spread application of ground beef, meat industry use many non-meat ingredients including salt, phosphates, bicarbonates, and starches.

Salt and phosphate are common non-meat ingredients used in meat (Boles and Shand 1999) to create reconstructed meat products. However, applications of salt in reconstructed beef products greatly enhance quality defects and discoloration (Trout 1983). Non-meat ingredients tend to extract myofibrillar proteins, which are used for binding the restructured beef into a desired product. Myofibrillar proteins are extracted with phosphates, salt, and mechanical force. Once cooked the extracted myofibrillar proteins creates due to the heat (Boles and others 1998). Flour and starches are popular binders within the food industry. Common flours are wheat, barley and corn and its starches are potato starch and modified food starch. The flour helps bind large quantities of water and starches are added for its taste and texture characteristics (Aberle and others 2001; Shewry and Tatham 2000). Flours increase the yield and decreased the shrinking in beef. However, these can provide undesirable flavors and vary the beef's texture (Brewer 2012). Although these are common and useful binders used in ground beef products, effects of sodium and potassium bicarbonate as non-meat ingredients remains to be further explored in details.

$NaHCO_3$, commonly known as baking soda, is a GRAS (generally recognized as safe) food ingredient mainly used in baked goods as a leavening agent. Many Asian cuisines use $NaHCO_3$ to tenderize meats in the form of liquid marinades (Sultana and others 2009). It is also widely used in foods at levels up to 2% for leavening, pH control, and taste and texture development (Corral and others 1988; Curran and others 1989). $NaHCO_3$ has been used to increase the pH (Bechtel and others 1985) and water holding capacity in pale, exudative, and soft (PSE) textured meat products (Lawrie 2006).

Some common applications of $KHCO_3$ include being a leavening agent in baked goods, potassium supplement, the ability to control pH in food, and being a color preservative in food (Armand Products Company). Due to the nutritional attributes of $KHCO_3$, especially potassium it has often times been used in ruminant feed to act as a dietary supplement for the cattle (Schonewille and others 1999). It has also acted as an antimicrobial and fungicide in fruits and vegetables (Mitre and others 2009). According to the FSIS direct list of safe and suitable ingredients used in the production of meat and poultry products, it has been used for removing feathers from poultry carcasses (USDA 2013).

There has been limited research documenting the detailed physicochemical properties of NaCl, $NaHCO_3$, $KHCO_3$ and starches (modified food starch and potato starch) as non-meat ingredients in ground beef and its function. Therefore, the objective of this research was to: 1) investigate the pH, surface color, water holding capacity, metmyoglobin, and instrumental textural properties of sodium bicarbonate, potassium bicarbonate, salt, 2) and to evaluate the effects of the bicarbonates in ground beef in comparison with common food industry non-meat ingredients such as modified food starch, and potato starch.

Materials and Methods

Raw Materials

Fresh raw ground beef (80% lean; 20% fat) (±2%) was obtained from two local ground beef processors (FPL Foods, Augusta, GA and US Foods, Atlanta GA). The ground beef was kept frozen at -34°C until further tests were performed.

Chemicals

The ground beef was treated with different levels of NaCl (Food grade, Fisher Scientific, Fairlawn, NJ) distilled water, $NaHCO_3$ (Food grade, Fisher Scientific, Fairlawn, NJ) at, $KHCO_3$ (Food grade, Fisher Scientific, Fairlawn, NJ), potato starch (NOVATION® 6600, National Starch, Bridgewater, NJ), and modified dent corn food starch (PURE-GEL® B990, Grain Processing, Muscatine, IA). The overall formulation for each treatment and sample name abbreviations are is found in Table 3.1.

Ground Beef Preparation

The ground beef was mixed in a cold room at temperatures between 4 to 7°C. The ground beef was prepared to mimic a meat loaf type of product, sectioned into different containers of aluminum pans and then placed into aluminum tray pans (Wal-mart Stores, Inc., AR). Dimensions for the aluminum tray pans were 5.3” width x 7.8” depth x 1.75” height. Ground beef meat loafs and patties were used to perform the physical analysis. All ground beef treated samples were mixed according to the formula listed in Table 3.1. The non-meat ingredients (NaCl, $NaHCO_3$, $KHCO_3$, modified food starch and potato starch), were first diluted in water (10% dilution) to create a more homogeneous meat loaf product. Each sample was mixed in a Hobart mixer (Model C-100 T, The Hobart Mfg. Co., Troy, Ohio) and done in triplicate for better statistical analysis.

The ground beef sample was mixed with different formulations (Table 3.1) for about 10 seconds in a mixing bowl on speed 1 (144 RPM). The non-meat ingredients such as salt and water were added first followed with bicarbonates and mixed at successive rotational speeds in a Hobart mixer for different intervals of time. The NaCl and water solution were added at different time intervals. A portion of the treated ground beef was mixed in the following order on the following speeds: 1 minute on mixer speed 1 and, 2 minutes on mixer speed 2 (258 RPM), then for 1 minute three times on speed 3 (450 RPM). Next, the bicarbonate and salt diluted solutions were mixed into each respective ground beef assigned treatments. This was performed for 20 seconds on mixer speed 1. The mixer was turned off to scrape sides of the bowl. It was then mixed for 1 minute on speed 2, which was performed twice. For the last 30 seconds, the ground beef was mixed for the last time on mixer speed 2 and placed into their respective aluminum pan trays. Modified food starch and potato starch was mixed separately. The ground beef portion without any ingredients added, served as the control.

After the ground beef meat loaf samples were thoroughly mixed, a 2-pound portion was placed into an aluminum tray for texture profile analysis (TPA). Another two pounds of the treated ground beef was utilized to manufacture hamburger like patties (180g each). The patties were used to evaluate the surface color, metmyoglobin reducing activity, and water holding capacity. The aluminum trays with the treated ground beef were placed in large 11 x 22-inch polyvinylidene chloride (PVdC) barrier shrink vacuum package bags (Winpak, Winnipeg MB). The ground beef patties for metmyoglobin reducing activity and water holding capacity tests were placed in nylon polyethylene vacuum pouches (Prime Source International LLC, Westerville, Ohio). Both the vacuum packaged aluminum trays and ground beef patty portions were vacuum packaged utilizing the Henkelman 600 vacuum package machine (Hertogenbosch, Netherlands). Each meat loaf and patty treated product was placed and held in a blast freezer at a temperature of (-40°C) for further physical analysis.

pH

The pH of the raw ground samples were measured before and after the treatment application. The pH was measured three times for each treatment type and then averaged for statistical analysis. A digital pH meter (Model H260G, HACH, Loveland, CO) was utilized to measure pH. The metal pH-piercing probe (Model pH 77-SS, IQ Scientific, HACH, Loveland, CO) was calibrated before its use with pH 4.0 and 7.0 standard buffer solutions (SB101-500, SB107-500, Fisher Scientific, Fairlawn, NJ).

Water Holding Capacity

The water holding capacity (WHC) of the raw ground beef was measured according to the method outlined in the American Meat Science Association guidelines for sensory, physical, and chemical measurements in ground beef (1983) with slight modifications. The procedure is also based on the method performed by Dagbjartsson, (Dagbjartsson 1972). The WHC was measured in duplicate for each sample, repeated 3 times, and averaged for statistical analysis. Approximately 0.5 g (±0.02 g) of a molecular sieve, 60/80 mesh, (Supelco Analytical, Belafonte, PA) was measured into 50 mL polycarbonate conical centrifuge tubes. Two Whatman filter paper discs (no. 42, 7cm) were cut to the size of the tube's diameter allow for a tight fit on the surface of the molecular sieve. The weight of the tube (without the lid), filter paper, and molecular sieve using an analytical navigator weighing scale (Model NOD110, Ohaus Corporation, Switzerland) was recorded. Utilizing liquid nitrogen, 1.0 g (±0.20 g) of ground beef was flash frozen and then pulverized into a powder using a blade coffee grinder (Kitchenaid, St. Joseph, MI). After the meat was thawed completely and after all of the nitrogen (N_2) evaporated, the weight of the meat was determined by reweighing the centrifuge tube and its contents. The centrifuge tube with its contents was capped and four tubes were placed into the Fiberlite F21 8 × 50 rotor (Thermo Fischer Scientific Inc., Waltham, MA) for equal weight distribution. The tubes were then centrifuged for 10 minutes at 12,000 × *g* (10,000 RPM) using the Sorval RC6 Plus centrifuge (Thermo Fischer Scientific Inc., Waltham, MA) at 2 °C. The meat cakes were then gently removed with forceps from the surface of the filter paper while ensuring no meat remained. The tube was re-weighed and the WHC was expressed as the amount of water lost per gram of meat. WHC was calculated using the following equation and based upon previous experiments:

$$\text{WHC} = (W_{\text{before}} - \text{Water Loss})*100/\, W_{\text{before}}$$

W_{before}= weight of meat before centrifuged

Water Loss = Total weight of tube without meat after centrifugation – Total weight of tube without meat before centrifugation

Metmyoglobin Reducing Activity

The procedure for metmyoglobin reducing activity (MRA) measurement was based on the Meat Color Measurement Guidelines handbook (AMSA 2012) with slight modifications. The MRA was measured in duplicate for each sample, repeated in triplicate, and then averaged for statistical analysis. A 23 g sample ground beef sample was removed from the allotted portion for the test. The ground beef sample was placed into the corner of small 6 × 8 inch clear, nylon polyethylene vacuum pouch (Prime Source International LLC, Westerville, Ohio). The Impulse Sealer (Model 210-12E, Clamco Corp, Cleveland, Ohio) was used to section off the meat portion in the corner of the vacuum bag. The surface to be measured was wide enough for the colorimeter aperture to accurately make measurements.

The ground beef sample was immersed in a 0.3% solution of sodium nitrite ($NaNO_2$) for 20 minutes at room temperature (20-25°C). For metmyoglobin (MMb) formation to begin, small pin size holes were poked into each cornered section, to create an 8 × 8 grid. The bag was slightly massaged inside the $NaNO_2$ solution to allow for the meat sample to be completely submerged. After 20 minutes, the bag was removed and the meat sample was thoroughly squeezed of the solution. It was blotted with Whatman filter paper (no. 42, 7 cm) to remove excess $NaNO_2$ solution and placed into another vacuum packaged bag for spectrophotometric evaluation. The vacuum bags were slightly flattened and immediately scanned with the Miniscan EZ 4500L spectrophotometer (Hunterlab Assoc. Lab, Reston, VA) for a reflectance measurement (400- 700nm) to determine the initial amount of MMb formed on the surface. The sample was then placed into an incubator (Gravity Convection incubator, Precision Scientific Corp., Chicago, IL.) at 30 °C for two hours. After the meat samples were cooled to room temperature the reflectance was scanned at the same wavelengths in order to measure the remaining amount of MMb or the final MMb. The % MMb and MRA (% of MMb reduced) was calculated using the following equation:

%MMb = *[K/S572 / K/S525* (for 100% DMb)]- [K/S572 / K/S525 (sample)]/ [K/S572 / *K/S525* (for 100% DMb)] - *[K/S572*/ K/S525 (for 100% MMb)] [x 100]

where, DMb = Deoxymyoglobin

K/S= Absorbance and Scattering coefficient values for meat, respectively (Table C.1)

MRA (% of MMb reduced) = [(Initial %MMb - Final %MMb) -Initial %MMb] x 100

Texture Analysis

The attributes measured for texture analysis were hardness and adhesiveness for raw ground beef. These textural attributes and procedures were obtained from the Research Guidelines for Cookery, Sensory Evaluation, and Instrumental Tenderness Measurements of Fresh Meat (AMSA 1995), Bourne and others (2002), and through the technical guidance of Drew Lambert and Michele Sink at Food Technology Corporation (Sterling, VA). In order to perform the test a #12 brass cork borer with a fixed diameter (1 cm) and length (2 cm) was used to make the six cores from the ground beef meat loaf samples. The length of each core was determined by using a centimeter ruler. A compression test was performed on each sample and each attribute was reported as the mean of the six cores. The vacuum packaged frozen ground beef meat loaf samples were thawed overnight in a cooler (2-5°C). Before coring, the ground beef was brought up to room temperature (25°C) to allow for a uniform temperature. A TA-94, 45 mm diameter, compression plate (Food Technology Corporation, Sterling, VA) was used to compress the cores on the TMS-Pro texture analyzer (Food Technology Corporation, Sterling, VA). The test samples were placed on a plate that was installed onto a heavy-duty platform. The conditions of the test for each sample included two compression cycles, a 50% strain, with a crosshead speed of 250 mm/min (Herrero, 2008). Hardness (N) was calculated as the peak force during the first compression cycle in a texture profile analysis (TPA) graph. Adhesiveness (Nmm) can be calculated as the negative area in the TPA graph during the first bite. It also represents the work necessary to pull the compression plate away from the meatloaf sample.

Surface Color Measurement Methodology

The method for measuring surface color was done in accordance with the American Meat Science Association Meat Color Measurement Guidelines (2012). Raw ground beef patties were prepared using 180g of ground beef and molded to patties using a manual, handheld meat patty maker (The Perfect Burger Press, Model MS-19-041-500-11, Wal-Mart Stores, Inc., Bentonville, AR). The experiment was replicated three times for each treatment. The patties were placed onto styrofoam trays (Model 1S Tray, Genpak, Glens Falls, NY) with absorbent purge pads (Dri-loc AC-25, Sealed Air Cryovac Food Packaging Systems, Elmwood Park, NJ) and overwrapped with polyvinyl chloride (PVC) film **(**21700 cm^3 oxygen/m^2/24 h**)** using a heat sealer (Model 600 A, Heat seal, LLC, Cleveland, Ohio). The trays were stored and displayed at 2-4°C in a retail display case (Model M3-8EA, Type 1 Display Refrigerator, Hussmann, Missouri) to mimic the retail distribution. The color measurements were recorded over a specific time interval, on days 0, 1, 2, 3, 5, and 7. The top surface color of each raw patty was measured using the Hunterlab Miniscan EZ 4500L spectrophotometer (Hunterlab Assoc. Lab, Reston, VA). The *CIE L** (lightness), *a**(redness), *b**(yellowness), hue angle (H°), chroma (intensity of redness) and reflectance values of wavelengths (400-700 nm) were recorded. The hue angle was calculated using the following equation:

$$\text{Hue angle (HA)} = [\text{arctangent } (b^*/a^*)].$$

The chroma (saturation index) was calculated through the following equation:

$$\text{Chroma or Saturation Index} = \sqrt{(a^{*2}+b^{*2})}.$$

Statistical Analysis

The experimental design was a randomized complete block with repeated measurements. Type-3 tests of fixed effects for pH, WHC, MRA, instrumental surface color changes during retail display, and instrumental textural attributes were evaluated using the mixed procedure of SAS (SAS Institute Inc. in Cary, North Carolina.). Least square means were calculated for significant F-tests ($p<0.05$) and separated using the pdiff option. Superscripts for each table were assigned for each treatment to show differences in the treated samples. Samples labeled with an 'a' contained the lowest value and each subsequent letter corresponds to the increasing values.

Results and Discussion

pH

The effects of the non-meat ingredients on the raw ground beef pH before and after the treatment, is shown in Table 3.2. The pH of raw ground beef before treatment was within the normal pH range (5.6-5.8) for beef. As expected, the pH of the raw ground beef increased after mixing different percentages of NaCl, $NaHCO_3$, $KHCO_3$, and starches (SMFS2 and SPS2). SMFS2 and SPS had higher ($p<0.05$) pH than NT. Samples SBC1, PBC05, PBC1, SSBC05, SSBC1, SPB05, and SPBC1 were found to have no differences in pH after it was treated. All ground beef samples except for the control (NT) and SMFS2 and SPS2, had a higher pH before and after the treatment.

The primary focus of this research in raw ground beef was to investigate the functionality of NaCl, $NaHCO_3$, $KHCO_3$, and starches. There was a significant increase in pH with the addition of $NaHCO_3$ or $KHCO_3$ only to the ground beef (SBC05, SBC1, PBC05, and PBC1) ($p<0.05$). Sheard and Tali (2004) reported a similar finding of increased pH's when $NaHCO_3$ and $NaHCO_3$ with NaCl were added to pork. Bechtel and others (1985) reported an increase in pH with the inclusion of $NaHCO_3$ in frankfurters. Further investigations portrayed that PBC1 increased the after pH by 0.2 units in PBC05. This increase was larger than SBC05 and SBC1. Neither $NaHCO_3$ nor $KHCO_3$ were able to fully dissociate in solution (Wimberley and others 1985). This in turn caused the differences in observed pH values. The pH did not significantly increase ($p<0.05$) with MFS and PS (SMFS2 and SPS2). Starches did not induce a significant ionic charge to the meat protein system and therefore do not increase the pH largely. Prestes and others (2012) also observed as light increase in pH with the addition of modified food starch.

Water Holding Capacity

The least squares means of the bicarbonate treated ground beef's WHC are shown in Table 3.2. The addition of $NaHCO_3$ and $KHCO_3$ at both 0.5% and 1.0% levels increased ($p<0.05$) the WHC of the ground beef. Further supplementation of NaCl with $NaHCO_3$ and $KHCO_3$ at concentration levels of 0.5% and 1.0% did not impact the WHC of the ground beef. Although numerically, $KHCO_3$ added samples held more water than those with $NaHCO_3$, they were not statistically different ($p<0.05$). The ground beef samples mixed with starches (SMFS2 and SPS2) had the least ($p<0.05$) WHC suggesting that both the starch forms were least effective in their ability to hold the water. Samples PBC05 through SPBC1 showed that there was no difference ($p<0.05$) in WHC between both bicarbonate added samples and those with added bicarbonates and NaCl. Overall, there was an increase in WHC with the inclusion of salt,

$NaHCO_3$, and $KHCO_3$. This is a great attribute for the raw ground beef as it decreases the purge or the liquid that is released when in the retail display case.

An increase in pH is often associated with an increased WHC (Sheard and Tali 2004). The increase in WHC by the bicarbonates can be attributed to the pH shifting away from the isoelectric point and contracting the proteins. They have a higher net charge and provide the ability to hold more water (Bechtel and others 1985). The myofibrillar proteins, actin and myosin are not as tightly bound therefore creating more space for the water to be held (Aberle and others 2001). The bicarbonates increase the number of ions, which shift the protein charges away from the isoelectric point and increase hydration (Yang and others 2006). This was seen in this current study and both $NaHCO_3$ and $KHCO_3$ did impact on the WHC. However, the samples with bicarbonates had a higher water holding capacity than the control (NT) and the samples with MFS, PS, and NaCl only.

Metmyoglobin Reducing Activity

Table 3.2 showed the effects of treated raw ground beef on its MRA. MRA values indicate the percentage of metmyoglobin (MMb) reduced in the meat samples treated. MMb is an oxidized redox form of the meat protein myoglobin and is considered an important indicator of meat color stability. The discoloration occurs on the surface of raw ground beef as the myoglobin is oxidized causing the heme iron to convert Fe^{2+} from Fe^{3+}. Consumers do not find discolored meat desirable, as it does not exhibit a fresh-like color. Large MRA values are preferred as they indicate lower amounts of MMb within the meat and lower the discoloration on the surface. This also translates into a more stable meat color on the shelf (AMSA 2012). The application of NaCl (0.5%) did not seem to influence ground beef MRA as compared with samples containing bicarbonate and starch formulations. NT had the highest ($p<0.05$) MRA activity at 66.9% as compared with all other treatment formulations. Sample S05 had the lowest ($p<0.05$) MRA activity (~ 31%). SBC05, SBC1, PBC05, and PBC1 had MRA levels (38.6% to 59.6%) lower ($p<0.05$) than NT. The addition of NaCl with $NaHCO_3$ or $KHCO_3$ at both 0.5% and 1.0% concentration levels did not increase ($p<0.05$) the MRA compared to the control (NT). The application of the bicarbonates and starches decreased the MRA, which increases MMb and the brown color. These findings are different from Greene and Price (1975) as $NaHCO_3$ was added to raise the pH to raw dark- cutting beef. The percentage of MMb was measured and substantial pigment protection was provided. Ledward and others (1977) have reported that mincing of meat destroys the MMb reducing system. The mincing increases the exposure of ground beef to oxygen and therefore can stop the ability for MMb to be reduced and instead increase MMb levels.

Samples SBC05, SSBC05, SPBC05, and SMFS2 appeared similar to each other, as the MRA percentages were not significantly different to each other ($p>0.05$). SBC1 (47.8%), SSBC1 (48.6%), SPS2 (51.5%) were similar to each other ($p>0.05$). This shows that when ground beef treated with 1% $NaHCO_3$, the combination with NaCl did not show a significant difference ($p<0.05$).

Texture Analysis of Raw Ground Beef

In Table 3.3, the adhesiveness and hardness values of the treated raw ground beef are presented. S05 exhibited the highest level of hardness (4.86 N) while the lowest value was observed for SSBC1 (2.74 N). SMFS2 and SPS2 were harder than the samples containing bicarbonates alone and a combination of bicarbonates and NaCl. SSBC05, SSBC1, SPBC05, and

SPBC1 had the lowest hardness values of 3.21 N, 2.74 N, 3.20 N, and 2.74 N, respectively. All 4 samples were tenderer than the rest of the treated ground beef samples. The $NaHCO_3$ only (SBC05 and SBC1) and $KHCO_3$ only (PBC05 and PBC1) treated ground beef samples were different ($p<0.05$) from each other.

The texture data showed that the ground beef treated with 0.5% NaCl (S05) was tenderer ($p<0.05$) than the non-treated control (NT). Similar to the findings in this study, Puolanne (2001) reported that the addition or increase of NaCl caused tenderization of the meat products. Sultana and others (2008) reported hardness values to be less with salt-bicarbonate treated meat in beef muscle, *bicep femoris*, and was largely attributed to the large amounts of water retained within the meat. The increase in pH again shows the increase in WHC. This shows why samples with salt and bicarbonates have lesser hardness values. Adhesiveness is determined as the negative area in the TPA cycle during first bite. It is also expressed as the work needed to pull the compression plate away from the ground beef sample. Inclusion of bicarbonate and salt impacted the adhesiveness of the ground beef. Ground beef samples mixed with 0.5% salt and 1% $KHCO_3$ (SPBC1) was the most adhesive at 3.55 Nmm, while S05 was the least adhesive at 0.70 Nmm. Mixed with modified food starch (SMFS2) and potato starch (SPS2) had lower adhesiveness values ($p<0.05$) than the bicarbonate treated ($NaHCO_3$ and $KHCO_3$) treated raw ground beef. The trend suggests that both bicarbonate forms ($NaHCO_3$ and $KHCO_3$) alone or in combination with 0.5% NaCl exhibited increased adhesiveness compared to the control, NT, and S05. The adhesiveness increased even more with the inclusion of $KHCO_3$ (PBC05 and PBC1). As NaCl was added to both $NaHCO_3$ and $KHCO_3$ it was at its highest level ranging from 3.27 Nmm to 3.55 Nmm (SSBC05, SSBC1, SPBC05, and SPBC1). The increased adhesiveness can be attributed to a greater extraction of the myofibrillar proteins, especially myosin and actin. The extraction of proteins produces a sticky exudate, which can allow for a better ability to mold the raw ground beef into desired shapes or meat products. Also, an increase in the sticky exudate may increase the work needed to pull the compression plate away from the treated ground beef.

The use of either $NaHCO_3$ or $KHCO_3$ alone did not make a significant difference ($p<0.05$) between each other on the adhesiveness or hardness of the ground beef ($p<0.05$). With the addition of NaCl, results suggested that hardness slightly decreased and adhesiveness increased ($p<0.05$). Overall, the hardness values decreased ($p<0.05$) (softer) and adhesiveness values increased ($p<0.05$) in regards to the control (NT). The decreased hardness with the increased adhesiveness from incorporating bicarbonates to ground beef, may enable a reduction in salt within meat products. The consumption of sodium in the diet is of great concern in developed counties. It is highly recommended to decrease the amount of sodium in order to reduce high blood pressure or hypertension. This can be accomplished by lowering the sodium content in meat products (Puolanne and others 2001). This is imperative as today's consumers are riddled with health problems associated with high amounts of sodium. (Ruusunen and Puolanne, 2005) NaCl cannot be entirely removed due to its WHC, pH, and meat protein extraction abilities. Puolanne and others (2001) have reported that a 25% decrease of NaCl within meat will not detrimentally affect the flavor, texture, and shelf life. Within this study NaCl is present at a small percentage (0.5%). $KHCO_3$ can increase adhesiveness even more. These bicarbonates demonstrate to be good alternatives or additions to salt in meat products.

Surface Color

*L**- values were measured of the treated raw ground beef surfaces, which are provided in Table 3.4. For all treatments, *L**- values decreased over a seven day display period ($p<0.05$)

showing that as display days advanced, the meat became darker. This can be attributed to the high pH resulting from the treatment of the ground beef with bicarbonates, NaCl and starches. Meats that have a high ultimate pH look to be darker as the surface disperses less light than meat with a low ultimate pH (Lawrie 2006). Adversely, *L**- values for the sample SPS2 increased ($p<0.05$), exhibiting a lighter color although, not significantly different ($p<0.05$) over the seven day display period. The starch samples (SMFS2 and SPS2) had the highest ($p<0.05$) *L**- value than the rest of the samples. NT, S05, SSBC05, SSBC1, SPBC05, SPBC1, SMFS2, and SPS2 had a lesser impact on their *L**- values on day 0 and on day 7 ($p<0.05$). The $NaHCO_3$ and $KHCO_3$, treated samples were darker than the control over the seven-day period as the *L**- values are lower. When bicarbonate samples were combined with NaCl (SSBC05, SSBC1, SPBC05, and SPBC1), *L**- values decreased, creating a darker product. These results are in agreement with Yang and others (2006) as $NaHCO_3$ treated samples lowered the meat's lightness color significantly in pork loins.

Table 3.5 shows the a*-values of the surface of raw ground beef treated with differing amounts of NaCl, bicarbonates, and starches. The trend shows that with all samples, *a**-values decreased and were significantly different ($p<0.05$) from each other on day 0 to day 7. The bicarbonate samples at 1.0% alone, were not able to maintain the higher *a**-values or redness. SBC05, SSBC1, SPBC05, and SPBC1 maintained its a*-values or maintained the bright red color over the entire display time. NT and S05 samples had the highest *a** values at day 0 of 31.2 and 32.0, respectively. The treatments with bicarbonates only, bicarbonates with NaCl, and starches had lower ($p<0.05$) *a**-values at day 0. SPBC05 and SPBC1 had the lowest ($p<0.05$) *a** values at day 0. PBC05 and PBC1 were able to maintain high *a**-values compared to NT and S05 on day 0. Samples SBC05 and SBC1 were effective in maintaining the red color. However, compared to the control (NT) $NaHCO_3$ and $KHCO_3$ treated samples overall were less red over the seven day period. This is normal, as the quality of ground beef will slowly reduce in quality due to bacteria or other spoilage organisms. The addition of NaCl and both bicarbonates decreased the *a** over the seven day period. When bicarbonate samples were combined with NaCl (SSBC05, SSBC1, SPBC05, and SPBC1), *a**- values decreased even more. This displayed a reduction of red color over the seven days. These results are in contrast with Yang and others (2006) as it was reported that $NaHCO_3$ treated samples contained a high redness compared to the control.

Over the seven day retail display period, the *b**- values were measured to investigate the ground beef surface color and are displayed in Table 3.6. Results showed that there was a decline in *b**- values over the seven day retail period. All of the samples had lower *b**- values on day 0 through day 7. Treatments combining both bicarbonates and salt, and the starch treatments had the same *b**-values after day 1 ($p<0.05$). The samples in combination with salt and bicarbonates and salt with starches did not decrease the *b**-values significantly ($p<0.05$). It was not until day 5 that that *b**- values were different and displayed a more blue pigment. Samples ranging from NT to PBC1, had *b**- values that were different from day 0 to day 1 and declined much earlier than the other samples. From day 2 to day 7, the *b**- values were significantly different from day 0 to day 2.

According to the hue angle color wheel scale, the red pigments lie between 0° to 360°. Values closer to 0 degrees show a stronger red pigment as where values seen towards 45 degrees exhibit a browner and more yellow color. Hue angle values also confirm with *a**-values that the redness hues or color decreased over time (Table 3.5 and Table 3.7). Larger values indicate a less red color, more MMb and displays a well done like cooked color (AMSA 2012). Results indicate that all the samples had an increase in hue angle over the seven-day retail period. The samples combining NaCl with bicarbonates, the hue angle values increased. These results are different to Yang and others (2006) as $NaHCO_3$ treated with pork loins showed the surface color to be redder. Although findings are not consistent from Yang and others 2006, this may be due to the natural variations in muscle between pork and ground beef. Hue angles for most of the treated samples were different and increased from day 0 to day 7 ($p<0.05$). SPBC05 and SPBC1, SPBC05, and SPBC1 were the treatments with the highest hue angle values at day 0. Day 7 had highest hue angle values for treatments with bicarbonates. From day 5 to day 7, the hue angle values were all different ($p<0.05$).

Table 3.8 shows the chroma values of the surface of raw ground beef. Chroma is used as an indicator of red color saturation (Little, 1976) and myoglobin concentration. The chroma values are also related to the *a**-values (Table 3.5) as chroma and a*-values are directly proportional to each other. This provides the redness color in the ground beef. Data revealed that there was a decrease in saturation of color over the seven-day retail display period. With the addition of bicarbonates, the chroma values furthermore declined over the seven-day display period. This is in agreement with Yang and others (2006) as chroma values were lowered due to the inclusion of $NaHCO_3$. Treatments with bicarbonates and in combination with NaCl were not different ($p<0.05$) from the control (NT) or those mixed with both starches (SMFS2 and SPS2). SBC05, SMFS2, and SPS2 displayed similar chroma values on day 0 and day 7 ($p<0.05$). On day 2, the chroma values were different ($p<0.05$) for SBC05, SMFS2, and SPS2 ($p<0.05$). The other treatments (NT, S05, SBC1, PBC05, PBC1, SSBC05, SSBC1, SPBC05, and SPBC1) had chroma values that were different ($p<0.05$) throughout the seven days. This suggests that both bicarbonates with NaCl (SSBC05, SSBC1, SPBC05, and SPBC1), NT, and S05 had an impact on the decline of chroma values. NT and S05 had the highest chroma values compared to other treatments on day 0 but had one of lowest values on day 7.

Conclusion

This study explored the effects of $NaHCO_3$, $KHCO_3$, and NaCl in raw ground beef. It was compared to other non-meat ingredients, such as modified food starch and potato starch. Bicarbonates with or without salt improved the water holding capacity as it held more water than both MFS and PS. $KHCO_3$ with NaCl provided the best adhesiveness values for raw ground beef. The hardness values were significantly different ($p<0.05$) between samples of $NaHCO_3$ with salt and $KHCO_3$ with salt. The ground beef decreased in hardness or became tenderer with the inclusion of bicarbonates. Over the seven day period the meat did darken with lower *L**-values and the redness decreased with lower *a**- values with the use of bicarbonates.

This study suggests that the use of bicarbonates can increase the WHC due to an increased pH and produces raw ground beef that is more tender and adhesive in texture. The increased tenderness within raw ground beef will allow for a more tender ground beef product after being cooked. Consumers today expect to have cooked ground beef products that are tenderer in texture as they exhibit a more favorable mouth feel. However, it does create a darker raw ground beef product. Future work must be accomplished to analyze other aspects of the treated ground beef. Those aspects include microbial testing of the raw ground beef and should be done of the bicarbonate treated ground beef. Due to the increased pH within the meat, this allows for bacterial growth that may be harmful to consumers. Testing other bicarbonates at differing usage rates may also be beneficial for meat industry experts.

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List of Tables

Table 3.1: Mixture formulations for ground beef treated with differing levels of $NaHCO_3$, $KHCO_3$, NaCl, modified food starch, and potato starch.

Sample	**Description**[a]	**%**[c]				
		NaCl	**$NaHCO_3$**	**$KHCO_3$**	**Modified food starch**	**Potato Starch**
NT (Control)	None[b]	-	-	-	-	-
S05	NaCl	0.5	-	-	-	-
SBC05	$NaHCO_3$	-	0.5	-	-	-
SBC1	$NaHCO_3$	-	1.0	-	-	-
PBC05	$KHCO_3$	-	-	0.5	-	-
PBC1	$KHCO_3$	-	-	1.0	-	-
SSBC05	NaCl + $NaHCO_3$	0.5	0.5	-	-	-
SSBC1	NaCl + $NaHCO_3$	0.5	1.0	-	-	-
SPBC05	NaCl + $KHCO_3$	0.5	-	0.5	-	-
SPBC1	NaCl + $KHCO_3$	0.5	-	1.0	-	-
SMFS2	NaCl + Modified Food Starch	0.5	-	-	2.0	-
SPS2	NaCl + Potato Starch	0.5	-	-	-	2.0

[a] NaCl, $NaHCO_3$, $KHCO_3$, modified food starch, and potato starch were all diluted in distilled water for better homogeneity and dispersability.
[b] No ingredient (NaCl, $NaHCO_3$, $KHCO_3$, modified food starch, or potato starch) were added except distilled water.
[c] Percent composition of individual ingredient added to the ground beef as a formulation.

Table 3.2: Least squares means for pH, water holding capacity (WHC) and metmyoglobin reducing activity of raw ground beef treated with differing levels of $NaHCO_3$, $KHCO_3$, NaCl, potato starch, and modified food starch.

Treatment^{m}	**pH before**	**pH after**	**WHC (%)**	**MRA (%)**
NT	5.6^{ax}	5.6^{ax}	80.5^{b}	66.9^{f}
S05	5.5^{ax}	6.0^{by}	79.4^{b}	31.0^{a}
SBC05	5.6^{ax}	6.0^{by}	88.7^{c}	38.6^{b}
SBC1	5.5^{ax}	6.7^{cy}	89.7^{c}	47.8^{c}
PBC05	5.5^{ax}	6.7^{cy}	88.8^{c}	59.6^{e}
PBC1	5.5^{ax}	6.9^{cy}	90.2^{c}	53.1^{d}
SSBC05	5.5^{ax}	6.5^{cy}	90.1^{c}	40.9^{b}
SSBC1	5.5^{ax}	6.7^{cy}	88.9^{c}	48.6^{cd}
SPBC05	5.6^{ax}	6.7^{cy}	90.6^{c}	37.8^{b}
SPBC1	5.7^{ax}	6.8^{cy}	90.1^{c}	59.6^{e}
SMFS2	5.7^{ax}	5.9^{bx}	65.2^{a}	41.8^{b}
SPS2	5.8^{ax}	5.9^{abx}	66.5^{a}	51.5^{cd}

^{m}NT = No NaCl, Bicarbonates & H_2O, S05 =NaCl (0.5%), SBC05= $NaHCO_3$ (0.5%), SBC1 = $NaHCO_3$ (1.0%), PBC05= $KHCO_3$ (0.5%), PBC1 = $KHCO_3$ (1.0%), SSBC05 = NaCl (0.5%), $NaHCO_3$ (0.5%), SSBC1 =NaCl (0.5%), $NaHCO_3$ (1.0%), SPBC05= NaCl (0.5%), $KHCO_3$ (0.5%), SPBC1 = NaCl (0.5%), $KHCO_3$ (1.0%), SMFS2= NaCl (0.5%), Modified Food Starch (2.0%), SPS2 = NaCl (0.5%), Potato Starch (2.0%)
±SE = 0.115 for pH; 1.49 (NT, PBC1,SSBC05, SSBC1, SBC05, SPBC1, SMFS2, SPS2), 1.83 (S05, SBC05, SBC1, PBC05) for WHC, 1.60 for MRA
Means with different superscripts within a column (a,b,c,d,e,f) and within a row (x,y) are significantly different ($p<0.05$)

Table 3.3: Least squares means for texture analysis attributes of adhesiveness and hardness values of raw ground beef treated with differing levels of $NaHCO_3$, $KHCO_3$, NaCl, modified food starch, and potato starch.

Treatment^{m}	**Texture Attributes**	
	Adhesiveness (Nmm)^{x}	**Hardness (N**^{y}**)**
NT	0.73^{ab}	4.86^{e}
S05	0.70^{a}	4.24^{c}
SBC05	1.67^{c}	3.96^{c}
SBC1	1.52^{c}	4.16^{c}
PBC05	2.15^{d}	4.73^{de}
PBC1	3.10^{e}	3.56^{b}
SSBC05	3.35^{ef}	3.21^{b}
SSBC1	3.48^{f}	2.74^{a}
SPBC05	3.27^{ef}	3.20^{b}
SPBC1	3.55^{f}	2.74^{a}
SMFS2	0.95^{ab}	4.17^{c}
SPS2	1.09^{b}	4.40^{cd}

^{m}NT = No NaCl, Bicarbonates & H_2O, S05 =NaCl (0.5%), SBC05= $NaHCO_3$ (0.5%), SBC1 = $NaHCO_3$ (1.0%), PBC05= $KHCO_3$ (0.5%), PBC1 = $KHCO_3$ (1.0%), SSBC05 = NaCl (0.5%), $NaHCO_3$ (0.5%), SSBC1 =NaCl (0.5%), $NaHCO_3$ (1.0%), SPBC05= NaCl (0.5%), $KHCO_3$ (0.5%), SPBC1 = NaCl (0.5%), $KHCO_3$ (1.0%), SMFS2= NaCl (0.5%), Modified Food Starch (2.0%), SPS2 = NaCl (0.5%), Potato Starch (2.0%)
±SE = 0.1286 for TPA Adhesiveness; 0.1293 for TPA Hardness
Means with different superscripts within a column are significantly different ($p<0.05$)
^{x}Nmm = TPA Adhesiveness units of Newton millimeters
^{y}N = TPA Firmness/Hardness units of Newton

Table 3.4: Least squares mean for surface colorimeter *L** (lightness) values of raw ground beef treated with differing levels of $NaHCO_3$, $KHCO_3$, NaCl, modified food starch, and potato starch.

Treatment^m	**Retail Display Days**					
	0	**1**	**2**	**3**	**5**	**7**
NT	57.1^{a}	55.7^{a}	56.2^{a}	56.7^{a}	55.8^{a}	55.9^{a}
S05	58.3^{b}	57.8^{b}	55.3^{a}	55.6^{a}	55.4^{a}	54.9^{a}
SBC05	55.0^{b}	57.8^{c}	52.7^{a}	53.5^{a}	52.6^{a}	52.7^{a}
SBC1	56.2^{d}	55.0^{cd}	52.7^{a}	52.8^{ab}	54.1^{bc}	53.1^{ab}
PBC05	56.5^{d}	55.2^{c}	53.3^{ab}	54.0^{bc}	52.6^{a}	53.3^{ab}
PBC1	57.3^{b}	56.4^{b}	53.0^{a}	53.6^{a}	54.2^{a}	53.8^{a}
SSBC05	56.9^{c}	55.1^{b}	52.7^{a}	53.0^{a}	54.7^{b}	53.3^{a}
SSBC1	56.8^{bc}	53.7^{a}	55.3^{b}	55.4^{b}	55.3^{b}	56.1^{b}
SPBC05	55.7^{b}	52.0^{a}	54.9^{b}	54.7^{b}	54.6^{b}	54.7^{b}
SPBC1	56.4^{b}	54.0^{a}	55.5^{b}	56.1^{b}	56.0^{b}	56.0^{b}
SMFS2	61.4^{b}	59.5^{a}	60.8^{ab}	61.7^{b}	62.3^{c}	61.9^{bc}
SPS2	57.9^{ab}	57.7^{a}	58.4^{ab}	59.0^{b}	58.6^{ab}	59.0^{b}

^{m}NT = No NaCl, Bicarbonates & H_2O, S05 =NaCl (0.5%), SBC05= $NaHCO_3$ (0.5%), SBC1 = $NaHCO_3$ (1.0%), PBC05= $KHCO_3$ (0.5%), PBC1 = $KHCO_3$ (1.0%), SSBC05 = NaCl (0.5%), $NaHCO_3$ (0.5%), SSBC1 =NaCl (0.5%), $NaHCO_3$ (1.0%), SPBC05= NaCl (0.5%), $KHCO_3$ (0.5%), SPBC1 = NaCl (0.5%), $KHCO_3$ (1.0%), SMFS2= NaCl (0.5%), Modified Food Starch (2.0%), SPS2 = NaCl (0.5%), Potato Starch (2.0%)
± SE = 0.5352 for *L**
Mean values with different superscripts within a row are significantly different ($p<0.05$)

Table 3.5: Least squares mean for surface colorimeter *a** (redness) values of raw ground beef treated with differing levels of $NaHCO_3$, $KHCO_3$, NaCl, modified food starch, and potato starch.

Treatment^{m}	**Retail Display Days**					
	0	**1**	**2**	**3**	**5**	**7**
NT	31.2^{f}	28.2^{e}	24.2^{d}	22.3^{c}	17.1^{b}	12.9^{a}
S05	32.0^{f}	28.3^{e}	25.1^{d}	22.5^{c}	18.0^{b}	12.3^{a}
SBC05	28.3^{e}	28.3^{f}	21.6^{d}	20.0^{c}	17.7^{b}	14.9^{a}
SBC1	29.6^{f}	23.9^{e}	21.3^{d}	20.0^{c}	17.8^{b}	13.9^{a}
PBC05	29.4^{f}	24.5^{e}	21.7^{d}	20.0^{c}	18.3^{5}	13.8^{a}
PBC1	29.9^{f}	23.6^{e}	20.8^{d}	19.3^{c}	16.9^{b}	14.8^{a}
SSBC05	29.3^{f}	22.8^{e}	20.3^{d}	18.4^{c}	16.3^{b}	12.5^{a}
SSBC1	22.4^{e}	19.9^{d}	17.9^{c}	16.3^{b}	13.4^{a}	13.2^{a}
SPBC05	21.1^{d}	20.0^{d}	18.2^{c}	16.8^{b}	16.7^{a}	13.4^{a}
SPBC1	21.3^{e}	18.3^{d}	17.2^{c}	15.7^{b}	13.1^{a}	12.9^{a}
SMFS2	23.7^{e}	22.9^{e}	21.1^{d}	19.3^{c}	14.9^{b}	12.2^{a}
SPS2	23.4^{d}	22.7^{cd}	21.7^{c}	19.9^{b}	15.1^{a}	15.6^{a}

^{m}NT = No NaCl, Bicarbonates & H_2O, S05 =NaCl (0.5%), SBC05= $NaHCO_3$ (0.5%), SBC1 = $NaHCO_3$ (1.0%), PBC05= $KHCO_3$ (0.5%), PBC1 = $KHCO_3$ (1.0%), SSBC05 = NaCl (0.5%), $NaHCO_3$ (0.5%), SSBC1 =NaCl (0.5%), $NaHCO_3$ (1.0%), SPBC05= NaCl (0.5%), $KHCO_3$ (0.5%), SPBC1 = NaCl (0.5%), $KHCO_3$ (1.0%), SMFS2= NaCl (0.5%), Modified Food Starch (2.0%), SPS2 = NaCl (0.5%), Potato Starch (2.0%)
± SE = 0.4696 for *a**
Mean values with different superscripts within a row are significantly different ($p<0.05$)

Table 3.6: Least squares mean for surface colorimeter *b** (yellowness) values of raw ground beef treated with differing levels of $NaHCO_3$, KHCO3, NaCl, modified food starch, and potato starch.

Treatment^{m}	**Retail Display Days**					
	0	**1**	**2**	**3**	**5**	**7**
NT	24.6^{e}	23.6^{d}	21.2^{c}	20.2^{bc}	18.3^{ab}	17.3^{a}
S05	24.8^{d}	23.1^{cd}	21.6^{bc}	20.3^{ab}	19.0^{a}	18.0^{a}
SBC05	22.2^{c}	23.1^{c}	19.6^{b}	19.1^{ab}	18.2^{ab}	17.0^{a}
SBC1	23.5^{c}	20.5^{b}	19.5^{ab}	18.9^{ab}	18.5^{ab}	17.4^{a}
PBC05	23.3^{c}	20.9^{b}	19.6^{b}	19.2^{ab}	18.8^{ab}	17.2^{a}
PBC1	23.5^{c}	20.1^{b}	19.1^{ab}	18.7^{ab}	18.1^{ab}	17.3^{a}
SSBC05	23.0^{c}	19.4^{b}	18.6^{ab}	17.8^{ab}	17.2^{ab}	16.5^{a}
SSBC1	18.8^{c}	18.7^{bc}	17.6^{abc}	17.0^{abc}	16.3^{a}	16.2^{a}
SPBC05	18.0^{a}	19.0^{a}	17.7^{a}	17.2^{a}	17.7^{a}	17.0^{a}
SPBC1	18.3^{b}	17.4^{ab}	17.1^{ab}	16.6^{ab}	15.9^{a}	15.7^{a}
SMFS2	21.7^{c}	22.4^{bc}	21.7^{bc}	20.9^{abc}	19.5^{ab}	19.0^{a}
SPS2	20.7^{ab}	21.0^{b}	20.7^{ab}	20.4^{ab}	19.3^{ab}	18.5^{a}

^{m}NT = No NaCl, Bicarbonates & H_2O, S05 =NaCl (0.5%), SBC05= $NaHCO_3$ (0.5%), SBC1 = $NaHCO_3$ (1.0%), PBC05= $KHCO_3$ (0.5%), PBC1 = $KHCO_3$ (1.0%), SSBC05 = NaCl (0.5%), $NaHCO_3$ (0.5%), SSBC1 =NaCl (0.5%), $NaHCO_3$ (1.0%), SPBC05= NaCl (0.5%), $KHCO_3$ (0.5%), SPBC1 = NaCl (0.5%), $KHCO_3$ (1.0%), SMFS2= NaCl (0.5%), Modified Food Starch (2.0%), SPS2 = NaCl (0.5%), Potato Starch (2.0%)
± SE = 0.3116 for *b**
Mean values with different superscripts within a row are significantly different ($p<0.05$)

Table 3.7: Least squares mean for surface colorimeter hue angle values of raw ground beef treated with differing levels of $NaHCO_3$, KHCO3, NaCl, modified food starch, and potato starch.

Treatment^m	**Retail Display Days**					
	0	**1**	**2**	**3**	**5**	**7**
NT	38.27^a	39.91^{ab}	41.27^b	42.19^b	47.06^c	53.30^d
S05	37.80^a	39.25^{ab}	40.72^b	41.94^c	46.70^d	55.65^e
SBC05	38.20^a	39.25^a	42.24^b	43.66^b	45.78^c	48.83^d
SBC1	38.49^a	40.72^b	42.36^{bc}	43.41^c	46.16^d	51.34^e
PBC05	38.41^a	40.41^b	42.07^{bc}	43.81^c	45.84^d	51.35^e
PBC1	38.18^a	40.38^b	42.50^c	44.12^c	46.98^d	49.46^e
SSBC05	38.18^a	40.49^b	42.55^c	44.00^c	46.52^d	53.02^e
SSBC1	39.98^a	43.18^b	44.44^{bc}	46.22^c	50.61^d	50.84^d
SPBC05	40.57^a	43.62^b	44.22^{bc}	45.65^{cd}	46.71^d	51.80^e
SPBC1	40.70^a	43.53^b	44.99^{bc}	46.56^c	50.63^d	50.53^d
SMFS2	42.55^a	44.40^b	45.76^b	47.27^{bc}	52.69^d	57.41^e
SPS2	41.50^a	42.82^{ab}	43.64^b	45.66^c	51.93^d	49.94^e

^{m}NT = No NaCl, Bicarbonates & H_2O, S05 =NaCl (0.5%), SBC05= $NaHCO_3$ (0.5%), SBC1 = $NaHCO_3$ (1.0%), PBC05= $KHCO_3$ (0.5%), PBC1 = $KHCO_3$ (1.0%), SSBC05 = NaCl (0.5%), $NaHCO_3$ (0.5%), SSBC1 =NaCl (0.5%), $NaHCO_3$ (1.0%), SPBC05= NaCl (0.5%), $KHCO_3$ (0.5%), SPBC1 = NaCl (0.5%), $KHCO_3$ (1.0%), SMFS2= NaCl (0.5%), Modified Food Starch (2.0%), SPS2 = NaCl (0.5%), Potato Starch (2.0%)
± SE = 0.01156 for hue angle
Mean values with different superscripts within a row are significantly different ($p<0.05$)
^{x} Values are reported in degrees

Table 3.8: Least squares mean for surface colorimeter saturation index (chroma) values of raw ground beef treated with differing levels of $NaHCO_3$, $KHCO_3$, NaCl, potato starch, and modified food starch.

Treatment^{m}	**Retail Display Days**					
	0	**1**	**2**	**3**	**5**	**7**
NT	39.7^{f}	36.8^{e}	32.2^{d}	30.1^{c}	25.1^{b}	21.6^{a}
S05	40.4^{f}	36.5^{e}	33.1^{d}	30.3^{c}	26.2^{b}	21.8^{a}
SBC05	36.0^{e}	36.5^{e}	29.2^{d}	27.6^{c}	25.4^{b}	22.6^{a}
SBC1	37.8^{f}	31.5^{e}	28.9^{d}	27.5^{c}	25.7^{b}	22.2^{a}
PBC05	37.5^{f}	32.2^{e}	29.2^{d}	27.7^{c}	26.2^{b}	22.0^{a}
PBC1	38.1^{f}	31.0^{e}	28.2^{d}	26.9^{c}	24.8^{b}	22.7^{a}
SSBC05	37.3^{f}	30.0^{e}	27.6^{d}	25.6^{c}	23.7^{b}	20.7^{a}
SSBC1	29.3^{e}	27.3^{d}	25.1^{c}	23.6^{b}	21.1^{a}	21.0^{a}
SPBC05	27.7^{e}	27.6^{d}	25.4^{c}	24.0^{bc}	24.3^{b}	21.7^{a}
SPBC1	28.1^{d}	25.3^{c}	24.3^{c}	22.8^{b}	20.6^{a}	20.3^{a}
SMFS2	32.1^{e}	32.0^{e}	30.2^{d}	28.4^{c}	24.5^{b}	22.6^{a}
SPS2	31.2^{e}	30.9^{de}	30.0^{d}	28.5^{c}	24.5^{b}	24.3^{a}

^{m}NT = No NaCl, Bicarbonates & H_2O, S05 =NaCl (0.5%), SBC05= $NaHCO_3$ (0.5%), SBC1 = $NaHCO_3$ (1.0%), PBC05= $KHCO_3$ (0.5%), PBC1 = $KHCO_3$ (1.0%), SSBC05 = NaCl (0.5%), $NaHCO_3$ (0.5%), SSBC1 =NaCl (0.5%), $NaHCO_3$ (1.0%), SPBC05= NaCl (0.5%), $KHCO_3$ (0.5%), SPBC1 = NaCl (0.5%), $KHCO_3$ (1.0%), SMFS2= NaCl (0.5%), Modified Food Starch (2.0%), SPS2 = NaCl (0.5%), Potato Starch (2.0%)
± SE = 0.4922 for Saturation Index
Mean values with different superscripts within a row are significantly different ($p<0.05$)

CHAPTER 4

EFFECTS OF SODIUM AND POTASSIUM BICARBONATES ON THE PHYSIOCHEMICAL AND SENSORY PROPERTIES OF COOKED GROUND BEEF [1]

[1]Jaico T, Mohan A, Brambila GS. To be submitted to Journal of Food Science

Abstract

This study investigated the physiochemical and sensory effects of sodium bicarbonate ($NaHCO_3$), potassium bicarbonate ($KHCO_3$), and salt (NaCl) of cooked ground beef. The ground beef (80% lean, 20% fat) was prepared as meatloaves and mixed with different levels of $NaHCO_3$ (0.5% and 1.0%), $KHCO_3$ (0.5%, and 1.0%) and NaCl (0.5%). The meatloaves were cooked to an internal temperature of 60°C. The cooked ground beef samples were then compared to common food industry non-meat ingredients of modified food starch (2.0%) and potato starch (2.0%) with NaCl at 0.5%. The results obtained from cook loss and expressible moisture measurements showed that ground beef samples without any treatment (control) had the highest cooked loss. Instrumental texture (texture analysis and Warner-Bratzler Shear Force) and sensory analysis showed that ground beef with salt (0.5%) was the chewiest and hardest. Ground beef mixed with salt (0.5%) and $NaHCO_3$ (0.5%) was among the least chewy and least hard (tender) samples according to instrumental texture analysis and sensory analysis. Data also showed that textural cohesiveness increased as bicarbonate amounts increased from 0.5% to 1.0%. Ground beef treated with $KHCO_3$ at 1.0% and NaCl at 0.5% was the juiciest product according to panelists. Internal cooked color measurement data revealed that ground beef treated with $NaHCO_3$ and $KHCO_3$ had a higher *a**- value and pinkish red in color. Overall, instrumental texture and sensory results with the inclusion of bicarbonates at 0.5% and salt at 0.5%, the ground beef shows to be the least chewy and most tender.

Keywords: Ground Beef, Sodium Bicarbonate, Potassium Bicarbonate, Texture Analysis, Warner-Bratzler Shear Force, Sensory Analysis, Color Analysis, Expressible moisture, Cook Loss

Introduction

In the current food market, beef is one of the most sought-after meat products. From steaks, to ribs, beef cubes, hamburgers, ground beef and many other beef products, it is extremely versatile. Worldwide, more than 20 percent of consumers use beef as their meat protein source (Davis and others 2005). Beef, a great source of protein, provides numerous vitamins (B6 and B12), and minerals (iron, zinc, and niacin) to the consumer (Brewer 2012). Compared to other meat protein sources of chicken and pork, beef ranks third in the world in per capita consumption (Davis and others 2005). In 2009, about 26.9 billion pounds of beef was consumed in the United States (Brewer 2012). Within the US beef industry, beef has become highly profitable with a retail sales value of \$60 billion in 2002 and rising to \$79 billion in 2011 (Matthews and others 2010). Today's economic decline has driven consumers to select/favor ground beef over steaks or roasts due to its low cost and versatility of creating more affordable and delicious meals (Griffing and others 2012). Ground beef is created from the trimmings sourced from different locations on the cattle, which can be attributed to its low cost (Mohan and others 2012). However to maintain consumers interest and wide spread use of ground beef, many non-meat ingredients are utilized including salt, phosphates, bicarbonates, and starches.

Some common non-meat ingredients used within ground beef include salt and phosphates to form reconstructed meat products (Boles and Shand 1999). Salt within reconstructed beef products intensify the quality defects and discoloration (Trout 1983). These non-meat ingredients tend to extract myofibrillar proteins. The ingredients bind the restructured beef into a desired product. Boles and Shand (1998) used phosphates with salt and force to extract the myofibrillar proteins and create a heat-set protein during cooking (Boles and Shand 1998). Phosphates tend to stabilize color, improve water-holding capacity, and protect the flavor of the finished meat product (Romas and others 2004; Aberle and others 2001).

Sodium bicarbonate ($NaHCO_3$) and potassium bicarbonate ($KHCO_3$) are non-meat ingredients that are utilized in ground beef. $NaHCO_3$ is a generally recognized as safe (GRAS) food ingredient and can be incorporated into any meat product. According to the USDA (2013), there is a limit of 0.5% of $NaHCO_3$ allowed in an injected solution for product formulation. The common name of $NaHCO_3$ is “baking soda”, mainly used in baked goods as a leavening agent. In many Asian cuisines, $NaHCO_3$ is used as a meat tenderizer often mixed in with liquid marinades (Sultana and others 2009). In food products at levels of up to 2%, $NaHCO_3$ is used for leavening, pH control, and taste or texture development (Corral and others 1988; Curran and others 1989).

$KHCO_3$ is commonly used for color stability and leavening agent in baked goods (Armand Products Company). The nutritional benefits of $KHCO_3$ allow for it to be used in ruminant feed to act as a dietary supplement for cattle (Schonewille and others 1999). The FSIS direct list of safe and suitable ingredients used in the production of meat and poultry products, states $KHCO_3$ can be utilized to remove feathers from poultry carcasses (USDA 2013). However, few studies have focused on the direct application of $KHCO_3$ in ground beef as a non-meat ingredient binder and texture enhancer.

Meat loaves, meatballs, and hamburgers are all foods that are traditionally made with ground beef. Cooking is essential for these products as consumption of raw ground beef can be unsafe for consumers. The conditions used to cook the meat product can substantially affect the hardness. Therefore a standard method is needed to measure the texture (Wheeler and others 1997). Instrumental texture analysis is important as it can mimic the way in which consumers feel and breakdown the food in the mouth. Different attributes such as hardness, chewiness, cohesiveness, and many more can be measured through the instrumental texture analysis. One option is to utilize texture profile analysis (TPA), which is a compression test that mimics the deformations the food undergoes during mastication (Herrero and others 2008). A common method to measure meat tenderness is the Warner-Bratzler Shear Force (WBSF) method. WBSF simulates initial shearing or biting of the meat (Wheeler and others 1997). The textural attributes can then be compared to a sensory descriptive analysis to create an overall texture profile. Sensory descriptive analysis is essential as it provides the most accurate information of how the meat product is consumed.

Limited research has investigated the physicochemical properties of $NaHCO_3$ and $KHCO_3$ as non-meat ingredients in cooked ground beef. The objective of this research was to: 1) investigate the internal cooked color, expressible moisture, cook loss, and instrumental textural properties of cooked ground beef with sodium bicarbonate, potassium bicarbonate, modified food starch, and potato starch and 2) analyze the sensory properties of the cooked ground beef incorporated with the bicarbonates and starches and provide the correlation to the instrumental texture attributes.

Materials and Methods

Raw Materials

Raw ground beef (80% lean and 20% fat) (±2%) was received from two ground beef processors (FPL Foods, Augusta, GA; US Foods, Atlanta GA). The ground beef was stored in a blast freezer at -34°C until further testing.

Chemicals

The ground beef was treated with varying levels of NaCl (Food grade, Fisher Scientific, Fairlawn, NJ) distilled water, $NaHCO_3$ (Food grade, Fisher Scientific, Fairlawn, NJ), at $KHCO_3$ (Food grade, Fisher Scientific, Fairlawn, NJ), potato starch (NOVATION® 6600, National Starch, Bridgewater, NJ), and modified dent corn food starch (PURE-GEL® B990, Grain Processing, Muscatine, IA). The different formulations of $NaHCO_3$, $KHCO_3$, modified food starch, potato starch, and salt with sample name abbreviations are provided in Table 4.8.

Ground Beef Preparation

The ground beef was prepared into different containers of aluminum pans and vacuumed packaged into bags for the physiochemical and sensory tests. The ground beef was mixed in a cold room at temperatures ranging from 4°C to 7°C and placed into aluminum tray pans (Wal-mart Stores, Inc., AR). Dimensions for the aluminum tray pans were 5.3 inches (W) x 7.8 inches (D) x 1.75 inches (H). All of the powdered non-ingredients (NaCl, $NaHCO_3$, $KHCO_3$, modified food starch and potato starch), were initially diluted with distilled water (10% dilution) to provide a more homogeneous mixture and allow for better dispersability. Each sample that was mixed was done in a Hobart mixer (Model C-100 T, The Hobart Mfg. Co., Troy, Ohio) and made in triplicate for better statistical analysis.

Ground beef samples were mixed with the bicarbonates, salt, and starches for approximately 10 seconds in a mixing bowl on speed 1 (144 RPM). It was mixed at successive rotational speeds in the Hobart mixer for different intervals of time. The non-meat ingredients such as salt and water were initially added followed by bicarbonates and mixed. The solution of NaCl and water was added in varying times. The treated ground beef portions were mixed in the following order on the following speeds: 1 minute on mixer speed 1, 2 minutes on mixer speed 2 (258 RPM), then for 1 minute three times on speed 3 (450 RPM). Thereafter, the bicarbonate and salt diluted solutions were mixed into each ground beef assigned treatments. On mixer speed 1, this was done for 20 seconds. The mixer then was turned off to scrape the bowl. It was then mixed twice for 1 minute on speed 2. The ground beef was mixed for the last 30 seconds on mixer speed 2 and placed into their individual trays. Modified food starch and potato starch was mixed separately. The control treatment served as the ground beef portion without any added ingredients.

After the ground beef samples were thoroughly mixed, it was placed into three separate aluminum trays. The first tray was utilized for texture analysis testing and Warner-Bratzler Shear Force (WBSF), and expressible moisture. The second tray was used for cook loss analysis, and internal color evaluation. Lastly, the third tray was cooked and utilized for sensory analysis. The treated ground beef in aluminum trays were placed in large 11x22-inch Polyvinylidene chloride (PVdC) barrier shrink vacuum package bags (Winpak, Winnipeg MB) and were vacuum packaged (Henkelman 600 vacuum package machine, Hertogenbosch, Netherlands). After the ground beef samples were prepared and vacuum packaged, they were placed into a blast freezer (-34°C) for future sensory and physiochemical tests.

Cooking Methodology

Preliminary experiments were performed in order to determine the optimal cooking times and temperatures for ground beef sample. Prior to cooking, the ground beef sectioned in the aluminum trays, were removed from the blast freezer (-34°C) and thawed in the refrigerated cooler room (6.6°C) for 14 hours. Thermocouples were inserted into ground beef samples at room temperature (23°C-25°C) to measure its temperature within the oven. Utilizing a hollow meat spear and type T wired thermocouples (Omega, Stamford, CT) they were inserted into the approximate geometric center of each meat loaf. Each thermocouple was connected to a digital handheld thermometer (Model HH21A, Omega, Stamford, CT) (Model RDXL4SD, Omega, Stamford, CT). The ground beef samples were then cooked to an internal temperature of 60°C with a pre-heated oven temperature of 93.3°C. According to various other cooking methods, (Lennon and others 2010; Boles and others 1999; Trout and others 1992; Baardseth and others 2005) beef products were cooked to an internal temperature of 70°C-78°C. However, due to the numerous previous experiments, it was best to reach an internal temperature of 60°C so not to dry the ground beef. According to the American Meat Science Association and National Livestock and Meat board (2005) this produces a doneness of beef steaks to be rare being red in the center third and reddish pink to outer surface (Romas and others 2001).

After the ground beef samples were cooked to 60°C in a convection oven (Blodgett Dual Flow Convection Oven, Burlington, VT). Each tray was removed from the oven and placed at room temperature (20-25 °C) to cool and rest for 30 minutes. The meat loaf samples were cut into half for the Warner-Bratzler Shear Force and cooked texture analysis tests. After the cooling period, the meat loaves were removed from their aluminum trays and heat-sealed with the Impulse Sealer (Model 210-12E, Clamco Corp, Cleveland, Ohio) into clear plastic vacuum bags. For the sensory test, each meat loaf was given 30 minutes to rest and cool after being cooked and then cut into 8-10 cubes (2 cm X 2 cm) for sensory evaluation. All the cubes were then vacuum packaged into vacuum packaged bags and placed in a refrigerated cooler room (6.6 °C) for the future sensory test.

Cook Loss

The ground beef samples were thawed and cooked in aluminum tray pans according to the cooking methodology previously mentioned. The initial weight of the raw ground beef in its tray was measured. The ground beef samples were weighed before and after cooking , allowing for a 30 minute cooling time. The cooked meat was weighed to determine the final weight. Cook loss was then calculated by the following equation (Sheard and Tali 2004; Sindelar and others 2003; Sultana and others 2008):

$$\% \text{ Cook loss} = [(\text{weight}_{raw} - \text{weight}_{cooked})/\text{weight}_{raw}] \times 100$$

The average of triplicate measurements was used for statistical analysis.

Expressible Moisture

The methodology for expressible moisture was performed with slight modifications according to the filter press method of Wierbicki and Deatherage (1958). The treated and untreated ground beef samples used were cooked according to the cooking methodology previously mentioned. Meat loaf samples were brought up to room temperature 24 hours after cooking. Samples were cored out using a #12 brass cork corer to provide a uniform diameter of 1 cm and cut to a height of 1 cm. The weights of each cored meat sample and Whatman filter paper (no. 1, 9cm) were recorded. Both the meat sample and filter paper were placed in between two plexiglass plates. A 1.0 kg metal load cell weight was placed above the top plate in which the meat sample was compressed for 1 minute. After compression, the metal weight was removed and the meat sample along with the filter paper was re-weighted. The expressible moisture was calculated as a percentage by the following equation:

$$\% \text{ Expressible moisture} = [(W_{final} - W_{initial}) / \text{sample weight}] \times 100$$

where, W_{final}= weight of filter paper after compression

$W_{initial}$= initial weight of filter paper

Internal Cooked Color Measurement

The internal cooked color of the meat loaves was measured according to the AMSA Meat Color Guidelines (2012). The surface of the internal cooked area of the meat loaf was covered with saran wrap to allow for instrumental color measurements without causing meat juice or fat to touch the lens. Triplicate readings were performed on the internal portions of the meat loaf using the Hunterlab Miniscan EZ 4500L spectrophotometer (Hunterlab Assoc. Lab, Reston, VA). The *L** (lightness), *a**(redness), *b**(yellowness), hue angle, chroma (intensity of redness) and reflectance values (400-700 nm) were recorded. The hue angle was calculated using the following equation: The hue angle was calculated by the following equation: Hue angle (HA) = [arctangent (b^*/a^*)] The chroma (saturation index) was calculated through the following equation: Chroma or Saturation Index= $\sqrt{(a^{*2}+b^{*2})}$.

Texture Analysis of Cooked Ground Beef

The texture attributes measured were tenderness or hardness, cohesiveness, and chewiness for the cooked meat loaf. These attributes and procedures to measure the texture were obtained from the Research Guidelines for Cookery, Sensory Evaluation, and Instrumental Tenderness Measurements of Fresh Meat (AMSA 1995), Bourne (2002), and through the technical guidance of Drew Lambert and Michele Sink at Food Technology Corporation (Sterling, VA). A #12 brass cork borer was used to make six cores (1cm x 2cm) from the ground beef meat loaf samples. The test was performed on each sample and shear values were reported as the mean of six cores. A TA-94, 45 mm diameter, compression plate (Food Technology Corporation, Sterling, VA) was used to compress the cores on the TMS-Pro texture analyzer (Food Technology Corporation, Sterling, VA). The test samples were placed on a plate, which was installed on a heavy-duty platform. The conditions of the test for each sample included two cycles, a 50% strain, with a crosshead speed of 250 mm/min (Herrero and others, 2008). Hardness was calculated as the peak force during the first compression cycle of a TPA graph. Cohesiveness was calculated as the ratio of area under the second curve to the area under the first curve and relates to the samples strength of internal bonds. Springiness was calculated as the ratio of distance traveled by the probe on the second cycle, (from the sample contact point with a set compression percentage) to the distance the probe traveled on the 1st down-stroke. Hardness, cohesiveness, and springiness are the three attributes needed to calculate for chewiness. Therefore multiplying hardness, cohesiveness, and springiness can derive chewiness. The following texture parameters were quantified and reported: chewiness (mJ), hardness (N), and cohesiveness (dimensionless ratio).

Warner-Bratzler Shear Force Test

The Warner-Bratzler Shear Force (WBSF) test was performed to determine the tenderness of the cooked ground beef samples (AMSA, 1995). A V-shaped WBSF blade was used to shear the cores on the TMS-Pro texture analyzer (Food Technology Corporation, Sterling, VA) utilizing a 500N load cell. The WBSF test was performed on the meat loaf samples and the results were reported as the mean of six cores. The procedure to core the meat loaf was the same one as the previous texture analysis method. The test samples were placed on a plate, which was installed into a heavy-duty platform. The platform was adjusted to allow the blade to pass through the slotted plate. The crosshead speed of the blade was set at 250 mm/min. Shear force (N) and work of shearing (Nm) was determined as the area under the force deformation curve by the TMS- Pro texture analyzer. Shear force was measured by the highest force or peak in which the meat was thoroughly cut. Work of shear is the amount of force over a certain distance to shear the product, which is also the area under the WBSF curve.

Sensory Analysis

Sensory Panel Training for Ground Beef Meat loaf Samples

A panel of 6-10 participants (ages 22 to 60) was semi-trained during eight, one-hour sessions. Four training sessions were conducted to help each panelist become more familiarized with four attributes of juiciness, chewiness, and tenderness or hardness. These attributes were based upon the American Meat Science Association guidelines (1995) and the standards were developed by Meilgaard (2006), a previous study by Maughan (2011), and the sensory and texture training manual (Russell Research Center, USDA, Athens, GA). Standards for the attributes were given to each panelist. The intensity ratings for each standard were created on a scale ranging from zero to fifteen (Table 4.2). For juiciness, the standards were a banana (Kroger, Cincinnati Ohio), cucumber (without skin) (Kroger, Cincinnati Ohio), red delicious apple (Kroger, Cincinnati, Ohio), and a peeled orange (Kroger, Cincinnati, Ohio) (Meilgaard, 2006). For chewiness, the standards used were Cobblestone Mill Jewish rye bread (Flowers Foods, Thomasville, GA), Brach's spicette gum drops (Farley's and Sathers Candy Company, Round Lake, Minnesota) and tootsie rolls (Tootsie Roll Industries LLC, Chicago, IL) (USDA). For tenderness/ hardness, the standards used were Philadelphia light cream cheese (Kraft, Northfield, Illinois), pasteurized american cheese (Kraft, Northfield, Illinois), Hebrew National frankfurters (Con Agra Foods, Omaha Nebraska), and carrots (Kroger, Cincinnati, Ohio) (Meilgaard, 2006).

Four training sessions were conducted by implementing four food products to simulate the sensory analysis of the treated ground beef samples. The four food examples used were crispy chicken tenderloins (Market Pantry, Target Brands, Inc.), fajita grilled chicken breast strips (Market Pantry, Target Brands, Inc.), original meatballs (Armour, John Morrell Food Group), classic mini meat loaf (The Fresh Market, Inc.), and mini meat loaf (Kroger, Inc.). During these four training sessions each panelist were presented with the samples along with the standards previously mentioned and rated the product's three attributes on the fifteen point scale.

Sensory Evaluation and Experimental Design of Ground Beef Meat Loaf Samples

Sensory evaluation was performed in triplicate and each evaluation was performed inside individual booths. The references for each attribute were provided during the evaluations. Each panelist was then asked to rate the ground beef sample on a zero to fifteen-point scale. Water and unsalted crackers were used to cleanse the palate in between each sample. The order of presentation consisted of four randomized samples while each panelist undertook three sittings during each session with a break of 10 minutes between each sitting. The overall evaluation was performed in triplicate on three consecutive days to allow for better statistical analysis.

Statistical Analysis

The experimental design was a randomized complete block with repeated measurements. Type-3 tests of fixed effects for instrumental color changes, texture attributes, WBSF, cook loss, and sensory values were evaluated by using the mixed procedure of SAS (SAS Institute Inc. in

Cary, North Carolina). The experimental design for the sensory analysis was a randomized complete block with repeated measurements. Least square means were created for and separated using the pdiff option for significant F-tests ($p<0.05$). For the sensory analysis and texture analysis correlation data, the r and R^2 values were determined using the Pearson square correlation. Superscripts were assigned for each treatment to show statistical ($p<0.05$) differences among the treated and untreated samples. Samples labeled with an 'a' contains the lowest value and each subsequent letter corresponds to the increasing values.

Results and Discussion

Cook Loss

Cook loss data of the cooked ground beef is shown in Table 4.3. Compared to the control, all samples except for SPS2 were different from each other ($p<0.05$). Results showed that SPBC1 had the lowest ($p<0.05$) cook loss of 6.1% and S05 had the highest cook loss of 34.7%. This was higher than with bicarbonates only and with the combination of salts and bicarbonates. SMFS2 and SPS2 had a higher cook loss than those treated with bicarbonates alone and in combination with NaCl. SSBC05 and SSBC1 had extremely low cook losses of 7.5% and 6.8%, respectively. This shows that $NaHCO_3$ with NaCl exhibited a lower cook loss. SBC05, SBC1, PBC05, and PBC1 samples had a higher cook loss than those combined with NaCl (SSBC05, SSBC2, SPBC05, SPBC1). The cook loss decreased with the increase of bicarbonate concentrations of 1.0% ($p<0.05$) as shown with samples SSBC1 and SPBC1. Potato starch treated ground beef (SPS2) had a higher ($p<0.05$) cook loss than modified food starch (SMFS2).

Results showed that ground beef samples treated with $NaHCO_3$ or $KHCO_3$ alone, had cook losses that was higher than in combination with salt. Sheard and Tali (2004) had reported similar results in pork loin and they observed that it was due to a low injection level of the bicarbonate solution. Yang and others (2006) reported an increase in cooking loss with decreasing amounts of $NaHCO_3$ at 0.25M, 0.40M, and 0.75M. The results of this study show a decrease in cook loss with samples treated with bicarbonates only and in conjunction with NaCl.

Expressible Moisture

Table 4.3 shows the results obtained for expressible moisture of the untreated and treated ground beef samples. Ground beef samples NT, SBC05, and SBC1 had the lowest ($p<0.05$) expressible moisture, while SSBC05 had the highest expressible moisture at 6.5%. When compared to the sensory juiciness scores, SSBC05 resulted in the highest juiciness score of 5.67. However, the panelists did not perceive SSBC05 to be the juiciest product. Additionally, panelists perceived $KHCO_3$ only ground beef samples as juicier than $NaHCO_3$ only treated samples. Expressible moisture and juiciness scores did agree with each other as ground beef samples NT, S05, SBC05 and SBC1 expressed the least amount of moisture and were the least juicy (Table 4.3). The results obtained for expressible moisture revealed no significant differences ($p>0.05$) among samples with $KHCO_3$, $NaHCO_3$, and starches (PBC05, PBC1, SSBC1, SPBC05, SPBC1, SMFS2, and SPS2). Results showed that NaCl with bicarbonates and NaCl with starches expressed more moisture.

Ground beef treated with salt (S05) and with bicarbonates had more moisture. Ground beef treated with MFS and PS expressed less moisture than the control (NT). The starches allowed the ground beef to hold more water after cooking. Li and Yeh (2002) showed that in surimi, starches enhance gel strength due to the swelling of the starch granules with the protein gel. This compressed the meat matrix and allows for less moisture loss.

Internal Cooked Ground Beef Color

The *CIE L*a*b** color characteristics of the cooked ground beef's internal cooked color is shown in Table 4.4. The *a** -values display the redness of the internal cooked portion. Large hue angle values reveal a less red product (Tapp and others 2011). Chroma exhibits the saturation of colors and is related primarily to myoglobin concentration (Sen and others 2006).

The findings for *L**- values showed that PBC05 had the highest *L**-value of 48.3 and SMFS2 was the darkest meat product with a *L**- value of 56.4. SBC05 and SPS2 were most similar to NT (control). There was no significant difference ($p<0.05$) between the ground beef samples treated with NaCl and $KHCO_3$ at 0.5% and 1.0%. Modified food starch and potato starch treated ground beef (SMFS2 and SPS2) displayed the lightest internal color values with the highest *L**- values. With the inclusion of both bicarbonates, the *L**-values decreased and created a darker product. These results are in agreement with Yang and others (2006) as $NaHCO_3$ treated samples lowered the meat's lightness color significantly in pork loins. They have stated that due to the high pH of the $NaHCO_3$ treated samples, the *L** - values were lower and resulted in the dark color of the pork loin. The high pH could be the reason for lower *L**-values or darker color in ground beef.

The *a** -values for the cooked ground beef show its redness in Table 4.4. S05 had the highest internal red color with *a**-values of 27.3 and NT had the lowest *a** -value of 11.0. The trend in Table 4.4 showed that ground beef treated with NaCl and bicarbonates had higher *a** -values than those with potato starch and modified food starch (SMFS2 and SPS2). Ground beef treated with only $KHCO_3$ (PBC05 and PBC1) yielded higher *a** -values (26.1 and 24.8, respectively) than those with $NaHCO_3$ only (SBC05 and SBC1) (20.6 and 22.4, respectively). With the combination of NaCl and each of the bicarbonates separately, the red color was more prominent at bicarbonate levels of 0.5%. At a bicarbonate concentration level of 0.5% and with salt, the internal ground beef redness was more prominent. The *a**- values increased with the inclusion of both bicarbonates compared to the control (NT). This increase in redness can be attributed to the increase in pH with bicarbonates (Sen and others 2006). An increase in redness was reported in pork with increasing amounts of $NaHCO_3$ (Yang and others 2006).

The *b**-values of the ground beef is shown in Table 4.4. The samples with $KHCO_3$ and $NaHCO_3$ at 0.5% with and without NaCl, exhibited higher *b**- values. NT had the lowest *b**-value of 16.4 and S05 had the highest *b**- value at 21.9. As expected, NT was different from all the other treated samples showing that the non-meat ingredients had an impact on the color ($p<0.05$). However, there was not a trend of increasing or decreasing values. The *b**values were higher at bicarbonate levels of 0.5% than at 1.0% but not significantly different ($p>0.05$).

The measured hue angle values (Table 4.4) lie in the red color range or the upper right quadrant of the Hunter Color Space (AMSA 2012) for hue angle. Hue angle values closer to 0 degrees show a stronger red pigment and values moving towards 45 degrees exhibit a browner and yellow color**.** NT had a hue-angle value of 56.1° and PBC1 had the least red internal color of 36.8°. The trend shows that modified food starch and potato starch (SMFS2 and SPS2) were comparable to NT ($p>0.05$). All treatments with $NaHCO_3$, $KHCO_3$ and NaCl were different and had lower hue angle values than NT ($p<0.05$)**.** Ground beef treated with only $NaHCO_3$ (SBC05 and SBC1) and only $KHCO_3$ (PBC05 and PBC1) had hue angle values that were higher at 0.5% than at 1.0%. When treated with a combination of NaCl and bicarbonates, the internal color displayed higher hue angle values with bicarbonates at 1.0% than at 0.5%. However, they were not different from each other ($p<0.05$).

In Table 4.4 chroma, also known as saturation index, is the measurement of red color intensity. NT had a chroma value of 19.8 while S05 had the highest color saturation of 35.1. Modified food starch and potato starch (SMFS2 and SPS2) ground beef samples lowered the saturation index values as compared with bicarbonate ($NaHCO_3$ and $KHCO_3$) treated ground beef. Ground beef treated with NaCl and both bicarbonates, the saturation index was higher at concentration levels of 0.5%. Overall, the chroma values increased with the inclusion of bicarbonates and starches as compared to the control (NT) ($p<0.05$).

Texture Analysis of Cooked Ground Beef

The chewiness texture of the treated cooked ground beef is found in Table 4.5. S05 was the chewiest with a value of 223 mJ and SSBC05 was the least chewy with a value of 44.76 mJ. Ground beef mixed with both bicarbonates only at 1.0%, had higher chewiness values than those in combination with NaCl and the bicarbonates. Hardness and chewiness values were directly proportional to each other.

The hardness values of the treated cooked ground beef is shown in Table 4.5. The ground beef samples most similar to the control (NT) was SBC05 and SBC1, as it contains only $NaHCO_3$. S05 had the highest hardness value of 74.03 N, making it the hardest or least tender treated ground beef product. Ground beef with modified food starch and potato starch were comparable in hardness to the samples treated in combination with the bicarbonates and NaCl. The addition of bicarbonates and NaCl displayed a trend of a softer product, although there was no significant difference ($p>0.05$). The treated ground beef samples with only $NaHCO_3$ and $KHCO_3$ at levels of 0.5% (SBC05 and PBC05), were harder than at levels of 1.0%. These samples were also harder than those in combination with NaCl, SSBC05, SSBC1, SPBC05 and, SPBC1 ($p<0.05$).

Results have shown that S05 yields the highest chewiness (223.13 mJ) and hardness (74.03 N) values. The results agree with WBSF values and sensory hardness chewiness scores. WBSF data support that with salt at 0.5%, it was the most difficult to shear the meat and requires the most work to shear it. Panelists also showed in the sensory evaluation (Table 4.7) that S05 was the chewiest with the highest rating score of 4.81 on a fifteen point scale. Panelists also found S05 to be the hardest meat to process within the mouth with a rating score of 7.81 on a fifteen point scale (Table 4.7). The least chewy and hard ground beef sample was SSBC05 according to TPA. This revealed that with the inclusion of bicarbonates the hardness values and chewiness values decreased compared to the control. Comparing between $NaHCO_3$ and $KHCO_3$ only treated ground beef, $KHCO_3$ samples had significantly lower chewiness and hardness levels. The ground beef treated with MFS and PS are not significantly different ($p>0.05$) than the ground beef with bicarbonates alone and combined with salt. Sheard and Tali (2004), reported that the decreased chewiness and hardness values was due when the product was heated and CO_2 was released forming air pockets. This disabled the load bearing structure within the pork loins to make it less hard. These air pockets were also found in all of the bicarbonate and starch treated ground beef samples

The cohesiveness results are shown in Table 4.5. As NaCl was combined with bicarbonates cohesiveness was slightly less with $NaHCO_3$ than $KHCO_3$. SMFS2 had the lowest cohesiveness of 0.38 showing that with modified food starch, the ground beef deformed the least. PBC1 and SSBC1 both had the highest cohesiveness at 0.5 and deformed the most. Modified food starch and potato starch showed a trend of lower cohesiveness values than samples treated with NaCl and bicarbonates. Ruusunen and Puolanne (2005) reported that NaCl increased the cohesiveness of meat batter. Cohesiveness did not follow the same pattern as chewiness and hardness in which S05 had the highest level and SSBC05 had the lowest level. There was not much difference between the bicarbonate treated and bicarbonate with salt treated ground beef. In cod sausages, cohesiveness increased with higher amounts of $NaHCO_3$ when at 0.15% and 0.30% (Cardoso and others 2009).

Warner-Bratzler Shear Force of Cooked Ground Beef

The WBSF test was performed to measure the shear value and work of shear values, which provided the tenderness of the ground beef (Table 4.6). Shear force was measured by the maximum force or peak in the curvature in which the meat was thoroughly cut (Miranda and Aguilera 2006). S05 required the most amount of force to shear the product with the largest shear value of 15.80 N. SPBC1 had the lowest shear value of 5.88 N. PBC1 was similar to NT without any treatment ($p>0.05$). $KHCO_3$ at 0.5% had a higher shear value than at 1.0%, regardless of the inclusion of NaCl.

Work of shear or total shear work is the amount of force with a certain distance to shear the product, which is the area under the curve (Rothschild and Ruvinsky 2011). S05 required the most work to shear the product with a work of shear value of 249.09 Nm and SSBC1 had the least amount of work needed to shear the ground beef at 100.67 Nm. When comparing the starches, SMFS2 had higher work of shear values, 175.15 Nm, than SPS2 of 134.28 Nm. For samples with $KHCO_3$ only (PBC05 and PBC1) more work was needed to shear at 0.5% than at 1.0%. The NaCl and bicarbonate combination had low work of shear values. With the bicarbonates only, more work was needed to shear the treated ground beef.

Sheard and Tali (2004) have shown that the pork containing $NaHCO_3$ (3%) had reduced shear force values. The bicarbonate treated pork developed air-filled pockets during the cooking process. Sheard and Tali (2004) reported that the air filled pockets decreased the load bearing meat muscle and therefore decreased the shear force value. In the current study, shear values with $NaHCO_3$ and salt were lower than the control (NT). With $KHCO_3$ only the shear values increased but it seemed that the inclusion of both bicarbonates ($NaHCO_3$ and $KHCO_3$) and salt, the shear values declined compared to the control. S05 exhibited the largest shear value (15.80 N) and work of shear (249.09 Nm). These high values were similar to the TPA and sensory hardness results found in this study. NaCl had an impact on the hardness of the ground beef as it extracts the myofibrillar proteins (Aberle and others 2001; Romas and others 2001). The myofibrillar proteins are soluble in salt solutions and its extraction can create a sticky exudate. This allows for the meat to be easily formed into the desired ground beef products such as hamburgers, meatballs, and meat loaves. The shear value of the ground beef with only bicarbonates was slightly more than when combined with salt. This was also seen with the bicarbonate treated pork loins experiments performed by Sheard and Tali (2004).

Sensory Analysis

Panelists evaluated and rated the sensory attributes of chewiness, hardness, and juiciness on a fifteen-point scale (Table 4.7). Sensory evaluation scores showed that S05 was the hardest sample and the chewiest with intensity rating scores of 7.81 and 4.81, respectively. The trend of decreasing chewiness and hardness ratings with the inclusion of bicarbonates, bicarbonates with salt, and with the starches is shown in Table 4.7. For hardness most of the samples were similar to each other except for the samples without any treatment or with only NaCl (NT and S05)

($p<0.05$). Overall the range of hardness scores was between 5.61 and 7.81 and on a total 15-point scale. The intensity rating scores showed that the bicarbonates at 0.5% tend to be harder or less tender than at 1.0%. $NaHCO_3$ or $KHCO_3$ only ground beef samples at levels of 1.0% provided a more tender meat product. The range of scores for chewiness was from 2.87 to 4.81. The panelists showed that SBC1 was the least hard (5.61) or tender sample and also the least chewy (2.87) ($p<0.05$).

Sensory scores showed that ground beef treated with only salt (S05), its hardness and chewiness scores were the highest. The high scores are in agreement with the instrumental tests (WBSF and texture analysis) performed in this study. This revealed that the panelists did agree with the objective or instrumental findings. Bechtel and others (1985) reported lower tenderness scores with salt, indicating a harder meat sample or a higher hardness score in frankfurters. In this study, the ground beef samples with salt and the bicarbonates, and with both bicarbonates alone, the tenderness score increased. This was in agreement with a study by Bechtel and others (1985) in which frankfurters were mixed with bicarbonates. Compared to the control, panelists perceived the $NaHCO_3$ and $KHCO_3$ treated ground beef to be less chewy, although not statistically different.

Juiciness scores revealed that ground beef treated with only salt (S05) had one of the lowest juiciness scores of 3.33. This shows that ground beef treated with only salt, yielded high chewiness and hardness values and low intensity rating scores of juiciness. The least juicy sample determined by the panelists was NT and the juiciest was SPBC1. Overall, with the inclusion of bicarbonates at 1.0% and with salt, the meat was perceived to be the juiciest. The bicarbonates aid in increased juiciness as scores indicate an increase in juiciness scores of up to 6.39 on a 15-point scale. With the addition of NaCl to bicarbonates, the juiciness scores are at its highest. In broiler chickens, the juiciness scores of the bicarbonate treated samples were very high showing a rating of 7.0 on an 8 point scale (Sen and others 2005). According to Romas and others (2001) ground beef with a lean percentage of 80% and fat percentage of 20% is considered the standard content in hamburgers that will provide the optimal juiciness and flavor. Ground beef is also considered less appetizing and fulfilling when the amount of fat has decreased. This is more evident when the fat is reduced to approximately 5 to 10% (Troutt and others 1992). Ground beef samples NT and S05 were both different ($p<0.05$) than all the samples treated with bicarbonates and NaCl, and starches (SSBC05, SSBC1, SMFS2, and SPS2). The samples with bicarbonates alone or in combination with NaCl had larger juiciness scores at bicarbonate levels of 1.0%. NT and S05 were perceived to have the lowest sensory scores by the panelists and the least percentage of moisture expressed. Again, this shows that the instrumental or objective measurement was similar to the sensory analysis.

Correlation Between Textural and Sensory Attributes

Correlations were performed between the attributes of hardness to investigate the relationship between the sensory analysis and instrumental TPA measurements. The scatter plot correlation matrix for hardness (Figure 4.1) showed NT had the strongest positive correlation ($r = 0.98$). Overall, there was a good fit of data within the 95% confidence limits. The ground beef treated with $KHCO_3$ and/or NaCl (SPBC05 and SPBC1) the correlation was higher than when mixed with only $KHCO_3$ (PBC05 and PBC1). SPBC05 and SPBC1 have the same correlation with $r = 0.87$. SMFS2 ($r = -0.95$) and SPS2 ($r = -0.70$) have a strong negative correlation.

Figure 4.2 displays the scatter plot correlation matrix for the attribute, chewiness. It examines the relationship between the sensory profile and TPA instrumental analysis. The scatter plot correlation matrix also displays the fit of the data within a 95% confidence limit. When adding $KHCO_3$ a strong correlation can be seen in samples PBC05 (r = 0.82), PBC1 (r=0.70), SPBC05 (r = 0.94), and SPBC1 (r = -0.73). A stronger correlation in instrumental and sensory chewiness was observed with NaCl and bicarbonates. Overall, $NaHCO_3$ treated ground beef had a correlation that was less strong than the ground beef samples treated with $KHCO_3$. Similar to $KHCO_3$ the addition of NaCl with $NaHCO_3$ to the ground beef also had a stronger correlation than with only $NaHCO_3$. This was evident as the chewiness r-values for SSBC05 and SSBC1 were -0.67 and -0.59, respectively. Additionally, SBC05 and SBC1 were -0.13 and -0.27, respectively. With $NaHCO_3$ the increased amount of $NaHCO_3$ yielded a higher chewiness correlation. Without any treatments, NT was the most strongly correlated (r = -0.99). SMFS2 (r = -0.85) and SPS2 (r = -0.79) were also strongly correlated.

Textural instrumental analysis is a better analysis as it provides objective and quantifiable measurements of the treated ground beef products for the food industry but the sensory analysis is better as it is a better representation of the human or consumer perception.

Conclusion

Ground beef treated with salt only at 0.5% (S05) was the chewiest and hardest product. This was evident through instrumental texture analysis, WBSF, and sensory evaluation. According to WBSF data, S05 required the highest amount of work to shear the product and had the highest shear value. SSBC05 was the least chewy and least hard according to the texture analysis. The sensory evaluation results also show low chewiness and hardness ratings of sample SSBC05. As $NaHCO_3$ and $KHCO_3$ increased the cohesiveness of the ground beef increased as well. Ground beef treated with $KHCO_3$ at 1.0% and NaCl at 0.5% (SPBC1) was the juiciest product according to panelists. Internal cooked color measurement results revealed that ground beef treated with $NaHCO_3$ and $KHCO_3$ had a higher *a**-values showing a red pinkish internal color. Overall, the bicarbonates decreased the hardness, shear value and work of shear compared to the control. This shows that bicarbonates had a great tenderizing effect and increased juiciness within the ground beef. Therefore, the application of bicarbonates in ground beef will aid in creating various types of food dishes such as hamburgers, meatloaves, or meatballs. Future work should be focused on the inclusion of bicarbonates in ground beef with different internal temperatures.

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List of Tables

Table 4.1: Instrumental texture profile analysis (TPA) definitions for hardness/tenderness, chewiness, and other attributes.

Attribute	Instrumental Definition	Units
Primary	4 basic parameters used to determine how food moves and handles within the mouth	
Hardness/Tenderness	Highest peak in the first compression cycle	Newton (N)
Springiness	Height in which the food recovers in the time elapsed between the end of the first bite and the start of the second	Meters (m)
Adhesiveness	The negative area for the first bite. This shows the amount of work necessary to pull the plate away from the food sample.	Joules (J)
Cohesiveness	The ratio of positive area during the second to that of the first downward stroke compression cycle	Ratio (Dimensionless)
Secondary	3 other parameters using the primary attributes to describe more detailed movements within the mouth	
Fracturability	Initial substantial break in the first compression cycle	Newton (N)
Gumminess	Calculation: Hardness x Cohesiveness	Newton (N)
Chewiness	Calculation: Gumminess x Springiness	Joules (J)

Food Technology Corporation, Szczesniak 1963, Bourne 2002

Table 4.2: Sensory descriptive attribute definitions and reference samples used for the cooked ground beef sensory evaluation.

Descriptor	Definition/Instruction	Reference Sample	Preparation of Samples	Intensity Rating[a]
Juiciness	Amount of juice/moisture perceived in mouth or the amount of moisture leaving the product and into the mouth after 7-10 chews between molars	Banana	0.5 inch slice	1
		Cucumber	0.5 inch slice without skin	8
		Red Delicious Apple	0.5 inch wedge without skin	10
		Florida or Valencia Orange	0.5 inch wedge	15
Tenderness/Hardness	Force to attain a given deformation such as force to compress between molars, first bite or force required to bite through molars (very soft to very hard). 5 chews between molars	Cream Cheese	One spoonful of Kraft, Philadelphia Light or 1/3 fat	1
		Pasteurized Yellow American Cheese	0.5 inch cubed cheese	4
		Hebrew National Frankfurter	0.5 inch slice cooked	7
		Carrots	0.5 inch slice- peeled & raw	11
Chewiness	Measurement of chewiness utilizing molars on 2nd to 3rd chew	Jewish Rye Bread	0.5 square inch slice	2
		Orange Slices[b]	1 piece	6
		Tootsie roll	1 piece	13

[a]Intensity Rating of samples are based on a 0-15 scale
[b]Reference sample created for this particular sensory study
Meilgaard and others 2007; USDA; AMSA, 1995

Table 4.3: Least squares mean for expressible moisture (%) and cook loss (%) values of raw ground beef treated with different levels of $NaHCO_3$, KHCO3, NaCl, modified food starch, and potato starch.

Treatment^m	Expressible Moisture (%)	Cook Loss (%)
NT	0.0^{a}	29.3^{e}
S05	0.0^{a}	34.7^{f}
SBC05	0.0^{a}	14.2^{b}
SBC1	0.0^{a}	21.5^{c}
PBC05	3.3^{b}	27.0^{d}
PBC1	4.1^{b}	19.9^{c}
SSBC05	6.5^{c}	7.5^{a}
SSBC1	3.5^{b}	6.8^{a}
SPBC05	3.9^{b}	14.9^{b}
SPBC1	4.6^{bc}	6.1^{a}
SMFS2	3.5^{b}	27.1^{d}
SPS2	3.4^{b}	29.8^{e}

^{m}NT = No NaCl, Bicarbonates & H_2O, S05 =NaCl (0.5%), SBC05= $NaHCO_3$ (0.5%), SBC1 = $NaHCO_3$ (1.0%), PBC05= $KHCO_3$ (0.5%), PBC1 = $KHCO_3$ (1.0%), SSBC05 = NaCl (0.5%), $NaHCO_3$ (0.5%), SSBC1 =NaCl (0.5%), $NaHCO_3$ (1.0%), SPBC05= NaCl (0.5%), $KHCO_3$ (0.5%), SPBC1 = NaCl (0.5%), $KHCO_3$ (1.0%), SMFS2= NaCl (0.5%), Modified Food Starch (2.0%), SPS2 = NaCl (0.5%), Potato Starch (2.0%)

Means with different superscripts within a column are different ($p<0.05$)

± SE = 0.77 for Expressible moisture, 0.68 for Cooked Loss

Table 4.4: Least squares mean for surface colorimeter readings of *L** (lightness), *a** (redness), *b** (yellowness), Hue angle (Degrees), and saturation index (Chroma) of cooked ground beef treated with different levels of $NaHCO_3$, $KHCO_3$, NaCl, modified food starch, and potato starch.

Treatment^m	**Color Characteristics**				
	L*	***a****	***b****	**Hue Angle (°)**	**Saturation Index (Chroma)**
NT	54.2^{d}	11.0^{a}	16.4^{a}	56.1^{c}	19.8^{a}
S05	50.5^{b}	27.3^{e}	21.9^{e}	38.7^{ab}	35.1^{h}
SBC05	52.9^{cd}	20.6^{bc}	20.6^{bcde}	45.3^{b}	29.1^{de}
SBC1	49.5^{ab}	22.4^{bcd}	19.8^{bcd}	41.9^{ab}	29.9^{def}
PBC05	48.3^{a}	26.1^{de}	20.3^{bcde}	38.1^{ab}	33.1^{fgh}
PBC1	50.1^{ab}	24.8^{cde}	18.5^{b}	36.8^{a}	30.9^{defg}
SSBC05	50.5^{ab}	25.3^{de}	20.0^{bcde}	38.4^{ab}	32.3^{efgh}
SSBC1	51.3^{bc}	23.1^{bcde}	18.5^{b}	38.7^{ab}	29.6^{de}
SPBC05	50.7^{b}	25.6^{de}	21.3^{de}	39.5^{ab}	33.3^{gh}
SPBC1	50.7^{b}	19.7^{b}	18.8^{bc}	45.2^{b}	27.7^{cd}
SMFS2	56.4^{e}	14.8^{a}	20.8^{cde}	54.7^{c}	25.5^{bc}
SPS2	54.9^{de}	13.3^{a}	19.2^{bc}	55.4^{c}	23.3^{b}

^{m}NT = No NaCl, Bicarbonates & H_2O, S05 =NaCl (0.5%), SBC05= $NaHCO_3$ (0.5%), SBC1 = $NaHCO_3$ (1.0%), PBC05= $KHCO_3$ (0.5%), PBC1 = $KHCO_3$ (1.0%), SSBC05 = NaCl (0.5%), $NaHCO_3$ (0.5%), SSBC1 =NaCl (0.5%), $NaHCO_3$ (1.0%), SPBC05= NaCl (0.5%), $KHCO_3$ (0.5%), SPBC1 = NaCl (0.5%), $KHCO_3$ (1.0%), SMFS2= NaCl (0.5%), Modified Food Starch (2.0%), SPS2 = NaCl (0.5%), Potato Starch (2.0%)
Means with different super scripts within a column are significantly different ($p<0.05$)
± SE = 0.79 for *L**; 1.63 for *a**; 0.73 for *b**; 2.59 for Hue Angle; 1.32 for Chroma

Table 4.5: Least squares mean for the texture analysis attributes of chewiness, hardness, and cohesiveness values of cooked ground beef treated with different levels of $NaHCO_3$, $KHCO_3$, NaCl, potato starch, and modified food starch.

Treatment^{m}	**Texture Analysis**		
	Chewiness (mJ)^{x}	**Hardness (N)^{y}**	**Cohesiveness (ratio)**
NT	103.01^{de}	43.01^{c}	0.41^{b}
S05	223.13^{g}	74.03^{d}	0.48^{c}
SBC05	105.07^{de}	43.73^{c}	0.49^{d}
SBC1	127.12^{f}	42.39^{c}	0.49^{d}
PBC05	121.15^{ef}	40.24^{c}	0.49^{d}
PBC1	98.22^{d}	31.48^{b}	0.51^{e}
SSBC05	44.76^{a}	19.53^{a}	0.50^{de}
SSBC1	60.08^{bc}	21.53^{a}	0.51^{de}
SPBC05	66.86^{bc}	26.21^{b}	0.49^{d}
SPBC1	52.77^{ab}	22.72^{a}	0.49^{d}
SMFS2	46.64^{ab}	24.57^{a}	0.38^{a}
SPS2	74.09^{c}	32.53^{b}	0.42^{b}

^{m}NT = No NaCl, Bicarbonates & H_2O, S05 =NaCl (0.5%), SBC05= $NaHCO_3$ (0.5%), SBC1 = $NaHCO_3$ (1.0%), PBC05= $KHCO_3$ (0.5%), PBC1 = $KHCO_3$ (1.0%), SSBC05 = NaCl (0.5%), $NaHCO_3$ (0.5%), SSBC1 =NaCl (0.5%), $NaHCO_3$ (1.0%), SPBC05= NaCl (0.5%), $KHCO_3$ (0.5%), SPBC1 = NaCl (0.5%), $KHCO_3$ (1.0%), SMFS2= NaCl (0.5%), Modified Food Starch (2.0%), SPS2 = NaCl (0.5%), Potato Starch (2.0%)
Means with different super scripts within a column are different ($p<0.05$)
± SE = 6.90 for Chewiness; 2.22 for Hardness; 0.007 for Cohesiveness
^{x} = TPA Chewiness units of millijoules
^{y} = TPA Hardness units of Newtons
^{z} = TPA cohesiveness units are dimensionless and is the ratio of area under the second curve to the area under the first curve of the TPA graph cycle

Table 4.6: Least squares means for Warner-Bratzler Shear Force (WBSF) shear value and work of shear values of cooked ground beef treated with differing levels of $NaHCO_3$, $KHCO_3$, NaCl, modified food starch, and potato starch.

Treatment^m	**Warner-Bratzler Shear Force (WBSF)**	
	Shear Value (N)^x	**Work of Shear (Nm)**^{y}
NT	9.81^{cd}	178.28^{de}
S05	15.80^{e}	249.09^{f}
SBC05	7.86^{abc}	130.9^{bc}
SBC1	10.91^{d}	191.63^{e}
PBC05	11.33^{d}	195.77^{e}
PBC1	9.28^{cd}	149.21^{cd}
SSBC05	7.62^{abc}	104.49^{ab}
SSBC1	6.47^{a}	100.67^{a}
SPBC05	11.11^{d}	178.56^{de}
SPBC1	5.88^{a}	103.06^{ab}
SMFS2	11.30^{d}	175.15^{de}
SPS2	8.79^{bc}	134.28^{c}

^{m}NT = No NaCl, Bicarbonates & H_2O, S05 =NaCl (0.5%), SBC05= $NaHCO_3$ (0.5%), SBC1 = $NaHCO_3$ (1.0%), PBC05= $KHCO_3$ (0.5%), PBC1 = $KHCO_3$ (1.0%), SSBC05 = NaCl (0.5%), $NaHCO_3$ (0.5%), SSBC1 =NaCl (0.5%), $NaHCO_3$ (1.0%), SPBC05= NaCl (0.5%), $KHCO_3$ (0.5%), SPBC1 = NaCl (0.5%), $KHCO_3$ (1.0%), SMFS2= NaCl (0.5%), Modified Food Starch (2.0%), SPS2 = NaCl (0.5%), Potato Starch (2.0%)
Means with different super scripts within a column are significantly different ($p<0.05$)
± SE = 0.69 for Shear Value; 10.04 for Work of Shear
^{x} = WBSF Shear Value units of Newtons
^{y} = WBSF Work of Shear units of Newton Meters

Table 4.7: Least squares means for sensory descriptive intensity ratings of cooked ground beef treated with different levels of $NaHCO_3$, $KHCO_3$, NaCl, modified food starch, and potato starch.

Treatment^m	**Sensory Analysis Characteristics***		
	Hardness	**Chewiness**	**Juiciness**
NT	6.48^{b}	3.72^{de}	2.96^{a}
S05	7.81^{d}	4.81^{g}	3.33^{ab}
SBC05	6.15^{ab}	3.54^{de}	4.30^{bc}
SBC1	5.61^{a}	2.87^{f}	5.57^{de}
PBC05	6.07^{ab}	3.31^{ef}	4.09^{bc}
PBC1	5.81^{ab}	3.04^{d}	4.67^{cd}
SSBC05	6.00^{ab}	3.29^{a}	5.67^{de}
SSBC1	5.83^{ab}	3.69^{bc}	6.33^{ef}
SPBC05	6.43^{bc}	3.78^{bc}	5.00^{cd}
SPBC1	6.05^{ab}	3.15^{ab}	6.39^{f}
SMFS2	6.21^{ab}	3.43^{ab}	5.39^{de}
SPS2	6.11^{ab}	4.24^{c}	5.02^{cd}

^{m}NT = No NaCl, Bicarbonates & H_2O, S05 =NaCl (0.5%), SBC05= $NaHCO_3$ (0.5%), SBC1 = $NaHCO_3$ (1.0%), PBC05= $KHCO_3$ (0.5%), PBC1 = $KHCO_3$ (1.0%), SSBC05 = NaCl (0.5%), $NaHCO_3$ (0.5%), SSBC1 =NaCl (0.5%), $NaHCO_3$ (1.0%), SPBC05= NaCl (0.5%), $KHCO_3$ (0.5%), SPBC1 = NaCl (0.5%), $KHCO_3$ (1.0%), SMFS2= NaCl (0.5%), Modified Food Starch (2.0%), SPS2 = NaCl (0.5%), Potato Starch (2.0%)
Means with different super scripts within a column are significantly different ($p<0.05$)
*Data based on hedonic scale scores of 0 to 15
± SE = 0.28 for Hardness; 0.35 for Chewiness; 0.39 for Juiciness

Table 4.8: Mixture formulations for ground beef treated with differing levels of $NaHCO_3$, $KHCO_3$, NaCl, modified food starch, and potato starch.

Sample	**Description**[a]	**%**[c]				
		NaCl	**$NaHCO_3$**	**$KHCO_3$**	**Modified food starch**	**Potato Starch**
NT (Control)	None[b]	-	-	-	-	-
S05	NaCl	0.5	-	-	-	-
SBC05	$NaHCO_3$	-	0.5	-	-	-
SBC1	$NaHCO_3$	-	1.0	-	-	-
PBC05	$KHCO_3$	-	-	0.5	-	-
PBC1	$KHCO_3$	-	-	1.0	-	-
SSBC05	NaCl + $NaHCO_3$	0.5	0.5	-	-	-
SSBC1	NaCl + $NaHCO_3$	0.5	1.0	-	-	-
SPBC05	NaCl + $KHCO_3$	0.5	-	0.5	-	-
SPBC1	NaCl + $KHCO_3$	0.5	-	1.0	-	-
SMFS2	NaCl + Modified Food Starch	0.5	-	-	2.0	-
SPS2	NaCl + Potato Starch	0.5	-	-	-	2.0

[a] NaCl, $NaHCO_3$, $KHCO_3$, modified food starch, and potato starch were all diluted in distilled water for better homogeneity and dispersability

[b] No ingredient (NaCl, $NaHCO_3$, $KHCO_3$, modified food starch, or potato starch) were added except distilled water

[c] Percent composition of individual ingredient added to the ground beef as a formulation

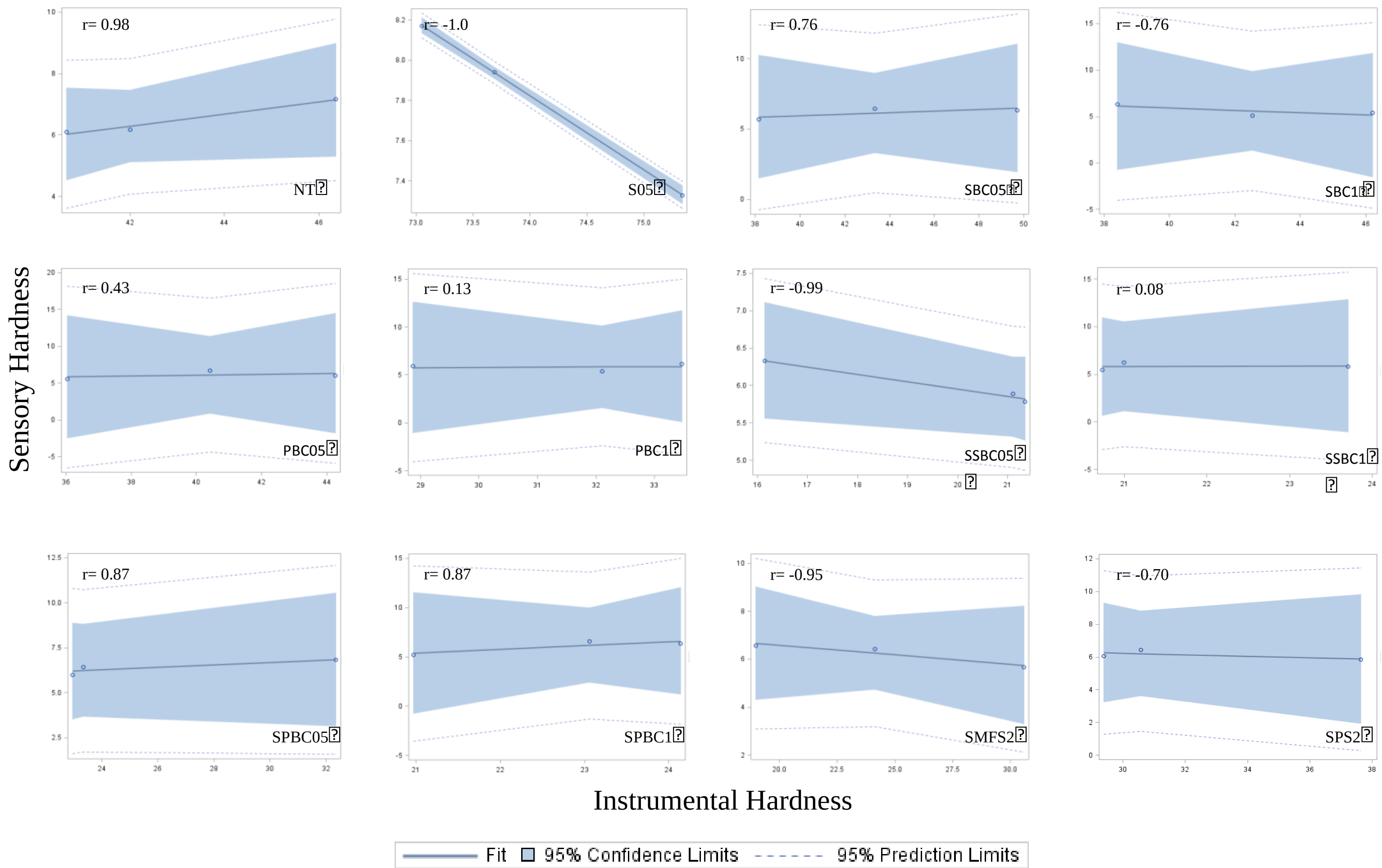

Figure 4.1: Scatter plot correlation matrix comparing the hardness sensory descriptive analysis and instrumental texture profile analysis of ground beef treated with different levels of $NaHCO_3$, $KHCO_3$, NaCl, modified food starch, and potato starch.

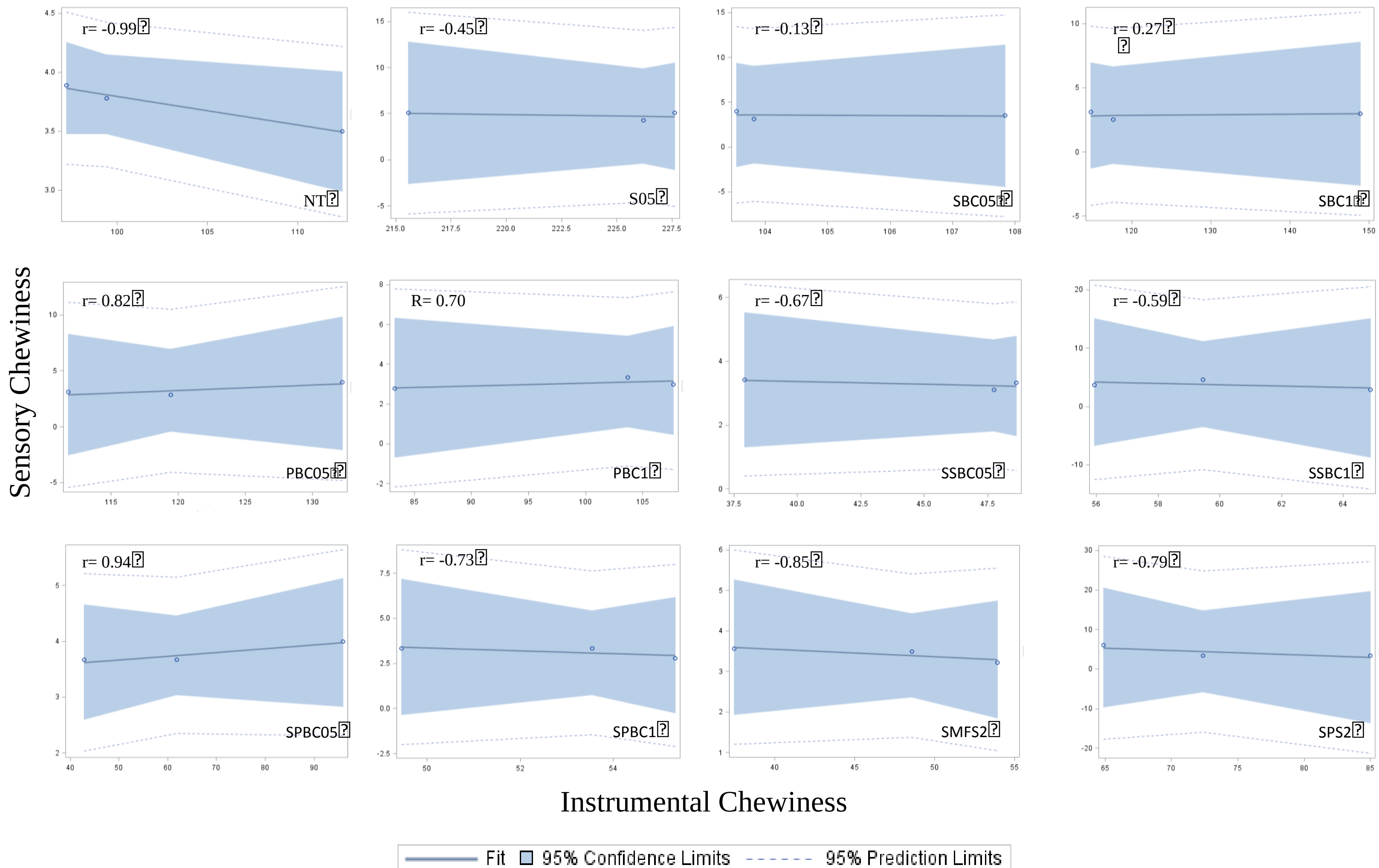

Figure 4.2: Scatter plot correlation matrix comparing the chewiness sensory descriptive analysis and instrumental texture profile analysis of ground beef treated with different levels of $NaHCO_3$, $KHCO_3$, NaCl, modified food starch, and potato starch.

CHAPTER 5

CONCLUSION

The effects of $NaHCO_3$, $KHCO_3$, and salt in raw and cooked ground beef were investigated in this study. It was compared to other common food industry non-meat ingredients, modified food starch and potato starch. In raw ground beef bicarbonates with or without salt improved the water holding capacity as it held more water than both MFS and PS. $KHCO_3$ with NaCl provided the best adhesiveness values within ground beef. Hardness decreased creating a more tender raw ground beef product with the inclusion of the bicarbonates and NaCl from the control. Hardness values showed there was a significant difference when adding $NaHCO_3$ or $KHCO_3$ and with salt. Over the seven day period the raw meat darkened with lower L^*- values and the redness decreased over the same period of time with lower a^*- values with the use of bicarbonates. This study suggests that the use of bicarbonates can increase the WHC due to increased pH and produces raw ground beef that is more adhesive and softer in texture.

Cooked ground beef treated with salt only at 0.5% (S05) was the chewiest and hardest product. This was seen through instrumental texture, WBSF, and sensory analysis. According to Warner-Bratzler shear force data, S05 required the highest amount of work to shear the product and had the highest shear value. SSBC05 was the least chewy and least hard according to the texture analysis. Through WBSF and sensory analysis results, SSBC05 also showed to be the most tender samples and least chewy. As $NaHCO_3$ and $KHCO_3$ increased the cohesiveness of the ground beef increased as well. Ground beef treated with $KHCO_3$ at 1.0% and NaCl at 0.5%

(SPBC1) was the juiciest product according to panelists. Overall, the bicarbonates decreased the hardness, shear value, and work of shear compared to the control. This shows that bicarbonates had a great tenderizing effect and increased juiciness within ground beef. Therefore the application of bicarbonates can be used in ground beef to create various types of food dishes such as hamburgers, meatloaves, or meatballs that cater to the consumer's desires.

Future work should focus on other aspects of the bicarbonate treated raw and cooked ground beef. They include microbial testing of the raw ground beef should be done of the bicarbonate treated ground beef. Due to the increased pH within the meat, this allows for bacterial growth that may be harmful to consumers. Future research should be focused on the inclusion of bicarbonates in ground beef with different internal temperatures. The binding effects of the bicarbonate treated ground beef should be calculated by measuring its bind index. Testing the bicarbonates with and/or without salt at differing usage rates may be beneficial for meat industry experts. Lastly, it will also be best cook the ground beef at different temperatures to investigate more of the bicarbonates effects.

APPENDICES

A. Metmyoglobin Reflectance Values

Table A.1: Reflectance values of ground beef at 100% myoglobin and are used to calculate MRA percentage values.

Reflectance	OXYMYOGLOBIN	DEOXYMYOGLOBIN	METMYOGLOBIN
470	13.13	22.06	17.01
480	15.04	23.74	16.88
520	15.47	15.94	16.2
530	11.4	14.09	16.96
570	10.28	10.93	22.12
580	9.4	12.79	22.01
610	47.02	30.01	25.95
474	13.90	22.73	16.96
525	13.44	15.02	16.58
572	10.10	11.30	22.10
610	47.02	30.01	25.95
474 K/S	2.67	1.31	2.03
525 K/S	2.79	2.40	2.10
572 K/S	4.00	3.48	1.37
610 K/S	0.29	0.82	1.06

B. Ground Beef Sensory Analysis Ballot

Figure C.1: Ground beef sensory questionnaire for the trained sensory panel

Panelist #____

Sample_____

Please rinse mouth with water and cracker between each sample. Taste the product sample (1-2 sips at a time for the flavor descriptors and 2-3 chews at a time for the textural descriptors) and mark a vertical line on the horizontal line below that corresponds with the intensity of each descriptor.

0-15 point scale

Juiciness: (standard = banana: 1, cucumber (w/o skin): 8, apple (skinless): 10, orange (skinless): 15)

0 ... 15
None ... Extremely

Description: amount of moisture leaving from product and into the mouth

Tenderness/Hardness: (standard = light cream cheese: 1, American Cheese: 4, frankfurters: 7, carrots: 11)

0 ... 15
Soft ... Hard

Instructions: measure tenderness/hardness with molar teeth

Chewiness: (standard = rye bread: 2, orange candy slice: 6, tootsie roll: 13)

0 ... 15
None ... Extremely

Instructions: measure chewiness with molars after 2-3 chews

Other comments:
Please write down any other comments about the product.