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**Effect of Vacuum Tumbling Time, Salt Level, and Phosphate Alternatives on
Processing Characteristics of Natural Deli-style Turkey Breast**

By

Derek J Schroeder

A THESIS

Presented to the Faculty of
The Graduate College at the University of Nebraska
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Under the Supervision of Professor Dennis E. Burson

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Effect of Vacuum Tumbling Time, Salt Level, and Phosphate Alternative on Processing Characteristics of Natural Deli-style Turkey Breast

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University of Nebraska, 2013

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Three studies were conducted to determine the effect of vacuum tumbling time on the processing characteristics of reduced sodium natural deli-style turkey breast. Production of sodium reduced natural deli-style turkey breast without phosphate is lower ($P<0.05$) in texture and processing properties than deli-style turkey breast produced with phosphate. Reducing salt concentration to 1.0% produces natural deli-style turkey breast with less acceptable ($P<0.05$) texture and processing characteristics compared to 1.5% or 2.0% added salt. Preblending was used to improve texture characteristics in reduced salt products. Control treatments had improved ($P<0.05$) texture properties, decreased color values, and improved processing attributes. Preblending had no effect on TPA, while reduced salt negatively impacted processing attributes, and color values, when compared to control. Functionality of phosphate alternatives was evaluated for effectiveness at improving texture parameters of natural deli-style turkey breast when compared to no alternative and control treatments. The alternatives had no effect on TPA attributes. Treatments with no phosphate alternatives had higher hardness, gumminess, and chewiness values compared to alternatives. Salt level was more important than phosphate alternative. There were no differences for color values between treatments for alternatives, the control had lower L^* and b^* values. The dehydrated turkey collagen treatments had higher ($P<0.05$) water activity than the no alternative treatments.

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Introduction

There is a large body of research that links excessive sodium intake to hypertension and a variety of cardiovascular diseases. It has been reported that two-thirds of all Americans suffer from hypertension or pre-hypertension (Doyle, M.E., 2008). Hypertension has been linked to increased kidney disease, diabetes, heart disease, and stroke. It is widely accepted and supported that populations with high sodium intakes display elevated blood pressures. According to the USDA (2011), Americans should maintain a sodium intake of around 2,300 mg per day. A reduction to 1,500 mg per day is recommended for adults over the age of 51 in addition to African Americans of any age, and people who suffer from diabetes or any chronic kidney disease. The USDA (2011) reports the average sodium intake of all Americans over the age of two is nearly 3,400 mg per day. Reducing the sodium in processed meat products has become an area of great interest to scientists and health professionals.

Sodium chloride, or salt, has been used in meat preservation for thousands of years for preservation purposes. Salt plays a role in inhibiting the growth of several pathogenic bacteria, primarily by lowering the water activity of the product. Furthermore, salt imparts a distinct, usually desirable flavor, while enhancing other flavors in the meat products. Salt is essential for the extraction of myofibrillar proteins of meat products, and increases the ability of actin and myosin to bind water and fat. Thereby improving the texture and yield of processed meat products. Approximately 75% of dietary sodium is consumed from processed foods and foods from restaurants.

Replacement strategies must address the functional properties provided by salt: flavor, texture, quality characteristics, and preservation. There are halide salts like potassium chloride, magnesium chloride, and sodium chloride that have been used to replace or lower sodium content of processed products. Research has revealed that these substitutes impart a bitter flavor to the products, and cannot completely replace salt. Several alternatives have been considered when exploring how to reduce sodium and maintain product texture and quality. Included in this research is the form of salt used, flaked or dendritic crystals compared to the common granular form. The use of various phosphates, which have lost favor in recent years due to the trendiness of natural and clean label products, has also been extensively researched. Non-meat protein sources have also been incorporated to replace the protein binding function of salt. Soy and milk proteins were used, as well as plant carbohydrates such as potato starch, and carrageenan's to improve product texture. Organic acids have been tested to replace salt preservative effects. Weak acids aid flavor development as many contain lesser amounts of sodium.

Technological advances may also lend a hand in the battle to reduce sodium in processed meats. High pressure processing has been shown to inhibit the growth of pathogen and spoilage organisms in Ready to Eat (RTE) meat products and other packaged products. Massaging meat products has been shown to cause cellular disruption and aid in brine distribution throughout the product. Tumbling is similar in that it uses physical action to disrupt muscle fiber structure. Long-term physical action (tumbling and massaging) is shown to produce an exudate on the surface of meat, which

is primarily myofibrillar proteins that aid in product binding. The reduced pressure pulls gases such as oxygen from meat preventing a frothy or foamy appearance.

The objective of this research was to produce a reduced sodium deli-style turkey breast that would match the texture and processing traits of a traditional polyphosphate turkey breast. Research was conducted in three phases. The first of which investigated the effects of extended tumbling time and its effects on TPA and processing traits of reduced sodium natural deli-style turkey breast. In the second phase, preblending was used at 3.0% salt and 4.0% salt to maximize protein extraction and subsequently formulate reduced sodium natural deli-style turkey breast. In the final phase of research, two phosphate alternatives and their impacts on TPA, processing traits, and sensory attributes of reduced sodium natural deli-style turkey breast.

Review of Literature

Salt

One of the most important and commonly used ingredients in meat products is salt. It has been included in meat products for thousands of years in order to preserve meat, to enhance the flavor profile, and improve quality characteristics of restructured or further processed meat products. Before the advent of refrigeration salt was the primary way to preserve meat during the warmer months. The main functions of salt in today's industry are for flavor, protein extraction, and maintaining or improving quality attributes such as desirable texture, juiciness and tenderness. Meat naturally contains 50-75mg Na/100g (Doyle, 2008). In agreement with this report, Ruusunen and Puolanne (2005) reported that meat contains less than 100mg Na/100g in the form of salt. However, during processing additional salt is added.

Flavor

The development of a desirable flavor profile is essential to producing a quality product. Traditionally, processed meat formulas use about 2% sodium chloride. Price and Schweigert (1987) report a typical inclusion of 1.5%-5.0% sodium chloride in meat products. This imparts a salty flavor that the majority of consumers find pleasing. Each consumer holds varying thresholds for salt level. Doyle (2008) reported that a significant decrease in salt in some foods may make them unpalatable for a quarter of the population, while another quarter will be unable to detect the difference. Additionally, sodium may play a role in maintaining flavor due to its role in regulating the growth of microbes and regulating certain proteolytic enzymes. The perceived saltiness of an ingredient is based

on the size of the anion, as the size of the anion increases, its perceived saltiness decreases (Doyle and Glass, 2010). Chloride is the smallest of the group used, thus it can more effectively interact with taste receptors. Reddy and Marth (1991) concluded that the sodium cation is primarily responsible for the salty flavor, while the anion imparts its own taste. Chloride is the anion that imparts the least inhibitory taste Bartoshuk (1980). There seems to agreement between researchers that the overall weight of the anions and cations impart their own flavor characteristics. Heavier cations such as potassium and magnesium have bitter tastes.

Preservation

The preservative function of salt is primarily due to the ability of salt to lower product water activity, Aberle *et al* (2001). Water activity can be described as the water that is chemically available to microorganisms for their metabolic activities. Most pathogenic food-borne bacteria, including *Clostridium botulinum*, *E.coli* O157:H7, *Listeria monocytogenes*, *Salmonella* spp, and the spoilage bacteria *Psuedomonas* spp. do not grow below water activity 0.92. Salt concentrations of 8-11% are needed to reduce water activity enough to inhibit the growth of bacteria according to the Aberle *et al* (2001). The high concentrations far exceed levels currently being used in production, and would render products inedible to most consumers. At the low concentrations being targeted there is little antimicrobial effect of salt. Salt inclusion in processed meat products is not to control microbes, but inclusion of other antimicrobial ingredients may yield significant reductions in bacterial population and growth.

Functional Properties

Protein Extraction

The addition of salt to restructured meat products is known to result in improved binding of proteins. Research indicates that a minimum salt concentration of 0.5% to 0.75% is required to achieve adequate protein extraction. This is mainly due to the increased electrostatic repulsion forces associated with the addition of salt (Hamm, 1960). Salt effects are primarily ionic and act to solubilize myosin. The solubility of myosin increases with increasing salt concentrations (Siegel and Schmidt, 1979). Cheng and Sun (2008), report that the chloride anion serves to bind to muscle proteins, increasing electrostatic repulsions and subsequent unfolding. Salt addition facilitates protein-protein binding, thereby improving the bind and overall texture of restructured meat products (Doyle, 2008). In a review of literature, Booren (1980) summarized that there was an increase in bind strength with an increase in salt addition.

Binding Proteins

There are 3 classifications of meat proteins of concern to meat processors 1) myofibrillar, 2) sarcoplasmic, and 3) stromal or connective tissues. Connective tissue is insoluble or displays low solubility in salt solutions and provides little to no contribution to the protein binding of restructured meat products. However, connective tissue plays an important role in improving water holding capacity. A review of research conducted by Booren (1980) summarized conclusions that the majority of particle binding is performed by the myofibrillar protein myosin. In addition, a review of the literature conducted by Sun and Holley (2011) was in agreement with the conclusions of Booren (1980). It was

reported that myosin comprises approximately 45% of myofibrillar proteins present in muscle tissue (Sun and Holley, 2011). While actin represents approximately 20%. Actin can be found in two forms; a filamentous F-actin form, and a globular G-actin form. F-actin is not capable of forming stable gels. However many researchers report that the presence of F-actin improves myosin gel formation.

Water Holding Capacity

Water holding capacity (WHC) is the ability of meat to retain naturally occurring or added water during the application of external forces such as cutting, heating, grinding, or pressing/stuffing (Aberle *et al*, 2001). WHC impacts processed meat in many ways including cook yield and texture properties. There are many factors that determine WHC of meat including pH, formation of actomyosin, species, age, sex, type of muscle, and postmortem aging (Lamkey, 1984). WHC is important when producing restructured meats in order to ensure a product has adequate bind and desirable textural properties. Improved WHC leads to products that score higher tenderness and juiciness values. WHC can be associated with higher cook yields, which ultimately allows for more pounds of product to sell.

The minimum WHC occurs when the net charge of the protein molecule is zero. This is referred to as the isoelectric point (pI). At this point intermolecular interactions between myofibrillar proteins are maximized; as a result there are minimal interactions with water molecules. Offer and Trinick (1983) suggested that increasing the electrostatic repulsion in the myofibril increases swelling. These interactions are

responsible for an increase in tenderness associated with improved WHC and reduced water loss during thermal processing (Doyle, 2008).

The addition of salt alone does not directly alter the pH of meat (Neer and Mandigo, 1977; Medyinski *et al*, 2000). However, salt affects the WHC by shifting the pI towards a basic pH. Chloride ions are more strongly bound to the proteins than are sodium ions, resulting in a net increase in negative charges (Ruusunen and Puolanne, 2005). Improved WHC of meat products with the addition of salt may be attributed to the preferential chloride anion binding to protein molecules. This preferential binding at pHs above the isoelectric point is due to the increase in the net negative charge of the meat, resulting in repulsive forces and allowing for the binding of additional water molecules. Conversely, at pHs below the isoelectric point chloride anion neutralizes the positive charges. As a result there is a reduction in the net positive charge and a reduction in WHC (Albarracin *et al*, 2011). This illustrates the concept that as pH is adjusted either direction from the isoelectric point, the WHC is increased or decreased based on the net charge of the system. This increase in WHC improves the tenderness of meat products. Processes that lead to an increase in repulsion, or opening of the muscle structure improve tenderness (Hamm, 1960).

The addition of salt is one such process that increases repulsive forces, thereby improving protein-water interactions resulting in improved cook yield. In a study investigating the effects of salt and sodium tripolyphosphate (STP) on flaked and cured pork, smokehouse yields increased linearly to the 2.25% salt and decreased at the 3.0% level (Neer and Mandigo, 1977). In the same study, smokehouse yields increased linearly with STP addition.

Sodium Contributors

Although salt is the major sodium contributing ingredient added to meat products, numerous ingredients contribute small amounts to the total sodium concentration of restructured meat products (Table 1). Formulating reduced sodium products presents challenges and requires the use of other ionic compounds (Doyle and Glass, 2010). These sources each serve a unique function in meat processing; ranging from improving WHC and protein binding strength, enhancing flavor, extending shelf life, and color stability. Nonetheless, the presence of sodium in these compounds contributes to the final product concentration. With the current industry goals for lowering sodium in RTE meat products, new sodium reduction techniques are being explored. Such research should take into account all sodium containing ingredients in order to more completely track the source and contribution of each.

Table 1--Sodium contribution of additives (Doyle, 2008)

Sodium Compound	Typical Usage	% Na	Grams of Na/100g food
Chloride	1.5-2.0%	39.34	0.59-0.79
Diacetate	0.1-0.4%	16.18	0.016-0.065
Lactate	1.5-3.0%	20.51	0.31-0.62
Nitrite	0.01%	33.32	0.004
Acid Pyrophosphate	0.35%	20.72	0.1
Tripolyphosphate	0.35%	31.24	0.16
Pyrophosphate	0.35%	34.57	0.17
Hexametaphosphate	0.35%	22.55	0.11

Diacetate

Deprotonated acids are commonly added to meat products to perform an antimicrobial function, many commonly contain sodium. Taormina (2010) summarized

research that suggested a synergistic relationship between the use of sodium lactate, sodium diacetate and sodium chloride in extending shelf life of cooked turkey breasts. Furthermore, it was reported that an extended shelf life and a 40% reduction in NaCl could be achieved through the combination of potassium lactate, sodium diacetate, and NaCl. Additionally, one of the most important functions of sodium diacetate is to inhibit the growth of *Listeria monocytogenes*.

Lactates

Sodium lactate is the sodium salt of lactic acid. It is permitted for use as a flavor enhancer, while also extending shelf life due to its bacteriostatic effect. The use of organic acid salts has become popular in deli style products because they can inhibit the growth of *Listeria monocytogenes*. It also contributes to the salty flavor as sodium makes up about 20.5% of its molecular weight (Doyle, 2008). Ruusunen and Puolanne (2005) stated that sodium lactate can be used to extend shelf life and enhance the perceived saltiness of products.

Potassium lactates have also been used for processed meat sodium reduction. The potassium salt provides a bacteriostatic effect, while not contributing sodium to the formulation. Similarly to potassium chloride, a bitter aftertaste may be imparted if too much is included in the formula (Pearson and Gillett, 1996). Inclusion of potassium lactate up to 30% caused serious texture and flavor defects (Taormina, 2010).

Nitrite

Nitrite has long been recognized as one of the most useful and powerful ingredients in meat processing. It serves four major functions in the production of restructured meats 1) it provides an effective bacteriostatic effect, 2) provides the distinct cured meat color, 3) improves flavor, and 4) nitrite serves as an antioxidant (Pearson and Gillett, 1996). It's most commonly used in thermal processed, vacuum packaged products that are categorized as ready-to-eat (RTE). Without the use of nitrites *Clostridium botulinum* spores would be permitted to proliferate and produce toxin. According to the Processing Inspectors Calculations Handbook (1995) sodium nitrite can be added to comminuted/ground sausage or poultry products at a level not exceeding 156 ppm. This level (0.5 oz/ 100lbs) is needed to achieve the bacteriostatic effect against *C. botulinum*, while just 40 ppm level is sufficient to achieve the cured meat color associated with cured products.

In regards to sodium reduction, potassium nitrite can be used in place of sodium nitrite. Sodium comprises 33.32% of the molecular weight of the compound.

Phosphate

Phosphates are used in meat products primarily to reduce purge loss, increase cook yield, and improve WHC, and improve protein extraction. They also serve to improve color stability, and reduce lipid oxidation. Inclusion concentrations typically range from 0.15% to 0.40% in meat products (Romans *et al*, 1994), while the legal limit is 0.50%. Additionally, a variety of phosphates exist to perform different functions when included in meat products. Functions are determined by chain length, pH, and solubility

in water. The number of phosphates in the molecule is typically given in the name of the ingredient. The typical names are as follows:

- Monophosphates- contains only one phosphate group.
- Pyrophosphates- contain two phosphate groups bound together.
- Polyphosphates- contains three or more phosphates bound together in a chain.
- Metaphosphates- a ring structure containing 6, 7, or 13 phosphates.

Characteristics of phosphates vary. Alkaline phosphates, pH greater than 7.0, are useful for increasing the WHC of restructured meat products. Conversely, acid phosphates aid in color stability and prevent off-flavors (Maddock, 2012; Long *et al*, 2011). In almost all cases phosphate blends are used to achieve the desired effect.

Kin *et al* (2010) found that all phosphate treatments tested improved the quality of injected catfish fillets. Blended sodium phosphate improved cook yield and color. The finding indicated high pH, and variable chain length of the blended phosphates improved WHC. The higher pH of the blend changes the pH of the solution, shifting the isoelectric point, increasing electrostatic repulsion, stimulating protein unfolding and water binding. In support of these effects Neer and Mandigo (1977) reported linear increases in smokehouse yield with sodium tripolyphosphate inclusion, which is in agreement with the work of Ockerman *et al* (1978), Krause *et al* (1978), Graham and Trout (1986), Long *et al* (2011), Smith and Young (2007), and Graham and Trout (1984).

Krause *et al* (1978) reported a significant improvement in cook yield and sliceability, taste, aroma, and external color with the use of sodium tripolyphosphate.

This is in agreement with Ockerman *et al* (1978) and Offer and Trinick (1982) who reported that as little as 0.3% phosphate in the finished product can improve cook yield by 5%.

Protein Extraction

Phosphates facilitate protein extraction in restructured meat products through their capability to dissociate the actomyosin bonds formed during rigor (Offer and Trinick, 1983). Simply put, actomyosin bonds restrict the myofibril swelling phenomena. The dissociation of these bonds allows for salt to more effectively extract the myosin proteins (Yamazaki *et al*, 2010). The effectiveness of phosphates decreases with increasing phosphate chain length (Trout and Schmidt, 1984). Trout and Schmidt (1984) also reported that effectiveness of phosphates: pyrophosphate > tripolyphosphate > tetrapolyphosphate > hexametaphosphate. Pyrophosphate is analogous to ATP in regards to cleaving the actomyosin bonds. Tripolyphosphate must first be hydrolyzed to pyrophosphate in order to be as effective at improving WHC and extracted myosin.

pH

Increasing the pH of meat products has been shown to increase the system's ability to retain water. It has also been reported that increasing the pH of a meat batter or system can improve the stability of the final matrix, resulting in an improved overall bind and texture of the product (Siegel and Schmidt, 1979). Barbut (1997) reported that increasing pH from 4.5-7.5 yielded a more stable meat batter. As covered in earlier sections, shifting the pH above the isoelectric point increases the number of negative charges present. A higher pH, or larger net negative charge, provides an environment

where protein-water interactions are favorable. Trout and Schmidt (1984) report that phosphates can increase the pH of a meat system, 0.1 to 0.7 pH units in cooked and uncooked restructured meat products. It is also reported that chain length affects the phosphates capability to alter the pH, in part due to the molecular weight of each phosphate (Trout and Schmidt, 1986).

Ionic Strength

Trout and Schmidt (1986) report that cook yield and tensile strength increase with increasing ionic strength until a maximum pH level is reached. Additionally, short chain phosphates increased cook yield and tensile strength more than long chain phosphates. This may be attributed to the ability of shorter chain length phosphates to dissociate more readily than longer chain phosphates. Trout and Schmidt (1986) reported that at low ionic strengths (0.15) the phosphates increased the cook yield and tensile strength to the same extent as no phosphate. An ionic strength of 0.15 equates to a salt concentration of 0.88% in the product. This result illustrates the ineffectiveness of phosphates at low salt concentrations. Trout and Schmidt (1986) also report that with increasing ionic strength, there is a corresponding increase in phosphates ability to improve cook yield and tensile strength. This finding supports the synergistic relationship of salt and phosphate. Cheng and Sun (2008) summarized the effects of sodium chloride and phosphates on myofibrillar swelling and increased ionic strength. Sodium chloride has an ionic effect, whereas phosphates adjust the pH to create a synergistic relationship between the ingredients.

pH

It is widely accepted that pH affects the gelation properties of myofibrillar proteins. Proteins are the least soluble at their isoelectric point (pI), resulting in unstable gel formations. Sun and Holley (2011) summarized results from numerous reports regarding pH and isoelectric point and their subsequent effects on protein gelation and the proteins ability to retain water and interact with other proteins. The pI of myofibrillar proteins is near pH 5.2-5.3, where protein-protein interactions are greatest and protein-water interactions are limited. Sun and Holley (2011) reported that the optimal pH for the myosin gelation pH 6 at low salt concentrations. It was reported that the stability of turkey meat batters increased with increasing pH from 4.5 to 7.5 for breast meat, while thigh meat batter increase stability from pH 4.5 to 6.5 (Barbut, 1997). This result is attributed to the differing characteristics of the different muscle fiber types. The pH in meat can be adjusted either up or down through the use of acids or alkaline ingredients to improve the water hold capacity (WHC) of restructured meat products. Ingredients such as organic acids, salts and phosphates are used for such purposes. Cheng and Sun (2008) reported that addition of phosphates has a role in increasing the pH of meat systems, thereby increasing the WHC.

Water Holding Capacity (WHC)

Water holding capacity is defined as the ability of a meat system to retain both inherent and added water during the application of forces including grinding, heating, stuffing/pressing (Hamm, 1960). WHC is an important product trait to the meat industry

because it plays a role in several economical and quality attributes. The ability of meat to retain water becomes important when evaluating cook yields, as excess water loss will affect consumer acceptance and producer profitability. With respect to quality attributes juiciness and tenderness can be affected by differences in WHC. Offer and Trinick (1983) concluded that the primary site of swelling and subsequent water binding is the myofibril. Additionally, it was concluded that the addition of polyphosphates further facilitated swelling, especially at lower salt concentrations. Maximum water uptake/swelling was reported at salt concentrations of 4.6%-5.8%; however salt concentrations traditionally around 2% are used in restructured meat production (Offer and Trinick, 1983).

The addition of sodium chloride, or chloride salts in general, will improve the WHC of meat products. The influx of anions, negatively charged molecules, increases the electrostatic forces that are present between the protein molecules in the myofibril. This allows for an unfolding and swelling effect to take place, thereby increasing the binding sites on protein side chains permitting a greater opportunity for protein-water interactions. In comminuted/ground products, the muscle structure and fibers are broken down and more charges are available. The introduction of chloride salts can more readily interact and improve WHC.

Processing Technology

Mixing

Mixing is the process in which a uniform distribution of fat and lean can be coated with salt soluble proteins and other ingredients (Pearson and Gillett, 1996). Price

and Schwiegert (1987) report that mixing for short periods of time, 30 minutes, can improve bind; extending the time can be detrimental to binding strength. Coon *et al* (1983) reported that peak break force (PBF) as measured by Instron, increased with increased mixing times. Likewise, the addition of 1% salt increased the PBF of pre-rigor meat nearly 140% over 0% salt; and 30% in post-rigor meat. Booren *et al* (1981a, 1981c) concluded that cook yields, and tenderness of restructured beef increased over mixing times. Moreover, flavor, juiciness and tenderness were superior when compared to intact strip steaks. Finally, it was reported that 12 minutes of mixing time yielded the most desirable results. Booren *et al* (1981b) went on to evaluate the influence of vacuum mixing on restructured steak quality. It was reported that adhesion improved from 6 to 12 minutes of vacuum mixing, however there were no significant differences in overall quality attributes.

Preblending

Preblending first became popular in the mid-1960's (Pearson and Gillett, 1996). Preblending is the grinding and mixing of meat with all the salt, cure, and sometimes water and held over a period of 8-72 hours, then added to a meat block to achieve the final product composition. The advantages of preblending include: control of final product composition, helps control spoilage, can maximize protein extraction in prerigor meat, optimize production schedule and use of equipment, and retards oxidation (Pearson and Gillett, 1996; Romans *et al.* 1994). Puolanne and Terrell (1983) reported that preblends of 4% salt significantly increased WHC of frankfurter type sausages made from prerigor pork, when formulated to 1.5% and 2.0% salt in the final product. Hand *et*

al (1987) reported that preblending had little effect on color and textural properties of low-fat and/or low-salt frankfurters.

Massaging

Massaging is less vigorous than tumbling and mixing, it involves frictional energy created when rubbing meat surfaces together. Massagers usually are comprised of a vat with a mechanism that slowly stirs or rubs the surface of the product. The rubbing creates friction which disrupts muscle structure and aids in brine uptake (Price and Schweigert, 1987). Massagers were developed because simple mixers have difficulty with large whole muscle type products. Addis and Schanus (1979) describe massaging being more suitable for use with delicate proteins such as poultry and pork; whereas firm tissues such as beef and mutton can be subjected to impact tumbling.

In a discussion on massaging, Claus *et al* (1990) summarized that adequate bind could be achieved using a 4 hour massage, but that a 16-20 hour massage further improved the bind of ham products. Rejt *et al* (1978) reported that massaging led to a decrease in cook loss, and an increase in intracellular space. These researchers also reported massaged muscles displayed a greater WHC than non-massaged muscles. Theno *et al* (1978) studied the effect of massaging length on the ultrastructure of porcine muscle structure. Four hours massaging resulted in an exudate on the meat surface and the structure of the fibers had begun to open up. After 24 hours of massaging there was severe destruction of myofibrils, to the extent that textural properties of the final product were compromised. It was concluded from this research that 4-8 hours is a sufficient massaging time when complemented with traditional levels of salt and phosphate.

Tumbling

Tumbling involves the use of a rotating drum or paddles or baffles to transfer kinetic energy to the meat product in order to increase brine uptake, and protein extraction (Price and Schweigert, 1987). Increasing brine uptake is thought to be the result of damage to structural components resulting in increased potential for swelling (Cheng and Sun, 2008 and Theno *et al*, 1978) It can be done with or without vacuum. A vacuum removes the air, and prevents it from becoming incorporated into the protein gel structure, and creating a frothy foam in place of a tacky exudate. A drop of three feet has been recommended for maximum benefit (Price and Schwiegert, 1987).

Intermittent tumbling has proven to be more effective than continuous tumbling. A possible explanation is the idea that maximum absorption occurs while there is no change in appearance, internal ham color, sliceability, taste, yield and aroma (Krause *et al*, 1978). These authors noted the significant improvement in cook yield between 18 hour intermittent tumbling and 9.5 hours intermittent and 3 hour continuous tumbling. The quality improvements were attributed to tumbling's disruptive effect on muscle structure. Lin *et al* (1990) found that total tumbler revolutions significantly increased all texture profile analysis (TPA) parameters except for cohesiveness, while the speed of tumbling effected those and elasticity.

The objective of this research is to produce reduced sodium, natural deli-style turkey breast that displays similar cook yield, sliceability, and texture characteristics to conventional turkey deli-meats. Studies were designed and conducted to evaluate ingredient and physical action on reduced sodium natural deli-style turkey breast. In

study one; the objective was to explore the effects of sodium reduction and varying vacuum tumbling times on cook yield, sliceability, and texture parameters

Study 2 will build on the results of study one. Preblending salt concentrations will be used to formulate reduced sodium natural deli-style turkey breast, and will compare either 1 or 3 hours of vacuum tumbling and there effects on texture and processing characteristics.

Study 3 will build on the results of the study two with the objective producing reduced sodium natural deli-style turkey breast with similar TPA, processing trait, and sensory traits to a control. Phosphate alternatives will be explored with the intention of improving product texture, processing, and quality traits comparable to conventional products that include sodium polyphosphates.

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Phase 1

Effects of Vacuum Tumbling Time and Salt Concentration on the Processing and Quality Characteristics of Reduced Sodium Natural Deli-style Turkey Breast.

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Effects of Vacuum Tumbling Time and Salt Concentration on the Processing and Quality Characteristics of Reduced Sodium Natural Deli-style Turkey Breast.

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The objective was to evaluate the effect of vacuum tumbling time and salt concentration on processing and quality characteristics of reduced sodium natural deli-style turkey breast (NDSTB). Treatments with varying salt concentrations of 1.0%, 1.5%, 2.0% salt were compared to a control; formulated to include 2.0% salt, 1.0% sugar, 0.35% phosphate. Treatments were tumbled for 1 or 3 hours under refrigeration (35°C), stuffed into 6Mx42m casings, and cooked to an internal temperature of 71°C. Treatments were sliced into 13mm slices for texture profile analysis (TPA), or 2mm slices for sliceability and fold tests. Data were analyzed using PROC GLIMMIX in SAS. Mean treatment values for hardness ($P=0.36$) and sliceability ($P=0.06$) were similar for all treatments. The slices from the control treatment had greater ($P<0.05$) mean values for springiness, cohesiveness, and chewiness when compared to the natural treatments for all salt concentrations and mixing time combinations. The slices from the natural treatments with 1.0% salt had lower ($P<0.05$) mean values for springiness, cohesiveness, and fold test than the slices from 2.0% salt treatments and the slices from the phosphate added control. Treatments were analyzed in a 3x2 factorial without the control exploring effects of salt level and mixing time. Tumbling time was not significant ($P>0.05$) for all measured traits. Slices from 2.0% salt treatments were significantly greater ($P<0.05$) than 1.0% treatments for springiness, cohesiveness, chewiness, sliceability, fold test, and cooking yield, but were similar for 1.5% and 2.0%. Sliceability, and fold test for 1.0% salt slices were lower ($P<0.05$) than slices from 1.5% salt treatments. Producing NDSTB

without phosphate is lower in texture and processing properties than deli-style turkey breast produced with phosphate. Reducing salt concentration to 1.0% produces NDSTB with unacceptable texture and processing characteristics compared to 1.5% or 2.0% salt.

Keywords: Vacuum tumbling time, Natural deli-style turkey, Sodium reduction, texture profile analysis

Introduction

In recent years consumer demand has shifted to an increasingly more health conscious diet, including reduced sodium, and natural label products. Current sodium intake for Americans age 2 and over is estimated at 3,400 mg per day, according to the Dietary Guidelines for Americans (2010). The USDA recommends a reduction to 2,300 mg per day and a further reduction to 1,500 mg per day for people 51 and over, as well as African Americans of all ages, people with hypertension, diabetes, or kidney disease. It is known that sodium is an essential nutrient needed by the body to perform basic functions. Additionally, salt performs some of the most crucial roles in meat processing, including improved protein extraction, water holding capacity, product bind, flavor, and antimicrobial characteristics.

Reducing sodium in processed meat products can reduce cook yield, decrease product bind, reduced textural properties complications, and reduced flavor. Neer and Mandigo (1977) reported that cook yields increased from 0.0% salt to 2.25% salt concentrations and decreased at the 3.0% salt. Siegel and Schmidt (1979) reported that both salt and phosphate increased the binding ability of proteins. Salt is also one of the most important ingredients that impacted the flavor of processed meat products. People desire the salty flavor imparted by sodium chloride. Coon *et al* (1983) reported that by adding 1.0% salt increased the peak break force (PBF) 140% over the 0% salt formulations.

These product texture issues are magnified in natural label products because of the regulations that prohibit the inclusion of phosphate products. Cook yields increase

linearly as phosphate inclusion increases (Neer and Mandigo, 1979, Trout and Schmidt, 1984 and 1986; Siegel and Schmidt, 1979).

Mechanical action including grinding, mixing, tumbling, massaging, and stuffing can increase protein extraction. Ockerman and Organisciak (1978) reported that tumbling improved ingredient diffusion, becoming significant at 3 hours of tumbling. Theno *et al* (1978) also reported that after 4 hours of massaging fiber disruption became clear, even at the myofibril level.

Massaging or tumbling meat has been shown to improve cook yields (Rejt *et al*, 1977; Addis and Schanus, 1979; Krause *et al*, 1978; Booren *et al*, 1981a, 1981b). While Ockerman *et al* (1978) reported contrasting results in regards to cook yield when short term tumbling was studied. Booren *et al* (1981a) indicated that vacuum tumbling resulted in significant improvements in bind between meat pieces. They concluded that this improvement was due to the removal of air from the protein exudate, which eventually forms the matrix, for binding. This study also reported no differences in juiciness, flavor, and tenderness.

Increasing tumbling time has been reported to improve protein binding, and subsequent processing and quality traits. The objective of this experiment was to investigate the effect of increased vacuum tumbling times on the processing quality characteristics of reduced sodium natural deli-style turkey breast.

Materials and Methods

Vacuum tumbling times of 1 hour and 3 hours and salt concentrations of 1.0%, 1.5%, and 2.0% salt were used to determine the effect of vacuum tumbling time and salt concentration on the processing and quality characteristics of reduce sodium natural deli-style turkey breast. Treatments were replicated twice.

Raw Meat Materials

Frozen boneless, skinless Tom turkey breasts (specification number: 2041-40) were purchased from a wholesale distributor and stored in a freezer until needed. The breast were thawed at refrigeration temperatures and tempered at 2°C until production. Each treatment consisted of 9.61 kg of coarse ground (Kidney plate number 7/83), and 1.67 kg of fine ground (4.76 mm) turkey breast. Turkey breasts were ground using a Hobart Grinder (Model #4732, Hobart MFG. Co., Troy OH). Turkey breast was divided in to seven treatments of 11.3 kg.

Brine Preparation

Prior to production dry ingredients were weighed and labeled for each treatment. Water was chilled at 2°C overnight prior to brine mixing, and weighed out according to the treatment. Brines were mixed immediately prior to addition to the meat block and tumbled. Brines were prepared in a stainless steel container, and mixed using a Waring automatic mixer (WSB 120VAC). The order of ingredient addition to the brine was: water, salt, sugar for non-control treatments. When mixing the control brine 0.35% phosphate was added to the water first, followed by salt and sugar. Brines targeting 25%

addition were mixed to include either 1.0%, 1.5%, 2.0% salt, and 1.0% sugar on a meat block basis, with the remainder being water. Brines were added to the meat block when all the ingredients were completely dissolved.

Production

Brines for the 1.0%, 1.5%, and 2.0% treatments were added to the meat block and placed in a vacuum tumbler (Daniels Food Equipment, Model DVTS R2-250). A vacuum was pulled (20 mm/Hg), and treatments were vacuum tumbled for either 1 or 3 hours. After tumbling, treatments were vacuum stuffed into 6M x 42" fibrous, pre-stuck, pre-clipped casings. Low salt treatments were stuffed first, followed by increased salt concentration treatments. Rolls were pulled and clipped using a Tipper Clipper (Model # PR465L, Tipper Tie, Inc., Apex, NC), weighed, and loaded onto a smokehouse truck for thermal processing. Turkey rolls were thermally processed to an internal temperature of 71°C to achieve a fully cooked status, according to Appendix A (USDA, 1999). After thermal processing, Natural deli-style turkey breasts were chilled according to Appendix B (USDA, 1999). Temperature data-loggers were used to verify both thermal processing and chilling temperatures.

Slicing and Packaging

After chilling for approximately 14 hours, natural deli-style turkey breast rolls were weighed and cooking yields were calculated. Casings were peeled and discarded. Using a Bizerba slicer (Bizerba Model # SE12, Bizerba, Balingen, Germany) two slices, 13mm in thickness were sliced from each log and used for texture profile analysis (TPA). Furthermore, three sets of 25 slices 2 mm in thickness were obtained to determine

sliceability. Sliceability was defined as the percentage of intact slices from 3 sets of 25 slices, 2mm thick. Three sets of five slices, 2 mm thick from each roll were used to conduct a fold test, which is a measure of binding strength. Slices were packaged in 15.3 cm x 25.4 cm cyrovac pouches. Pouches were vacuum sealed using a Multivac (Model #C500, Sepp Haggenmuller GmbH and Co. KG, Wolfertschwenden, Germany).

Processing and Quality Measurements

Cook yield

Cook yield was calculated using the following equation:

$$\text{Cook Yield (\%)} = [1 - \frac{\text{initial weight} - \text{cooked weight}}{\text{initial weight}}] \times 100$$

Sliceability

Sliceability was determined by cutting 25 consecutive 2 mm slices, and recording the number of visually intact slices.

Fold Test

Five intact slices were used to conduct a fold test (Suzuki, 1981), which is a measure of bind strength. A 2 mm slice was folded in half and the extent of cracking was noted. The scores were marked as A, B, C, or D. Slices receiving the A score showing no cracks. Slices receiving a B score displayed a small crack on the folded portion. C score slices reveal serious cracking along the folded surface. Slices receiving a D score cracked completely, and separate into two pieces. In order to calculate a numerical average we assigned each letter score a number value as follows: A=4, B=3, C=2, D=1. A mean was calculated for each rep and treatment for statistical analysis.

Texture Profile Analysis

Six slices (13mm) per treatment were analyzed using 2,500-kg load cell on an Instron (Model number 1123, Instron Worldwide, Norwood, MA). Each slice was cut into a 4.0 cm x 4.0 cm square and double compressed to 75% of its original thickness. The following characteristics were calculated as described by Bourne (1978): hardness, springiness, chewiness, cohesiveness, and gumminess.

Statistical Analysis

Data were analyzed using the GLIMMIX procedure of SAS (SAS Version 9.2, Cary, NC 2002). This study was analyzed two different ways. The first compared salt level and vacuum tumbling time in a 3 x 2 factorial design. Treatments were then compared to a standard control in a standard analysis of variance (ANOVA).

Results and Discussion

Tables 1.2 and 1.3 shows the LS means of the factorial analysis for percent salt and vacuum tumbling time on texture profile analysis (TPA) parameters, sliceability, foldability (F), and cookhouse yield (CY) for salt concentrations. Table 1.2 shows the LS means of TPA parameters, sliceability, foldability (F), and cookhouse yield (CY) for vacuum tumbling times. The second analysis included the standard control that contained phosphate and was analyzed using ANOVA. Table 1.4 shows the LS means of all the treatments.

Effect of Salt

Higher salt concentrations significantly increased ($P<0.05$) the TPA parameters of springiness, cohesiveness, and chewiness. Product hardness, and gumminess were unaffected by salt concentration (Table 1.2). Treatments formulated with 2.0% salt had

higher springiness, cohesiveness, and chewiness values when compared to reduced salt treatments (1.0% and 1.5%). Chewiness values increased with increasing salt concentrations; the 1.0% treatments had significantly lower ($P<0.05$) chewiness values than the 2.0% salt treatments. Products with low (1.0%) salt revealed significantly lower ($P<0.05$) sliceability, foldability, and yield when compared to other salt treatments (Table 1.2). The increased salt concentration introduces a greater number of negative charges in the form of chloride anions. More negative charges leads to a higher ionic strength, and greater electrostatic repulsions; exposing more charges for water to be immobilized and proteins to interact. Results from the current study agree with Neer and Mandigo (1977) who reported that cook yield increased linearly from 0.0% salt to 2.25% salt. Siegel and Schmidt (1979) reported that both salt and phosphate improved binding strength of protein matrixes, thereby improving TPA parameters.

Effects of Tumbling Time

Vacuum tumbling time had no significant effect ($P>0.05$) on any of the measured parameters (Table 1.2). There was no vacuum tumbling time effect ($P=0.89$) on product springiness. This result agrees with Ockerman *et al* (1978) who reported that short term (30 minute) tumbling had no effect on texture parameters of cured canned pork. Krause *et al* (1978) reported that there was no tumbling time effect on ham external color, external appearance, internal color, sliceability, consistency, and taste and aroma of cured hams. Generally, as vacuum tumbling time increased gumminess and chewiness decreased. Vacuum tumbling time had no significant effect ($P>0.05$) on the cohesiveness of reduced sodium NDSTB. Lins' (1990) results suggest that tumbling speed is more important than tumbling time. Tumbling speed significantly improved all

ham TPA parameters except cohesiveness. Lin *et al* (1990) also reported that higher revolutions significantly decreased ham hardness, gumminess, and chewiness. There was no vacuum tumbling time effect ($P>0.05$) on sliceability, foldability, or yield (Table 1.3). Other studies were conducted using pork and beef (Booren *et al*, 1981a; Booren *et al*, 1981b; Ockerman and Organisciak, 1978; Kraus *et al*, 1978). Perhaps the 3 hour tumbling time disrupted the delicate turkey breast fibers beyond optimum functionality. This idea is supported by the data of Theno *et al* (1978), who observed that long massaging times disrupted muscle structure.

Natural vs. Control

When analyzed using ANOVA there were significant treatment effect ($P<0.05$) on the TPA parameters of springiness, gumminess, cohesiveness, and chewiness (Table 1.4). The inclusion of phosphate in the formulation led to greater springiness, gumminess, cohesiveness, and chewiness values. Theno *et al* (1978) reported that inclusion of salt and phosphate resulted in a more ordered matrix, potentially resulting in improved texture properties. Control treatments were springier, more cohesive, and much chewier than all other treatments ($P<0.05$). When compared to the control, 2.0% salt (both tumbling times), and the 1.5% salt/1 hour tumble treatments were similar to the control treatment ($P>0.05$). Trout and Schmidt (1986) reported that the addition of phosphates increased tensile strength and cook yield. They reported a more dramatic improvement in these parameters when phosphates were added at more traditional salt levels. Trout and Schmidt (1986) reported that at low ionic strength (0.15) phosphate treatments increased tensile strength (TS) and cook yield (CY) the same as no phosphate treatments.

There were significant treatment effects ($P<0.05$) on the slice quality characteristics of foldability and cook yield. Sliceability approached significance ($P=0.062$). Treatments formulated with 1.0% salt yielded slices that were significantly less foldable than all other treatments ($P<0.05$). The control treatment had significantly greater cook yields ($P<0.05$) than all other treatment groups, with the exception of the 2.0% salt/ 3 hr. and the 1.5% salt/ 1 hr. treatments ($P>0.05$). This agrees with Neer and Mandigo (1977), Ockerman *et al* (1978), Booren *et al* (1983), Trout and Schmidt (1986), trout and Schmidt (1984), and Krause *et al* (1978) who reported that inclusion of phosphates increase yields and binding strength.

Conclusion

Producing sodium reduced natural deli-style turkey breast without phosphate results in greatly reduced texture and processing properties than deli-style turkey breast produced with phosphate. Reducing salt concentration to 1.0% produces NDSTB with unacceptable visual, textural and processing characteristics compared to 1.5% or 2.0% added salt. Different methods should be investigated in an attempt to produce reduced sodium Natural deli-style ready-to-eat meats.

Tables

Table 1.1-Treatment formula for 1.0%, 1.5%, or 2.0% salt treatments to be tumbled for either 1 or 3 hours.

Ingredients	1.00% ^a	1.50% ^b	2.00% ^c	Control
Meat Block				
Preblend	-	-	-	-
Turkey	25	25	25	25
Ingredients				
Water	5.75	5.625	5.5	5.4125
Salt	0.25	0.375	0.5	0.5
Sugar	0.25	0.25	0.25	0.25
BK 512 ^d	-	-	-	0.0875
Total	31.25	31.25	31.25	31.25

1.0^a- Treatments had final salt concentration of 1.0%.

1.5^b- Treatments had final salt concentrations of 1.5%.

2.0^c- Treatments had final salt concentrations of 2.0%.

BK 512^d- Sodium tripolyphosphate blend.

Table 1.2- Least square means for TPA of reduced sodium NDSTB Slices with different salt concentrations

	Salt Concentration			
	1.0%	1.5%	2.0%	<i>P</i> >Value
Texture Profile				
Hardness	1430	1522	1441	0.3718
Springiness	0.3285 ^b	0.3285 ^b	0.3567 ^a	0.0156
Gumminess	356.24	392.63	394.46	0.0978
Cohesiveness	0.2473 ^b	0.2579 ^b	0.2736 ^a	0.0028
Chewiness	117.9 ^b	128.9 ^{ab}	140.3 ^a	0.0379
Sliceability				
Sliceability ^x (%)	60.7 ^b	93.3 ^a	99.7 ^a	0.0061
Fold ^y	1.6 ^b	3.2 ^a	3.7 ^a	0.0003
Yield ^z (%)	80.2 ^b	84.2 ^{ab}	86.4 ^a	0.098

^{ab}Different superscripts within rows indicate significance (*P*< 0.05).

Sliceability- reported as a percent of slices intact.

^y Fold- A, B, C, and D scores were assigned values of 1, 2, 3, and 4. A mean was calculated and used in analysis

^zYield- Cook Yield (%) = $\frac{[1-(\text{initial weight}-\text{cooked weight})]}{\text{initial weight}} \times 100$

Table 1.3- Least square means for TPA of reduced sodium NDSTB turkey slices produced with different vacuum tumbling times.

produced with different vacuum tumbling times.			
	Vacuum Tumbling Time		
	1 hour	3 hour	<i>P</i> >Value
Texture Profile			
Hardness	1509.6	1418.9	0.1367
Springiness	0.3376	0.3386	0.8865
Gumminess	395.5	366.7	0.0735
Cohesiveness	0.2616	0.2576	0.3632
Chewiness	133.5	124.6	0.159
Sliceability			
Sliceability ^x (%)	83.5	86.9	0.6753
Fold ^y	3.1	2.6	0.1178
Yield ^z (%)	84.3	82.9	0.5007

^{ab}Different superscripts within rows indicate significance ($P < 0.05$).

^x Sliceability- reported as a percent of slices intact.

^y Fold- A, B, C, and D scores were assigned values of 1, 2, 3, and 4. A mean was calculated and used in analysis

^zYield- Cook Yield (%) = $\frac{[1 - (\text{initial weight} - \text{cooked weight})]}{\text{initial weight}} \times 100$

Table 1.4-Least square means for TPA of reduced sodium NDSTB slices produced with different salt concentrations and vacuum tumbling times.

	1 hour			3 hour			Control	P>Value
	1.0%	1.5%	2.0%	1.0%	1.5%	2.0%		
Texture Profile								
Hardness	1506.8 ^{ab}	1592.1 ^a	1429.9 ^{ab}	1353.3 ^b	1451.9 ^{ab}	1451.4 ^{ab}	1459.7 ^{ab}	0.3567
Springiness	0.3370 ^{cd}	0.3253 ^d	0.3504 ^{bc}	0.3300 ^d	0.3327 ^{cd}	0.3630 ^b	0.4182 ^a	0.0004
Gumminess	382.36 ^{bc}	410.05 ^{ab}	394.70 ^{ab}	330.12 ^c	372.22 ^{bc}	394.70 ^{ab}	448.87 ^a	0.0369
Cohesiveness	0.2522 ^c	0.2572 ^{bc}	0.2718 ^b	0.2424 ^c	0.2535 ^{bc}	0.2718 ^b	0.3070 ^a	0.0012
Chewiness	129.6 ^b	133.2 ^b	137.8 ^b	106.3 ^c	124.8 ^{bc}	142.8 ^b	187.1 ^a	0.0004
Sliceability								
Sliceability ^x (%)	55.9 ^c	95.3 ^{ab}	99.3 ^a	65.3 ^{bc}	95.3 ^{ab}	100.0 ^a	100.0 ^a	0.0622
Fold ^y	2.0 ^b	3.3 ^a	3.9 ^a	1.2 ^b	3.2 ^a	3.5 ^a	3.9 ^a	0.0025
Yield ^z (%)	82.1 ^{cd}	86.7 ^{abc}	84.1 ^{bcd}	78.3 ^d	81.6 ^{cd}	88.7 ^{ab}	91.6 ^a	0.014

^{ab} Means with different superscripts within rows indicate significant difference ($P \leq 0.05$).

^x Sliceability- reported as a percent of slices intact.

^y Fold- A, B, C, and D scores were assigned values of 1, 2, 3, and 4. A mean was calculated and used in analysis

^z Yield- Cook Yield (%) = $\frac{[1-(\text{initial weight}-\text{cooked weight})]}{\text{initial weight}} \times 100$

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Phase 2

**Effects of Preblend Salt Concentration and Final Salt Concentration on the
Processing and Quality Characteristics of Reduced Sodium Natural Deli-style
Turkey Breast.**

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Effects of Preblending and Final Salt Concentration on the Processing and Quality Characteristics of Reduced Sodium Natural Deli-style Turkey Breast.

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This research was stimulated by consumer demands for low sodium products formulated with minimal ingredients. The objective of this study was to produce reduced sodium natural deli-style turkey breast by examining the effect of preblending and salt concentration on processing and quality characteristics. Natural deli-style turkey was formulated to final salt concentrations of 1.0%, 1.5%, and 2.0% on a meat block basis; all treatments had 1.0% sugar and water to total 25% added ingredients. A standard control was formulated to include 2.0% salt, 1.0% sugar, 0.35% phosphate, and 22.65% water. The meat block consisted of 85% coarse ground and 15% fine ground turkey breast. Two preblends with 3.0% or 4.0% salt were tumbled at refrigeration temperatures for 3 hrs, and held overnight (≈ 18 hrs.). The following day, 3 treatments were made (1.0%, 1.5%, and 2.0% salt concentration) from each preblend, and tumbled for an additional 3 hours, stuffed into casings, and cooked to an internal temperature of 71°C . Treatments were sliced into 13mm slices for texture profile analysis (TPA), or 2mm slices for sliceability, fold test, 4 packages of 10 slices 2mm thick were vacuum packaged for slice integrity determination. TPA was performed to quantify the characteristics of hardness, chewiness, cohesiveness, springiness, and gumminess. Data were analyzed using the PROC GLIMMIX procedure in SAS. Using preblend with 3.0% or 4.0% did not affect texture and processing traits ($P>0.05$). Salt significantly impacted ($P<0.05$) cohesiveness, L^* , b^* , and all processing traits. Control treatments had significantly greater ($P<0.05$) TPA means. Processing traits were significantly impacted by treatment

as well ($P<0.05$). b^* values were significantly reduced by inclusion of phosphate ($P<0.05$). Preblend salt concentration was ineffective at imitating the phosphate control effects on TPA and processing traits of reduced sodium turkey breast.

Keywords: Preblending, Sodium reduction, texture profile analysis, Natural deli-style turkey

Introduction

The consumer desire to purchase clean label processed meat products has stimulated research that focuses on formulations with minimal added ingredients. The current push leans on a reduction in overall sodium content, and exclusion of inorganic ingredients such as polyphosphates, and antimicrobial agents. Many of these ingredients contribute to protein extraction in one way or another. Sodium chloride facilitates the extraction of myofibrillar proteins through an increase in negatively charged anions and a subsequent increase in electrostatic repulsions. These repulsions lead to myofibrillar swelling improved water holding capacity (WHC), protein binding and an improvement in processing and quality traits (Offer and Trinick, 1983; Sofos, 1986; Coon *et al*, 1983; Neer and Mandigo, 1977; and Ockerman *et al*; 1978). Inorganic polyphosphates contribute to protein extraction and improved processing and quality traits through the compounds ability to dissociate the actomyosin bonds that essentially restrict the amount of myofibrillar swelling.

Processing methods have been developed to overcome the loss of protein functionality. Methods such as preblending attempt to maximize protein extraction by using a higher concentration of salt or curing ingredients, and then reducing total salt concentration by adding additional meat and non-meat ingredients. Pearson and Gillett (1996) define preblending as mixing part of the meat with part or all of the salt or curing agents. This method effectively boosts the ionic strength of the batter resulting in optimum extraction. This preblend can then be used to formulate lower fat or in this case salt concentration products. Schweigert and Price (1987) reported that temperatures in

the range of -5°C to 2°C yield maximum protein extraction. As such, preblending and subsequent tumbling was conducted at 1.6°C in the current study.

The goal of this study was to investigate the processing and quality traits effected by preblends formulated to two different salt levels (3.0% and 4.0%), and three different final product salt concentrations (1.0%, 1.5%, 2.0%). The six treatments were compared to a control treatment containing 2.0% salt, 1.0% sugar, 0.35% phosphate. Instron analysis, sliceability, foldability, slice integrity, cook yield, color values, pH, salt concentration, and water activity were analyzed.

Materials and Methods

Preliminary work suggested that preblended products showed improved processing traits compared to non-preblended products. Two preblends were prepared with 3.0% and 4.0% salt on a meat block basis. From each of the preblends, three treatments were formulated to final salt concentrations of 1.0%, 1.5%, 2.0% (on a meat block basis). A control was formulated using 2.0% salt, 1.0% sugar, and 0.35% polyphosphate. Previous research indicated that increasing mixing time alone does not result in sufficient protein extraction to produce reduced sodium natural deli-style turkey breast (NDSTB) rolls. Each treatment was replicated on three separate production days.

Raw Meat Materials

Frozen boneless, skinless Tom turkey breasts (specification number: 2041-40) were purchased from a wholesale distributor and stored in a freezer until needed. The breast were thawed at refrigeration temperatures and tempered at 2°C until production. Each treatment consisted of 9.61 kg of coarse ground (Kidney plate number 7/83), and 1.67 kg of fine ground (4.76 mm) turkey breast. Turkey breasts were ground using a Hobart Grinder (Model #4732, Hobart MFG. Co., Troy OH). Turkey breast was divided in to seven treatments of 11.3 kg.

Preblend Preparation

Turkey ground through a kidney plate was used to make two preblend batches containing 3.0% and 4.0% salt. The total amount of preblend was determined by calculating how much preblend (3.0% or 4.0%) is needed to formulate final salt

concentrations of 1.0%, 1.5%, and 2.0%. Coarse ground turkey was added to separate vacuum tumblers (3.0% and 4.0%) respectively; and the required amount of salt was added to the meat block. A vacuum (20 mm/Hg) was pulled, and meat was tumbled for 3 hours at refrigeration temperatures (2-4°C). Preblended product was allowed to sit over night for use in production the following morning.

Brine Preparation

Prior to production dry ingredients were weighed and labeled for each treatment. Water was chilled to 2°C prior to production, and weighed out according to the treatment. Brines were mixed in a stainless steel pail using a Waring automatic mixer, immediately prior to addition to the meat block and tumbled. The order of ingredient addition to the brine was: water, sugar for non-control treatments. When mixing the control brine, 0.35% phosphate was added to the water first, followed by salt and sugar. Brines targeting 25% addition were mixed to include 1.0% sugar and the remainder being water. Brines were added to the meat block when all the ingredients were completely dissolved.

Production

The meat block was composed of both preblended turkey breast and regular turkey breast. Varying amounts of each preblend (3.0% and 4.0%) were used to reach final salt concentrations of 1.0%, 1.5%, 2.0%, and a control formulated with no preblend. Batches were put in a vacuum tumbler (Daniels Food Equipment, Model DVTS R2-250), brine was added, and a vacuum was pulled (20 mm/Hg), and treatments were tumbled for 3 hours. Post-tumbling, treatments were vacuum stuffed into 6M x 42" fibrous, pre-stuck, pre-clipped casings. Low salt treatments were stuffed first, followed by increased

salt concentration treatments. Rolls were pulled and clipped using a Tipper Clipper (Model # PR465L, Tipper Tie, Inc., Apex, NC), weighed, and loaded onto a smokehouse truck for thermal processing. Turkey rolls thermally processed to an internal temperature of 71°C to achieve a fully cooked status, according to Appendix A (USDA, 1999). After thermal processing, Natural deli-style turkey breasts were chilled according to Appendix B (USDA, 1999). Temperature data-loggers were used to verify both thermal processing and chilling temperatures.

Slicing and Packaging

Prior to slicing, Natural deli-style turkey breasts were weighed and cooking yields were calculated and record. Casings were peeled and discarded. Using a Bizerba slicer (Bizerba Model # SE12, Bizerba, Balingen, Germany) two slices, 13mm in thickness were sliced from each log and used for texture profile analysis (TPA). Furthermore, 25 slices 2 mm in thickness were obtained to determine sliceability and fold test. Sliceability was defined as the percentage of intact slices from 4 sets of 25 slices, 2mm thick. Twenty slices, 10 from each roll were used to conduct a fold test, which is a measure of binding strength. An additional 40 slices, 2mm in thickness were used for a slice integrity evaluations. Slices were packaged in 15.3 cm x 25.4 cm cyrovac pouches. Pouches were vacuum sealed using a Multivac (Model #C500, Sepp Haggemuller GmbH and Co. KG, Wolfertschwenden, Germany). The unsliced portions were vacuum packaged and stored under refrigeration conditions.

Processing and Quality Characteristics

Cook yield

Cook yield was calculated using the following equation:

$$\text{Cook Yield (\%)} = \left[\frac{1 - (\text{initial weight} - \text{cooked weight})}{\text{initial weight}} \right] \times 100$$

Sliceability

Sliceability was determined by cutting 25 consecutive 2 mm slices, and recording the number of total intact slices.

$$\text{Sliceability (\%)} = \left[\frac{1 - (\text{total slices} - \text{intact slices})}{\text{Total slices}} \right] \times 100$$

Fold Test

A fold test was conducted as described by Suzuki (1981), with minor modifications. Five intact slices were used to conduct a fold test, which is a measure of bind strength. A 2 mm slice was folded in half and the extent of cracking recorded. The scores were marked as A, B, C, or D; with slices scoring A, having no cracks. Slices receiving a B score displayed a small crack on the folded portion. C score slices reveal serious cracking along the folded surface. Slices receiving a D score crack completely, and typically break. In order to calculate a numerical average we assigned each letter score a number value as follows: A=4, B=3, C=2, D=1. A mean was calculated for each rep and treatment for statistical analysis.

Slice Integrity

Slice integrity was used to further detect quality differences between regular and reduced salt concentrations. Four sets of 10 slices, 2mm in thickness were vacuum packaged as described above and tested the following day. Packages were opened, and

slices were peeled from the stack beginning at the top. The number of intact slices was record for each stack of ten and a total was calculated.

$$\text{Slice integrity (\%)} = \left[1 - \frac{(\text{total slices} - \text{intact slices})}{\text{Total slices}} \right] \times 10$$

Physical Traits

Color Analysis

Objective color was determined using a handheld Minolta Chromameter CR-400 (Shanghai, China) using a D65 light source and 2° standard observer. L*, a*, b* values were recorded using 3 readings per 13mm slice; two slices were evaluated per treatment. Readings were taken approximately 21 days post production.

Salt concentration

Ten grams of Natural deli-style turkey breast was chopped using a Black and Decker Handy chopper. Ninety milliliter of double distilled deionized water was added and homogenized for 30 seconds with a Polytron homogenizer (POLYTRON Kinimatica CH-6010, Switzerland). A double folded filter paper was inserted into the solution and a Quantab was used to measure the chloride ions and final salt concentration.

pH Determination

The pH was taken on ground samples after a period of refrigerated storage. The pH was taken on cooked product. A 13mm slice was chopped using a Black and Decker Handy Chopper, 10 grams were weighed into a plastic beaker and 90mL of double distilled deionized water was added. The mixture was homogenized for 30 seconds using a Polytron homogenizer (POLYTRON Kinimatica CH-6010, Switzerland). The beaker was then placed on a Barnstead Thermolyne stir plate with a magnetic stir bar was used to keep the solution homogenized. The readings were taken with an Orion PerPHect

Electrode with Ross pH Spear Tip (Thermo Electron Corporation, Beverly, WA) calibrated using a 7.0 and 4.0 buffer. The pH probe was rinsed with double distilled deionized water and wiped with a Kim wipe between each sample.

Water Activity

Water activity was determined using an Aqua Lab 4TE Dew Point and Water Activity meter. Samples were chopped, placed in a sampling cup, and placed in the measuring chamber and evaluated.

Texture Profile Analysis

Six slices (13mm) per treatment were analyzed using 2,500-kg load cell on an Instron machine (Model number 1123, Instron Worldwide, Norwood, MA). Each slice was cut into a 4.0 cm x 4.0 cm square and double compressed to 75% of its original thickness. The following characteristics were calculated as described by Bourne (1978): hardness, springiness, chewiness, cohesiveness, and gumminess. TPA was conducted following the slicing and packaging day.

Statistical Analysis

Data were analyzed using the GLIMMIX procedure of SAS (SAS Version 9.2, Cary, NC 2002). Hardness, springiness, cohesiveness, chewiness, gumminess, cook yield, sliceability, slice integrity, and fold score were analyzed as a 3 x 2 factorial. The standard control was included and analyzed as an ANOVA.

Results and Discussion

Tables 2.1 and 2.2 show the least square (LS) means for salt concentration and vacuum tumbling time on TPA parameters, sliceability, slice integrity, foldability (F),

and cookhouse yield (CY), Color values (L^* , a^* , b^*), pH, salt, and water activity (A_w). Results were also analyzed as an ANOVA to include the phosphate control. The initial analysis showed no interactions between final salt concentration and preblend salt concentration, as a result the main effects were evaluated. Additionally, the treatments were analyzed against the standard control in an Analysis of Variance (ANOVA).

Salt effect

Salt concentration had no significant effect ($P>0.05$) on TPA parameters. However, cohesiveness trended towards significance ($P=0.078$). Chewiness values were not significant, although values for chewiness decreased as salt level decreased.

Salt level significantly improved ($P<0.05$) the sliceability of natural deli-style turkey breasts (NDSTB). Both the 2.0% and 1.5% salt treatments had significantly higher ($P<0.05$) sliceability values than 1.0% salt treatments. These results indicate a more stable protein matrix. Trout and Schmidt (1984) reported that added homogenate over 18% increased tensile strength. Homogenate in their study was produced by fine chopping meat; acting as a more effective binding agent. The present study utilized 15% fine ground turkey breast to more readily extract proteins and act as a coating for the coarse ground pieces. Increasing tensile strength could lead to improved sliceability. Foldability significantly increased ($P<0.05$) as salt level increased. The fold test is good measure bind strength. The integrity of a stack of slices for each treatment group was significantly improved ($P<0.05$) with increasing salt level. Slice integrity for all treatments other than the 2.0% treatment group was greatly reduced. Mean values for slice integrity for 2.0%, 1.5%, and 1.0% were 95%, 59%, and 24% respectively.

When the phosphate control was included and analyzed as an analysis of variance (ANOVA) the TPA parameters of springiness, gumminess, cohesiveness, and chewiness were significantly improved ($P<0.05$). Hardness, L^* values, a^* values, and final product pH were not significantly ($P>0.05$) affected by treatment. This may be attributed to greater protein extraction in the higher salt preblend. Chewiness was significantly improved ($P<0.05$) with the addition of phosphate as well. Control treatments was significantly ($P<0.05$) more chewy than all other treatments.

The addition of phosphate significantly improved ($P<0.05$) product sliceability when compared to 1.0% salt treatments of either preblend salt concentration. Treatments formulated with 1.5% and 2.0% salt were similar ($P>0.05$) to the phosphate control treatment. Trout and Schmidt (1984) reported increased tensile strength with the inclusion of phosphates. Trout and Schmidt (1986) reported that phosphates have a strong positive effect at ionic strengths of over 0.15 (0.7% salt). Krause *et al* (1978) reported a significant improvement in ham sliceability with the inclusion of 3.3% phosphate in the brine.

Foldability was significantly reduced ($P<0.05$) as salt level decreased across all treatment levels. The 2.0% salt treatments were similar to the phosphate control ($P>0.05$). Treatments formulated to 1.0% salt were inferior to all other treatments, with both preblends yielding slices that received 1.88 and 1.66 mean values for the 1.0% salt/4.0% salt preblend and 1.0% salt/3.0% salt preblend treatments respectively.

Integrity was significantly reduced ($P<0.05$) as salt level decreased across all salt levels. The 2.0% salt treatments were similar to the phosphate control ($P>0.05$).

Although not significant ($P>0.05$) 3.0% salt preblend treatments displayed numerically greater slice integrity among salt levels.

There was a significant ($P<0.05$) treatment effect on cook yield of reduced sodium natural deli-style turkey breast. With the exception of the 2.0% salt/ 4.0% preblend treatment, the phosphate control had significantly greater ($P>0.05$) cook yields when compared to other treatments. This result is in agreement with Neer and Mandigo (1977), Ockerman *et al* (1978), Krause *et al* (1978), Smith and Young (2007), and Trout and Schmidt (1986). Neer and Mandigo (1977) and Ockerman *et al* (1978) reported that 0.25% phosphate maximized yields. Wierbicki (1976) reported that as little as 0.30% phosphate was needed in the final product to increase yield 5%. Smith and Young (2007) reported that phosphates improved the cook yield of marinated broiler breast meat by 10.0%. Siegel and Schmidt (1979) reported that the role of phosphate in improving cook yield was mainly due to phosphates ability to dissociate the actomyosin bonds and allow for increased myofibrillar swelling.

Hand *et al* (1987) reported that frankfurters formulated with low fat displayed lighter color values when sodium was reduced. Turkey breast meat is a low fat meat, and the results of the present study agree with Hand *et al* (1987) observations. L^* values significantly decreased ($P<0.05$) as salt level increased across all treatment groups. Reporting's from Neer and Mandigo (1977) agree with this result as well. In the former study conducted on flaked and cured pork; L^* values decreased until the 1.5% salt level then decreased slightly at higher levels.

There were no significant ($P>0.05$) salt effects on a^* or redness values of natural deli-style turkey breast rolls. Hand *et al* (1987) reported similar findings when studying fat and salt combinations in frankfurters. The group reported no changes in redness values when modifying the salt level, b^* values decreased as salt level increased, although not statistically significant ($P>0.05$). This again agrees with Hand *et al* (1987) who reported that as salt level increases products became less yellow.

When the phosphate control was included and analyzed using ANOVA, there were little treatment effects on reduced sodium natural deli-style turkey breast. The phosphate control had significantly lower L^* values ($P<0.05$) when compared to all other treatments, with the exception of the 2.0% salt/3.0% salt preblend treatment. Neer and Mandigo (1977) reported that as phosphate inclusion increases products become darker (decreasing L^* values). Hand (1987) reported that decreasing the salt level of low-fat frankfurters resulted in lighter products. The results of the current study contradict the reporting of Ockerman *et al* (1978) who reported that phosphate inclusion had no effect on color values. Smith and Young (2007) reported slight, but significant decreases in both L^* , and a^* values when marinating in a salt and phosphate brine. There were no other significant ($P>0.05$) treatment effects for L^* values in reduced sodium turkey products. There was no significant ($P>0.05$) treatment effects on a^* values in the current study. Treatment significantly effected ($P<0.05$) the b^* values in the current study. The phosphate control scored significantly ($P<0.05$) lower b^* values when compared to all other treatments with the exception of the 2.0% salt/4.0% preblend treatment ($P>0.05$). Generally, as salt level decreases, b^* values increase.

pH and A_w

As expected salt concentration in the finished product was significantly ($P<0.05$) different between treatment groups. Increasing salt level in the formulation leads to increased salt level in the finished product increases ($P<0.05$). Additionally, salt treatments had no significant effect ($P>0.05$) on pH values of treatments. This result agrees with Neer and Mandigo (1977), and Trout and Schmidt (1984). Likewise, Siegel and Schmidt (1979) reported that salt effects are primarily ionic and do not affect the pH. In regards to A_w , as salt levels in treatment groups increased, water activity decreased for all treatments ($P<0.05$). 2.0% salt treatments had the lowest water activity ($P<0.05$).

Inclusion of the phosphate control in an ANOVA analysis showed significant treatment effects on salt concentration and water activity ($P<0.05$). No significant treatment ($P>0.05$) effects were observed for pH values of treatments. Salt effects were expected as formulating treatments with reduced sodium would lead to less sodium in final products. The phosphate control had significantly ($P<0.05$) higher salt than the 1.0% treatments. As salt level decreased in the formulation, salt level in the final products significantly decreased ($P<0.05$) as well. There was no significant ($P>0.05$) treatment effects on pH. There were significant treatment ($P<0.05$) effects on water activity. Phosphate control and 2.0% salt treatments had significantly lower ($P<0.05$) water activity than the 1.0% salt treatments. In a review by Taormina (2010) summarizes that salt plays the greatest role in reducing A_w , however the treatments observed in the current study sufficiently reduced A_w to an acceptable level.

Preblending effect

Preblending had no significant effect ($P>0.05$) on any of the TPA parameters evaluated. This agrees with Knipe *et al* (1990), who reported that preblending alone with salt had no effect on emulsion stability or extractable protein parameters. Hand *et al* (1987) reported that preblending had minimal effects on color and texture of frankfurters produced using a combination of low fat/ low salt treatments.

Conclusion

This study suggests that there is little or no effect of preblend salt concentration, 3.0% or 4.0%, on any TPA parameters, processing characteristics, color values, or lab assays conducted ($P>0.05$). Reducing salt level in formulations negatively affected ($P<0.05$) product cohesiveness, all processing characteristics, and resulted in darker products. Using the processing parameters of preblend and tumbling time, reduced sodium natural deli-style turkey breast could not be produced to match the 2.0% salt treatments. Likewise, the phosphate control produced superior TPA results, and processing characteristics to reduced sodium treatments (1.5% and 1.0%). Natural products with comparable TPA and processing characteristics can be produced with 2.0% salt. However to match products made with phosphate, suitable phosphate alternatives are needed.

Tables

Table 2.1- Phase 2 formulations for 1.0%, 1.5%, 2.0% salt levels made with either 3.0% or 4.0% salt preblend

Ingredients	3.0% Salt Preblend			4.0% Salt Preblend			2.0%
	1.0 ^a	1.5 ^b	2.0 ^c	1.0 ^a	1.5 ^b	2.0 ^c	Control
Meat Block							
Preblend	8.33	12.50	16.67	6.25	9.38	12.50	0.00
Turkey	16.92	12.88	8.83	19.00	16.00	13.00	25.00
Ingredients							
Water	5.75	5.63	5.50	5.75	5.63	5.50	5.41
Salt	0.25	0.38	0.50	0.25	0.38	0.50	0.50
Sugar	0.25	0.25	0.25	0.25	0.25	0.25	0.25
BK 512 ^d	-	-	-	-	-	-	0.0875
Total	31.25	31.25	31.25	31.25	31.25	31.25	31.25

1.0^a- Treatments had final salt concentration of 1.0%.

1.5^b- Treatments had final salt concentrations of 1.5%.

2.0^c- Treatments had final salt concentrations of 2.0%.

BK 512^d- Sodium tripolyphosphate blend.

Table 2.2- Least square means of TPA, processing characteristics, color, and physical traits for preblend salt concentrations.

Texture Profile	Preblend		<i>P</i> <value
	3.00%	4.00%	
Hardness	1386.38	1402.67	0.7938
Springiness	0.3722	0.381	0.139
Gumminess	366.03	372.27	0.7264
Cohesiveness	0.2636	0.2645	0.8201
Chewiness	136.18	142.14	0.2807
Sliceability			
Sliceability ^v (%)	82.6	90.8	0.0867
Fold ^x	2.7	2.8	0.6294
Integrity ^y (%)	61.61	56.9	0.3745
Yield ^z (%)	84.5	85.2	0.6444
Color			
L*	82.32	82.48	0.6989
a*	3.65	3.59	0.6869
b*	11.23	11.1	0.4341
Physical Traits			
pH	5.76	5.71	0.4225
Salt (%)	1.14	1.13	0.877
Aw	0.989	0.989	0.4193

^{ab} Different superscripts within rows indicate significance ($P < 0.05$).

^vSliceability- reported as a percent of slices intact.

^xFold- A, B, C, and D scores were assigned values of 1, 2, 3, and 4. A mean was calculated and used in analysis.

^yIntegrity- A percent of intact slices removed from a stack slices

^zYield- Cook Yield (%) = $\frac{[1 - (\text{initial weight} - \text{cooked weight})] \times 100}{\text{initial weight}}$

Table 2.3- Least square means of TPA, processing characteristics, color, and physical traits for final salt concentrations.

Texture Profile	Salt Concentration			P<value
	1.00%	1.50%	2.00%	
Hardness	1393.23	1404.11	1386.24	0.9716
Springiness	0.3733	0.373	0.3835	0.2547
Gumminess	358.86	377.74	370.84	0.6793
Cohesiveness	0.2574 ^b	0.2675 ^a	0.2671 ^{ab}	0.0778
Chewiness	133.68	141.12	142.68	0.3618
Sliceability				
Sliceability ^v (%)	68.8 ^b	91.8 ^a	99.3 ^a	0.0002
Fold ^x	1.8 ^c	2.8 ^b	3.8 ^a	<0.0001
Integrity ^y (%)	24.4 ^c	58.8 ^b	94.6 ^a	<0.0001
Yield ^z (%)	81.7 ^b	85.2 ^{ab}	87.5 ^a	0.0197
Color				
L*	83.58 ^a	82.60 ^a	81.03 ^b	0.0005
a*	3.64	3.6	3.62	0.9743
b*	11.46 ^a	11.19 ^{ab}	10.84 ^b	0.0414
Physical Traits				
pH	5.73	5.71	5.76	0.7
Salt (%)	0.767 ^c	1.16 ^b	1.47 ^a	<0.0001
Aw	0.992 ^a	0.990 ^a	0.986 ^b	0.0014

^{abc} Different superscripts within rows indicate significance (P< 0.05).

^vSliceability- reported as a percent of slices intact.

^x Fold- A, B, C, and D scores were assigned values of 1, 2, 3, and 4. A mean was calculated and used in analysis.

^yIntegrity- A percent of intact slices removed from a stack slices

^zYield- Cook Yield (%) = $\frac{[1-(\text{initial weight}-\text{cooked weight})] \times 100}{\text{initial weight}}$

Table 2.3- Least square means for TPA, processing traits, and physical traits of turkey slices produced with different salt concentrations in preblends.

	3.0% Preblend			4.0% Preblend			2.0%	P<value
	1.00%	1.50%	2.00%	1.00%	1.50%	2.00%	Control	
Texture Profile								
Hardness	1413.11	1388.74	1357.28	1373.34	1419.47	1415.2	1513.05	0.831
Springiness	0.3657 ^b	0.3688 ^b	0.3821 ^b	0.3809 ^b	0.3773 ^b	0.3849 ^b	0.4520 ^a	0.0014
Gumminess	361.71 ^b	374.32 ^b	362.05 ^b	356.02 ^b	381.17 ^b	379.63 ^b	470.80 ^a	0.0336
Cohesiveness	0.2558 ^b	0.2684 ^b	0.2665 ^b	0.2590 ^b	0.2666 ^b	0.2677 ^b	0.3107 ^a	<0.0001
Chewiness	132.15 ^b	137.65 ^b	138.75 ^b	135.22 ^b	144.59 ^b	146.61 ^b	213.36 ^a	0.0001
Sliceability								
Sliceability ^v (%)	59.0 ^c	89.0 ^{ab}	99.7 ^a	78.7 ^b	94.7 ^a	99.0 ^a	100 ^a	0.0002
Fold ^x	1.7 ^c	2.8 ^b	3.8 ^a	1.9 ^c	2.9 ^b	3.8 ^a	4.0 ^a	<0.0001
Integrity ^y (%)	24.7 ^c	63.5 ^b	96.7 ^a	24.2 ^c	54.2 ^b	92.5 ^a	100 ^a	<0.0001
Yield ^z (%)	81.1 ^d	84.9 ^{bcd}	87.2 ^{bc}	82.2 ^{cd}	85.4 ^{bcd}	87.8 ^{ab}	92.9 ^a	0.009
Color								
L*	83.90 ^a	82.74 ^a	80.33 ^{ab}	83.26 ^a	82.47 ^a	81.72 ^a	69.32 ^b	0.1762
a*	3.56	3.55	3.83	3.56	3.66	3.41	3.45	0.6335
b*	11.45 ^a	11.24 ^{ab}	10.67 ^{bc}	11.47 ^a	11.13 ^{ab}	10.67 ^{bc}	10.10 ^c	0.0165
Physical Traits								
pH	5.76	5.73	5.8	5.71	5.69	5.73	5.89	0.5
Salt (%)	0.73 ^d	1.22 ^{bc}	1.45 ^a	0.80 ^d	1.10 ^c	1.50 ^a	1.40 ^{ab}	<0.0001
Aw	0.991 ^{ab}	0.991 ^{abc}	0.985 ^d	0.993 ^a	0.989 ^{bc}	0.988 ^{dc}	0.988 ^{dc}	0.0033

^{abc} Means with different superscripts within rows indicate significant difference ($P \leq 0.05$).

^v Sliceability- reported as a percent of slices intact.

^x Fold- A, B, C, and D scores were assigned values of 1, 2, 3, and 4. A mean was calculated and used in analysis

^y Integrity- A percentage of intact slices removed from stack of ten slices.

^z Yield- Cook Yield (%) = $\frac{1 - (\text{initial weight} - \text{cooked weight})}{\text{initial weight}} \times 100$

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Phase 3

Effects of Phosphate Alternatives and Final Salt Concentration on the Processing and Quality Characteristics of Reduced Sodium Natural Deli-style Turkey Breast.

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Effects of Preblending and Final Salt concentration on the Processing and Quality Characteristics of Reduced Sodium Natural Deli-style Turkey Breast.

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The objective was to produce reduced sodium natural deli-style turkey breast by evaluating the effect of two phosphate alternatives (PA) and salt concentration on processing, quality, and sensory attributes. Treatments were formulated to salt concentrations of 1.0% or 1.5% using a 4.0% salt preblend. Each with 1.0% PA, 1.0% sugar and water to equal 25% added ingredients. A standard control was formulated to include 1.0% sugar, 2.0% salt, 0.35% phosphate, and 22.65% water. Meat block consisted of 85% coarse ground and 15% fine ground turkey breast. Meat and salt were tumbled for 3 hours at refrigeration temperatures and held at refrigeration for ≈ 18 hrs. Preblend turkey was formulated with ground turkey to treatment salt concentrations of 1.0% or 1.5% for PA treatments. The phosphate control didn't include preblend. Treatments were tumbled for 3 hours, stuffed into casings and cooked to an internal temperature of 71°C . Treatments were sliced into 13mm slices for TPA, or 2mm slices for sliceability and fold tests. TPA was performed to quantify the characteristics of hardness, chewiness, cohesiveness, springiness, and gumminess. 60 slices per treatment were sliced and used for sensory panels. Data were analyzed using the PROC GLIMMIX procedure in SAS. PA had significant impacts on all TPA parameters except cohesiveness ($P < 0.05$). 1.5% treatments had significantly greater processing traits than did 1.0% treatments ($P > 0.05$). Control treatments had superior processing traits when compared to natural treatments ($P < 0.05$). Control treatments had lower L^* and b^* values than all others ($P < 0.05$). Salt had significant effect on all sensory attributes except off-

flavor ($P<0.05$). PA's effect overall acceptability of NDSTB ($P<0.05$). Control treatments had significantly greater sensory attributes than reduced sodium NDSTB treatments ($P<0.05$).

Keywords: Natural turkey breast, phosphate alternative, reduced sodium, TPA

Introduction

The current trend of reducing sodium, while striving for a clean, natural label has brought forth several challenges in regards to protein binding and the related processing and quality traits of deli-style processed meats. Sofos (1986) reported that reduced levels of salt reduced product acceptability due to lower firmness and flavor scores. To recover the loss texture and quality traits, effective alternatives must be explored. Hurtado *et al* (2011) found that porcine plasma was effective as an alternative for polyphosphates in frankfurters. However, panelists could detect flavor and odor modifications. In a study conducted on beef strip loin steaks, Lowder *et al* (2011) reported that dehydrated beef proteins could improve the juiciness of steaks, but resulted in slightly less tender steaks when evaluated by a trained panel. Kim *et al* (2013) reported that combined sodium hydrogen carbonate and high pressure improved the texture and palatability of hams produced without inorganic phosphates.

The need to improve the texture and processing traits of reduced sodium natural deli style products presents many challenges. The most imposing challenge is the inability to use polyphosphate blends, which researchers have shown to improve protein extraction, water holding capacity, and texture traits (Shults and Wierbicki, 1973; Krause *et al*, 1978; Ockerman *et al*, 1978; Neer and Mandigo, 1977; and Trout and Schmidt, 1986). Phosphates have a pH effect on meat batters, which act synergistically with salt which has an ionic strength effect. The two of these allow for maximum electrostatic repulsion and subsequent protein extraction and water holding capacity. In order for

natural phosphate alternatives to be viable in the processed meat industry, they must be able to mimic the functionality effects of inorganic phosphates.

The objective of this study was to evaluate the effectiveness of two natural phosphate alternatives at two salt levels (1.0% and 1.5%) on the processing and sensory characteristics reduced sodium natural deli-style turkey breast. These treatments were compared to a control treatment formulated to 2.0%, 1.0% sugar, and 0.35% phosphate.

Materials and Methods

The effects of two phosphate alternatives on the TPA parameters and processing characteristics were investigated at two reduced salt levels (1.0% and 1.5%), when formulated with a 4.0% salt preblend. 4.0% salt preblend was used to achieve maximum protein extraction during the preblending step. Phosphate alternatives were included at the 0.5% level at the recommendation of the manufacturers. The intention was to improve the quality, processing traits and sensory traits of reduced sodium natural deli-style turkey breast.

Raw Meat Materials

Frozen boneless, skinless Tom turkey breasts (specification number: 2041-40) were purchased from a wholesale distributor and stored in a freezer until needed. The breast were thawed at refrigeration temperatures and tempered at 2°C until production. Each treatment consisted of 9.61 kg of coarse ground (Kidney plate number 7/83), and 1.67 kg of fine ground (4.76 mm) turkey breast. Turkey breasts were ground using a Hobart Grinder (Model #4732, Hobart MFG. Co., Troy OH). Turkey breast was divided in to seven treatments of 11.3 kg.

Preblend Preparation

Coarse ground turkey breast was used to make one master batch of preblend containing 4.0% salt. Preblend was tumbled in 2 separate tumblers with equal amounts of meat and salt in each. The total amount of preblend was determined by calculating how much preblend was needed to formulate final salt concentrations of 1.0%, 1.5% on a

meat block basis. A vacuum (20 mm/Hg) was pulled, and meat was tumbled for 3 hours at refrigeration temperatures (2-4°C). Preblended product was held overnight (≈18 hrs.) for use in production the following morning.

Brine Preparation

Prior to production dry ingredients were weighed and labeled for each treatment. Water was chilled to approximately 2°C prior to production, and weighed out according to the treatment. Brines were mixed in a stainless steel pail, and mixed using a Waring automatic mixer, immediately prior to addition to the meat block and tumbling. The order of ingredient addition to the brine was: water, phosphate alternative, sugar for non-control treatments. When mixing the control brine, 0.35% phosphate was added to the water first followed by salt and sugar. Brines targeting 25% addition were mixed to include 1.0% sugar and the remainder being water. Brines were added to the meat block when all the ingredients were completely dissolved.

Production

The meat block was composed of both preblended turkey breast and regular turkey breast. The amounts of preblend added was calculated to reach final salt concentrations of 1.0%, or 1.5%, the two control formulations contained no preblend. Treatments were placed in a vacuum tumbler (Daniels Food Equipment, Model DVTS R2-250), brine was added, a vacuum was pulled (20 mm/Hg), and treatments were tumbled for 3 hours. Treatments were then vacuum stuffed into 6M x 42" fibrous, pre-stuck, pre-clipped casings. Low salt treatments were stuffed first, followed by increased salt concentration treatments. Vacuum stuffer was disassembled and cleaned between

phosphate alternative treatments. Rolls were pulled and clipped using a Tipper Clipper (Model # PR465L, Tipper Tie, Inc., Apex, NC). Natural deli-style turkey rolls were weighed and loaded onto a smokehouse truck for thermal processing. Turkey rolls were thermally processed to an internal temperature of 71°C. After thermal processing, Natural deli-style turkey breasts were chilled according to Appendix B (USDA, 1999). Temperature data-loggers were used to verify both thermal processing and chilling temperatures.

Slicing and Packaging

Prior to slicing, Natural deli-style turkey breasts were weighed and cooking yields were calculated and recorded. Casings were peeled and discarded. Using a Bizerba slicer (Bizerba Model # SE12, Bizerba, Balingen, Germany) two slices, 13mm in thickness were sliced from each log for texture profile analysis (TPA). Furthermore, 25 slices 2 mm in thickness were obtained to determine sliceability or fold tests. Sliceability was defined as the percentage of intact slices from 4 sets of 25 slices, 2mm thick. Twenty slices, 10 from each roll were used to conduct a fold test, which is a measure of binding strength. An additional 10 slices, 2mm in thickness were used for a slice integrity evaluations. Slices were packaged in 15.3 cm x 25.4 cm cyrovac pouches. Pouches were vacuum sealed using a Multivac (Model #C500, Sepp Haggenmuller GmbH and Co. KG, Wolfertschwenden, Germany). The unsliced portions were vacuum packaged and stored under refrigeration conditions.

Processing and Quality Characteristics

Cook yield

Cook yield was calculated using the following equation:

$$\text{Cook Yield (\%)} = \left[1 - \frac{(\text{initial weight} - \text{cooked weight})}{\text{initial weight}} \right] \times 100$$

Sliceability

Sliceability was determined by cutting 25 consecutive 2 mm slices, and recording the number of total intact slices.

$$\text{Sliceability (\%)} = \left[1 - \frac{(\text{total slices} - \text{intact slices})}{\text{Total slices}} \right] \times 100$$

Fold Test

Fold tests were conducted with modifications from Suzuki (1981). Five intact slices were used to conduct a fold test, which is a measure of bind strength. A 2 mm slice was folded in half and the extent of cracking recorded. The scores were marked as A, B, C, or D; with slices scoring A, having no cracks. Slices receiving a B score displayed a small crack on the folded portion. C score slices reveal serious cracking along the folded surface. Slices receiving a D score crack completely, and typically break. In order to calculate a numerical average we assigned each letter score a number value as follows: A=4, B=3, C=2, D=1. A mean was calculated for each rep and treatment for statistical analysis.

Slice Integrity

Slice integrity was used to further detect quality differences between regular and reduced salt concentrations. Four set of 10 slices, 2mm in thickness were vacuum packaged as described above and tested the following day. Packages were opened, and slices were peeled from the stack beginning at the top. The number of intact slices was recorded for each stack of ten and a total was calculated.

$$\text{Slice integrity (\%)} = \frac{[1 - (\frac{\text{total slices} - \text{intact slices}}{\text{Total slices}})] \times 100}{\text{Total slices}}$$

Texture Profile Analysis

Six slices (13mm) per treatment were analyzed using 2,500-kg load cell on an Instron machine (Model number 1123, Instron Worldwide, Norwood, MA). Each slice was cut into a 4.0 cm x 4.0 cm square and double compressed to 75% of its original thickness. The following characteristics were calculated: hardness, springiness, chewiness, cohesiveness, and gumminess. Instron analysis was conducted following the slicing and packaging day. Hardness is defined as the peak force during the first compression cycle it is measured in kilograms of force. Cohesiveness is the ratio of the positive force area during the second compression to the positive force area of the first compression (compression 2/ compression 1). Springiness is defined as the distance the product recovers during the time between the first and second compressions, measured in millimeters. Gumminess is the product of Hardness x Cohesiveness. Finally, chewiness is the product of Hardness x Cohesiveness x Springiness.

Color Analysis

Objective color was determined using a handheld Minolta Chromameter CR-400 (Shanghai, China) using a D65 light source and 2° standard observer. L*, a*, b* values were recorded using 3 readings per 13mm slice; two slices were evaluated per treatment. Readings were taken approximately 21 days post production.

Salt concentration

Ten grams of Natural deli-style turkey breast was chopped using a Black and Decker Handy chopper. Ninety milliliters of double distilled deionized water was added and homogenized for 30 seconds with a Polytron homogenizer (POLYTRON Kinimatica

CH-6010, Luzern, Switzerland). A double folded filter paper was inserted into the solution and a Quantab was used to measure the chloride ions and final salt concentration.

pH Determination

The pH was taken ground samples after refrigerated storage. A 13mm slice was chopped using a Black and Decker Handy Chopper, 10 grams were weighed into a plastic beaker and 90mL of double distilled deionized water was added. The mixture was homogenized for 30 seconds using a Polytron homogenizer (POLYTRON Kinimatica CH-6010, Switzerland). The beaker was then placed on a Barnstead Thermolyne stir plate with a magnetic stir bar was used to keep the solution homogenized. The readings were taken with an Orion PerPHect Electrode with Ross pH Spear Tip (Thermo Electron Corporation, Beverly, WA) calibrated using a 7.0 and 4.0 buffer. The pH probe was rinsed with double distilled deionized water and wiped with a Kim wipe between each sample.

Water Activity

Water activity was determined using an Aqua Lab 4TE Dew Point and Water Activity meter. Samples were chopped, placed in a sampling cup, and placed in the measuring chamber and evaluated.

Sensory Analysis

Two consumer panels were conducted on three separate days in two different locations to allow for maximum participation. Samples were removed from refrigeration the morning of the panels and 75 slices; 2mm in thickness were sliced from each treatment. Full slices were placed on paper plates and presented in a random sequence.

Each treatment was assigned a random number on each repetition day. Panelists were served a cup of water and crackers for use at their discrepancy. A series of questions regarding texture and flavor were asked using a 15 cm line scale (Appendix H).

Statistical Analysis

Data were analyzed using the PROC GLIMMIX procedure of SAS (SAS Version 9.2, Cary, NC 2002). Treatment combinations of salt level and phosphate alternative were analyzed as a 3 x 2 factorial for main effects and interactions. The control treatment was included to test for treatment effects using analysis of variance (ANOVA).

Results and Discussion

Tables 3.1 and 3.2 show the least square (LS) means for phosphate alternative and salt concentration on TPA parameters, sliceability, slice integrity, foldability (F), and cookhouse yield (CY), Color values (L^* , a^* , b^*), pH, salt, and water activity (A_w). Data was analyzed as both factorial design to test for interactions of the main effects of phosphate alternatives and final salt concentration and using an Analysis of Variance (ANOVA) to compare all treatments to the phosphate control (Table 3.3). The initial analysis showed no interactions between final salt concentration and phosphate alternative, as a result the main effects were evaluated.

Effects of Phosphate Alternatives

A summary of the least square means can be found in Table 3.1. Phosphate alternative treatments significantly impacted ($P < 0.05$) the TPA parameters of hardness, springiness, gumminess, and chewiness. Cohesiveness was not significantly impacted ($P > 0.05$). Treatments formulated with no phosphate alternative displayed significantly

greater values than both alternatives for hardness, gumminess, and chewiness ($P < 0.05$). Likewise, the no phosphate alternative treatment was similar ($P > 0.05$) to the dehydrated turkey broth (DHTB) treatment in regards to springiness, and cohesiveness; while being significantly ($P < 0.05$) more springy and more cohesive than the sodium carbonate (SC) treatments. No significant differences were observed between DHTB and SC treatments ($P > 0.05$).

The processing characteristics of sliceability, foldability, and integrity were not significantly impacted ($P > 0.05$). The SC treatments had significantly higher cook yield than DHTB or no phosphate alternative treatments ($P < 0.05$).

Color values of L^* and b^* were not significantly altered for phosphate alternatives ($P > 0.05$). Color values for a^* were significant ($P < 0.05$) with SC treatment displaying lower a^* values than the no alternative treatment.

There were no differences in pH and salt concentration for phosphate alternative treatments ($P > 0.05$). Water activity was significantly greater for DHTB treatments than other treatments ($P < 0.05$).

The results of the factorial analysis for phosphate alternatives suggest that the inclusion of alternatives negatively impacted texture parameters. Additionally, the SC treatment improved cook yield compared to the treatments. Color values were altered only slightly with the SC treatment being darker when evaluated instrumentally. SC treatments also had a higher pH than the no alternative treatment.

Effect of Salt Level

Treatments formulated with 1.0% salt had greater hardness values than 1.5% salt treatments ($P<0.05$). However, other TPA parameters were not significantly impacted by salt level, except for hardness ($P>0.05$).

Table 3.2 illustrates the significant impact ($P<0.05$) of salt level on processing characteristics of reduced sodium natural deli-style turkey breasts. Treatments formulated with 1.5% salt displayed significantly greater LS means for sliceability, foldability, slice integrity, and cook yield. These processing characteristics can be attributed to protein extraction and subsequent binding. This may be the primary explanation for the improved processing attributes of a product formulated with higher salt concentration. There was no salt effect on any of the color values ($P>0.05$). Treatments with 1.5% salt had a greater pH than 1.0% salt treatments ($P<0.05$). There was no significant salt effect ($P>0.05$) on the water activity.

Phosphate Effects

The TPA parameters of hardness, gumminess, and chewiness were significantly affected by treatment (Table 3.3). However, compared to the phosphate control 1.5% SC treatment was lower ($P<0.05$) for hardness, gumminess, and chewiness. In addition, the 1.5% DHTB treatment had lower hardness values than did the control as well ($P<0.05$); while all other treatments were similar to the control ($P>0.05$). No significant treatment effects were observed for the TPA parameters of springiness and cohesiveness ($P>0.05$). Processing traits of reduced sodium natural deli-style turkey breast were significantly impacted by treatment ($P<0.05$). All 1.0% salt treatments, regardless of phosphate alternative, had lower ($P<0.05$) sliceability than the phosphate control. The 1.0% treatments were significantly less foldable than the control treatment ($P<0.05$) regardless

of phosphate alternative. Phosphate control was superior to all other treatments ($P<0.05$) in regards to cook yield. Smith and Young (2007) reported similar improvements in yields when studying turkey breasts marinated in a phosphate solution. The 1.5% salt/SC treatment displayed significantly greater cook yields than all other reduced sodium natural treatments ($P<0.05$).

There were significant treatments effect on slice integrity ($P<0.05$). The phosphate control treatment was significantly superior ($P<0.05$) to all natural treatments. Among the 1.5% salt level, the DHTB treatment was significantly greater than the others ($P<0.05$). The 1.0% salt treatment groups were significantly lower in regards to slice integrity ($P<0.05$), when compared to all other treatments.

The color values of L^* and b^* were significantly affected by treatment ($P<0.05$) reduced with the inclusion of a standard phosphate (Table 3.3). The phosphate control group scored significantly lower L^* values than all other treatments ($P<0.05$). Lower L^* values result in darker products and lower b^* values indicate less yellow color. Lowder *et al* (2011) observed similar color results when using dehydrated beef protein (DBP) in place of sodium phosphate in beef strip steak. In that study, DBP treatments resulted in significantly higher L^* and b^* values ($P<0.05$) when compared to traditional treatments. There was no treatment effect on a^* values across any treatment group ($P>0.05$). The significant change a^* values was not reported in other reported by Gorsuch and Alvarez (2010). Smith and Young (2007) reported a significant decrease in a^* values of phosphate marinade turkey breasts. Hurtado *et al* (2012) reported an increase in redness of frankfurters formulated with porcine plasma as an alternative for phosphate. The difference maybe the visual color difference in the ingredients used.

The phosphate control treatment significantly increased pH ($P<0.05$) when compared to all natural treatments. This observation is in agreement with Lowder *et al* (2011) who reported that dehydrated beef protein used in place of sodium phosphate significantly increased the pH of beef strip loin steaks. Knipe *et al* (1985) also reported an increase in pH values of frankfurter meat batters upon the inclusion of sodium hydroxide or sodium phosphate. There was a significant treatment effect on salt concentration ($P<0.05$). Phosphate control had the highest salt concentration ($P<0.05$) as it was formulated with 2.0% salt. Each salt level was significantly different in regards to final salt concentration ($P<0.05$). The phosphate control had a significantly lower water activity than the natural treatments ($P<0.05$), with the exception of the 1.5% salt/SC and the 1.0% salt treatments.

Sensory Analysis

Salt Effect

There was a significant salt effect ($P<0.05$) on the texture and flavor sensory attributes of reduced sodium natural turkey breast (Table 3.4). Treatments formulated with 1.5% salt were harder, more rubbery, more moist, and received significantly greater ($P<0.05$) overall acceptability for texture attributes. Ruusunen *et al* (2003) reported that salt increased firmness and juiciness of sausages of low-salt phosphate-free frankfurters. Aaslyng *et al* (2014) reported that large reductions in the salt content (1.23%) of hotdogs negatively affected sensory attributes. In regards to flavor attributes, 1.5% salt treatments scored significantly higher marks for turkey flavor, saltiness, and flavor acceptability ($P<0.05$), while there was no difference in off-flavor ($P<0.05$) among treatment. Most importantly, 1.5% salt treatments received significantly higher ($P<0.05$) overall

acceptability scores when compared to treatments formulated with 1.0% salt. Neer and Mandigo (1977) reported that all sensory traits improved until salt levels reached 1.5%.

Phosphate Alternative Effect

Table 3.5 shows the effects of phosphate alternatives on sensory attributes of reduced sodium natural deli-style turkey breast (NDSTB). Phosphate alternatives significantly impacted the texture acceptability, and the overall acceptability of reduced sodium NDSTB ($P<0.05$). In both cases, the treatments formulated with a phosphate alternative were significantly more acceptable ($P<0.05$) than products formulated with no phosphate alternative. Kim *et al* (2013) reported ham made with sodium hydrogen carbonate and high pressure received higher palatability scores than non-treated controls.

Phosphate Effects

There were significant treatment effects ($P<0.05$) for all texture and flavor attributes, with the exception of off –flavor (Table 3.6). The phosphate control significantly ($P<0.05$) improved product hardness, rubbery-ness, moistness, and improved acceptability. In regards to flavor attributes, turkey flavor, saltiness, and flavor acceptability were significantly improved with the inclusion of polyphosphate ($P<0.05$). Most importantly, the control treatment received the highest ($P<0.05$) overall acceptability scores. Table 3.6 shows there were significant ($P<0.05$) flavor differences between treatments formulated with different salt levels for all measured traits. Neer and Mandigo (1977) reported that an increase in juiciness until 0.5%, while general acceptability was maximized as 0.375%. Ockerman *et al* (1978) reported an increase in flavor, tenderness, protein extraction and water holding capacity with the inclusion of phosphate.

Conclusion

Reducing salt levels from 1.5% to 1.0% negatively impacted sliced quality traits of sliced reduced sodium natural deli-style turkey breast. Additionally, a reduction to 1.0% salt decreased pH. TPA parameters were significantly decreased with the inclusion of a phosphate alternative when compared to products formulated with no alternatives. Treatments formulated with 1.5% salt were similar to the control in regards to sliceability and foldability, but could not match slice integrity or cook yield. Control treatments yielded lighter products as well. This study also suggests that a reduction in salt from 1.5% to 1.0% salt negatively impacts sensory attributes. The inclusion of phosphate alternatives produced more acceptable products when compared to no phosphate alternatives. Nonetheless, the control treatment received significantly higher marks for all sensory traits measured.

Tables

Table 3.1- Treatment formulations for 1.0% and 1.5% salt with either DHTB or SC as phosphate alternative.

	1.0% Salt			1.5% Salt			2.0%
	No PP	DHTB	SC	No PP	DHTB	SC	Control
Meat Block							
Preblend	6.25	6.25	6.25	9.375	9.375	9.375	0
Turkey	18.75	18.75	18.75	15.625	15.625	15.625	25
Ingredients							
Water	5.75	5.625	5.625	5.625	5.5	5.5	5.4125
Salt	0.25	0.25	0.25	0.375	0.375	0.375	0.50
Sugar	0.25	0.25	0.25	0.25	0.25	0.25	0.25
DHTB ^a	-	0.125	-	-	0.125	-	-
SC ^b	-	-	0.125	-	-	0.125	-
STPP ^c	-	-	-	-	-	-	0.0875
Total	31.25	31.25	31.25	31.25	31.25	31.25	31.25

DHTB^a - Dehydrated Turkey Broth.

SC^b - Sodium carbonate.

STPP^c - Sodium tripolyphosphate blend.

Table 3.2- Least square means of TPA, processing characteristics and physical traits for phosphate alternatives

Texture Profile	Phosphate Alternative			P<value
	No PP	DHTB^t	SC^u	
Hardness	1413.95 ^a	1310.59 ^b	1330.59 ^b	0.0004
Springiness	0.4209 ^a	0.4158 ^{ab}	0.4037 ^b	0.0459
Gumminess	384.65 ^a	340.67 ^b	334.97 ^b	0.0051
Cohesiveness	0.2705	0.26	0.2526	0.0672
Chewiness	161.88 ^a	142.37 ^b	135.04 ^b	0.0063
Sliceability				
Sliceability ^v (%)	78.5	80.5	83.3	0.8143
Fold ^x	3.2	2.9	2.8	0.205
Integrity ^y (%)	30.8	43.8	34.2	0.0694
Yield ^z (%)	82.9 ^b	81.8 ^b	84.6 ^a	0.0017
Color				
L*	80.1	80.5	80.9	0.4632
a*	4.6 ^a	4.4 ^{ab}	4.2 ^b	0.0499
b*	12.5	12.5	12.4	0.4812
Physical Traits				
pH	5.9 ^b	5.9 ^{ab}	5.9 ^a	0.0945
Salt (%)	0.77	0.74	0.75	0.6168
Aw	0.992 ^b	0.996 ^a	0.992 ^b	0.0194

^{abc} Different superscripts within rows indicate significance (P< 0.05).

^tDHTB- Dehydrated Turkey Broth

^uSC- Sodium Carbonate

^x Sliceability- reported as a percent of slices intact.

^y Fold- A, B, C, and D scores were assigned values of 1, 2, 3, and 4. A mean was calculated and used in analysis.

^zYield- Cook Yield (%) = $\frac{[1-(\text{initial weight}-\text{cooked weight})] \times 100}{\text{initial weight}}$

Table 3.3- Least square means of TPA, processing characteristics and physical traits for salt concentrations.

Texture Profile	Salt Level		P<value
	1.00%	1.50%	
Hardness	1374.20 ^a	1329.22 ^b	0.018
Springiness	0.4143	0.4127	0.7751
Gumminess	362.93	343.93	0.1117
Cohesiveness	0.2632	0.2589	0.4615
Chewiness	150.66	142.2	0.1714
Sliceability			
Sliceability ^y (%)	71.4 ^b	90.1 ^a	0.0088
Fold ^x	2.5 ^b	3.5 ^a	0.0001
Integrity ^y (%)	13.9 ^b	58.6 ^a	<0.0001
Yield ^z (%)	82.6 ^b	84.6 ^a	<0.0001
Color			
L*	80.9	79.9	0.0606
a*	4.3	4.5	0.0691
b*	12.4	12.5	0.5206
Physical Traits			
pH	5.86 ^b	5.92 ^a	0.0105
Salt (%)	0.62 ^a	0.89 ^b	<0.0001
Aw	0.993	0.993	0.7032

^{abcd} Different superscripts within rows indicate significance (P< 0.05).

^x Sliceability- reported as a percent of slices intact.

^y Fold- A, B, C, and D scores were assigned values of 1, 2, 3, and 4. A mean was calculated and used in analysis.

^zYield- Cook Yield (%) = $\frac{[1-(\text{initial weight-cooked weight})] \times 100}{\text{initial weight}}$

Table 3.4- ANOVA table of least square means of TPA, processing characteristics and physical traits for phosphate alternative and salt concentration.

	1.0% Salt			1.5% Salt			2.0%	
Texture Profile	No PP	DHTB ^t	SC ^u	No PP	DHTB ^t	SC ^u	Control	<i>P</i> <value
Hardness	1430.71 ^a	1328.00 ^{bc}	1293.17 ^{abc}	1397.19 ^{ab}	1363.89 ^c	1297.30 ^c	1375.19 ^{ab}	0.0071
Springiness	0.4195 ^{ab}	0.4183 ^{ab}	0.4049 ^{ab}	0.4224 ^{ab}	0.4133 ^{ab}	0.4025 ^b	0.4248 ^a	0.2138
Gumminess	395.05 ^a	348.87 ^{bc}	344.87 ^{bc}	374.25 ^{ab}	332.48 ^{bc}	325.07 ^c	373.43 ^{ab}	0.0359
Cohesiveness	0.2745 ^a	0.2627 ^{ab}	0.2524 ^b	0.2666 ^{ab}	0.2573 ^{ab}	0.2527 ^b	0.2699 ^{ab}	0.2717
Chewiness	165.92 ^a	146.86 ^{abc}	139.20 ^{abc}	157.83 ^{ab}	137.89 ^{bc}	130.87 ^c	158.68 ^{ab}	0.0415
Sliceability								
Sliceability ^v (%)	74.7 ^{bcd}	65.7 ^d	74.0 ^{cd}	82.3 ^{abcd}	95.3 ^{ab}	92.7 ^{abc}	100 ^a	0.0271
Fold ^x	2.8 ^{bc}	2.5 ^c	2.2 ^c	3.6 ^a	3.4 ^{ab}	3.8 ^{ab}	4.0 ^a	0.0003
Integrity ^y (%)	13.3 ^d	15.8 ^d	12.5 ^d	48.3 ^c	71.7 ^b	55.8 ^c	100 ^a	<0.0001
Yield ^z (%)	81.7 ^{de}	80.1 ^e	82.9 ^{cd}	84.0 ^c	83.6 ^c	86.3 ^b	91.2 ^a	<0.0001
Color								
L*	81.1 ^a	80.4 ^{ab}	81.4 ^a	79.0 ^b	80.6 ^{ab}	80.3 ^{ab}	77.1 ^c	0.0011
a*	4.49 ^a	4.34 ^{ab}	3.96 ^b	4.75 ^a	4.42 ^{ab}	4.39 ^{ab}	4.39 ^{ab}	0.1045
b*	12.45 ^{ab}	12.36 ^{ab}	12.48 ^{ab}	12.52 ^{ab}	12.69 ^a	12.27 ^b	11.71 ^c	0.0012
Physical Traits								
pH	5.8 ^c	5.9 ^c	5.9 ^{bc}	5.9 ^{bc}	5.9 ^b	5.9 ^b	6.1 ^a	0.0004
Salt (%)	0.60 ^d	0.64 ^d	0.61 ^d	0.94 ^b	0.85 ^c	0.89 ^{bc}	1.19 ^a	<0.0001
Aw	0.990 ^{bc}	0.993 ^a	0.993 ^{ab}	0.993 ^{ab}	0.996 ^a	0.990 ^{bc}	0.988 ^c	0.0126

^{abcd} Different superscripts within rows indicate significance (*P* < 0.05).

^tDHTB- Dehydrated Turkey Broth

^uSC- Sodium Carbonate

^v Sliceability- reported as a percent of slices intact.

^x Fold- A, B, C, and D scores were assigned values of 1, 2, 3, and 4. A mean was calculated and used in analysis.

^y Integrity- A percentage of intact slices removed from stack of ten slices.

^z Yield- Cook Yield (%) = [1-(initial weight-cooked weight)/initial weight] x 100

Table 3.5- Least square means of salt effect on sensory attributes of reduced sodium turkey breast.

	Salt Concentration		
	1.00%	1.50%	<i>P>value</i>
Texture			
Soft/Hard	4.86 ^b	5.27 ^a	0.0245
Mushy/ Rubbery	4.89 ^b	5.78 ^a	<0.0001
Dry/ Moist	5.01 ^b	6.21 ^a	<0.0001
Unacceptable/ Acceptable	5.28 ^b	6.93 ^a	<0.0001
Flavor			
Lacking/ Intense(Turkey Flavor)	6.21 ^b	7.19 ^a	<0.0001
Lacking/ Intense (Saltiness)	4.63 ^b	5.68 ^a	<0.0001
Lacking/ Intense (Off-Flavor)	5.49	5.31	0.4486
Unacceptable/ Acceptable	5.79 ^b	7.21 ^a	<0.0001
Overall Acceptability	5.54 ^b	7.05 ^a	<0.0001

^{abcd} Different superscripts within rows indicate significance ($P < 0.05$).

Sensory triats were measured using on a 15 cm line and measured to calculate means for each trait.

Table 3.6- Least square means of phosphate alternative effect on sensory attributes of reduced sodium natural deli-style turkey breast.

	No Phosphate	DHTB ^x	SC ^y	<i>P</i> <value
Texture				
Soft/Hard	4.86	5.3	5.05	0.1479
Mushy/ Rubbery	5.14	5.44	5.43	0.3484
Dry/ Moist	5.33	5.69	5.81	0.1901
Unacceptable/ Acceptable	5.72 ^b	6.23 ^a	6.37 ^a	0.0197
Flavor				
Lacking/ Intense(Turkey Flavor)	6.56	6.71	6.84	0.4201
Lacking/ Intense (Saltiness)	4.91	5.17	5.39	0.0679
Lacking/ Intense (Off-Flavor)	5.44	5.42	5.34	0.9409
Unacceptable/ Acceptable	6.33	6.49	6.68	0.3504
Overall Acceptability	5.92 ^b	6.43 ^a	6.53 ^a	0.025

^{abcd} Different superscripts within rows indicate significance ($P < 0.05$).

^xDHTB- Dehydrated Turkey Broth

^ySC- Sodium Carbonate

Sensory traits were measured using on a 15 cm line and measured to calculate means for each trait.

Table 3.7- Least square means of treatment effects on sensory attributes of reduced sodium natural deli-style turkey breast.

	1.0% Salt			1.5% Salt			2.00%	
Texture	No Phosphate	DHTB ^x	SC ^y	No Phosphate	DHTB ^x	SC ^y	Control	<i>P<value</i>
Soft/Hard	4.60 ^d	5.26 ^{bc}	4.73 ^{cd}	5.12 ^{bc}	5.33 ^b	5.36 ^b	7.71 ^a	<0.0001
Mushy/ Rubbery	4.73 ^d	5.03 ^{cd}	4.91 ^d	5.55 ^{bc}	5.85 ^b	5.95 ^b	8.66 ^a	<0.0001
Dry/ Moist	4.93 ^d	5.10 ^d	5.04 ^d	5.74 ^c	6.32 ^{bc}	6.58 ^b	7.41 ^a	<0.0001
Unacceptable/ Acceptable	4.92 ^d	5.52 ^d	5.41 ^d	6.52 ^c	6.95 ^{bc}	7.32 ^b	8.96 ^a	<0.0001
Flavor								
Lacking/ Intense(Turkey Flavor)	5.98 ^c	6.24 ^c	6.41 ^c	7.14 ^b	7.17 ^b	7.27 ^b	8.20 ^a	<0.0001
Lacking/ Intense (Saltiness)	4.34 ^c	4.77 ^c	4.78 ^c	5.48 ^b	5.57 ^b	6.01 ^b	7.18 ^a	<0.0001
Lacking/ Intense (Off-Flavor)	5.5	5.46	5.51	5.37	5.38	5.16	4.77	0.5587
Unacceptable/ Acceptable	5.58 ^c	5.90 ^c	5.89 ^c	7.08 ^b	7.08 ^b	7.48 ^b	8.90 ^a	<0.0001
Overall Acceptability	5.04 ^d	5.84 ^c	5.74 ^c	6.81 ^b	7.02 ^b	7.31 ^b	9.19 ^a	<0.0001

^{abcd} Different superscripts within rows indicate significance ($P < 0.05$).

^xDHTB- Dehydrated Turkey Broth

^ySC- Sodium Carbonate

Sensory traits were measured using on a 15 cm line and measured to calculate means for each trait.

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Recommendations for future research

The results of these studies have shown that the production of a 1.0% salt natural deli-style turkey breast still presents formidable challenges. Extending tumbling time was ineffective at improving processing and TPA attributes. Phosphate alternatives slightly improved some TPA, processing traits, and sensory traits. Future research should continue to focus on the reduction of sodium to 1.25%-1.75% levels while maintaining protein functionality similar to that of the polyphosphate control.

A reduction in tumbling time should be explored. Turkey is a delicate protein and the 3 hour to 6 hour tumbling time more than likely disrupted the proteins beyond functionality. Reduce the length of tumbling after the inclusion of the preblended turkey breast. These procedures use preblended turkey that has been subjected to 3 hours of tumbling to achieve maximum extraction. After formulation with coarse ground turkey, a shorter tumbling time could be used to allow mixing and reduce the risk of over working the proteins.

I feel that recording and targeting raw batter pH should be done when producing these types of products. The literature reports that increased pH and ionic strength improve bind and WHC. The work with phosphate alternatives needs to have this information recorded. See Table 3.1, which reports that SC treatments increased pH, and saw a significantly higher cook yield. Future work with phosphate alternatives could focus on varying the levels used in the formulations. In the current work, 1.0% PA was used. Perhaps a higher level would be beneficial.

Other processing techniques could be investigated as well. Perhaps the inclusion level of fine ground turkey breast could be reduced. A procedure could be explored where whole boneless turkey breast are injected with the brine, tumbled, and coarse ground and stuff. The possibility of including a phosphate alternative in the preblend could be explored.

Perhaps using these procedures and products on a more durable protein source would yield different results.

Appendix A: Phase 1 Production Protocol

The first trial run will test the effects of three vacuum tumbling times (1, 2, 3 hours) on three salt levels (1.0%, 1.5, and 2.0%). Targeting a 25% brine pick up in the final product. A standard control was formulated using 2.0% salt, 1.0% sugar, and 0.35% STPP.

Procedure

1. Grind the turkey breasts through the kidney plate.
2. Fine grind 15% of the batch weight through a 1/8 inch plate.
3. Divide the kidney plated product into 3 batches of 9.61 kg; add 1.67 kg (15%) of fine ground product to separate vacuum tumblers. This will make a total of 11.3 kg of turkey.
4. Dissolve the pre-weighed salt and sugar in cold water (STPP in control formulation).
5. Add the brine directly to the vacuum tumbler with the ground product.
6. Pull a vacuum to 21 mm/Hg
7. Tumble the product for the assigned length of time. (1, 2, or 3 hours)
8. Stuff product into a 6M x 42' fibrous casing.
9. Weigh each treatment prior to thermal processing to calculate cook yields.
10. Cook to an internal temperature of 71°C.
11. Chill cooked product according to Appendix B.
12. Slice product using the Bizerba into 13mm slices for TPA, or 2mm slices for slice integrity sliceability, and foldability

Appendix B: Phase 2 Production Protocol

Phase 2 of this study investigated the effects of different salt levels (1.0%, 1.5%, 2.0%) formulated with 3.0% salt or 4.0% salt preblend. Targeting a 25% brine pick up in the final product. A standard control was formulated using 2.0% salt, 1.0% sugar, and 0.35% STPP.

Procedure

1. Formulate treatments to desired salt level based on preblend salt concentration.
2. Add the sugar and water directly to the vacuum tumbler with the ground product and preblend.
3. Pull a vacuum to 21 mm/Hg
4. Tumble the product for 3 additional hours.
5. Stuff product into a 6Mx42' inch fibrous casing.
6. Weigh each treatment prior to thermal processing to calculate cook yields.
7. Cook to an internal temperature of 71°C.
8. Chill cooked product according to Appendix B.
9. Slice product using the Bizerba into 13mm slices for TPA, or 2mm slices for slice integrity sliceability, and foldability.

Appendix C: Phase 3 Production Protocol

This phase investigate the effectiveness of two phosphate alternatives (DTB and SC) at two salt levels (1.0% and 1.5%) and their impacts on TPA, slice quality characteristics, and sensory attributes. Targeting a 25% brine pick up in the final product. A standard control was formulated using 2.0% salt, 1.0% sugar, and 0.35% STPP.

Procedure

10. Formulate treatments to desired salt level based on preblend salt concentration.
11. Add the sugar and water directly to the vacuum tumbler with the ground product and preblend.
12. Pull a vacuum to 21 mm/Hg
13. Tumble the product for 3 additional hours.
14. Stuff product into a 6Mx42' inch fibrous casing.
15. Weigh each treatment prior to thermal processing to calculate cook yields.
16. Cook to an internal temperature of 71°C.
17. Chill cooked product according to Appendix B.
18. Slice product using the Bizerba into 13mm slices for TPA, or 2mm slices for slice integrity sliceability, and foldability.
19. Store remaining sections at refrigeration temperatures for sensory analysis.

Appendix D: Preblend Production

Preblending is a technique used to control fat and salt content of meat products.

In the current research we used preblending to maximize protein extraction by adding 3.0% or 4.0% salt to a coarse ground turkey. Coarse ground turkey was vacuum tumbled with the calculated salt percent for 3 hours at 35°F.

Table 2.5- Preblend
Formulation for phase 2

	3.00%	4.00%
Meat Block		
Preblend	-	-
Turkey	37.5	28.13
Ingredients		
Water	-	-
Salt	1.125	1.1252
Sugar	-	-
DTB ^a	-	-
SC ^b	-	-
STPP	-	-
Total	38.625	29.2552

Table 3.8- Preblend
Formulation for phase 3

	3.00%	4.00%
Meat Block		
Preblend	-	-
Turkey	-	46.875
Ingredients		
Water	-	-
Salt	-	1.875
Sugar	-	-
DTB ^a	-	-
SC ^b	-	-
STPP	-	-
Total	-	48.75

Appendix E: Fold Test

The test was conducted to evaluate the strength of protein binding. Procedures were based on the protocol describe by Suzuki (1981), with minor modifications. In the current research 2mm slices were used instead of 5mm slices used by Suzuki (1981). Different protein sources were used as well. The scores were marked as A, B, C, or D; with slices scoring A, having no cracks. Slices receiving a B score displayed a small crack on the folded portion. C score slices reveal serious cracking along the folded surface. Slices receiving a D score crack completely, and typically break. In order to calculate a numerical average we assigned each letter score a number value as follows: A=4, B=3, C=2, D=1. A mean was calculated for each rep and treatment for statistical analysis.

Appendix E: Foldability Reference

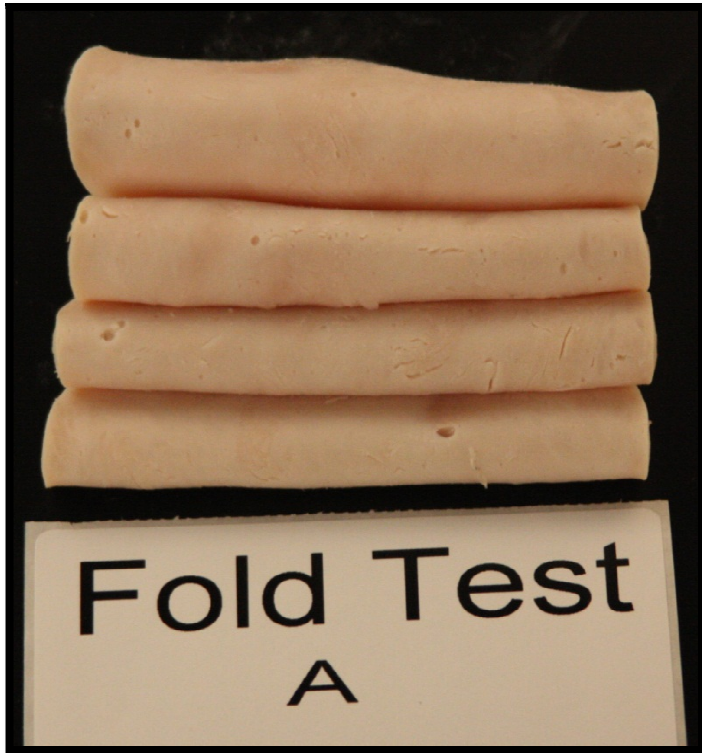


Figure A- Represents an A grade/score for a fold test. Notice no major cracks along the folded edge of the 2mm slice.

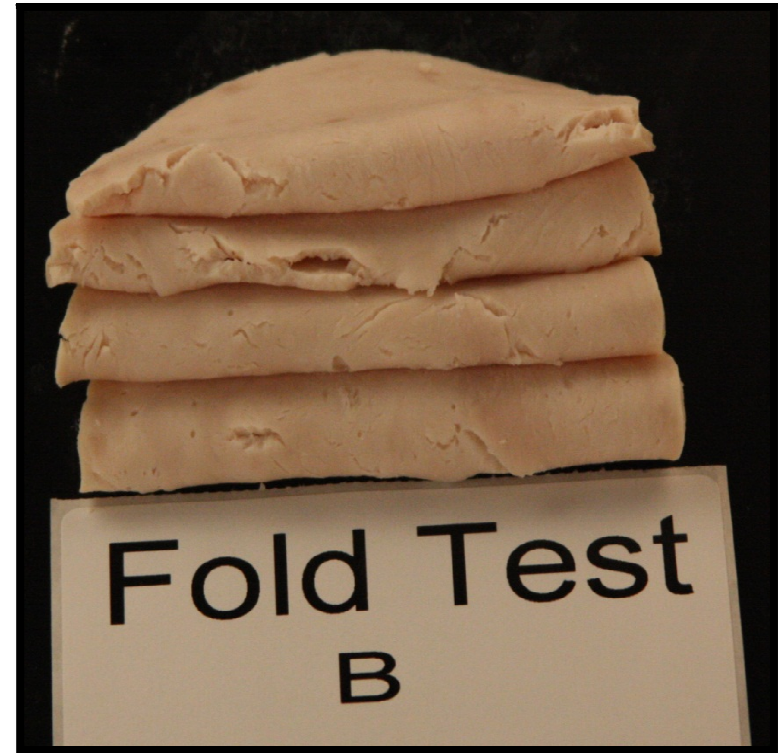


Figure B-- This picture shows a B grade/score for a fold test. Note the development of minor cracks along a portion of the folded edge.

Appendix E: Foldability Reference

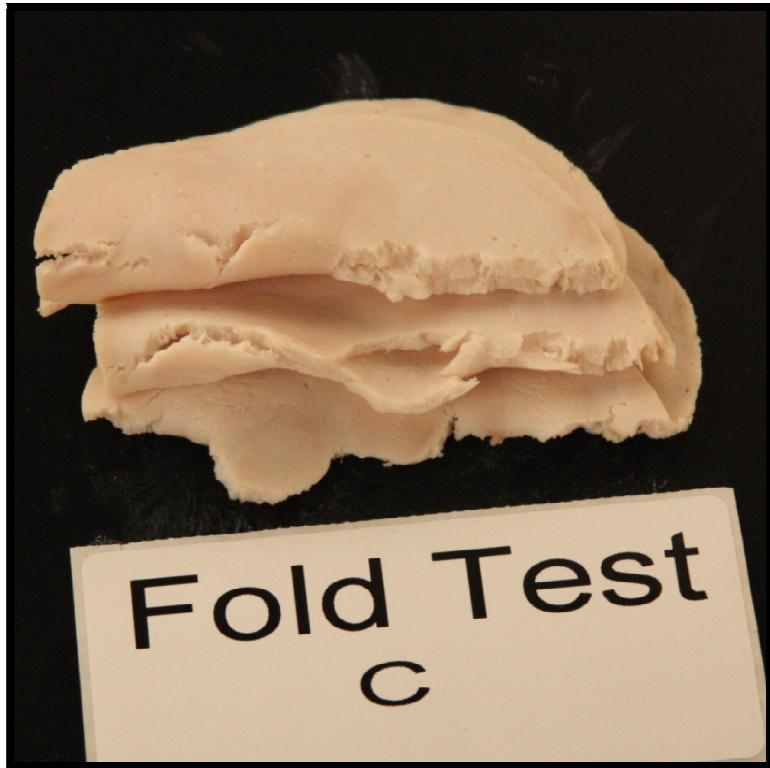


Figure C- This picture represents a C grade/score for a fold test. Note the cracks extending nearly the entire length of the folded edge.

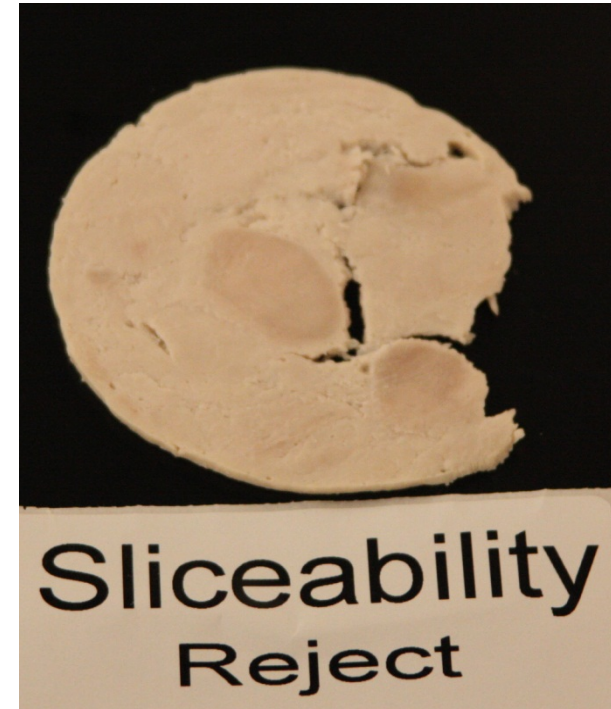
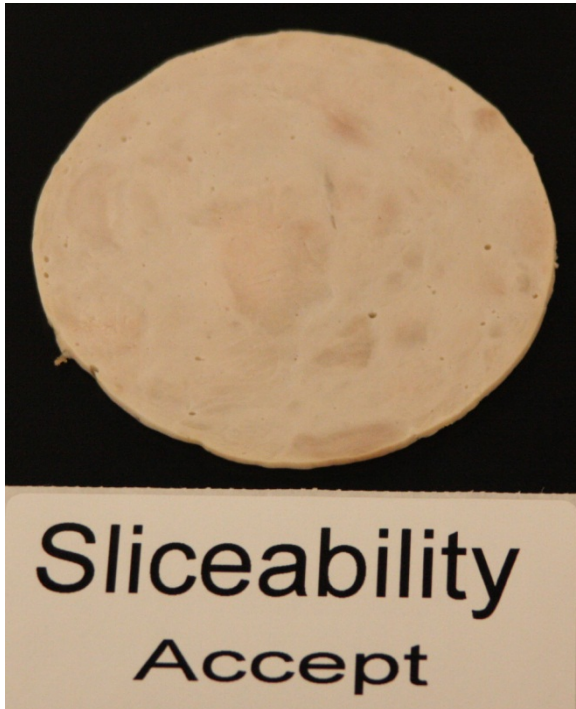


Figure D- This picture represents a D grade/score for a fold test. Notice the complete break along the folded edge.

Appendix G: Sliceability Procedure

Sliceability is measure of protein binding. When determining sliceability of reduced sodium natural deli-style turkey breast, four sets of 25 slices 2 mm thick were slices from each treatment. The total number of intact slice was divided by the total number of slices used for the test. Krause *et al* (1978) study ham quality and yield, defined sliceability as the ability of a ham slice to hold together.

Appendix G: Sliceability Reference



Appendix H: Slice Integrity Procedure

The slice integrity procedure was developed to imitate the conditions sliced products are subjected to during slicing and packaging and later opening the package. Ten slices 2 mm in thickness were placed in vacuum bag and sealed, and stored for a period of time. Bags were opened and slices were removed individually. Slices that could be removed intact were recorded and the number of intact slices was divided by the total number of slices and a percentage was reported. Four packages of 10 slices each were used per treatment.

Appendix I: Sensory Analysis form

Sample Code: _____

You will be given 7 samples to evaluate. Make a vertical line on the provided horizontal line at the point that best describes your perception of the attribute. You may take a bite of cracker and drink of water to cleanse your palate between samples. Please use a new sheet for each sample evaluated.

Texture

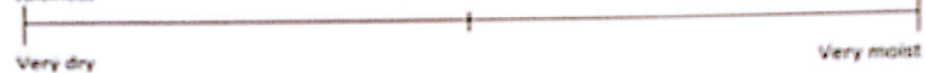
Chewing Texture



Chewing Texture



Juiciness

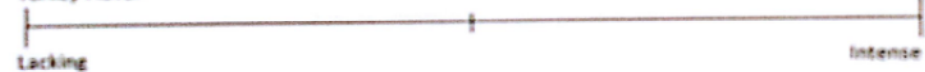


Acceptability of texture

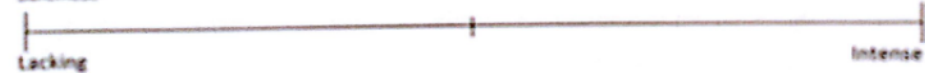


Flavor

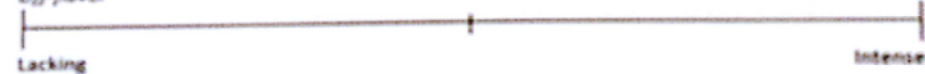
Turkey flavor



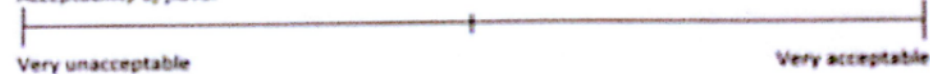
Saltiness



Off-flavor



Acceptability of flavor



Overall acceptability

