EFFECT OF INJECTION OF SODIUM CHLORIDE, SODUIM TRIPOLYPHOSPHATE, AND SODIUM LACTATE ON WARNER-BRATZLER SHEAR AND SENSORY CHARACTERISTICS OF PRE-COOKED INSIDE ROUND ROASTS

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Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1998

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
Degree of
Master of Science
July, 2000

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SODUIM TRIPOLYPHOSPHATE, AND SODIUM

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Thesis Approved:

Thesis Advisor

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ACKNOWLEDGEMENTS

I would like to express a sincere thank you to all of the people involved in making my academic career at Oklahoma State University, a truly enjoyable and rewarding experience. First I would like to thank Dr. Fred Ray for sparking my interest in meat science, and for seeing something in me, and giving me the opportunity to pursue a Master's degree. To Dr. Brad Morgan, I sincerely appreciate the opportunity to pursue this degree under your guidance. Thank you for having patience with me even when I make mistakes. To Dr. David Buchanan, I would like to thank you for your patience and help with my statistics.

The completion of this project would not have been possible without the help and support of many individuals. Thanks to Dan Webb of Cryovac Sealed Air Corp. for providing the packaging materials. To Jake Nelson at the OSU FAPC, your help in scheduling, cooking, and processing are greatly appreciated. To Betty Rothermel, the work you do for us in the office is invaluable. Thanks to Kris Novotny and Linda Guenther for their guidance and help in the lab. I will never forget how to perform TBA analysis. I would also like to thank all of my fellow graduate students. I greatly appreciate all of your help with this project, as well as your friendship throughout the last two years. The time I have spent at OSU, and at Dodge, will not soon be forgotten. A sincere thank you also goes out to Shon Rupert. Your support, friendship, and encouragement throughout the last several years has been a valuable source of strength for me, when things weren't going as expected. I would like to express my sincere gratitude and love to my wife Leanne. Your support and love throughout the last two years have been a constant encouragement for me to succeed in all I do.

Lastly, I would like to thank my Lord and Savior, Jesus Christ. Without his strength I would be able to accomplish nothing. And without him in my life I would be nothing. Thank You.

DEDICATION

This thesis is dedicated to my family, who has been so supportive through the many years of my education. They have always encouraged me to pursue my dreams and that no task was impossible if I put my mind to it. Thank you for allowing me to pursue my goals and dreams. Thank you for teaching me the value of a good education as well as the value of a hard day's work.

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FORMAT OF THESIS

This Thesis is presented in the Journal of Animal Science style format, as outlined by the Oklahoma State University Graduate College Stlye Manual. The use of this format allows for independent chapters to be prepared suitable for submission to scientific journals.

CHAPTER I

INTRODUCTION

Currently the U.S. meat consuming population is shifting from traditional ways of preparing meals for American families to preparation techniques that decrease the time necessary for meal preparation. Harry Balzer (NPD Group, Chicago, IL) has said, "The joy of cooking is just a myth. Cooking is a daily task or job (Meating Place, 1994)." In 1987 43% of all meals eaten in the U.S. included at least one made from scratch item, by 1997 it has fallen to 38% (Time, 1998). One key driver that can be attributed to this trend is that adults are spending their time doing other things instead of cooking. According to (USA Today, 1999) many parents are now spending more time with their children (up 11%), involved in other activities outside the home (i.e., movies, etc.; up 8%), and spending more time getting ready for the day (up 7%). Another factor that has affected this change is that there are many beef cuts that require time and cooking knowledge to prepare the item correctly. This has led to a loss of market share by the beef industry. Purcell (1997) has demonstrated that if the current trend continues, by 2005 the beef industry will hold only 26% of the total U.S. consumption, compared to 39% in 1999. The beef industry must find more attractive ways to merchandise its products in order to maintain and hopefully improve its market share (Hollingsworth, 1997). With the increasing popularity of the microwave oven, Starrak and Johnson (1982), found that the number of people using the microwave to cook meat is increasing. However, the majority of these people are dissatisfied with end product quality and presentation.

Therefore, the advent of home meal replacement systems, or more specifically pre-cooked beef items have presented an ideal opportunity to capture consumer confidence through improved quality and taste. Food Marketing Institute has shown that in 1997, 22% of consumers have bought ready-made food items. That is almost double the 12% that consumers bought in 1996. The Seattle Insider (2000) reported that 34% of all home-cooked meals included at least one item that was just "warmed" or "reheated." There are many beneficial results that can be foreseen through the development of this type of product. By developing a pre-cooked product, whether it is partially or fully cooked, the manufacturer would know that the product has previously been cooked to an appropriate end-point temperature in order for the product to be considered safe. Another advantage would be to provide the consumer with a healthy meal that would be ready to eat within a matter of minutes. With these foods now accounting for almost 50 percent of restaurant offerings since 1994, the National Restaurant Association (NRA) predicts that home meal replacement may become an $80 billion to $100 billion category by the end of this year (AMI, 2000). Also according to Food Marketing Institute (FMI, 2000), when available 34% of consumers are willing to buy pre-cooked meat items at the supermarket.

Several of the qualities that consumers look for in fresh meat will still hold true for pre-cooked products as well. Miller (1995) showed that meat tenderness as viewed by the consumer, is the number one characteristic of beef quality. Boleman et al. (1997), has shown that consumers are willing to pay a premium for beef that is known to be tender as compared to a less tender counterpart. A study performed at Colorado State (Vote et al., 2000) involving injection of a solution containing sodium lactate, sodium tripolyphosphate, sodium chloride, and water into longissimus dorsi muscle showed a positive effect on tenderness and juiciness when compared to non-injected controls.

However, no research has been conducted utilizing beef cuts that are traditionally less tender, such as cuts from the chuck and round. The objective of this study was to examine the effects of injecting a solution of sodium lactate, sodium tripolyphosphate, and sodium chloride in the semimembranosus muscle from U.S. Select carcasses on tenderness, cooking loss and sensory characteristics of pre-cooked beef.

CHAPTER II

LITERATURE REVIEW

Consumer Perceptions of Beef

Customer satisfaction describes how well products meet or exceed a consumer's expectations (Neely et al., 1998). One very important component of meat palatability is beef flavor intensity. The importance of tenderness, juiciness, and flavor to the consumer in deciding what to purchase at the marketplace was shown in the National Consumer Retail Beef Study (Savell et al., 1989). Of the three palatability drivers, the National Consumer Retail Beef Study (1983) determined that tenderness was the single most important factor in determining eating satisfaction of cooked beef. A pleasant eating experience is very important in maintaining customer satisfaction and confidence. Since beef is priced higher than other protein sources, consistent palatability is a must if consumer satisfaction is going to be achieved (Brooks et al., 2000). In fact, according to Boleman et al. (1997), consumers are willing to pay extra for beef steaks that are guaranteed as being tender. Tenderness is determined by such factors as genetic makeup of the animal, feeding of a high concentrate diet, and the age at which the animal is harvested. Beef tenderness can be altered or enhanced through several different means. In the past, many studies have been performed to identify those qualities that consumers most look for when making their meat purchase decisions. George et al. (1999) reported one out of four steaks, according to trained sensory panelists, is less than desirable in tenderness. In 1987 the National Beef Tenderness Survey (NBTS) showed that eighteen percent of loin steaks and thirty-one percent of top round steaks were "slightly tough" or tougher (Morgan et al., 1991). Researchers at Texas A&M University concluded in 1993 that one tough beef carcass could impact as many as 542 consumers (Harris and Savell, 1994).

Beef Enhancement

To enhance, as defined by Webster's Dictionary (1993), is to raise to a higher degree, or to increase the value, attractiveness or quality of a product. The meat industry is always trying to further enhance its products, by either enhancing the image of beef, or improving the actual product itself. With the past decline of beef market share, many techniques have been discussed as possible ways to regain some of that lost market share. Many companies and researchers are investigating the use of value-added, enhanced beef products into their operations. One recent addition that has gained a great deal of popularity is precooked beef products. In the spring of 2000, Hormel Foods introduced some new beef items into its "Always Tender" fully cooked product line in the southern and central regions of the United States. Three items that were introduced were beef roast, beef tips with gravy, and meat loaf with tomato sauce. All three products have been extremely successful and the company has plans for full national distribution by late summer of 2000 (Hormel). In a recent study by Vote et al. (2000), strip loins from U.S. Choice and U.S. Select carcasses were injected with a solution containing sodium tripolyphosphate (STTP), sodium lactate, and sodium chloride. Injection levels were 0%, 7.5%, 10%, 12.5%, and 15%. All injection solutions were formulated to contain .25% STTP, .5% sodium chloride, and 2.5% sodium lactate. They found that all injected treatments were superior to the untreated controls in the areas of improved sensory panel tenderness and juiciness ratings, as well as lowered shear force values.

Beef Quality

The quality of any product is a measure of its excellence (St. Angelo, 1996). The word quality also makes one think of superiority. Foods provide essential nutrients which are needed to sustain life, and they must also be consumed to realize this benefit (Pearson, 1994). Overall meat quality is evaluated by many different factors.

While not always a true indicator of the actual quality of the meat, although it is very important from a consumer standpoint, color is a very important factor in determining meat quality. The color of the lean is indicative of the age of the animal in that the darker the color the older the animal is in most cases (Romans et al., 1985). The color of lean also becomes darker as the product is stored or displayed for increasing amounts of time. Color of fat, while still not a true indicator of quality, still gives us an idea about the animal the product came from. A nice creamy white fat is characteristic of an animal that has been grain fed and fattened. A quality fat is one that is dry hard and flaky (Romans et al., 1985). When yellow fat is present on an animal or cut of meat, it is often associated with an animal that has been fed grasses and other forages. This is often a sign of an older animal as well and Prost et al. (1975) showed that as age increases tenderness decreases. Lastly, the color of the bone is an indicator of quality as well. As an animal increases in chronological age the bone becomes more ossified. This ossification causes the bone to become denser and lose its red color causing it to turn white. Likely the single most important factor in determining meat quality is marbling.

Marbling is also the primary factor in determining quality grade of grain fed cattle or carcasses in the Unites States, and Canada, even though it is a poor indicator relative to tenderness (Dubeski et al. 1997). Marbling is the deposition of fat between the muscle fiber bundles. It occurs only in animals that are very near or have already reached maturity. Since marbling does appear in older animals, something about the animal's age must be known in order to gain a true sense about the quality of the meat. Appearance, texture, and flavor are the three most common attributes consumers look at when judging the acceptability of cooked meats (Liu et al., 1995).

Lipid Oxidation

Lipid oxidation and the biochemical changes that are associated with it are one of the major causes of meat quality deterioration. When lipids are oxidized, primary and secondary products are formed. These products are formed from the spontaneous reaction of atmospheric oxygen and other organic compounds which yield degradative changes that effect the case life of a product (Gordon, 1990). This reaction produces a free radical chain of events that adversely affects muscle pigment and lipid stability (Kanner, 1994; Gordon, 1990). Lipids can be classified into two categories. There are depot lipids and tissue lipids

(Love, 1971). Depot lipids are usually found in areas like connective tissue, where they are stored in large quantities. Tissue lipids however can usually be found in lean tissue in small quantities. Prior studies have shown that lipids play an important role in the variation of meat flavor among different species, but these flavors are very dependent upon lipid oxidation.

When molecular oxygen reacts with unsaturated fatty acids the process of lipid oxidation begins, which results in the formation of acylhydroperoxides, otherwise known as peroxides. Lipid oxidation can be divided into two categories. Oxidation that occurs rapidly after the cooking process and oxidation that takes place during storage. This oxidation after cooking results in some undesirable off-flavors, if the product is being reheated following refrigerated storage. Chang et al. (1961) showed that precooked slices of beef develop rancid off odors and have correspondingly high thiobarbituric acid (TBA) values as well when exposed to air at room or refrigerator temperatures. Tims and Watts (1958) were the first to term these off-flavors as a "warmed over" flavor (WOF). This term is used to describe the stale and rancid flavor of meat that has been cooked, stored, and then reheated. It is often agreed that lipid oxidation is the cause of WOF. It has been thought that since the microwave is a much faster way of heating, as opposed to conventional methods, that it has the potential of reducing these off flavors associated with reheating. However, Albrecht and Baldwin (1982) found that there was no significant difference in either WOF or warmed over aroma (WOA) of roast pork reheated by microwaves or by conventional ovens. Likewise, Hsieh and Baldwin (1984) also found that reheating method, microwave or conventional oven, had no significant influence on WOF or WOA, nor did it have an effect on TBA values. Conversely, in a study by Johnston and Baldwin (1980) roast beef samples reheated in the microwave had significantly less WOA when compared to conventional oven reheated samples but there was no difference in WOF.

Effect of Muscle Pigment Oxidation on Beef Quality

The color of meat is essentially the chemistry of heme pigments, primarily myoglobin. Biologically it is not the most important of the pigments, but in the bled animal it is the only one in significant quantities to color the meat. Myoglobin is part of the sarcoplasmic proteins in muscle and is soluable in dilute salt solutions and in water. When the myoglobin in the meat is devoid of oxygen it is said to be in the reduced state. Its color is a dark purple. Once the myoglobin is exposed to molecular oxygen it becomes (ferrous) oxymyoglobin a process know as oxygenation. Liu et al. (1995) showed that when the surface of the meat in the reduced state is exposed to oxygen it becomes the bright cherry red color that the consumer associates with freshness. Once exposed to air oxymyoglobin will form in thirty to forty-five minutes. On the other hand when the iron molecule in myoglobin is reduced from the ferrous to the ferric state it is known as metmyoglobin. In this ferric state the meat becomes a very undesirable brown color. Lawrie (1966) showed that when approximately 60% of the myoglobin pigments in a specific area are oxidized to metmyoglobin the brown color becomes visible.

Oxygen partial pressure has a profound effect on myoglobin pigment states. This is of particular importance in different types of retail packaging systems. Some types of films used have a low oxygen permeability rate, and therefore the meat tissue utilization of oxygen will be greater than that which can permeate through the film. This creates a low partial pressure of oxygen and this type of environment heavily favors the oxidation of oxymyoglobin to the brown metmyoglobin (Faustman et al., 1998). When the meat is exposed to oxygen, the oxygen will penetrate into the meat. The depth at which oxygen will penetrate is highly dependent upon the partial pressure of oxygen. A high partial pressure will penetrate further into the meat than will a low partial pressure. The deepest point at which the oxygen penetrates is referred to as the Met-Line. This line is very important in determining the rate of discoloration (M-TEK, 1997). As oxygen penetrates into the product the partial pressure is reduced. (Schuler, 1990) showed that as the pressure begins to decrease, this is where the Met-Line is formed and begins the formation of metmyoglobin. Therefore it is possible that in high oxygen packaging systems the resulting Met-Line being formed deeper within the meat will result in a longer display life of the product.

Components in Cooked Beef:

A.) Sodium Lactate

There are many current uses of sodium lactate. Sodium lactate is currently being used in the meat industry for flavor enhancement and shelf-life extension properties (Duxbury, 1988). It has also been shown that palatability is positively influenced by sodium lactate (Papadopoulos, 1991). Using both taste panel and Warner-Bratzler shear force, it was shown that tenderness values of samples with added sodium lactate levels higher than 2% were not significantly different (P< .05) from other treated samples (Papadopoulos, 1991). Sodium lactate is a salt that is derived from organic acids. It has been used for close to 30 years, to aid in the retention of moisture in meat. In a study by Hammer and Wirth (1985), they showed that sodium lactate could possibly lower the water activity in various meat products. In another study using hams, it was found that while addition of 1% sodium lactate to ham muscles lowered water activity, it did not however have a significant effect on color, flavor, or pH (Anonymous, 1988). In a study by Anders et al. (1987), sodium lactate was shown to have some antibotulinal properties as well. With the addition of 1.5% to 3.5% sodium lactate, growth of *Clostridium botulinum* was delayed in fish, chicken, and turkey. In a similar study, Maas et al. (1989) reported that in vacuum-packaged turkey products, addition of sodium lactate showed a concentration dependent antibotulinal effect. In this study sodium lactate was added to processed, cooked turkey samples that had been inoculated with *Clostridium botulinum* at levels of 0, 2, 2.5, 3, and 3.5%. Samples contained toxin levels high enough to cause botulism if consumed in 3, 4 to 5, 4 to 6, 7, or 7 to 8 days respectively. In a study performed by Miller and Acuff (1994), they found that with the addition of 3% or 4% sodium lactate there was some proliferation control on *S. typhimurium, L. monocytogenes,* and *E. coli* 0157:H7 when compared to control (0%) and 2%. Papadopoulos (1991a) reported that addition of 3% sodium lactate increased cooking yields but there was, however, no differences in fat content of raw and cooked top round roasts. The sodium lactate also caused a reduction in homo- and heterofermentative *Lactobacillus* species.

B.) Sodium Tripolyphosphate

The molecular structure of sodium tripolyphosphate (TPP) is $Na_5 P_3 O_{10}$ (See Figure 1). Sodium phosphates are produced commercially by the reaction of phosphoric acid with a sodium alkali, usually sodium bicarbonate. It is primarily used as a detergent (45%), Industrial cleaner (31%), food uses (13%), and miscellaneous industrial uses (11%) (Chemexpo, 2000). However, food uses are the most rapid growing segment at four to five percent per year. TPP helps to sequester multivalent metal ions, thereby inhibiting oxidative rancidity in food products. It also aids in the reduction of moisture loss during thawing and cooking. TPP also promotes the emulsification of fat and protein, and improves solubility. The mode of action by which TPP increases moisture retention is not completely understood despite many exhaustive studies. The action possibly involves the influence of pH changes, specific phosphate anion interactions with myofibrillar proteins and divalent cations, and effects of ionic strength. It is believed that calcium complexing and the resulting loosening of the tissue structure is a major function of polyphosphates. Binding of polyphosphate anions to proteins and the cleavage of cross-linkages between actin and myosin results in increased electrostatic repulsion between peptide chains and a swelling of the muscle system (Lindsay, 1985).

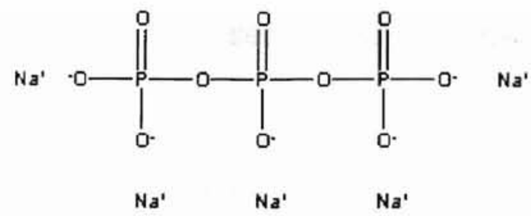

Figure 1.1: Structure of sodium tripolyphosphate (Chemfinder, 2000).

One problem that has been seen in precooked meat products is a wide variation in cooked meat color (Hunt and Kropf, 1987). It is a sporadic and unpredictable problem. Trout (1989) proposed two possible reasons for this problem: (1) during heating myoglobin has been converted to a pink hemochrome, or (2) complete denaturation of the myoglobin has not occurred. Trout (1989) found that with the addition of sodium tripolyphosphate in precooked ground beef, the amount of myoglobin denaturation was increased by 5 to 10%. The addition of phosphates into meat has several desirable effects. Phosphates have been shown to stabilize ground meat color for extended periods of time (Savich and Jansen 1954). It has also been reported that the addition of phosphates, either by dipping or by injection, increases the tenderness of the product (Carpenter, 1961; Hopkins and Zimont, 1957). Mahon et al. (1970) reported that when using alkaline phosphates such as sodium tripolyphosphate, moisture retention in the meat was at its highest. Ellenger (1972) showed that the effect on flavor by addition of phosphate, was due to retention of proteins and the reduction of oxidative rancidity (Keeton, 1983). It has also been shown by Sheard et al. (1990) that sodium tripolyphosphate has a significant effect on cooking loss. In their research they found that the higher the levels of phosphate injected, cooking losses tended to be lower.

C.) Sodium Chloride

Sodium chloride is one of the most common salts used in food processing to reduce cooking losses and effect inner-particle adhesion (Sheard et al., 1990). Salt was originally used to prevent the meat from spoiling. Meat that has been salted for preservation exhibits an unattractive gray color. In a study performed by (Trout, 1989) it was found that with the addition of sodium chloride in ground beef, percent myoglobin denaturation was increased as compared to ground beef with no added sodium chloride. This will decrease the amount of pinkness in the cooked meat product. Salt inhibits spoiling largely by reducing the amount of water available for microbial growth. Today, however, salt is not generally used at high enough levels (i.e., > 2% by weight) to greatly effect preservation, although some preservative action will occur at low concentrations. Sodium chloride is also used in sausage emulsions to solubilize myofibrillar proteins into the aqueous state to become available for coating fat particles. One very important benefit of addition of sodium chloride is increased water holding capacity. Hamm (1970) reported that as addition of salt decreases water holding capacity. They also found that fat and protein content decrease with increasing salt levels. Shackelford (1989) also found that as salt levels increased protein content decreased. This was due to the increased water retaining ability and its dilution effect on the meat. However, a study by Johnson et al. (1989) is in disagreement with these findings. These results clearly demonstrate no clear evidence to the effect of influencing salt levels on protein and fat percentages. Shackelford (1989) also found that higher salt levels (1.25%) caused a decrease in cooking losses and increased total yields when compared to the lower salt level (1%) treatment. These increased yields appeared to be mainly due to the decreased cooking losses caused by an increased water holding capacity that is associated with high salt containing products (Mandigo, 1982; Brewer et al., 1984; Cordray and Huffman, 1984; Chow et al., 1986; Lamkey et al., 1986).

Types of Cooking and Reheating Methods of Meat Products

A.) Conventional Cooking

According to the American Meat Science Association (Cross et al., 1978) there are three methods of cookery that were determined to be the most popular and widely used in meat research. These cooking methods are broiling, roasting, and braising, which are also quite common for cooking in the home as well. Broiling and roasting are considered to be dry heat cookery methods, while braising is a moist heat cookery method. Dry heat cookery involves the use of high temperatures over a relatively short cooking period. Cross et al. (1978) has shown that the roasting method is accomplished by the transfer of heat to the meat through convection in a closed oven that has been preheated to 165° C. This method is commonly used for more tender cuts, which are placed in a pan so that they are able to baste in their own drippings. Tender cuts should be used because this method does not do an adequate job of solubilizing the connective tissue present in meat (Cross et al., 1978).

Moist heat cookery methods include braising, pressure cooking, and any other method that employs water. Although all meats can be cooked in this manner, it is typically used for meats that are high in connective tissue. This provides the amount of water necessary for hydrolysis of the collagen into gelatin. Cross et al. (1978), described this manner of cooking to be browning the meat in a small amount of fat, placing the meat in a covered pan with a small amount of liquid, and cooking it slowly at an oven temperature of 165° C. Another method of cooking would be through conduction. A very popular method of conduction cooking would be grilling. This is also a dry heat cookery method. Again only tender cuts should be utilized for this method due to the inability to break down the connective tissue. It has been shown in numerous studies that the conventional cooking method is a more time consuming process than is microwave cooking (Marshall, 1960, Pollack et al., 1960, and El-Shimi, 1992).

B.) Microwave Cooking

Microwave cooking is a method that gained a great deal of popularity for use in the home within the last decade. There are many benefits of using this type of cooking method. El-Shimi (1992) found that when cooking 500 g of beef using a conventional oven resulted in average cooking times of 45 minutes, whereas when cooked using a microwave cooking time was reduced to only 15 minutes. In this study they found that mean cooking losses were consistently higher for products cooked in the microwave when compared to those cooked in a conventional oven. Likewise, Janicki and Appledorf (1974) also found that meat processed in the microwave had consistently higher cooking losses than meat processed by other methods. In another study by Voris and Van Duyne (1979) they found that when cooking top round roasts in the microwave versus conventional methods, the conventional roasting method had significantly less drip loss. There was however no significant difference in evaporation loss or total cooking loss between the two cooking methods. In this same study, Warner-Bratzler shear force values were not significantly different between cooking methods when utilizing the semimembranosus muscle. However, the adductor muscle however was significantly tougher when cooked using conventional methods as compared to the microwave. Research performed by Law et al. (1967), reported no significant differences among top round steaks in juiciness, shear force, flavor, or moisture when comparing microwave and conventionally cook top round steaks. They did however report that conventionally cooked top round steaks had significantly less drip and cooking loss, as well as higher sensory scores for tenderness when compared to round steaks cooked in the microwave. The top-round steaks cooked in the microwave did however show a higher percent of total proteins and significantly less collagen than the steaks cooked conventionally.

C.) Reheating Procedures

With the increasing popularity of home meal replacement products there are two main ways that are considered when deciding how to reheat a product. First there is the traditional way using a conventional oven, and there is the faster more modern way of using a microwave oven. In a study by El-Shimi (1992), they compared conventional and microwave reheating effects of roast beef.

They found that reheating time using a conventional oven averaged 25 minutes and only 6 minutes when using the microwave method. Cooking losses for the conventional method of reheating were an average of 9.25% whereas microwave cooking losses were 11.50%. In a study by Sawyer et al. (1982) they found that in microwave reheated beef mean cooking losses were approximately 9% greater than that of beef loaf that was reheated by conduction or in a convection oven. In the study by El- Shimi mean sensory panel scores for juiciness, tenderness, flavor, and overall palatability were reported. While statistical differences were not presented, conventionally cooked and reheated beef had only slightly higher sensory panel ratings as compared to microwave cooked and reheated beef. Past research has been performed on other muscle proteins as well. Research looking at turkey and pork have shown that microwave reheated muscle is more like freshly cooked muscle than that of conventionally reheated muscle (Cipra et al.; 1971, Bowers, 1972; Penner and Bowers, 1973).

CHAPTER III

EFFECT OF INJECTION OF SODIUM CHLORIDE, SODUIM TRIPOLYPHOSPHATE, AND SODIUM LACTATE ON WARNER-BRATZLER SHEAR AND SENSORY CHARACTERISTICS OF PRE-COOKED INSIDE ROUND ROASTS

M.R. McGee, J.B. Morgan, F.K. Ray

ABSTRACT

Paired inside rounds (n=30 pairs) were captured from randomly selected U.S. Select quality grade carcasses. Each round was fabricated (length vs. width) in half, and assigned either to a 0 (control), 5, 7, or 9% injection treatment containing .25% sodium tripolyphosphate, .35% sodium chloride, and 2% sodium lactate. Following injection, all samples were stored for 24 hours to allow for equilibration. Samples were then primary cooked to an internal temperature of 68° C +/- 1° C in an Alkar single truck smokehouse, controlled by Microsoft Windows 95 (Alkar, A Division of DEC Int'l, Inc., Lodi., WI). Following primary cooking, roast sections were chilled to 3° C +/- 1° C and subsequently fabricated into 2.54 cm steaks and individually packaged in vacuum package cook-in bags (Oxygen Transmission Rate: 20cc/m^2/24 hr at 1 atmosphere; 23° C at 0% Relative Humidity) for shear force and sensory determination. Steaks were then stored at 4° C +/- 1° C for 7d then reheated in an Amana microwave oven (1500 watts, Model # WM714) to an internal temperature of 43° C +/- 3° C. Sensory steaks were stored for 21, 28, or 35 d. Lipid oxidation (TBARS) was measured on storage days 0 and 14 for each treatment group.

Analysis of samples showed that injected treatments were significantly more tender (P<.05) than control products. These results were consistent utilizing both Warner-Bratzler shear force and consumer sensory panel ratings. When comparing primary cooking loss as well as reheating loss, all injected treatments had significantly lower (P< .0001) cooking and reheating loss percentages when compared to control samples. Lipid oxidation in injected treated samples was significantly reduced (P< .0005) as compared to control meat samples. Results of lipid oxidation also revealed that 14 day samples were significantly (P< .0001) less than 0 day samples. The results of this study would indicate that the antioxidative properties of sodium tripolyphosphate possibly played a role in the decreased TBA values.

Introduction

Currently the U.S. meat consuming population is shifting from traditional ways of preparing meals for American families to preparation techniques that decrease the time necessary for meal preparation. Harry Balzer (NPD Group, Chicago, IL) has said, "The joy of cooking is just a myth. Cooking is a daily task or job" (Meating Place, 1994). In 1987, 43% of all meals eaten in the U.S. included at least one made from scratch item, by 1997 it has fallen to 38% (Time, 1998). One key driver that can be attributed to this trend is that adults are spending their time doing other things instead of cooking. According to (USA Today, 1999) many parents are now spending more time with their children (up 11%), involved in other activities outside the home (i.e., movies, etc.; up 8%), and spending more time getting ready for the day (up 7%). Another factor that has affected this change is that there are many beef cuts that require time and cooking knowledge to prepare the item correctly. This has led to a loss of market share by the beef industry. Purcell (1997) has demonstrated that if the current trend continues, by 2005 the beef industry will hold only 26% of the total U.S. consumption, compared to 39% in 1999. The beef industry must find more attractive ways to merchandise its products in order to maintain and hopefully improve its market share (Hollingsworth, 1997). Food Marketing Institute has shown that in 1997, 22% of consumers have bought ready-made food items. That is almost double the 12% that consumers bought in 1996. The Seattle Insider (2000) reported that 34% of all home-cooked meals included at least one item that was just "warmed" or "reheated." By developing a pre-cooked product, whether it is partially or fully cooked, the manufacturer would know that the product has previously reached an appropriate temperature for the product to be considered safe. This would also provide the consumer with a healthy meal that would be ready to eat within a matter of minutes. According to Food Marketing Institute (FMI, 2000), 34% of consumers will buy pre-cooked meat items at the supermarket.

One quality that consumers will always insist one is beef tenderness. Miller, (1995) showed that meat tenderness as viewed by the consumer, is the number one characteristic of beef quality. Boleman et al. (1997), has shown that consumers are willing to pay a premium for beef that is known to be tender as compared to a less tender counterpart. A study performed at Colorado State (Vote et al., 2000) involving injection of a solution containing sodium lactate, sodium tripolyphosphate, sodium chloride, and water, into the longissimus dorsi muscle showed a positive effect on tenderness and juiciness when compared to controls.

However, no research has been conducted utilizing beef cuts that are traditionally less tender, such as cuts from the chuck and round. The objective of this study was to examine the effects of injecting a solution of sodium lactate, sodium tripolyphosphate, and sodium chloride in the semimembranosus muscle of U.S. select cattle on tenderness, cooking loss and sensory characteristics of pre-cooked beef.

Experimental Procedures

Meat Samples

Paired beef inside rounds (n=30 pairs) (IMPS # 169a) were individually identified and obtained from 30 randomly selected, U.S. Select quality grade carcasses, at a commercial beef processing facility. Meat samples were transported to the Oklahoma State University Food and Agricultural Products Center and stored at 4° C +/- 1° C for a total of 14 days. Following postmortem aging, paired samples were removed from the packaging material, trimmed of external fat and the gracilis muscle was removed. A custom made stainless steel box (40.64 cm x 15.24 cm x 15.24 cm), was used to remove a section of the inside round parallel to the muscle fiber orientation. Paired muscle samples were horizontally cut in half (20.32 cm x 15.24 cm) and assigned to one of four injection treatment groups (0% (control), 5%, 7%, and 9% injection levels). Samples were injected using a Formaco (Model FGM 20/20) injection machine

(Robert Reiser & Co., Inc., Canton, MA). All injection treatments were formulated to contain .25% sodium tripolyphosphate (FMC Worldwide, Phosphorus Chemicals Division, Philadelphia, PA), .35% sodium chloride, and 2% sodium lactate (Purac America, Lincolnshire, IL, 60% food grade). Following injection, samples were stored for 24h at 4° C +/– 1° C to allow for equilibration. Samples were weighed and place in CN530 vacuum package cook-in bags (Cryovac Sealed Air Corp., Duncan, S.C.). Oxygen transmission rate (OTR) of the cook-in bags was $20cc/m^2/24$ hr at 1 atmosphere (23° C at 0% Relative Humidity). The samples were then cooked to a primary internal temperature of 68° C +/– 3° C in an Alkar single truck smokehouse, controlled by Microsoft Windows 95 (Alkar, A Division of DEC Int'l, Inc., Lodi., WI). Cooked samples were then chilled to 4° C +/– 1° C overnight. The following morning, meat samples were removed from bags and weighed for cooking loss and fabricated into 2.54cm steaks (n=4). Steaks were then individually bagged in Cryovac CN530 cook-in bags. The steaks were used for sensory, Warner-Bratzler shear (WBS), and thiobarbituric acid (TBA) (half for 0d and half for 14d) analysis. Steaks were then boxed and put in storage at 4° C +/– 1° C. After seven days of storage WBS samples were removed, individually reheated in an Amana microwave oven (1500 watts, Model # WM714) to an internal temperature of 44° C +/– 5° C (approximately 190 seconds). A Nordic Ware 10" compact Micro-Go-Round (automatic food rotator) was placed in the geometric center of the microwave and samples were the placed in the center of the food rotator to ensure uniform reheating of all steaks. Samples were then allowed to cool for thirty minutes at room temperature. Six cores per steak, parallel to muscle fiber orientation, were taken and each core was sheared using a Universal Instron Testing Machine (Model 4502, Instron, Canton, MS) with a Warner-Bratzler shear attachment. Individual shear force values for each steak were then calculated by averaging all core shear values from each steak.

Storage

Samples utilized for sensory panel ratings and TBA determination were stored in the absence of light at 4° C +/– 1° C. For TBA determination analysis was performed on all samples for days 0 and 14. After fourteen days post primary cook the 14d TBA samples were frozen at –17° C ± 2° C until further analysis was performed. The samples used for sensory evaluation were randomly assigned to a storage period, with an equal representation of all treatments present for all storage days. All sensory samples were stored for 21, 28, or 35 days at which time they were removed for sensory analysis.

Sensory Evaluation

An untrained consumer panel, consisting of at least 8 people evaluated samples for sensory characteristics. Aroma, overall appearance, juiciness, flavor, overall tenderness, and overall acceptability were the six sensory characteristics that panelists were asked to evaluate. Aroma, overall appearance, flavor, and overall acceptability were evaluated on a 7 point scale with 1=dislike very much and 7=like very much. Juiciness and overall tenderness were evaluated using an 8 point scale with 1=extremely tough or dry and 8=extremely juicy or tender. The evaluation method described by Cross et al.

(1978) was used for these attributes. Steaks used for sensory evaluation were reheated using the same method as described in determining shear force values. After reaching an internal temperature of 44° C +/– 5° C, steaks were placed into aluminum foil pouches until evaluation. A minimum of eight panelists were present for each evaluation session.

Thiobarbituric Acid Analysis

On days 0 and 14 post primary cook samples from each treatment group were frozen at –17° C ± 2° C until further analysis. Thiobarbituric Acid (TBA) analysis was performed using the procedure outlined by Whitte et al. (1970) with the following modifications. A 10g sample was used in the extraction step, and 35 ml of the slurry was centrifuged at 2500 rpm for 25 minutes prior to filtration. Results were reported as thiobarbituric acid reactive substances (TBARS) representing mg malondialdehyde (MDA) equivalents per kg of meat.

Statistical Analysis

Data were analyzed using the mixed model procedures (SAS, 1998). The statistical model included fixed effects for treatment (no injection, 5%, 7%, 9%), day (0, 14 for TBA, and 21, 28, 35 for sensory), and two-way interactions among fixed effects. The model also included ID as a random effect. Means were separated by Least Significant Difference.

Results and Discussion

Shear Force Analysis

Results outlining the effect of injection on shear force values of inside round steaks are presented in Table 3. Three rows of data are presented for each characteristic, with the first row indicating the least squares means corresponding to the treatment (superscripts denote statistical differences between treatments). The second row of data, are mean difference values between injected roast sections and the corresponding untreated roast section. Statistical tests for the values in the second row of data are presented in the third row of data.

Least squares means comparing Warner-Bratzler shear values (Tables 1 and 3) showed that untreated control steaks were significantly ($P < .05$) less tender than all of the injected steaks. There were however, no significant differences between any of the treatment groups. This is in agreement with a previous study by Vote et al. (2000), in that injected treatments were significantly different ($P < .05$) from the controls with no significant differences among controls. Similarly, in a study by Stites et al. (1989) they concluded that when injecting beef roasts to 10% of their original weight with a solution containing sodium tripolyphosphate and sodium chloride, Warner-Bratzler shear force values were significantly lowered ($P < .05$) when compared to control roasts. This would suggest that injection of beef with sodium tripolyphosphate, sodium lactate, and sodium chloride has a beneficial effect on tenderness.

Sensory Panel Ratings

Mean sensory panel ratings and shear force values of untreated controls are presented in Table 1. Tables 2, and 3 represent a comparison between untreated and injected steaks. Significant differences ($P < .05$) were found between untreated steaks and all treatment steaks irregardless of injection level for all sensory characteristics across all sensory days (21, 28, and 35 days). The only exception to this was the 5% injection treatment, which was not significantly different (P= .14) from the control group when comparing visual appearance across all sensory days.

Additionally, day effects for flavor, tenderness, and acceptability were observed (Table 4). Panelists found flavor at 28 days to be significantly better (P< .05) when compared to the 35 day samples. There were, however, no flavor differences between 21 and 28 day samples or 21 and 35 day samples. For tenderness, panelist ratings were significantly (P< .05) higher comparing 21 and 28 day samples to the 35 day samples. No differences in tenderness were seen between 21 and 28 days. Lastly, panelists found acceptability in 28 day steaks to be significantly better (P< .05) than the acceptability of 35 day steaks. No other differences were found between the 21 day steaks and 28 or 35 day samples. For the attribute of juiciness there was a treatment by day interaction. Within the 5% treatment group, a significant difference (P< .05) was found among the 21 and 35 and 28 and 35 day steaks. The 5% treatment group at 35 days was significantly different (P< .05) from both the 7% and 9% treatments for all sensory days. These data are in agreement with the findings of Papadopoulos et al. (1991) who found that with the addition of sodium lactate, along with .5% sodium chloride and .3% sodium tripolyphosphate, sensory panel tenderness was increased. Sensory panel rating also showed that addition of sodium lactate improved juiciness when compared to controls at 0 days of storage as well as having a stabilizing effect throughout the storage periods.

Cooking Loss

When measuring cooking loss at the primary cooking stage of the roasts, a significant difference ($P < .05$) was found between all treatment groups when compared to controls as seen in Table 5. There were however no significant differences between any of the injected treatments. In the same study mentioned previously by Papadopolous et al. (1991), they found that with increasing levels of sodium lactate cooking loss decreased. Sheard et al. (1990) also found that when UK-style grillsteaks were injected with varying amounts of sodium tripolyphosphate and sodium chloride, cooking loss was significantly effected. Cooking loss was decreased when adding sodium tripolyphosphate alone, and when adding sodium chloride alone as well. Maximum benefit as seen by decreased cooking losses was seen however, when a combination of the two were added to the product.

Cooking loss was also measured at the reheating stage as well. Cooking loss for all injected treatments was significantly lower than the controls, with no significant differences between the injected treatments. There was however an observed treatment by day effect. These data can be seen in Table 6. Significant differences ($P < .05$) were observed in the 5% treatment group across all storage days when compared to all controls at all storage days with the one exception showing up at 35 days for both treatments. When comparing the 7% treatment with controls for all storage periods, only three treatment by day interactions were not found to be significant. These were seen at 28 and 35, 35 and 28, and 35 and 35 days for 7% injection samples and controls samples respectively. Lastly comparing 9% injected products with controls, again only three interactions were found not significant. These occurred when comparing storage day 21 for the injected treatment, and days 21, 28, and 35 for controls. Among the three significantly different interactions between injected treatments, no real pattern was established. Therefore a conclusion regarding the effect of varying levels of injected solution on cooking loss cannot be made.

Thiobarbituric Acid

Lipid oxidation indicated by thiobarbituric acid reactive substances was found to be significantly lower ($P < .05$) in injected steaks when compared to controls (Table 4). Likewise when compared over storage days, 14 day sample values were significantly lower ($P < .05$) than 0 day values. Paterson et al. (1988) measured TBA values beef roasts injected with .475% sodium tripolyphosphate and 1% sodium chloride. When compared to control roasts, TBA values for treated samples were significantly reduced. While values did increase during storage, they were still much lower than controls. These results were attributed to the antioxidative properties of sodium tripolyphosphate. In another study on the effects of further processing and storage on TBA values presented by Ang (1986), when stored at 2° C, TBA values for franks and bologna's decreased over time as well. TBA values for franks were measured at 1, 5, 9, 14, 21, and 42 days. A significant reduction in values were seen at day 5 and continued throughout the storage periods. Similarly, a reduction in the TBA values of bologna was found throughout storage. These findings were attributed to the possibility of addition of polyphosphate, erythorbate, nitrite and/or other ingredients effectiveness in inhibiting oxidation rate. A study by Keeton (1983) showed that with the addition of phosphates in ground pork, oxidative rancidity was reduced. Results of this study indicate that injection of sodium tripolyphosphate, sodium chloride, and sodium lactate in select beef inside rounds is a potential way of increasing tenderness, enhancing sensory characteristics, and decreasing cooking loss and lipid oxidation.

Implications

Injection of sodium tripolyphosphate, sodium chloride, and sodium lactate is one tactic that may be used by U. S. beef processors in order to help meet consumer demands of a product that is a higher quality and more consistent product.

Table 1. Least squares means showing shear force and sensory panel rating of untreated control top round steaks.

Trait[a]	Select	SEM
Aroma	4.2448	.08868
Appearance	3.9483	.1308
Juiciness	2.6759	.1605
Flavor	2.8207	.1319
Tenderness	3.2451	.2091
Acceptability	2.7572	.1922
WBS, kg	4.5311	.08663

Aroma, appearance, flavor, and acceptability were all evaluated using a seven point rating scale (7= like very much, 1= dislike very much) Juiciness and tenderness were scored using an eight point scale (8= extremely juicy or tender, 1= extremely dry or tough).

Table 2. Mean panel ratings on effects of injection treatments (TRT) on aroma, appearance, juiciness, and flavor as compared to untreated controls in inside round steaks.

	Injection Treatments[a]			
Trait[b]	5%	7%	9%	SEM (pooled)
Aroma				
Panel rating	4.50^{c}	4.68^{c}	4.53^{c}	
Difference from control	.255	.435	.288	.0876
P>|t| for TRT vs. control	.0425	.0007	0221	
Appearance				
Panel rating	4.22^{c}	4.58^{d}	4.65^{d}	
Difference from control	.271	.628	.698	.1292
P>|t| for TRT vs. control	.1412	.0008	.0002	
Juiciness				
Panel rating	4.43^{c}	4.79^{c}	4.74^{c}	
Difference from control	1.75	2.11	2.07	.1585
P>|t| for TRT vs. control	<.0001	<.0001	<.0001	
Flavor				
Panel rating	4.30^{c}	4.68^{d}	4.52^{cd}	
Difference from control	1.48	1.86	1.70	.1303
P>|t| for TRT vs. control	<.0001	<.0001	<.0001	

[a] Inside round roasts were injected to either 5, 7, or 9% of their original weight with a solution containing sodium lactate (NaL), sodium chloride (NaCl), and sodium tripolyphosphate (TPP). Injection solutions for all treatments were formulated to contain 2% NaL, .35% NaCl, and .25% TPP.

[b] Aroma, appearance, and flavor were all evaluated on a seven point scale (7= like very much, 1= dislike very much). Whereas juiciness was scored on an eight point scale (8= extremely juicy, 1= extremely dry).

[c,d] Means in the same row not sharing a common superscript are significantly different (P< .05).

Table 3. Mean panel ratings on effects of injection treatments (TRT) on tenderness, acceptability, and shear force values (WBS) as compared to untreated controls in inside round steaks.

	Injection Treatments[a]			
Trait [b]	5%	7%	9%	SEM (pooled)
Tenderness				
Panel rating	4.74[c]	5.09[c]	5.06[c]	
Difference from control	1.49	1.85	1.81	.2779
P>|t| for TRT vs. control	<.0001	<.0001	<.0001	
Acceptability				
Panel rating	4.23[c]	4.60[c]	4.55[c]	
Difference from control	1.47	1.84	1.79	.1918
P>|t| for TRT vs. control	<.0001	<.0001	<.0001	
WBS				
Mean value, kg	3.57[c]	3.64[c]	3.70[c]	
Difference from control	-.962	-.889	-.831	.8694
P>|t| for TRT vs. control	<.0001	<.0001	<.0001	

[a] Inside round roasts were injected to either 5, 7, or 9% of their original weight with a solution containing sodium lactate (NaL), sodium chloride (NaCl), and sodium tripolyphosphate (TPP). Injection solutions for all treatments were formulated to contain 2% NaL, .35% NaCl, and .25% TPP.

[b] Tenderness was scored on an eight point scale (8= extremely tender, 1= extremely tough). Whereas acceptability was evaluated on a seven point scale (7= like very much, 1= dislike very much).

[c] Means in the same row not sharing a common superscript are significantly different (P< .05).

Table 4. Effect of day on mean sensory panel ratings for flavor, tenderness, and acceptability of microwave reheated inside round steaks.

	Sensory Attribute		
Item	Flavor	Tenderness	Acceptability
Storage Days			
Day 21	4.11^{ab}	4.60^{a}	4.08^{ab}
Day 28	4.37^{b}	4.69^{a}	4.24^{b}
Day 35	3.76^{a}	4.08^{b}	3.66^{a}

^{a,b} Means within a column having superscripts that differ are significantly different ($P < .05$)

Table 5. Effect of injection treatment and storage on TBA values (mg malondialdehyde/kg), and cooking loss (%).

	Means	
Item	TBA	Cooking Loss
Treatment		
0%	1.24[a]	25.58[a]
5%	.649[b]	17.69[b]
7%	.733[b]	17.54[b]
9%	.743[b]	18.58[b]
SEM	.122	.549
Storage Day		
0	1.26[a]	
14	.415[b]	

[a,b] Means in the same column, within a main effect with different superscripts are significantly different ($P < .05$).

Table 6. Effects of injection treatments on the mean values for reheating loss percentages of microwave reheated inside round steaks.

	Injection Treatments			
Item	Control	5%	7%	9%
Reheating Cooking Loss %				
Day 21	15.85^{a}	12.32^{ef}	11.93^{f}	13.37^{cde}
Day 28	15.09^{ab}	12.66^{def}	13.08^{cdef}	13.18^{cde}
Day 35	14.46^{bc}	13.14^{cdef}	14.11^{bcd}	13.15^{cdef}

^{a,b,c,d,e,f} Means within the table having superscripts that differ are significantly different ($P < .05$)

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Master of Science

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