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Utilization of Deionized Water and Non-Meat Adjuncts to Combat Quality Issues in Boneless Cured Ham Associated with using Pale Raw Material

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UTILIZATION OF DEIONIZED WATER AND NON-MEAT ADJUNCTS TO COMBAT QUALITY ISSUES IN BONELESS CURED HAM ASSOCIATED WITH USING PALE RAW MATERIAL

By

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UTILIZATION OF DEIONIZED WATER AND NON-MEAT ADJUNCTS

TO COMBAT QUALITY ISSUES IN BONELESS CURED HAM

ASSOCIATED WITH USING PALE RAW MATERIAL

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The effects of deionized water and PSE pork percentage on the quality of smoked deli ham and retorted ham with and without adjuncts were evaluated. Quality was determined through evaluation of water holding capacity, color, protein bind, and sensory quality. A randomized complete block design with replications was utilized to test treatment effects in three separate experiments. The retorting process showed the potential to reduce the effect of PSE meat on color that is present in raw meat material. In retorted ham, modified food starch and soy protein concentrate reduced ($p<0.05$) cook loss and starch improved color. Deionized water can be utilized to improve yields (1 %) in smoked deli hams, and 25 % pale pork can be used without negatively affecting ($p>0.05$) quality in a retorted ham product. Modified food starch can also be utilized to increase yields in a retortable-pouched ham without significantly affecting sensory quality.

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CHAPTER I

INTRODUCTION

Since the 1950's, the focus of the pork industry has been lean meat production (McLaren and Schultz, 1992). This demand for lean pork has caused pork producers to genetically select for lean, fast growing swine. By genetically selecting for these characteristics, other traits were inadvertently amplified such as an increased proportion of white muscle fibers, insufficient structural integrity of connective tissue, and inability of muscles to regulate sequestering of calcium (Solomon et al. 1998). These traits tend to make swine more susceptible to stress, which can cause rapid postmortem biochemical reactions and elevated protein denaturation (Briskey and Wismer-Pedersen, 1961). The concomitant protein denaturation results in the production of pale, soft and exudative (PSE) pork meat. PSE pork meat has an undesirable pale color, low water holding capacity, and soft texture. Kauffman et al. (1992) defined PSE pork as pH < 5.6, CIE L* > 50, and drip loss % > 5.0.

Pale, soft and exudative (PSE) pork meat is a problem for the pork industry since pork meat with a greyish-pale appearance is undesirable to consumers (Young, 1996), and processed products formulated with PSE raw meat material exhibit poor texture, water holding capacity, color, and protein-protein binding (Solomon et al., 1998; Schilling et al, 2004a, 2003). With the occurrence of PSE as high as 30 percent (Kauffman et al., 1992), it has been estimated that this condition may cost the U.S. pork industry as much as $32 million annually (Li & Wick, 2001).

Due to the decreased functional properties of PSE raw meat material, pork classified as PSE is often utilized in sausage production, which is a lower value product when compared to some other means of pork utilization. Scientists have studied the possibility of using PSE meat in higher valued products. Motzer et al. (1998) and Schilling et al. (2003, 2004a) reported the utilization of 25 to 50 % PSE raw meat material could be included in the formulation of higher value deli hams without negatively affecting texture.

Industrial tests have revealed that utilizing deionized water in the place of municipal water increased yields and improved texture in deli meats, especially when water hardness is a problem in meat plants. The use of deionized water instead of municipal water is theorized to improve yields since it does not have calcium or magnesium cations that may be found in traditional water sources that are unfiltered. These cations are naturally found in raw meat materials but are controlled by the addition of phosphate to the brine solution. By controlling the outside source of these cations, the phosphate can be fully utilized by the natural cations found within the raw meat materials and maximize its effect on protein unfolding and water holding capacity. In restructured products, modified food starch and soy protein serves both functional and economic purposes. The addition of these non-meat adjuncts increases water binding and protein-protein binding (Pearson and Gillett, 1996).

This multi faceted research project was designed to determine the effect of utilizing deionized water in chunked and formed ham products. The first objective was to determine the effect of deionized water usage on the quality of smoked deli hams and to determine if the use of deionized water would allow higher levels of PSE meat to be utilized in deli smoked ham without negatively effecting ham quality. The second objective of the research was to examine the effect of PSE meat and deionized water on product quality and to produce a retortable-pouched product with a potential market opportunity. The third objective was to determine the effect of non-meat adjuncts, and deionized water on the quality of retortable-pouched ham formulated with 25 % PSE pork.

CHAPTER II

LITERATURE REVIEW

History

The demand for pork composition has shifted over time from carcasses with large deposits of fat to demand for lean pork meat. Prior to 1950, pork production was focused on the production of lard for use in cooking and secondly as a source of meat (McLaren and Schultz, 1992). Even though pale, soft and exudative (PSE) pork was documented as early as 1914 (Herter and Wilsdorf, 1914), the high incidence of PSE meat associated with post WWII swine was not present. After the 1950's, the development of alternative cooking oils and soaps as well as consumer demand for healthier foods caused lean meat to be the primary focus of pork production (McLaren and Schultz, 1992). Pork producers selected for the production of lean, fast growing swine to meet consumer demand for lean pork, but this selection seemed to lead an increased occurrence of PSE in swine. When pork producers genetically selected the characteristics for lean muscle and rapid growth, other traits were also altered that made these animals more prone to stress trauma that can cause quality defects in the meat. The quality condition, in which pork meat has undesirable color, low water holding capacity, and soft texture, is known as pale, soft and exudative (PSE).

The chemical characteristics of PSE pork are pH < 5.6, CIE L* > 50, and drip loss % > 5.0 Kauffman et al. 1992). PSE pork is a major concern for the pork industry (Bendell and Swatland, 1989) due to decreased consumer appeal and reduced functionality in processed products (Young, 1996; Soloman et al., 1998).

Antemortem Causes

Both Topel et al. (1975) and Chea et al. (1984) indicated that the quality of pork can be attributed to both antemortem and postmortem factors. Antemortem factors include swine genetics, nutrition, and environmental factors. Solomon et al. (1998) reported that genetic selection for the trait of rapid muscle production increased the occurrence of PSE pork by causing the animal to become easily stressed. O'Brien (1986) indicated that a homozygous recessive halothane gene in swine causes a single frame genetic mutation leading to a greater risk of PSE pork production through increased stress susceptibly. This condition is described by Briskey (1964) and is referred to as Porcine Stress Syndrome (PSS).

When the halothane gene is homozygous recessive, there is a mutation at the sarcoplasmic reticulum and T tubules interface in the ryanodine receptor. This mutation prevents the muscle from regulating the influx of calcium in and out of the sarcoplasmic reticulum. This mutation causes calcium to be released without the protein receiving a contraction signal. The uncontrollable contraction of the muscles leads to stress in the living animal (Briskey, 1964). The high stress level in halothane positive animals prevents many of these animals from ever reaching harvesting age, but the halothane gene positive animals that do live to harvesting age have an increased incidence of PSE meat when compared to animals that do not have the halothane gene (Christian, 1995; Velarde et al., 2001). Though this condition has all but been eliminated form porcine genetics, there is still a high incidence of PSE meat in the pork industry.

Solomon et al. (1988) stated that purging the halothane gene from swine reduces the occurrence of PSE but does not eliminate the condition. Additional genetic causes can contribute to the occurrence of PSE pork. The selection for rapid growth produced physiological structural irregularities that may elevate the potential for stress (Solomon et al, 1998, Swatland, 1989; Swatland, 1990). Swatland (1990) indicated that muscle connective tissue cannot grow as rapidly as the muscle fibers, which can cause increased stress levels. Another such irregularity is an elevated white muscle fiber concentration (Bandman, 1985; Maruyama and Kanemaki, 1991). White muscle fibers contain less myoglobin than red muscle. The low myoglobin level reduces the occurrence of aerobic metabolism and increases the occurrence of glycolysis (Peter et al., 1972), thus contributing to a reduced rate of lactic acid removal (Cassens et al., 1969; Cooper et al., 1969). These conditions all contribute to elevated stress levels in swine and an increased incidence of PSE meat.

Many nutritional and environmental factors affect the stress level in swine. The addition of supplements into the diet of swine has been shown to reduce the occurrence of PSE pork. Creatine phosphate reduces the build up of lactic acid (Berg et al., 2000), and the addition of Vitamin E has been utilized to increase membrane strength and decrease the occurrence of PSE incidence in pork (Cheah et al., 1995;

Kerth et al., 2001). Henry et al. (1992) demonstrated that a deficiency in the amino acid tryptophan increased the potential for elevated stress levels in swine. Fasting with access to water 24 hours prior to harvesting reduced the occurrence of PSE meat by improving color and decreasing drip loss (Eikelenboom et al., 1991).

Environmental temperatures also affect PSE incidence. Forrest et al., (1963), Dalrymple and Kelly (1969), Nishio (1976), and Park et al. (1985) reported that the highest incidence of PSE occurs in the summer months when the ambient temperature is the hottest. The authors also report that incidences of PSE meat are lower in the winter months when ambient temperature is the coldest. On the other hand, O'Neill et al. (2003b) reported a high occurrence of PSE in the winter months, but attributed the elevated rate of PSE to an increased demand for pork meat. Harvesting swine influences the stress levels and indirectly the incidence of PSE pork meat. CO^2 stunning produces the least amount of stress of the three procedures because the method does not cause excessive muscle contraction that occurs due to electrical stunning (Velarde et al., 2001).

Postmortem Causes

Ultimately, PSE results from an increase in the rate of postmortem biochemical reactions that deplete the remaining energy found in muscles of the carcass. Harvesting the animal removes the inflow of oxygen to the muscles that allows aerobic metabolism and increases the rate of glycolysis, which induces lactic acid formation. Stress can lead to rapid build up of lactic acid which lowers the pH below 6.0 prior to 45 min postmortem, thus causing protein denaturation and an increased potential for PSE formation (Bendell et al., 1966). Denaturation of the myofibrillar proteins, specifically myosin and actin, decreases the ability of the proteins to bind water and leads to a decrease in the functionality of the meat (Joo et al., 1999). In animals that possess the halothane gene, the rate of postmortem biochemical reactions are increased due to the mutation of the ryanodine receptor, causing an increased flow of calcium. The increase in calcium levels accelerates the rate of glycolysis through activation of ATPase (Young and Gregory, 2001). Due to the activation of the ATPase from the leaking calcium, conformational changes in the myosin head causes it to slide along actin (Nelson, 2005). With the onset of rigor mortis, the actin and myosin filaments are drawn closer together in comparison to non- PSE meat (Young and Gregory et al., 2001). This increase in contraction causes increased expressible moisture from within the proteins and increases purge loss. Improper cooling also increases the rate of glycolysis and elevates the potential for PSE occurrence. The rate of glycolysis can be decreased by rapid chilling of the carcass, thus decreasing the occurrence of PSE (Borchert and Briskey, 1964; Woltersdorf and Troeger, 1988; Kerth et al., 2001). Rapid chilling of the carcass can also lead to cold shortening, which causes decreased sarcomere length and the production of non-tender meat. This problem has been addressed in the industry through the addition of water, salt, and phosphate.

Studies have been conducted in order to discover methods to prevent the rapid drop in pH that causes protein denaturation. Wynveen et al. (2001) investigated the use of phosphate and bicarbonate injections to counteract the development of PSE meat. These researchers reported that the injection of phosphate and bicarbonate slowed the pH decline, leading to color, water-holding capacity, and shear value improvements.

Utilization of PSE

Traditionally, consumer acceptance of PSE pork is low due to a greyish-pale appearance (Young, 1996). Solomon et al. (1998) reported that PSE pork possesses poor water holding capacity and cohesiveness when utilized in deli hams. This author reported undesirable results such as increased purge loss, cook loss, and textural cracking. PSE meat is often utilized in sausage production but Townsend et al. (1980) reported that the use of 100 % PSE raw material in fermented dry sausage caused grainy texture, poor sliceability and decreased shear values. These researchers also found that the addition of PSE raw material to the formulation of fermented dry sausage can reduce the drying time of the product by 50-60 % in comparison to products utilizing 100 % normal pork. Scientists have studied the possibility of using PSE meat in higher valued products. Studies revealed that 25 % PSE and possibly 50 % raw meat material could be added to deli hams with out negatively affecting texture (Motzer et al., 1998, Schilling et al., 2003, 2004a). Schilling (2004a) reported that chunked and formed deli hams formulated with 75 and 100 % PSE raw meat material suffered cracking and were found unacceptable.

Economic Problems

PSE has been a problem in the pork industry since the 1950's. This condition has been reported to occur in 10.2 % of swine carcasses (Cannon et al., 1996). In a 1992 audit of U.S. pork plants, Kauffman reported of the pork surveyed, only 16 % were ideal quality and 10 to 30 % were PSE. Yearly, this condition costs the pork industry an estimated $0.35 per head of swine produced in the US with an estimated loss to the pork industry of approximately $32,000,000 (Li & Wick, 2001). Cooked hams produced with a percentage of PSE meat have a greater cook loss than cooked hams produced with out PSE meat. O'Neill et al. (2003a) reported as high as a 12.6% increase in cook loss between PSE and normal ham. This researcher (2003a) also reported greater cooking loss (approximately 4%) than other researchers for PSE ham when compared to ham produced from normal raw material (Wirth, 1972; Van der Wal, 1997). O'Neill's (2003a) research also indicated that the use of PSE ham had a negative effect on sliceability, water-holding capacity, color, and lipid oxidation.

Protein Properties

Proteins are made up of amino acids that are covalently linked to one another. The functionality or properties of proteins are controlled by the structural arrangement of the amino acids and the structure of the protein chain. Proteins are generally straight, coiled, or folded (Potter and Hotchkiss, 1998), and the functionality of muscle foods is attributed to its proteins (Fukawaza et al., 1961a). Protein binds both fat and water to form a meat matrix. This matrix is especially important in processed meat products. The ability of protein to bind fat and water contributes to cooking yield, structural stability, and ultimately consumer acceptability (Xiong and Kenney, 1999). In processed meat products, the most important attributes associated with functionality are protein binding and water-holding capacity (Samejima et al., 1985).

Proteins are classified by composition, structure, biological function, or solubility (Nielsen, 2003). Acton et al. (1983) stated that meat proteins are either myofibrillar, sarcoplamic, or stromal. In meat products, myofibrillar proteins are the most prevalent and are the most important to restructured meat products (Acton et al., 1983). Myofibrillar proteins, specifically myosin and actin are responsible for water binding, fat stabilization, and protein gelation (Rust, 1987). The strength of protein binding is predominantly attributed to the myofibrillar protein myosin (Fukawaza et al., 1961a, 1961b).

Acton et al. (1983) reported that the sarcoplasmic protein myoglobin is primarily responsible for the color of meat. In fresh meat, when myoglobin is reduced in the absence of oxygen, deoxymyoglobin is formed and the meat is purple in color. If myoglobin is reduced in the presence of oxygen, oxymyoglobin is formed and the meat is red in color. If myoglobin is oxidized, metmyoglobin is formed and the meat is brown in color. In cured meats, sodium nitrate or sodium nitrite is reduced to form nitric oxide. Nitric oxide combines with myoglobin to form the unstable nitric oxide myoglobin which when heated forms the stable compound nitrosylhemochrome (Aberle et al., 2001). Nitrosylhemochrome is responsible for the pink color of cured meats and is the key compound that controls warmed over flavor and prevents the growth of *Clostridium botulinum* (Aberle et al., 2001).

Restructured Meat

Restructured meats include chunked and formed, sectioned and formed, flaked and formed, and tearing and formed products with sectioned and formed being the most widely utilized (Pearson and Gillet, 1996). The use of restructuring methods can counteract preproduction issues associated with raw pork meats such as portion control and shelf life. Sectioning and forming consists of forming a single piece of meat from smaller pieces of intact muscles through gelation (Pearson and Gillet, 1996). Many restructured meat products use tumbling to promote protein extraction. The tumbling method for extraction of proteins consists of placing the meat pieces along with a brine solution into a stainless steel drum that contains baffles, which rotate with the drum under vacuum (MacFarlane, 1977). This method extracts proteins by mechanically massaging the meat pieces as the pieces fall at the top of the rotation of the drum under vacuum that expands the meat pieces to enhance brine absorption and improved final appearance. In addition to these protein extraction methods, tumbling usually includes the use of a salt brine. Rust (1987) indicated that salt elevates protein extraction by promoting protein unfolding and causes the proteins to be persuaded to the outer surface of the meat pieces through electrostatic repulsion of the Cl^- ion. Tumbling has also been shown to positively affect aroma, external appearance, sliceability, taste, and yields (Krause et al., 1978).

Retorted Products

Retortable pouches are a relativity new packing material. The origins of the retortable flexible pouch date back to the 1960's when the U.S. Army Natick

Development Center developed the packaging material to replace metal cans used to package military rations (Cecil and Woodroof, 1962; Downing, 1996). The retortable flexible pouch has advantages over the more traditional can. The pouch is smaller in size, weighs less, demands less storage space, and opens easier than metal cans (Chia et al., 1983; Downing, 1996). Also, Rizvi and Acton (1982) and Chia et al. (1983) reported a reduction in processing time by 1/2 to 2/3 in order to achieve the same level of microbial lethality. The reduction in time is due to an increased surface to volume ratio (Rizvi and Acton, 1982). Due to the decreased processing time and a decrease in brine needed for heat transfer, Rizvi and Acton (1982) reported an increase in the nutritional value of the consumable product. Retortable pouches are also becoming more prevalent in the grocery store as ready-to-eat tuna, chicken breast pieces, and processed meat products.

Deionized Water

Water is a major ingredient in restructured meat products. The addition of water to restructured meat products increases the juiciness and texture of the food, in addition to increasing yields and decreasing production costs for the producer. Industrial tests have revealed that utilizing deionized water in the place of municipal water increased yields and improved texture in deli meats, especially when water hardness problems are encountered in meat plants. The use of deionized water instead of municipal water is theorized to improve yields since it does not have calcium or magnesium cations that may be found in traditional water sources. These cations are naturally found in raw meat materials but are controlled by the addition of phosphate to the brine solution. By controlling the outside source of these cations, the phosphate can be fully utilized by the natural cations found within the raw meat materials and maximize its effect on protein unfolding and water holding capacity.

Soy Protein

Soy protein can be found in three forms that are usable as ingredients in meat products: soy flour, soy protein, and soy protein isolate (Pearson and Gillett, 1996). Soy flour contains at least 50 % soy protein and incurs the lowest cost. Soy protein concentrate contains at least 70 % soy protein but is more expensive than soy flour. Soy protein isolate contains at least 90 % soy protein and is the most expensive of the three. The functionality of soy protein is proportional to the level of protein. Rakowsky (1974) reported that soy protein increased water binding, fat binding and gelation. Schilling et al. (2004b) reported the addition of soy protein concentrate in formulations with 25 % PSE for deli style ham rolls decreased cook loss. Soy protein concentrate's ability to bind water is due to gelation upon heating. Soy protein forms a gel with an ordered arrangement of molecules that traps water molecules within the protein matrix (Hermansson, 1986). In restructured meat products, soy protein concentrates are ideal due to the functional improvements of the protein, low off flavor, and the cost effectiveness of the ingredient.

Modified Food Starch

Modified food starch is used to improve water binding (Whistler and Daniel, 1985) in restructured meat products through gelatinization. Food starch is derived from the plant seed's energy source until photosynthesis occurs (Whistler and Daniel, 1985). Most food starches used in meat formulations are modified to produce desirable characteristics. These modifications include the addition of acetate, phosphate, and/or esters to the structures of the starches, which aid in preventing retrogradation in the final food product. Addition of modified food starch to restructured hams containing PSE raw meat material improved texture by decreasing expressible moisture and reducing cook loss (Motzer et al., 1998; Schilling et al., 2004a). Motzer et al. (1998) reported that restructured ham formulated with 50% PSE, modified food starch and anionic phosphate resulted in a product equal in quality to normal restructured ham.

CHAPTER III

MATERIALS AND METHODS

Porcine Raw Meat Materials

For each of the three experiments, porcine S*emimembranosus* muscles were obtained from a pork processing facility in Mississippi. Potential pale, soft, and exudative (PSE) and red, firm, and non-exudative (RFN) samples were selected based on appearance and textural perception according to visual color and hand feel. Samples were then evaluated based on CIE L* values utilizing a chroma meter (Model CR-410, Konica Minolta Sensing, Inc., Osaka Japan) and pH (Model IQ 240, IQ Scientific Instruments, Inc., San Diego, Ca).

Upon arrival at the Mississippi State University Meats Laboratory, CIE *L values were taken in three similar locations and pH was taken in a similar location for each PSE sample to ensure proper raw material selection. PSE and RFN samples were identified as having a CIE L* > 55 with a pH < 5.5 and a CLE L* <50 and pH of > 5.8, respectively. Each sample was vacuum sealed (Model HVT-30, Hollymatic Corp., Countryside, IL) at -90 kPa and placed in a cooler at 4^{o}C prior to performing each replication.

Treatment Combinations

For experiment 1, three replications of six (6) individual treatments were processed into chunked and formed boneless cured pork rolls. Treatments consisted of three (3) levels of PSE raw meat material (0 % PSE+100 % RFN, 25 % PSE+75 % RFN, 50 % PSE+ 50 % RFN) crossed with two levels of deionized water (0, 100 %).

For experiment 2, three replications of six (6) individual treatments were processed into chunked and formed ham packaged in retortable pouches. Treatments consisted of three (3) levels of PSE raw meat material (0 % PSE+100 % RFN, 25 % PSE+75 % RFN, 50 % PSE+ 50 5 RFN) crossed with two levels of deionized water (0, 100 %).

For experiment 3, three replications of six (6) individual treatments were processed into chunked and formed boneless cured pork in retortable pouches. Results from experiment 2 revealed that 25 % PSE pork could be utilized in a final product without a significant loss in quality. Treatments consisted of 25 % PSE raw meat material, 25 % PSE raw meat material and 3.5% functional soy protein concentrate (Promine DS, Solae St. Louis, Mo), 25 % PSE raw meat material and 3.0% modified food starch (Firm-Tex, National Starch & Chemical Company, Bridgewater, NJ) crossed with two levels of deionized water (0, 100 %).

Sample Processing

Semimembranosus muscles were trimmed of external fat and cut into 2.54 cm by 2.54 cm cubes and combined to make each 2.3 kg treatment in all three experiments. To increase bind, ten percent of the total meat weight of the treatment was ground with a food processor (Model 106848, General Electric, Fairfield, CT). A brine solution was utilized that consisted of 32 % water on a Meat Weight Basis (MWB), 0.5 % phosphate (MWB), 156 ppm nitrite (Finished Product Basis, FPB), 550 ppm sodium erythorbate (FPB), 1% dextrose (FPB), and 2 % salt (MWB). Each treatment was tumbled with the appropriate brine solution under vacuum (-124 to – 138 PSI) (Model A 200/15, Multivac, Kansas City, MO) in a 4°C cooler for 40 min, stopping every 15 min for 10 min to increase brine absorption. After tumbling of raw material in Experiment 1, each treatment was manually stuffed into cellulose casings, sealed (Tipper Clipper, Tipper Tie, Apex, NC) and stored at 4° C. In experiments 2 and 3, 200 g of sample were placed into one retortable pouch and sealed by a vacuum sealer at -90 kPa. Approximately ten retortable pouches were used for each treatment. In all experiments, samples were stored in a 4°C cooler until all treatments in a replication had been tumbled and packaged.

In experiment 1, the samples were weighed and placed on stainless steel racks and processed in a Kemetec smoke house (Model 100XLT, Kemetec, Charlotte, North Carolina) with a Kemetec smoke generator (Model 910, Kemetec, Charlotte, North Carolina). The ham products were processed until an internal temperature of 71°C was attained. The first stage of the smokehouse schedule was 1 h for 54°C dry bulb and no wet bulb. The second stage was 2 h for 66°C dry bulb and 47°C wet bulb with a hot smoke cycle. The next stage was 1 h for 71°C dry bulb and 57°C wet bulb. The fourth stage was approximately 1 h 15min for 88°C dry bulb and 74°C wet bulb. The final stage was a cold shower for 15 min to reduce the temperature to < 10°C. Post smoking, the treatments were removed form the smoke house and reweighed to determine cook loss. The treatments were then placed back onto the stainless steel racks and moved into a cooler at 4^{o}C. Following a storage time of 8-12 hours, half of each boneless ham treatment was processed (Model 818 Meat Slicer, Berkel Incorporated, La Porte, Indiana) into 12.7 mm thick slices. Three randomly selected slices were removed for purge loss. The other slices were aerobically packaged and stored at 4^{o}C for additional testing. The other half of each boneless ham treatment was vacuum packaged (Model HVT-30, Hollymatic Corp., Countryside, IL) at -90 kPa and stored at 4^{o}C until sensory evaluation was performed.

In Experiments 2 and 3, random retortable pouches (6) were placed horizontally on top of one half of a 30cm x 36cm stainless steel ham press (35.5 cm x 30.5 cm stainless steel rack, Rebel Butcher Supply Co., Flowood, MS). The other half of the ham press was placed on top of the retortable pouches that were on the first half of the press and tied closed to form ham slices that were approximately 12.7 mm thick (Figure 1.1). A total of eight molds were used per replication for a total of 48 samples when expert evaluation was performed and ten molds were used for a total of 60 samples when consumer evaluation was performed. The loaded mold was placed vertically into a retort (Model 101-10, Loveless Manufacturing, Tulsa, OK) and filled with water. Live steam was injected into the retort until an internal water temperature of 120^{o}C and an internal pressure of 96.5 kPa were achieved. The temperature was maintained between 120^{o}C and 122^{o}C for 10 min. After the allotted time passed, cool water was flushed through the retort while maintaining at least 69 kPa with compressed air to maintain seal integrity until an internal water temperature of less than 40^{o}C was attained. Once the internal water temperature was below 40^{o}C, the internal air pressure was reduced at a rate of approximately 6.9 kPa per min. Once the internal air pressure returned to atmospheric levels, the molds containing the samples were removed and stored at 4^{o}C.

Expressible Moisture

Expressible moisture was only conducted in Experiment 1 due to lack of uniformity in samples in Experiments 2 and 3. Two boneless ham slices (12.7 mm) for each of the six treatments were randomly selected for expressible moisture determinations. Four cores with a diameter of 25.4 mm each were removed from each 12.7 mm thick slice for a total of eight samples per treatment (Schilling et al., 2003). Each core was weighed and placed in between two 12.5 cm Whatman #1 Filter papers. The core sample was axially compressed between two plates to a height of 3.2 mm by the use of an Instron Universal Testing Machine (Model 1011, Instron Corp., Canton, MA) with a crosshead speed of 100mm/min and a 500 kg compression load cell. Each sample was held at full compression for 15 s to facilitate moisture release. Post compression, each core sample was reweighed and expressible moisture was calculated as [(initial wt – final wt)/initial wt)] x 100 and reported as a percentage.

Purge Loss

In experiment 1, purge loss was conducted for three 12.7 mm thick slices from each treatment that were selected at random, weighed, and placed into vacuum bags. Each bag was vacuum packaged (Model HVT-30, Hollymatic Corp., Countryside, IL) (-90 kPa) and stored at 4^{o}C in a cooler for 72 h. After storage, the samples were removed from the packages and excessive surface moisture was removed with one paper towel. Each sample was reweighed and purge loss was calculated as [(initial wt – final wt) / initial wt] x 100 and reported as a percentage.

Cooking Loss

In Experiment 1, each boneless ham treatment was weighed prior to placement in the smokehouse. Once the cooking process was completed, excess surface moisture was removed with one paper towel and each boneless ham treatment was reweighed. Cooking loss was calculated as (raw weight-cooked weight/raw weight) x100 and reported as a percentage.

In experiments 2 and 3, the sample in the pouch was weighted after vacuum sealing. The weight of the packaged sample minus the weight of the bag (8.9grm) was recorded as the raw weight of the sample. After cooking and cooling of the samples, five pouches from each treatment were opened and the ham piece was removed from the pouch. Excess surface moisture was removed with a paper towel (and each boneless ham treatment was reweighed. Cooking loss was determined for each of the five pouches for each treatment and an average was calculated (raw weight-cooked weight/raw weight) x100 and reported as a percentage.

Instrumental Color Determination

For each of the three experiments, two randomly selected ham slices from each replication were used to evaluate cooked color for each of the six treatments. A chroma meter (Model CR-410, Konica Minolta Sensing, Inc., Osaka Japan) was calibrated (white plate No. 18433006; CIE L* 94.5, a* 0.3134, y* 0.3198) and used to determine CLE L*a*b* values. A total of four color measurements were taken for each treatment, one color measurement on each side of the two randomly selected ham slices.

Protein-Protein Bind

Protein-protein bind strength was evaluated using a procedure described by Schilling et al. (2003) that was modified from a procedure by Field et al. (1984) utilizing an Instron Universal Testing Machine (Model 1011, Instron Corp., Canton, MA). A steel ball (25.0 mm diameter) was attached to a rod that was secured in a 50 kg load cell with a chuck and used to penetrate through the center of five randomly selected ham slices from each treatment at a crosshead speed of 100 mm/min. Each sample was secured to a square holding device. The holding device was a square piece of plexiglass with a hole in the middle that was surrounded by a circular ring of nails so that the steel ball would go through the center of each ham slice and not come into contact with the holding device. Protein-protein bind was reported as the peak force (kg) required for the steel ball to penetrate through the center of the ham slice sample.

Sensory Evaluation

Consumer based sensory panels (n≥50) were conducted to determine the consumer acceptability of the chunked and formed ham treatments from each experiment. Consumer sensory evaluation panels were conducted at the Garrison Sensory Evaluation Laboratory at Mississippi State University, and Internal Review Board approval was received prior to conducting the consumer evaluation panels. Panelists were recruited by word of mouth and fliers posted around the Department of Food Science, Nutrition, and Health Promotion. Each panelist was required to complete a standard consent form before participating in the panel and then asked to evaluate the six chunked and formed cured smoked deli hams samples for overall acceptability using a nine-point hedonic scale (Meilgaard et al., 1991) where 1 represents 'dislike extremely', 2 represents 'dislike very much', 3 represents 'dislike moderately', 4 represents 'dislike slightly', 5 represents 'neither like nor dislike', 6 represents 'like slightly', 7 represents 'like moderately', 8 represents 'like very much' and 9 represents 'like extremely' (Figure 1.2). Each sample was randomly assigned a three-digit number. Each ham treatment was thinly sliced (2mm thick) to represent a typical sandwich style deli meat and placed into a labeled sealable plastic sandwich bag (17 cm x 20 cm Storage Bags Great Value, Wal-Mart, Bentonville, AR). The samples were then stored in a warm water bath (60-70 C) until the panelist evaluated the samples.

In Experiments 2 and 3, each retortable pouched product treatment was randomly assigned a three-digit number. Each ham treatment was cubed into bite size pieces (10mm x 10mm) and placed into a labeled sealable plastic sandwich bag (17 cm x 20 cm Storage Bags Great Value, Wal-Mart, Bentonville, AR). The samples were then stored in a warm water bath (60-70 C) until the panelist evaluated the samples. In experiment 3, agglomerative hierarchical clustering was also performed to cluster consumers together based on their preference of ham treatments.

In Experiments 2 and 3, trained panelists (minimum training of 2 years) were utilized specifically to perform expert evaluations. Each sample was evaluated for appearance and taste attributes. Each sample was randomly assigned a three-digit number. Each ham treatment was cubed into bite size pieces (10mm x 10mm) and placed into a labeled sealable plastic sandwich bag. The samples were then stored in a warm water bath (60-70 C) until the panelists evaluated the sample. The panelists evaluated each sample for 11 attributes (Figure 1.4). One sample from each treatment was randomly selected and the edges were trimmed to form a 7cm by 9cm rectangle for visual evaluation by all panelists. The panelists visually evaluated three attributes: uniformity of color, intensity of color, and cracking. The panelists evaluated seven attributes by mouth: cohesiveness, chewiness, overall texture, juiciness, saltiness, off-flavor, and overall flavor. All evaluations were scored on a 15 point hedonic scale with 0 being none, not pale, mushy or bland and 15 being uniform, pink, extreme, very, or tough (Meilgaard et al., 1991). The expert panelists evaluated overall acceptability for each of the samples using a nine-point hedonic scale identical to the consumer panels (Meilgaard et al., 1991).

Microbial Testing

In Experiments 2 and 3, three sample pouches were randomly selected from each replication for determination of standard plate counts to assure that the pouch had maintained their integrity and that the product was shelf-stable. Aseptic techniques were used to remove 10 g of sample and placed into a sterile stomacher bag (Stomacher '400' Closure Bag, Seward Medical, London UK) with 90ml of peptone solution. The sample bag was placed into the homogenizer (Stomacher 400 Lab Blender, Seward Medical, London UK) for 3min at medium speed. A one to one dilution was conducted in triplicate. The petri dishes were placed in an incubator (Model 4100, Napco Scientific Co., Tualatin, OR) at 32^{o}C for 48 h. After 48 hr, the plates were counted (AOAC, 966.23C). All samples were determined to be shelf-stable and safe for consumption due to a lack of colony forming units.

Statistical Analysis

In experiments 1 and 2, randomized complete block designs with four and three replications were utilized to test treatment effects of various levels of PSE raw meat materials (0, 25, and 50 %) and the usage of deionized water (0, 100 %) in the brine formulation (SAS 9.1, 2002, Cary, NC) on product quality characteristics. When significant differences occurred for a response at either a $P < 0.05$ or $P<0.10$ level, the Least Significant Difference test was performed to separate treatment means.

In experiment 3, a randomized complete block design with three replications was utilized to test treatment effects of soy protein concentrate and modified food starch and the usage of deionized water (0, 100 %) in the brine formulation (SAS 9.1, 2002, Cary, NC) on product quality characteristics in retortable-pouched ham. When significant differences occurred for a response ($P < 0.05$), the Least Significant Difference test was performed to separate treatment means.

In the third experiment, agglomerative hierarchical clustering was performed using Ward's Method to cluster consumers together based on their preference and liking of ham treatments. A dendrogram and a dissimilarity plot were used to determine how many clusters should be utilized to group together consumers. After this cluster analysis was performed, randomized complete block designs were utilized to determine differences ($P < 0.05$) among treatments within each cluster. When significant differences occurred for a response ($P < 0.05$) within each cluster, the Least Significant Distance Test was performed to separate treatment means.

CHAPTER IV

RESULTS AND DISCUSSION

Water Holding Capacity

Expressible moisture is a measurement of lightly bound water found in a food matrix that is determined by compressing a sample and recording the amount of moisture forced from the matrix (Jauregui, 1981). Expressible moisture is “often associated with water holding-holding capacity” (Motzer et al., 1998). On average, the substitution of municipal water with deionized water reduced ($P<0.10$) expressible moisture by 1 % in chunked and formed cured, smoked deli ham (Table 1.1). For chunked and formed cured, smoked deli hams formulated with 0 % PSE raw meat material, there was a reduction ($P<0.10$) in expressible moisture (1.8 %) when deionized water was used in the formulation, but there were no differences ($P>0.10$) among level of PSE treatments. These results are supported by the findings of Motzer et al. (1998) and Schilling et al. (2003). Their research revealed that there was no difference between 0 and 50 % PSE for expressible moisture, but that differences did exist between 0 and 100 % PSE treatments.

Table 1.1 AVERAGE EFFECTS OF MUNICIPAL OR DEIONIZED WATER ON MOISTURE RETENTION AND COOKED COLOR OF CHUNKED AND FORMED CURED AND SMOKED DELI HAM

Treatment	Expressible Moisture (%) ^	Cook Loss (%) *	Purge Loss (%) ^	Protein-Protein Bind (Kg) ^	CIE L* ^	CIE a* ^	CIE b* ^
Municipal Water	21.3[a]	11.2[a]	5.1[a]	0.94[a]	65.0[a]	13.6[a]	6.7[a]
Deionized Water	20.3[b]	10.3[b]	5.4[a]	0.92[a]	64.9[a]	13.5[a]	6.6[a]
Standard Error	0.44	0.64	0.37	0.85	0.63	0.22	0.11

[a,b] Means within a column with the same letter are not different ^(P>0.05), *(P>0.10)

The 0 % PSE with deionized water brine formulation had lower (P<0.05) expressible moisture than the municipal water formulations. Differences between municipal water and deionized water treatments could be prevalent if the municipal water source contained greater ion levels that could interfere with the protein-water interaction.

There was no difference (P>0.05) among the six treatments for purge loss. These results could be due to PSE raw materials not being severely denatured in which there was adequate water binding potential within the PSE samples, or the percent normal raw meat material in the formulation being sufficient to bind the water present. A low purge loss percent indicates a product that is juicy and therefore appealing to consumers (Daigle et al., 2005).

On average, the use of deionized water reduced (P<0.10) cook loss in chunked and formed cured, smoked deli hams by 0.8% (Table 1.1), but there were no differences (P>0.10) among individual treatment combinations of % PSE and water source (Table 1.2). These results are similar to those of Motzer et al. (1998) and Schilling et al. (2003). These researchers reported no difference in cook loss between 0 and 50 % treatments. Preliminary industry research demonstrated that in a retorted ham product, the use of deionized water decreased cook loss from 15.9 % (plant water) to 3.7 % (deionized water) a reduction of 12.2 %.

Table 1.2 EFFECTS OF MUNICIPAL OR DEIONIZED WATER ON MOISTURE RETENTION, COOKED COLOR, AND CONSUMER ACCEPTABILITY OF CHUNKED AND FORMED CURED AND SMOKED DELI HAM FORMULATED WITH 0 %, 25 %, AND 50% PALE, SOFT AND EXUDATIVE (PSE) RAW MEAT MATERIAL

Treatment	Expressible Moisture (%)*	Cook Loss (%)^	Purge Loss (%)^	Protein-Protein Bind (Kg)^	CIE L* ^	CIE a* ^	CIE b* ^	Consumer Acceptability ^
0 % PSE Municipal Water	21.5[a]	11.1[a]	5.2[a]	0.90[a]	63.3[d]	14.0[ab]	6.3[c]	7.19[a]
25 % PSE Municipal Water	21.0[a]	11.5[a]	5.3[a]	0.96[a]	64.3[bcd]	13.8[ab]	6.6[bc]	6.94[a]
50 % PSE Municipal Water	21.5[a]	11.1[a]	5.0[a]	0.89[a]	67.5[a]	12.6[c]	7.2[a]	7.36[a]
0 % PSE Deionized Water	19.7[b]	9.6[a]	5.5[a]	0.96[a]	63.7[cd]	14.0[a]	6.3[c]	6.90[a]
25 % PSE Deionized Water	20.5[ab]	10.4[a]	5.5[a]	0.93[a]	65.2[bc]	13.6[ab]	6.8[b]	6.83[a]
50 % PSE Deionized Water	20.8[ab]	10.9[a]	5.3[a]	0.93[a]	65.9[ab]	13.3[b]	6.8[b]	7.20[a]
Standard Error	0.45	0.65	0.35	0.085	0.63	0.24	0.11	0.20

[a,b] Means within a column with the same letter are not different ^(P>0.05), *(P>0.10)

Brody (2006) indicated that the use of retortable pouches and trays is increasing every year and "will surely be a major category for our food science and technology future." For chunked and formed cured and retorted pouch ham, the use of deionized water did not reduce ($P>0.10$) cook loss at any level of PSE tested (Table 1.3). There was a ($P<0.10$) difference between 0 % PSE / municipal water and 50 % PSE / deionized water. On average, 50 % PSE formulations were higher ($P<0.05$) in % cook loss than 0 % and 25 % PSE treatments. Schilling et al. (2003) demonstrated no difference in cook loss between 0 %, 50 %, and 100 % for smoked boneless cured ham and Motzer et al. (1998) reported no difference in cook loss between 0 %, and 50 % for deli ham that was cooked in water. This research demonstrates that a more severe processing technique decreases the amount of PSE meat that can be incorporated into the product before cook loss is significantly increased. On average, deionized water did not affect ($P>0.05$) cook loss. These results may be attributed to PSE raw meat material possessing adequate water holding ability or the municipal water source not containing high levels (<50 ppm) of metal ions that may be present at some locations.

Table 1.3 EFFECTS OF MUNICIPAL OR DEIONIZED WATER ON MOISTURE RETENTION, PROTEIN-PROTEIN BIND, AND COOKED COLOR OF CHUNKED AND FORMED CURED AND RETORTED HAM FORMULATED WITH 0 %, 25 %, AND 50 % PALE, SOFT AND EXUDATIVE (PSE) RAW MEAT MATERIAL

Treatment	Cook Loss (%)	Protein-Protein Bind (Kg)	CIE L*	CIE a*	CIE b*
0 % PSE Municipal Water	27.2^{c}	1.31^{a}	64.7^{a}	13.5^{a}	8.0^{a}
25 % PSE Municipal Water	28.3^{bc}	1.67^{a}	65.3^{a}	13.5^{a}	8.0^{a}
50 % PSE Municipal Water	30.5^{ab}	1.50^{a}	64.4^{a}	13.8^{a}	8.1^{a}
0 % PSE Deionized Water	28.0^{bc}	1.39^{a}	64.1^{a}	13.8^{a}	10.0^{a}
25 % PSE Deionized Water	28.3^{bc}	1.45^{a}	64.3^{a}	14.0^{a}	8.0^{a}
50 % PSE Deionized Water	31.9^{a}	1.44^{a}	65.4^{a}	13.1^{a}	8.2^{a}
Standard Error	1.00	1.19	0.41	0.24	0.85

[a,b] Means within a column with the same letter are not different (P>0.05)

Extenders are commonly added to restructured meat products to improve texture and flavor, decrease formulation cost, improve physical characteristics, and increase water-holding capacity (Aberle et al., 2001). The previous experiment and research conducted by Schilling et al. (2004b) indicated that a level of 25 % PSE raw material resulted in an acceptable product. Therefore, a chunked and formed cured and retortable pouch ham with 25 % PSE and 75 % normal pork raw meat material was used in all treatments in the third experiment. Chunked and formed, cured and retorted ham was formulated with no non-meat adjuncts, 3.5 % functional soy protein concentrate, or 3.0 % modified food starch. There was no reduction ($P>0.05$) in cook loss due to deionized water use in the control, soy protein concentrate, or modified food starch treatments (Table 1.4). The average effect of utilizing deionized water in a cured retorted ham product was also not significant ($P>0.05$) (Table 1.5). The addition of 3.5 % functional soy protein concentrate or 3.0 % modified food starch to the formulation decreased ($P<0.05$) cook loss when compared to formulations without non-meat adjuncts (Table 1.6). Adding soy protein concentrate decreased cook loss by 8 % when compared to the control treatment containing no non-meat adjuncts, which supports the findings of Motzer et al. (1998) and Schilling et al. (2004a, 2004b). These researchers reported that the addition of soy protein reduces cook loss in restructured ham products. Daigle et al. (2005) demonstrated similar results for the addition of soy protein concentrate to chunked and formed turkey deli rolls containing PSE-like turkey raw materials. This reduction in cook loss could have occurred due to the ability of soy protein concentrate to gel upon heating and become an ordered arrangement of molecules, thus binding free water (Hermansson, 1986). The addition of modified food starch reduced cook loss by 13.5 % when compared to a control treatment containing no non-meat adjuncts. These results are similar to those of Motzer et al. (1998) and Schilling et al. (2004b) who demonstrated that the addition of modified food starch reduces can be attributed to the swelling of starch molecules during heating. This swelling and heat induces the breaking of intermolecular bonds, which opens up additional hydrogen bonding sites for water entrapment (Whistler and Daniel, 1985). The modified food starch treatment had lower ($P<0.05$) cook loss than the soy protein concentrate treatment. Modified food starch may bind water better than soy protein concentrate since soy protein functions similarly to the meat protein already in the product and starch is a carbohydrate that binds water through a different mechanism. During heating, modified food starch is hydrated and swells, which entraps water molecules by hydrogen binding as well as by forming an irreversible gel (Whistler and Daniel, 1985; Hermansson, 1986; Schilling, 2004b).

Table 1.4 EFFECTS OF MUNICIPAL OR DEIONIZED WATER ON MOISTURE RETENTION, PROTEIN-PROTEIN BIND, COOKED COLOR, AND CONSUMER ACCEPTABILITY OF CHUNKED AND FORMED CURED AND RETORTED HAM FORMULATED WITH NON-MEAT ADJUNCTS AND 25% PALE, SOFT AND EXUDATIVE (PSE) RAW MEAT MATERIAL

Treatment	Cook Loss (%) ^	Protein-Protein Bind (Kg) ^	CIE L* *	CIE a* ^	CIE b* ^	Consumer Acceptability ^
Control Municipal Water	29.3[a]	1.47[bcd]	65.4[ab]	13.6[c]	7.3[c]	6.74[ab]
Soy Protein Municipal Water	22.1[b]	1.62[ab]	65.4[ab]	12.5[d]	9.3[a]	6.36[bc]
Starch Municipal Water	16.1[c]	1.29[d]	64.2[bc]	14.2[ab]	8.1[b]	6.86[ab]
Control Deionized Water	29.8[a]	1.57[abc]	64.5[bc]	13.9[bc]	7.4[c]	7.02[a]
Soy Protein Deionized Water	21.2[b]	1.71[a]	66.2[a]	12.2[d]	9.7[a]	6.67[ab]
Starch Deionized Water	16.1[c]	1.37[cd]	63.3[c]	14.5[a]	8.1[b]	6.06[c]
Standard Error	0.98	0.06	0.59	0.12	0.13	0.21

[a,b] Means within a column with the same letter are not different ^(P>0.05), *(P>0.10)

Table 1.5 AVERAGE EFFECTS OF MUNICIPAL OR DEIONIZED WATER ON MOISTURE RETENTION, PROTEIN-PROTEIN BIND, AND COOKED COLOR OF CHUNKED AND FORMED CURED AND RETORTED HAM FORMULATED WITH NON-MEAT ADJUNCTS AND 25% PALE, SOFT AND EXUDATIVE (PSE) RAW . MEAT MATERIAL

Treatment	Cook Loss (%)	Protein-Protein Bind (Kg)	CIE L*	CIE a*	CIE b*
Municipal Water	22.5[a]	1.46[a]	65.0[a]	13.5[a]	8.3[a]
Deionized Water	22.4[a]	1.54[a]	64.6[a]	13.5[a]	8.4[a]
Standard Error	0.98	0.06	0.59	0.12	0.13

[a,b] Means within a column with the same letter are not different (P>0.05)

Table 1.6 AVERAGE EFFECTS OF NON-MEAT ADJUNCTS ON MOISTURE RETENTION, PROTEIN-PROTEIN BIND, AND COOKED COLOR OF CHUNKED AND FORMED CURED AND RETORTED HAM FORMULATED WITH 25% PALE, SOFT AND EXUDATIVE (PSE) RAW . MEAT MATERIAL

Treatment	Cook Loss (%)	Protein-Protein Bind (Kg)	CIE L*	CIE a*	CIE b*
Control	29.6[a]	1.52[b]	64.9[ab]	13.8[b]	7.4[c]
Soy Protein	21.6[b]	1.67[b]	65.5[a]	12.3[c]	9.5[a]
Modified Food Starch	16.1[c]	1.33[c]	63.8[b]	14.4[a]	8.1[b]
Standard Error	0.98	0.06	0.59	0.12	0.13

[a,b] Means within a column with the same letter are not different (P>0.05)

Cooked Color

The color of pork influences consumer preference (Brewer et al., 1998). Pork possessing a pale color has been shown to have a decreased consumer acceptance and is less likely to be purchased by consumers at regular retail value (Wachholz et al, 1978). In chunked and formed cured, smoked deli ham, there were differences ($P<0.05$) in CIE L*, CIE a*, and CIE b* among treatments (Table 1.2). The 50% PSE municipal water treatment was higher ($P<0.05$) in CIE L* value than all 25% and 0% PSE treatments. The 50% PSE deionized water treatment was higher ($P<0.05$) than all 0% PSE treatments for CIE L* value. On average, the CIE L* of 50 % PSE was higher ($P<0.05$) than 0 % PSE treatments. These results are similar to those of Motzer et al. (1998) and Schilling et al. (2004b). These researchers performed experiments on the effects of % PSE meat on the quality of restructured, boneless cured pork. The treatments followed the expected pattern for CIE L* value. The CIE L* value increased as the percentage of PSE increased. The replacement of municipal water with deionized water, increased ($P<0.05$) CIE a* in treatments with 50 % PSE thus increasing redness for that treatment. On average, as PSE level changed from 0 % to 50 % PSE, the CIE a* value decreased. These results disagree with the findings of Motzer et al. (1998). These researchers reported no difference between 0 and 50 % PSE treatments, but their results did reveal differences between 0 % PSE and 100 % PSE treatments for CIE a* value. The discrepancy may be due to the severity of PSE raw meat material used. The replacement of municipal water with deionized water decreased ($P<0.05$) CIE b* in treatments with 50 % PSE, indicating decreased yellowness for that treatment. On average, as PSE level changed from 0 % to 50 %

PSE, the CIE b* value increased. These results are supported by those of Motzer et al. (1998) and Zhu and Brewer (1998) who reported elevated CIE b* values for PSE pork in restructured cured pork and raw meat material. On average, the effect of utilizing deionized water in the formulation of chunked and formed cured and smoked deli ham did not effect CIE L*, CIE a*, or CIE b* values (P>0.05) (Table 1.1). In chunked and formed cured ham that was retorted in a flexible pouch, there was no difference (P>0.05) between treatments for CIE L*, CIE a*, or CIE b* values (Table 1.3). The use of deionized water also did not cause a difference in CIE L*, CIE a*, or CIE b* values (Table 1.7). On average, there was no difference (P>0.05) between percent PSE for CIE L*, CIE a*, or CIE b* (Table 1.8). These results differ from the results of the previous experiment and the results of Motzer et al. (1998), Schilling et al. (2003, 2004a, 2004b) and Daigle et al. (2005) who showed differences in color among percent PSE level. This discrepancy in results may be due to the severe heat and pressure processing that occurs during retorting in comparison to the smoking of a restructured meat product. Even though no statistical tests were performed, retorted ham products tended to have higher yellowness values for all treatments when compared to the smoked deli hams formulated in the first experiment.

Table 1.7 AVERAGE EFFECTS OF MUNICIPAL OR DEIONIZED WATER ON MOISTURE RETENTION, PROTEIN-PROTEIN BIND, AND COOKED COLOR OF CHUNKED AND FORMED CURED AND RETORTED HAM FORMULATED WITH 0 %, 25 %, AND 50 % PALE, SOFT AND EXUDATIVE (PSE) RAW MEAT MATERIAL

Treatment	Cook Loss (%)	Protein-Protein Bind (Kg)	CIE L*	CIE a*	CIE b*
Municipal Water	28.7[a]	1.5[a]	64.8[a]	13.6[a]	8.0[a]
Deionized Water	29.4[a]	1.5[a]	64.6[a]	13.6[a]	8.7[a]
Standard Error	1.00	0.06	0.41	0.24	0.85

[a,b] Means within a column with the same letter are not different (P>0.05)

Table 1.8 AVERAGE EFFECTS OF % PALE, SOFT AND EXUDATIVE (PSE) RAW MEAT MATERIAL ON MOISTURE RETENTION, PROTEIN-PROTEIN BIND, AND COOKED COLOR OF CHUNKED AND FORMED CURED AND RETORTED HAM

Treatment	Cook Loss (%)	Protein-Protein Bind (Kg)	CIE L*	CIE a*	CIE b*
0 % PSE	27.6[b]	1.3[a]	64.4[a]	13.6[a]	8.9[a]
25 % PSE	28.3[b]	1.5[a]	64.8[a]	13.7[a]	8.0[a]
50 % PSE	31.2[a]	1.5[a]	64.9[a]	13.5[a]	8.1[a]
Standard Error	1.00	0.06	0.41	0.24	0.85

[a,b] Means within a column with the same letter are not different (P>0.05)

In chunked and formed cured ham processed in a retortable pouch that were formulated with non-meat adjuncts, there were no differences (P>0.05) due to the use of deionized water in the formulation for CIE L* values (Table 1.5). The deionized water and modified starch formulation had a lower CIE L* value (P<0.05) than both the soy protein concentrate formulation and the no adjunct (control) / municipal water treatment (Table 1.4). The soy protein concentrate/deionized treatment was higher (P< 0.10) than the control / deionized water treatment and modified food starch/deionized water treatment in regards to CIE L*. On average, soy protein concentrate had a higher (P<0.05) CIE L* than modified food starch treatments (Table 1.6), and there was no difference (P>0.05) between the control treatment and either the soy protein concentrate or modified food starch treatments for CIE L* (Table 1.6). These results differ from those of Motzer et al. (1998) who reported that there was no difference in CIE L* value between modified food starch and soy protein isolate, but these results were similar to those of Schilling et al. (2004b) who reported differences in CIE L* between modified food starch and soy protein concentrate. The differences between these results and those of Motzer et al. (1998) maybe attributed to the use of soy protein isolate instead of soy protein concentrate and the use of a different heat processing technique during production. There was no difference (P>0.05) due to the use of deionized water in the formulation for CIE a* values / redness (Table 1.5) when compared to the use of municipal water. On average, there were differences (P<0.05) due to the addition of non-meat adjuncts when compared to the control treatment for CIE a* values. In comparison to the control treatment, the addition of modified food starch increased (P<0.05) redness and the addition of soy protein concentrate decreased (P<0.05) redness (Table 1.6). These results differ from those of Motzer et al. (1998), who reported no difference between control, soy protein isolate, and modified food starch for redness in deli hams. Schilling et al. (2004b) reported an increase in redness for both soy protein concentrate and modified food starch in smoked deli hams. Schilling et al. (2004b) hypothesized that modified food starch may be able to increase redness due to their ability to improve water holding capacity, thus tightening the structure and causing more reflection. This theory would not apply to soy protein concentrate due to its pale, yellow color. There was no difference (P>0.05) due to the use of deionized water in the formulation for CIE b* values / yellowness (Table 1.5) when compared to the use of municipal water. On average, there were differences (P<0.05) due to the addition of non-meat adjuncts when compared to the control treatment in regards to CIE b* values. The addition of modified food starch and soy protein increased (P<0.05) yellowness when compared to the control treatment (Table 1.6). Soy protein concentrate was higher (P<0.05) than modified food starch for CIE b* value. Both Motzer et al. (1998) and Schilling et al (2004b) reported similar results for CIE b* values due to the addition of soy protein to deli ham. Additionally, these researchers reported that modified food starch decreased yellowness.

When comparing the two processing methods (smoked deli hams vs. retortable pouches), retorting reduces the effect of the PSE raw material level in the treatment in regard to the paleness/CIE L* value. The addition of modified food starch to a retorted pouch product improved the CIE a* value. Kauffman et al. (1992) indicated that pale pork is not acceptable to consumers, and Schilling et al. (2004b) reported that increased redness is desirable to consumers. Therefore, adding modified food starch and using a retort process may allow processors to utilize a higher level of PSE without negatively affecting the color of the ham product.

Protein-Protein Bind

Bind strength was not affected (P>0.05) by deionized water utilization in the formulation of either chunked and formed deli ham or chunked and formed retorted ham with or without non-meat adjuncts. For the same products, the levels of PSE utilized in the formulation did not (P>0.05) affect bind strength. Schilling et al. (2003, 2004b) reported no significant difference in bind strength between 0 % and 50 % PSE, but Motzer et al. (1998) reported differences in bind strength between 0 % and 50 % PSE. These researchers also reported a difference in bind strength between 0 % and 100 % PSE. Differences in these researchers findings may be due to cooking methods and sample size since Motzer et al. (1998) cooked the product in ham molds beneath water and the study by Schilling et al. (2004) had much greater statistical power due to increased sample size. The 25 % PSE treatment retorted ham had lower (P<0.05) protein-protein bind when modified food starch was added to the product when compared to the control treatment (Table 1.6). Both Motzer et al (1998) and Schilling et al. (2003) reported no differences (P>0.05) in bind strength for the incorporation of modified food starch or soy protein in deli ham formulations when compared to a control. Daigle et al. (2005) reported similar results for soy protein concentrate when used in formulations for chunked and formed turkey deli rolls. Decrease in bind value may be due to the harsh retort process as well as increase in moisture retention when modified food starch was used in comparison to the control and soy protein concentrate treatments.

Sensory Evaluation

For boneless cured deli hams, there were no differences (P>0.05) in consumer acceptability among treatments (Table 1.2). All treatments scored between "like-slightly" and "like-moderately." For chunked and formed cured ham that was retorted in a flexible pouch, consumers did prefer (P<0.05) 50 % PSE / deionized water formulation over 50 % PSE / municipal water formulation (Table 1.9). On average, consumers preferred (P<0.10) a product formulated with deionized water over a product formulated with municipal water with a mean average of 6.71 and 6.37, respectively. Both water formulations received scores of "like-slightly." This reveals that there are no practical differences between formulations due to water used in the formulation with respect to consumer acceptability.

Table 1.9 EFFECTS OF MUNICIPAL OR DEIONIZED WATER ON CONSUMER ACCEPTABILITY OF CHUNKED AND FORMED CURED AND RETORTED HAM FORMULATED WITH 0 %, 25 %, AND 50 % PALE, SOFT AND EXUDATIVE (PSE) RAW MEAT MATERIAL

Treatment	Consumer Acceptability
0% PSE Municipal Water	6.66[ab]
25% PSE Municipal Water	6.34[ab]
50 % PSE Municipal Water	6.12[b]
0% PSE Deionized Water	6.60[ab]
25% PSE Deionized Water	6.72[a]
50% PSE Deionized Water	6.80[a]
Standard Error	0.21

[a,b] Means within a column with the same letter are not different (P>0.05)

For chunked and formed cured ham that was retorted in a flexible pouch, trained panelists found no differences (P>0.05) between treatments for visual characteristics: intensity of color and surface cracking, but there was a difference (P<0.05) for uniformity of color (Table 1.10). For both water sources, as percentage PSE increased, the uniformity of the product decreased (P<0.05). For texture characteristics, trained panelists found no differences (P>0.05) between treatments for cohesiveness, chewiness, and overall texture (Table 1.11). For flavor characteristics, trained panelists found no differences (P>0.05) between treatments for overall flavor, off flavor, saltiness and juiciness (Table 1.12). There was also no difference (P>0.05) between treatments for acceptability (Table 1.12). All treatments received a mean score between 6.7 and 7.3, which is between "like-slightly" and "like-moderately." These results are similar to the results from consumer acceptability studies.

For chunked and formed cured ham processed in a retortable pouch that was formulated with non-meat adjuncts, there were differences (P<0.05) in regards to consumer acceptability (Table 1.4). The starch/deionized water formulation was liked less (P<0.05) than all other formulations except for the soy protein / municipal water formulation. All treatments scored between "like-slightly" and "like-moderately" for consumer acceptability (Table 1.4).

Table 1.10 EFFECTS OF MUNICIPAL OR DEIONIZED WATER ON UNIFORMITY OF COLOR, INTENSITY OF COLOR, AND SURFACE CRACKING OF CHUNKED AND FORMED CURED AND RETORTED HAM FORMULATED WITH 0 %, 25 %, AND 50 % PALE, SOFT AND EXUDATIVE (PSE) RAW MEAT MATERIAL EVALUATED BY TRAINED PANELISTS

Treatment	Uniformity of Color	Intensity of Color	Surface Cracking
0% PSE Municipal Water	8.1[bc]	6.5[a]	5.7[a]
25% PSE Municipal Water	8.3[abc]	5.2[a]	5.5[a]
50 % PSE Municipal Water	10.2[a]	5.7[a]	6.1[a]
0% PSE Deionized Water	9.7[ab]	6.4[a]	6.4[a]
25% PSE Deionized Water	9.0[abc]	5.6[a]	7.4[a]
50% PSE Deionized Water	7.2[c]	5.5[a]	7.0[a]
Standard Error	1.4	1.3	1.3

[a,b] Means within a column with the same letter are not different (P>0.05)

Table 1.11 EFFECTS OF MUNICIPAL OR DEIONIZED WATER ON COHESIVENESS, CHEWINESS, OVERALL, AND TEXTURE OF CHUNKED AND FORMED CURED AND RETORTED HAM FORMULATED WITH 0 %, 25 %, AND 50 % PALE, SOFT AND EXUDATIVE (PSE) RAW MEAT MATERIAL EVALUATED BY TRAINED PANELISTS

Treatment	Cohesiveness	Chewiness	Overall Texture
0% PSE Municipal Water	8.6[a]	7.2[a]	6.8[a]
25% PSE Municipal Water	7.8[a]	6.5[a]	6.1[a]
50 % PSE Municipal Water	8.3[a]	7.1[a]	7.2[a]
0% PSE Deionized Water	8.0[a]	7.6[a]	6.6[a]
25% PSE Deionized Water	8.2[a]	6.6[a]	6.8[a]
50% PSE Deionized Water	7.5[a]	6.4[a]	6.3[a]
Standard Error	0.88	0.95	0.76

[a,b] Means within a column with the same letter are not different (P>0.05)

Table 1.12 EFFECTS OF MUNICIPAL OR DEIONIZED WATER ON COHESIVENESS, CHEWINESS, OVERALL TEXTURE, JUICINESS, AND JUICINESS OF CHUNKED AND FORMED CURED AND RETORTED HAM FORMULATED WITH 0 %, 25 %, AND 50 % PALE, SOFT AND EXUDATIVE (PSE) RAW MEAT MATERIAL EVALUATED BY TRAINED PANELISTS

Treatment	Overall Flavor	Off Flavor	Saltiness	Juiciness	Acceptability
0% PSE Municipal Water	10.7[a]	0[a]	4.8[a]	10.4[a]	7.3[a]
25% PSE Municipal Water	10.6[a]	0[a]	4.9[a]	10.2[a]	7.1[a]
50 % PSE Municipal Water	10.7[a]	0[a]	4.9[a]	10.0[a]	6.9[a]
0% PSE Deionized Water	10.8[a]	0[a]	5.0[a]	9.9[a]	7.2[a]
25% PSE Deionized Water	10.4[a]	0[a]	4.5[a]	9.8[a]	6.8[a]
50% PSE Deionized Water	10.5[a]	0[a]	4.7[a]	10.1[a]	6.7[a]
Standard Error	0.46	0.00	0.47	0.67	0.43

[a,b] Means within a column with the same letter are not different (P>0.05)

Table 1.13 MEAN SCORES FOR OVERALL CONSUMER ACCEPTABILITY OF SIX TREATMENTS OF CHUNKED AND FORMED CURED AND RETORTED HAM FORMULATED WITH NON-MEAT ADJUNCTS AND 25% PSE RAW MEAT MATERIAL ACCORDING TO DIFFERENT CLUSTERS OF CONSUMER SEGMENTS

Cluster[1]	Number of Consumers	Control Deionized Water	Soy Protein Deionized Water	Modified Food Starch Deionized Water	Control Municipal Water	Soy Protein Municipal Water	Modified Food Starch Municipal Water
1	4	4.75^{abc}	2.75^{cd}	2.25^{d}	3.50^{bcd}	5.25^{ab}	6.00^{a}
2	2	4.00^{cd}	5.00^{bc}	5.50^{bc}	8.50^{a}	2.00^{d}	7.00^{ab}
3	10	7.40^{a}	5.20^{b}	7.30^{a}	7.80^{a}	7.00^{a}	7.10^{a}
4	8	8.13^{ab}	8.38^{a}	7.63^{b}	8.00^{ab}	8.00^{ab}	8.50^{a}
5	12	6.83^{ab}	7.50^{a}	4.33^{c}	6.83^{ab}	7.08^{ab}	6.58^{b}
6	13	7.54^{a}	7.46^{a}	7.31^{a}	5.92^{b}	5.54^{b}	6.15^{b}

[a-d] Means with the same letter within each row are not significantly different (P>0.05).
[1] Hedonic scale was based on a 9-point scale (1= dislike extremely, 5= neither like nor dislike, and 9= like extremely)

Due to variations in consumer panelists' preference for retortable pouched ham that was formulated with non-meat adjuncts, agglomerative hierarchical clustering was performed to group consumers based on their preferences (Table 1.13). A dendrogram was utilized based on dissimilarity in panelists to group consumers into 6 clusters. Cluster 1 (8 % of panelists) did not like ham, especially the starch/deionized treatment. Cluster 2 (4 % of panelists) did not like soy protein added or the use of deionized water in ham, but did scored the control / municipal water formulation and starch / municipal water high. Cluster 2 preferred ($P<0.05$) the municipal water control and starch treatments over the deionized control treatment and the municipal water soy treatment. Cluster 3 (20 % of panelists) liked all ham except for the soy protein/deionized water treatment. This cluster scored all treatments excluding the soy protein/deionized water treatment "Like Moderately" and preferred all other treatments ($P<0.05$) when compared to the soy protein/deionized water treatment. Cluster 4 (16 % of panelists) liked all formulations of ham and scored all treatments at "Like Moderately" or Like Very Much." Cluster 5 (24 % of panelists) did not like modified food starch, especially coupled with deionized water. The starch deionized water treatment was less acceptable ($P<0.05$) than all other treatments. Cluster 6 (26 % of panelists) preferred ($P<0.05$) deionized water to municipal water in the formulation of retorted ham products. Consumer results reveal that all clusters but 1 and 2 (12 % of panelists) liked the ham product but 20 % of panelists that did like ham did not like soy and deionized water. Twenty-four percent of panelists that liked ham did not like starch addition, and 26 % of panelists who liked ham preferred deionized water to municipal water treatments. These results reveal that this retorted ham product is acceptable to a large group of consumers and that when deionized water or municipal water is used either in the control treatment or with modified food starch, this product may be marketable to consumers.

For chunked and formed cured ham processed in a retortable pouch that was formulated with non-meat adjuncts, trained panelists found differences ($P<0.05$) between treatments for visual characteristics (Table 1.14). The use of modified food starch in the formulations with municipal or deionized water increased uniformity when compared to other treatments utilizing municipal water. The modified food starch deionized water formulation was less ($P<0.05$) intense in color than treatments formulated without adjuncts. Treatments formulated with non-meat adjuncts and deionized water showed decreased ($P<0.05$) surface cracking when compared to the other treatments. Trained panelists found significant differences among treatments for visual characteristics (Table 1.15). The starch/deionized water treatment was less ($P<0.05$) cohesive than the control/municipal water formulation.

Table 1.14 EFFECTS OF MUNICIPAL OR DEIONIZED WATER ON UNIFORMITY OF COLOR, INTENSITY OF COLOR, AND SURFACE CRACKING OF CHUNKED AND FORMED CURED AND RETORTED HAM FORMULATED WITH NON-MEAT ADJUNCTS AND 25% PALE, SOFT AND EXUDATIVE (PSE) RAW MEAT MATERIAL EVALUATED BY TRAINED PANELISTS

Treatment	Uniformity of Color	Intensity of Color	Surface Cracking
Control Municipal Water	8.3[b]	5.4[ab]	5.7[a]
Soy Protein Municipal Water	8.0[b]	6.4[a]	5.9[a]
Starch Municipal Water	10.6[a]	4.9[abc]	6.1[a]
Control Deionized Water	9.1[ab]	5.6[ab]	6.3[a]
Soy Protein Deionized Water	9.5[ab]	4.9[bc]	2.6[b]
Starch Deionized Water	10.6[a]	3.6[c]	3.1[b]
Standard Error	1.3	1.2	1.4

[a,b] Means within a column with the same letter are not different (P>0.05)

Table 1.15 EFFECTS OF MUNICIPAL OR DEIONIZED WATER ON COHESIVENESS, CHEWINESS, OVERALL TEXTURE, AND JUICINESS OF CHUNKED AND FORMED CURED AND RETORTED HAM FORMULATED WITH NON-MEAT ADJUNCTS AND 25% PALE, SOFT, AND EXUDATIVE (PSE) RAW MEAT MATERIAL EVALUATED BY TRAINED PANELISTS

Treatment	Cohesiveness	Chewiness	Overall Texture
Control Municipal Water	10.1[a]	7.5[a]	8.7[a]
Soy Protein Municipal Water	8.6[ab]	5.7[ab]	7.6[ab]
Starch Municipal Water	8.5[ab]	4.9[b]	6.5[b]
Control Deionized Water	9.2[ab]	6.5[ab]	8.0[ab]
Soy Protein Deionized Water	9.1[ab]	5.8[ab]	7.9[ab]
Starch Deionized Water	7.8[b]	5.2[b]	7.0[b]
Standard Error	1.2	1.4	1.2

[a,b] Means within a column with the same letter are not different (P>0.10)

The addition of modified food starch to the formulation decreased ($P<0.10$) chewiness and ($P<0.05$) reduced toughness of overall texture when compared to the control/municipal water formulation. Trained experts reported no differences ($P>0.05$) among treatments in regards to juiciness, overall flavor, and saltiness (Table 1.16). The soy protein/municipal water treatment was higher ($P<0.05$) for off flavor and was lower ($P<0.10$) in acceptability when compared to all deionized water treatments (Table 1.16). All treatments scored between "like-slightly" and "like-moderately" excluding the soy protein/municipal water treatment, which scored between "neither like nor dislike" and "like slightly" (Table 1.16). The low score for the soy protein / municipal water treatment could be due to the increased off-flavor level. The acceptability scores of the trained panelists are similar to the consumer acceptability score for all treatments at between "like-slightly" and "like-moderately" (Table 1.4).

Table 1.16 EFFECTS OF MUNICIPAL OR DEIONIZED WATER ON OVERALL FLAVOR, OFF-FLAVOR, SALTINESS JUICINESS, AND ACCEPTABILITY OF CHUNKED AND FORMED CURED AND RETORTED HAM FORMULATED WITH NON-MEAT ADJUNCTS AND 25% PSE RAW MEAT MATERIAL EVALUATED BY TRAINED PANELISTS

Treatment	Overall Flavor	Off Flavor ^	Saltiness ^	Juiciness ^	Acceptability *
Control Municipal Water	9.9[a]	0.4[b]	4.1[a]	8.8[a]	6.3[ab]
Soy Protein Municipal Water	9.0[a]	1.1[a]	4.4[a]	10.5[a]	5.9[b]
Starch Municipal Water	9.8[a]	0.3[b]	3.7[a]	10.6[a]	6.5[ab]
Control Deionized Water	10.3[a]	0.1[b]	3.3[a]	9.9[a]	7.0[a]
Soy Protein Deionized Water	9.3[a]	0.2[b]	3.1[a]	9.6[a]	6.9[a]
Starch Deionized Water	9.5[a]	0.3[b]	3.5[a]	10.3[a]	6.8[a]
Standard Error	0.88	0.32	0.82	1.10	0.65

[a,b] Means within a column with the same letter are not different ^(P>0.05), *(P>0.10)

CHAPTER V

SUMMARY AND CONCLUSION

The use of deionized water can slightly improve the water holding capacity of boneless cured deli ham, but when there is not a problem with water hardness (<50 mg/L calcium carbonate), there are no overwhelming advantages to the use of deionized water that have been previously reported. Utilization of 50 % PSE meat decreased color quality and cooking yields in comparison to the 0 % PSE meat treatments.

In chunked and formed cured ham in a retorted pouched, the utilization of deionized water did not effect cooking loss. On average, the 50 % PSE formulation was significantly higher in cook loss than the both 0 and 25 % PSE formulations Results also indicate that the retorting process reduces color variability from the raw meat materials since there are less differences in color between treatments than in the raw material and boneless deli hams. All treatments received scores of “like-slightly in consumer testing and trained evaluation had similar results with acceptability scores between “like-slightly” and “like-moderately.”

In chunked and formed cured ham in a retorted pouched with non-meat adjuncts, modified food starch reduced cook loss the greatest amount with a reduction of 13.5 % and soy protein concentrate reduced cook loss by 8 % when compared to the control treatment. The addition of soy protein concentrate elevated CIE L* values when compared to modified food starch. When compared to the control, modified food starch increased and soy protein concentrate decreased CIE a* values while both non-meat adjuncts increased CIE b* values. Consumer acceptability testing revealed that all treatments scored between "like-slightly" and "like-moderately" with the starch/deionized treatment being liked significantly less than all other treatments except for soy protein/municipal water treatment. Agglomerative hierarchical clustering of the panelists in the consumer acceptability testing revealed that a retorted ham product formulated with either deionized or municipal water and/or modified food starch is acceptable to a large group of consumers. This analysis also revealed that a large group of consumers liked all treatments and that some consumers did not like ham formulated with a percentage of soy protein concentrate.

The results of this research reveal that the use of deionized water improved yields in chunked and formed cured smoked deli ham but showed little effect on the yields of retorted ham products. This research also demonstrated that 25 % PSE raw meat material could be incorporated into the formulation of chunked and formed cured smoked deli ham and chunked and formed cured retorted ham with or without non-meat adjuncts without causing reduced quality, and the retort process can reduce color variability due to raw meat materials in a ham product. The addition of modified food starch in a retorted ham product increases yields without causing a decrease in consumer acceptability among a majority of consumer clusters.

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APPENDIX A

FIGURES 1.1, 1.2, AND 1.3

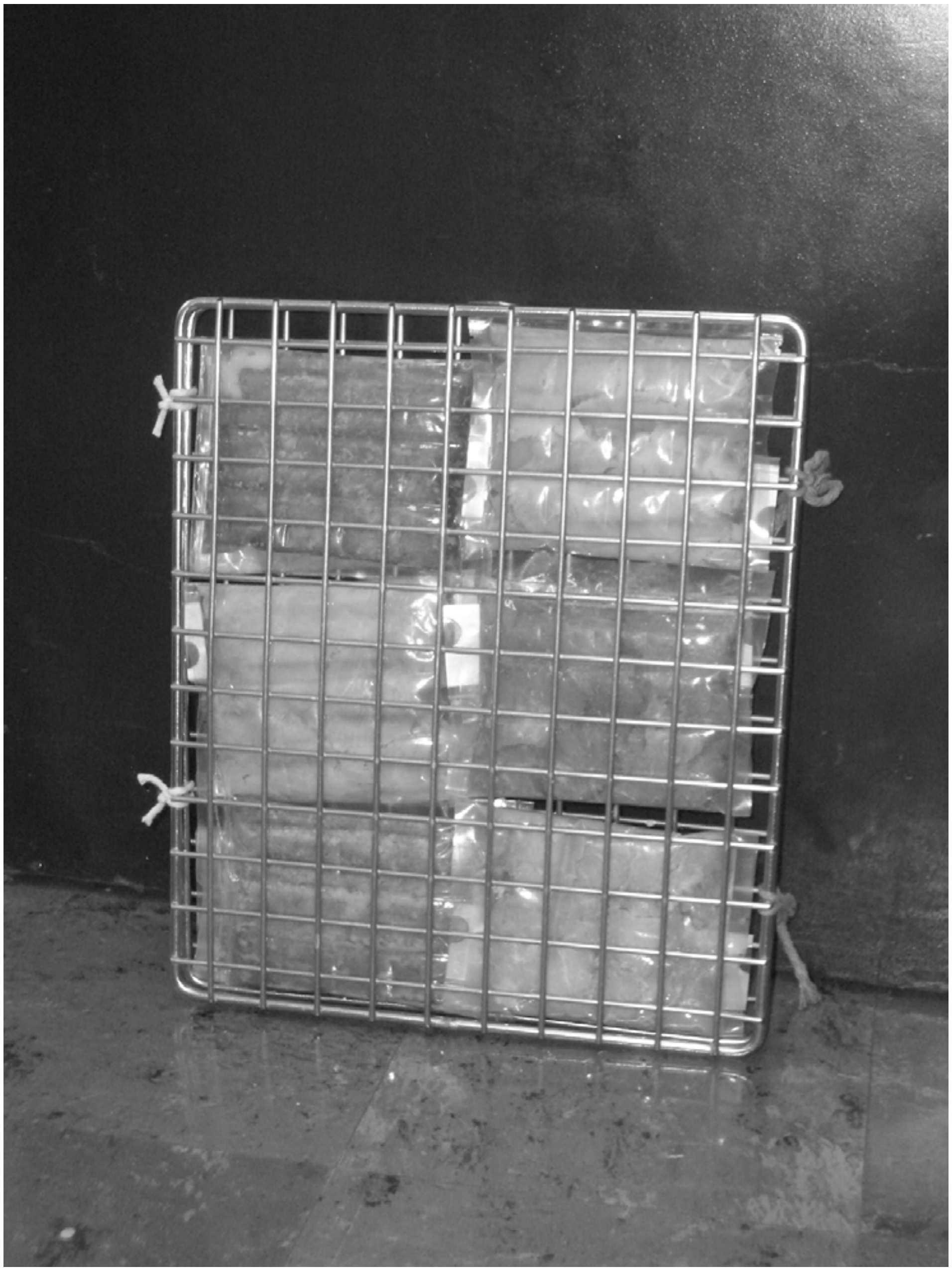

Figure 1.1 SIX RETORTABLE HAM POUCHES IN A 35.5CM X 30.5 CM STAINLESS STEEL MOLD

Product: Ham

Please rate ***Ham*** as follows: **Date:**___________________

Please taste each of the six (6) ham pieces starting with the sample number on the left and continuing to the right.

Please expectorate the sample and rinse your mouth with water in between samples.

Rate each sample for overall acceptability and place a check mark in your level of acceptability.

Each column will need one check mark.

OVERALL ACCEPTABILITY (LIKING)

490	878	176	593	238	909	
						Like extremely
						Like very much
						Like moderately
						Like slightly
						Neither like nor dislike
						Dislike slightly
						Dislike moderately
						Dislike very much
						Dislike extremely

Figure 1.2 EVALUATION INSTRUMENT FOR CONSUMER EVALUATION OF HAM PRODUCTS

Retorted Ham

Rep __

Name___________________

Date_____________

Sample Number____

Uniformity of Color

|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
0 5 10 15
not uniform uniform

Intensity of Color

|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
0 5 10 15
pale pink

Cracking

|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
0 5 10 15
no cracking extreme cracking

Cohesiveness

|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
0 5 10 15
not cohesive very cohesive

FIGURE 1.3 EVALUATION INSTRUMENT FOR EXPERT PANELIST EVALUATION OF RETORTED HAM PRODUCTS

Chewiness

|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
0 5 10 15
not chewy very chewy

Overall Texture

|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
0 5 10 15
mushy tough

Juiciness

|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
0 5 10 15
very dry very juicy

Salty

|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
0 5 10 15
not salty very salty

Off-flavor

|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
0 5 10 15
none very strong

Overall Flavor

|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
0 5 10 15
bland very flavorful

Overall Acceptability

1 2 3 4 5 6 7 8 9
dislike extremely — neither like nor dislike — like extremely

Figure 1.3 (CONTINUED)