5-1994

Effects of Whey Protein Concentrate, Phosphate, and Sodium Hydroxide on Texture and Acceptability of Turkey and Beef Rolls

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EFFECTS OF WHEY PROTEIN CONCENTRATE, PHOSPHATE, AND SODIUM HYDROXIDE ON TEXTURE AND ACCEPTABILITY OF TURKEY AND BEEF ROLLS

by

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A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Nutrition and Food Sciences

Approved:

UTAH STATE UNIVERSITY
Logan, Utah

1994

ACKNOWLEDGMENTS

I would like to thank Dr. Daren P. Cornforth for making it possible for me to come to Utah State University for working on this degree and for finding the funds for this project.

Appreciation is expressed to the other members of my graduate committee, Drs. Charles E. Carpenter and Deloy G. Hendricks, for their helpful suggestions and advice in the preparation of my thesis.

Thanks are also extended to my sponsor, Robert W. Thornley, for his financial and moral support of me and my family.

Special gratitude is expressed to my parents, Drs. Alla I. and Valentin P. Moiseev, for their moral support and encouragement.

Most of all I want to thank my beloved wife, Elena, for her moral support and helpful assistance. My son, junior Igor, has had to put up with a lot over the years so that I could reach this goal in my life.

Igor V. Moiseev

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ABSTRACT

Effects of Whey Protein Concentrate, Phosphate, and Sodium Hydroxide on Texture and Acceptability of Turkey and Beef Rolls

by

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Utah State University, 1994

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Processed turkey rolls were prepared with 1 or 3% whey protein concentrates WPC-50 (pH=5.80), WPC-60 (pH=4.53) and WPC-75 (pH=6.85) containing 50, 60 and 75% protein along with controls (phosphate and no phosphate). Control rolls made with 0.5% phosphate had the highest bind strength, and sensory evaluation scores. Only WPC-75 (1%) was acceptable as a binding agent and flavor enhancer. WPC-60 reduced pink discoloration of rolls, but flavor, bind and cohesiveness scores were unacceptably low. WPC-50 was not an effective binding agent. In general, rolls made with 3% WPC had lower scores for intensity of turkey flavor.

Bind strength and sensory characteristics were compared for restructured beef rolls formulated with 1% salt, 0.375% sodium tripolyphosphate (STPP) or 0.07% sodium hydroxide (NaOH), and 5, 10 or 20% added water. Controls also had 1%

salt, but no STPP or NaOH. Relative bind strength of rolls was STPP > NaOH > controls. Addition of 20% water reduced bind strength. Cooked yield, moisture content, beef flavor and texture of NaOH rolls were similar to STPP rolls. Bind strength and cohesiveness of NaOH rolls were lower than STPP rolls, but still acceptable.

For measuring bind strength of turkey and beef rolls, a sensitive and inexpensive penetrometer was developed. It was equipped with a top-loading balance, accessories, IBM-compatible personal computer and Quick-Basic program that allowed continuously collected penetration force data at specific time intervals. Penetrometer bind strength and taste panel cohesiveness of turkey and beef rolls were highly correlated (r=0.89 and r=0.93, respectively).

(114 pages)

CHAPTER I

INTRODUCTION AND OBJECTIVES

INTRODUCTION

Phosphate blends are widely used to increase cooked yield and improve texture of ham, poultry rolls and precooked roast beef. Phosphates are permitted up to 0.5% of final product weight (de Holl, 1981). However, phosphates are relatively expensive and are slow to dissolve in brines. There is also evidence that these phosphates impair absorption of zinc, calcium and iron (Zemel and Bidari, 1983; Mahoney and Hendricks, 1978). Thus, there is some interest in the development of alternative binding agents in cooked meats.

No limits are placed on the use of milk proteins in poultry rolls (de Holl, 1981). Work done by Dobson and Cornforth (1990) found that whey protein concentrate (34% protein, 50% lactose) was an effective binding agent in turkey rolls while calcium caseinate was a poor binding agent in absence of phosphate. Three percent of whey protein concentrate (WPC) was previously found to give good bind and cooked yield in turkey rolls, without producing any detectable "milk" flavor (Dobson and Cornforth, 1990).

It is permissible to use sodium hydroxide (NaOH) in combination with food grade phosphates in ham and bacon processing (Long *et al.*, 1982). Little information is available about use of NaOH in meat products. Knipe *et al.*

(1985) studied effects of NaOH, separately or in combination with various inorganic phosphates, on meat emulsion characteristics. The addition of 0.075% NaOH increased raw emulsion pH and solubilized protein more than addition of 0.30% tetrasodium pyrophosphate (NaPP), but NaPP resulted in more stable emulsions. NaOH also reduced product yields below that of the control. Anjaneyulu *et al.* (1990) evaluated sodium hydroxide and polyphosphate blends on the physico-chemical properties of buffalo meat and patties. Increasing the pH by NaOH incorporation improved emulsifying capacity, emulsion stability and patty yield while decreasing cooking loss and shrinkage, compared to controls. Thus, pH adjustment with NaOH can improve some physico-chemical parameters of meat products.

Texture and cohesiveness of restructured meat products may be evaluated by taste panelists, or by instrumental measurement of bind strength. Valid and predictive instrumental techniques of texture parameters are possible only when correlated with appropriate sensory evaluation procedures (Noble, 1975). An Instron Universal Testing Machine equipped with a penetrometer head has been recommended for bind measurements on restructured meats (Field *et al.*, 1984). However, an inexpensive penetrometer, which was developed here at Utah State University, can also be used for textural studies of restructured meat products (Dobson *et al.*, 1993).

OBJECTIVES OF THIS STUDY

The first objective in this study was to compare bind strength and sensory characteristics of turkey rolls made with 1 and 3% of commercial whey protein concentrates containing 50, 60 and 75% protein, compared to controls with and without phosphates.

The second objective was to compare the effects of 0.07% sodium hydroxide and 0.375% sodium tripolyphosphate, that give similar pH around 6.3, on bind strength, cooked yield, moisture, pH and sensory characteristics of beef rolls.

The third objective was to demonstrate application of the developed penetrometer for measuring bind strength on restructured meat products, and to determine correlation among instrumental and sensory data for turkey and beef rolls.

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CHAPTER II

PREVIOUS WORK - LITERATURE REVIEW

Non-Meat Binders in Comminuted Meat Products

The main functional properties of comminuted meat products include emulsifying capacity, emulsion stability, water binding, gelation and cohesion of meat particles. Improvement of meat protein functionality can be provided by adding non-meat ingredients to meat products. For many years, various non-meat additives have been used to improve the characteristics of meat products by binding either moisture or fat, a process which results in improved texture. Bind properties in meat products are improved when protein is extracted from the meat and can serve as a binder between the meat pieces. Non-meat binders can replace some of the functions of the extractable meat proteins. Several scientists have conducted research whereby protein additives of varying physical and chemical properties were studied in meat emulsions (Roberts, 1974). However, the results and conclusions of these studies have not been consistent. Most of the binders and fillers are various forms of milk products, soy products and cereal products such as flour from corn, wheat, barley, rice and potatoes. These and other non-meat ingredients have been used in the meat industry for many years, but little research has been published to document their effectiveness and performance.

Milk Proteins in Meat Products

In the United States, the use of milk protein is allowed in nonspecific meat products, such as loaves and imitation sausages. Examples of products that have milk proteins incorporated into their formulations are frankfurters, sausages, poultry nuggets, reformed roasts and reformed hams. Meat technologists continually look for new additives or procedures to make the most acceptable and cost efficient products possible. Milk proteins have been promoted as enhancing both the functional and sensory characteristics of various processed meat products. Reported benefits include increasing emulsion stability, increasing water-holding capacity, increasing cohesion between meat particles, reducing rancidity development, replacing phosphates and improving gel strength and color (whitening) (Andres, 1986; Hoogenkamp, 1989; van den Hoven, 1987).

Comminuted meat products basically consist of meat, fatty tissue, added water, salt, phosphate, spices and some minor ingredients. If the water and fat have not formed a stable emulsion before thermal processing, problems will occur such as decreased yield, loss of the fat from the protein matrix, poor binding of meat particles and unacceptable appearance of the product. The myofibrillar proteins (myosin, actin and actomyosin) are generally recognized as the major emulsifying proteins in meat products. Myosin and other salt-soluble myofibrillar proteins are able to emulsify fat and bind water (gelation) by forming hydrophobic and hydrophilic (stabilizing) bonds that make the meat products stable (Mittal and Usborne, 1985; van den Hoven, 1987). If extraction of these proteins is poor or the proteins remain in a native form, then the product may not be stable during cooking. Milk proteins are used to overcome stability problems. Milk proteins emulsify free fat in meat emulsions, thereby saving the salt-soluble proteins for water binding and gel matrix formation. However, they are less effective in emulsifying and gelation of meat products than are the myofibril proteins, but are more effective than the sarcoplasmic proteins or connective tissue (van den Hoven, 1987). Higher levels of protein in the meat products, due to addition of milk proteins, increased water-holding capacity after cooking of products (Hoogenkamp, 1989). Milk proteins may be successfully added to comminuted meat as jellies containing 10-15% milk protein in water, as pre-emulsions of milk protein, fat and water, or as dry milk powder at the beginning of the comminution process (van den Hoven, 1987).

Whey Protein Concentrate in Meat Products

Liquid whey is a by-product of cheese manufacture. The annual production of fluid whey is rising. In 1985, 20×10^9 kg of fluid whey was produced, much of which was never used (Kinsella and Whitehead, 1989). Only 20% of whey produced annually in the U.S. is processed into whey products used for human consumption (Casella, 1983). Whey proteins represent approximately 20% of the total protein found in milk (Morr, 1979). Whey protein concentrates (WPC) are good nutritional sources of protein and available at a relatively lower price than other currently used binders and extenders. Whey protein concentrate can be produced from either sweet whey or acid whey. Sweet whey or rennet whey is a by-product of natural cheese production. Acid whey is a byproduct of cottage cheese and casein production. When whey protein is concentrated, the processing method will affect the functionality of the finished product. However, WPC composition generally parallels composition of the whey itself (Josephson *et al.*, 1975; Matthews, 1978). A wide range of composition has been reported for WPC prepared by different techniques. The approximate compositional ranges reported are: from 29 to 95% protein, from 1.0 to 80% lactose, from 1.0 to 18% ash and from 1.0 to 9.0% fat (Delaney, 1976; Mavroupoulou and Kosikowski, 1973; Morr *et al.*, 1973). Since lactose is a major constituent of WPC, it may significantly contribute to the overall functionality of these milk proteins. Carbohydrates are known for their ability to form hydrogen bonds with water, with other polar molecules and among themselves. Lactose is able to entrap more polar molecules than monosaccharides are able to entrap (Swaisgood, 1985). In meat products, lactose is used to increase the total solids content of a brine, thus increasing the ionic strength. Lactose is also effective in masking strong salt, phosphate and bitter after-tastes. Lactose is a reducing sugar which helps in stabilizing the products to oxidation (van den Hoven, 1987). Other functions of lactose include enhancing flavor, increasing sweetness and adding browning to baked goods (Swaisgood, 1985). Whey proteins are an excellent source of essential amino acids, particularly lysine (Orr and Watt, 1968; Holsinger *et al.*, 1971). The high lysine content may be of benefit in replacing the lysine lost during cooking of meat products.

Lee *et al.* (1980) used NFDM, dry whey and WPC (18.7% and 32.5% proteins) in loaf products. Bind strength (as measured by Instron shear) and tenderness (as evaluated by a test panel) of these treatments were the same. The use of dry whey and WPC (32.5% protein) resulted in a juicier and more flavorful loaf product when compared with NFDM. Schmidt *et al.* (1984) reported that WPC did not possess the ability to be an active emulsifier due to the uniform distribution of the hydrophobic and hydrophilic regions. Dobson and Cornforth (1990) found that several milk powders (WPC, NFDM, calcium caseinate) increased cooked yield of turkey rolls compared to controls. They observed that in absence of phosphate, rolls containing WPC and NFDM had very acceptable bind and texture, while rolls containing the more expensive calcium caseinates had unacceptable texture. Improvement of cohesiveness in comminuted meat products with WPC could be explained by their gelation properties. WPCs are low in proline and have many S-S bonds, leading to a globular, strongly folded and organized structure. During cooking of meat products, WPC proteins unfold, and, depending on pH and concentration, they build intermolecular disulfide bonds with meat proteins resulting in a WPC-meat gel network. After WPC was approved by the USDA as a binder in sausages (USDA, 1982), Ensor *et al.* (1987) evaluated WPC at levels of 0, 1.75, 2.0 and 3.5% against soy protein isolate (SPI) and calcium-reduced nonfat dry milk (RNFDM) on their ability to form a stable emulsion in knockwurst, an emulsion-type product which used lean pork and beef. WPC proved to be a good alternative binder for emulsion-type sausages by providing similar stability, sensory and textural attributes in comparison to equal levels of SPI and RNFDM.

Whey Proteins

Whey proteins represent 20% of the total milk proteins (Brunner, 1977). They are characterized by their solubility at pH 4.6. Whey protein is a globular, strongly folded, organized protein due to the many disulfide bonds (van den Hoven, 1987). Whey protein also contains many hydrophobic regions more evenly distributed in the protein than in the caseinate (Schmidt and Morris, 1984). Whey protein contains five protein types: α-lactalbumin, β-lactoglobulin, bovine serum albumin, immunoglobulin and proteosepeptones.

β-lactoglobulin is the major protein in the whey fraction. With approximately 3.7 g/L of β-lactoglobulin present in milk, it represents 62% of the whey protein fraction (Kinsella and Whitehead, 1989). The primary amino-acid sequence of β-lactoglobulin can be found in Dalgleish (1989). β-lactoglobulin has a molecular weight of 18,362 for polymorph A and 18,276 for polymorph B. Monomeric β-lactoglobulin contains one free sulfhydryl group and two disulfide groups (Brunner, 1977). β-lactoglobulin is globular, with hydrophobic and sulfhydryl groups located in the interior. β-lactoglobulin undergoes time and temperature-dependent denaturation reactions at temperatures above 65^0 C, resulting in exposure of the internal sulfhydryl group, highly reactive hydrophobic groups and ϵ-NH_2-groups (Brunner, 1977). Oxidation of free sulfhydryls and thioldisulfide interchange reactions can be induced by heating whey-protein solutions, leading to polymerization of whey-protein molecules (Shimada and Cheftel, 1989).

α-lactalbumin accounts for 25% of the whey protein. It is globular, having a molecular weight of 14,000 and four disulfide bonds. It actively bonds calcium which may stabilize α-lactalbumin against denaturation (Kinsella and Whitehead, 1989).

Bovine serum albumin (BSA) is a large globular protein of 66,000 molecular weight, containing seventeen disulfide bonds and one free thiol group. BSA binds lipids and flavors, stabilizing them against denaturation (Kinsella and Whitehead, 1989).

The immunoglobulins and proteose-peptone fractions represent the remainder of the whey proteins. The immunoglobins are thermally unstable. The proteose-peptones are amphophilic and may affect protein functionality (Kinsella and Whitehead, 1989).

Efficient purification procedures for whey protein isolates (WPI) and whey protein concentrates have been developed. Ultrafiltration techniques are currently employed to isolate undenaturated WPCs. High performance hydrophilic ion exchange is used to purify WPIs. WPCs range from 25% to 80% whey protein, whereas WPIs have protein contents greater than 80%. Whey proteins are currently used in baked goods, confectionery, infant food and meat products, as well as in animal feed.

Use of Phosphate and Sodium Hydroxide in Meat Products

Phosphates are widely used to increase bind strength, water binding and yield of cooked meat products (Siegel and Schmidt, 1979). The addition of appropriate phosphates increases the water-holding capacity of raw and cooked meats (Hamm, 1970). Phosphates are used in the production of sausages and in the curing of ham, and to decrease drip losses in poultry and seafood. Sodium tripolyphosphate

($Na_5P_3O_{10}$) is the phosphate most commonly added to processed meat, poultry and seafood. It is often used in blends with sodium hexameta-phosphate [$(NaPO_3)_n$, n=10-15] to increase tolerance to calcium ions that exist in brines used in meat curing. Ortho- and pyrophosphates often precipitate if used in brines containing substantial amounts of calcium. The mechanism by which alkaline phosphate and polyphosphates enhance meat hydration and cohesiveness of comminuted meat products is not clearly understood despite extensive studies. The action may involve the influence of pH changes, effects of ionic strength and specific interactions of phosphate anions with divalent cations and myofibrillar proteins (Schmidt and Trout, 1982; Knipe *et al.*, 1985b). Product acceptability is largely dependent upon the degree of bind developed among meat particles. In comminuted meat products, such as bologna and sausage, the addition of sodium chloride (2.5-4.0%) and polyphosphate (0.35-0.5%) contributes to a more stable emulsion and to a cohesive network of coagulated proteins after cooking. Phosphates are permitted up to 0.5% of final product weight (de Holl, 1981). However, phosphates have been reported to decrease zinc (Cabell and Earle, 1965) and iron (Mahoney and Hendricks, 1978) absorption and utilization in animals. Thus, there is interest in alternatives to phosphates in cooked meats.

Alkaline or basic substances are used in a variety of applications in foods and food processing. Although the majority of applications involve buffering and pH adjustments, other functions include carbon dioxide evolution, enhancement of color and flavor, solubilization of proteins, and chemical peeling. Alkali treatments are imposed on several food products for the purpose of color and flavor improvement. Ripe olives are treated with solutions of sodium hydroxide (0.25-0.20%) to aid in the removal of the bitter principal and to develop a darker color (Matz, 1962). Pretzels are dipped in solution of 1.25% sodium hydroxide at 87-88^0 C prior to baking to alter proteins and starch so that the surface becomes smooth and develops a deep brown color during baking (Matz, 1972). It is believed that the NaOH treatment used to prepare hominy and tortilla dough destroys disulfide bonds, which are base labile.

It is permissible to use sodium hydroxide (NaOH) in combination with food grade phosphates in ham and bacon processing (Long *et al.*, 1982). Little has been published about use of NaOH in meat products. Knipe *et al.* (1985a) studied effects of NaOH, separately or in combination with various inorganic phosphates, on meat emulsion characteristics. The addition of 0.075% NaOH increased raw emulsion pH and solubilized protein more than the addition of 0.30% tetrasodium pyrophosphate (NaPP), but NaPP resulted in more stable emulsions. NaOH also reduced product yields below that of the control. Anjaneyulu *et al.* (1990) evaluated effects of pH and polyphosphates blends on the physico-chemical properties of buffalo meat and patties. Minced buffalo meat was blended with 2% sodium chloride (NaCl), and the pH of the meat was increased with 0.5 N NaOH to the pH of the meat containing 2% NaCl and 0.5% polyphosphates blends. Increasing the pH by NaOH incorporation significantly improved the water-holding capacity, emulsifying capacity, emulsion stability and yield of patties and decreased cooking loss of meat and shrinkage of patties as compared to controls. Addition of polyphosphate blends improved emulsifying capacity, increased emulsion stability and yield of patties and reduced cooking loss and shrinkage of patties as compared to the NaOH-treated meat, which had higher water-holding capacity.

Instrumental Measurements of Texture Attributes in Meat Products

Many instrumental procedures for determination of textural attributes of foods have been developed. They analyze the mechanical or rheological behavior of materials almost identical to the manner in which texture is perceived sensorially. Proctor *et al.* (1956) developed the Denture Tenderometer for oral simulation of food texture evaluation. A set of dentures was attached to arms which could duplicate the vertical and horizontal motions of the human jaw. The General Foods Texturometer was used for imitation of the human bite by deformation of food in a curved path, but only with vertical action (Friedman *et al.*, 1963). Friedman *et* *al*. (1963) defined the textural parameters of cohesiveness, hardness, adhesiveness, brittleness, gumminess, elasticity and chewiness. Quantitative values for the textural parameters usually derive from force-distance or force-time curves for two compression cycles or "bites" to provide an instrumental texture profile analysis. The Instron Universal Testing Machine is the most useful machine for measuring textural parameters of food products. It has precise control of drive speed and force, and it can be equipped with different types of accessories. Instron can compress or extend a test material in one direction or in cycles along a straight path. The force required to deform test material is recorded continuously when its cross head moves up or down at chosen constant speeds. Instron equipped with a penetrometer head has been recommended for bind measurements on restructured meats (Field *et al*., 1984). Instron is very versatile, when equipped with the proper accessories (Warner-Bratzler and Allo-Kramer shear devises), but it is also prohibitively expensive for many industrial and university laboratories. Sensitive and inexpensive penetrometers, such as the penetrometer that was assembled at Utah State University (Dobson *et al*., 1993), can be used to measure the force to deform or penetrate restructured meat products.

Valid and predictive instrumental techniques of texture evaluation are possible only when correlated with appropriate sensory evaluation procedures (Noble, 1975). Intensity ratings of specific sensory attributes may validly be correlated to instrumental measurements. However, mathematical correlation models, developed by statistical correlation methods between instrumental and sensory evaluation procedures, describe only a predictive relationship (Noble, 1975).

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CHAPTER III

COMPARISON OF WHEY PROTEIN CONCENTRATES AS BINDING AGENTS AND FLAVOR ENHANCERS IN TURKEY ROLLS

ABSTRACT

Processed turkey rolls were prepared with 1 or 3% whey protein concentrates [WPC-50 (pH=5.80); WPC-60 (pH=4.53); WPC-75 (pH=6.85)] containing 50, 60 and 75% protein along with controls (phosphate and no phosphate). Control rolls made with 0.5% phosphate had the highest bind strength and sensory evaluation scores. Only WPC-75 (1%) was acceptable as a binding agent and flavor enhancer. WPC-60 reduced pink discoloration of rolls, but flavor, bind and cohesiveness scores were unacceptably low. WPC-50 was not an effective binding agent. In general, rolls made with 3% WPC had lower scores for intensity of turkey flavor.

INTRODUCTION

Whey protein concentrates (WPC) are good nutritional sources of protein and are available at a relatively lower price than currently used binders and extenders. Using WPC as an ingredient also provides environmental benefits since this by-product of the cheese industry is often discarded. Much industry effort has been done to increase utilization of cheese whey through processing into different kinds of WPC suitable for food applications. WPC is a USDA-approved binder in sausages, at levels up to 3.5% (USDA, 1982). Ensor *et al.* (1987) proposed that WPC could be used as an alternative to soy binders for specific emulsion-type meat products, providing similar stability, textural and sensory attributes. WPC improves water- and fat-binding properties in processed meat products without adversely affecting their flavor or textural properties (Morr, 1979). Lee *et al.* (1980) found that the use of WPC resulted in equal bind, increased juiciness and improved flavor in a meat loaf when compared to an equal level of nonfat dry milk (NFDM). Dobson and Cornforth (1990) found that several milk powders (WPC, NFDM, calcium caseinate) increased cooked yield of turkey rolls compared to controls. They observed that in absence of phosphate, rolls containing WPC and NFDM had very acceptable bind and texture, while rolls containing the more expensive calcium caseinates had unacceptable texture. Whey proteins are an excellent source of essential amino acids, particularly lysine (Orr and Watt, 1968; Holsinger *et al.*, 1971). The high lysine content may be of benefit in replacing the lysine lost during cooking of meat loaves. Phosphates, widely used to increase bind strength, water binding and yield of restructured meat products (Siegel and Schmidt, 1979), have been reported to decrease zinc (Cabell and Earle, 1965) and iron (Mahoney and Hendricks, 1978) absorption and utilization in animals. An important aspect of the development of processes for new whey protein concentrates involves the determination of their functional properties in various food products.

The purpose of this study was to assess the potential of several commercially available WPC formulations to serve as a binder and flavor enhancer in processed turkey roll. The whey protein concentrates were added at 1 and 3% levels to meat mixtures consisting of different percent of protein and pH and compared to controls with (0.5%) or without phosphate.

MATERIALS AND METHODS

Ingredients and Formulation

Three trials of turkey rolls were made according to the formula in Table 1. One or 3% (percentage of total meat weight) of WPC-50 (pH=5.80), WPC-60 (acidified to pH=4.53) or WPC-75 ("high-gel," pH=6.85) were used as binding agents.

Table 1 - Formulation of turkey rolls

Ingredients	Percent[a] (%)	Amount (kg)
Skinless turkey breast fillets	90	4.086
Skinless-boneless thigh meat	10	0.454
Ice water	10	0.454
Salt	1	0.045
WPCs	1 - 3	0.045 - 0.135
Phosphate	0.5	0.227

[a] As a percentage of total weight.

Sweet whey from cheddar cheese production was the source of raw material for production of WPCs. The composition of WPCs is presented in Table 2. WPC-60 was acidified to pH=4.53 by citric acid, and pH of WPC-75 was increased by addition of phosphates to 6.85. WPC-50, WPC-60 and WPC-75 were purchased from a large U.S. producer of cheddar cheese and WPC. Control treatments were made without phosphate or with 0.5% commercially available phosphate (Brifisol 414 "instantized," B.K. Ladenburg Corp., Cresskill, N.J.).

Table 2 - Composition of whey protein concentrates[a]

Component		WPC-50	WPC-60	WPC-75
Protein (%)		52.18	64.22	76.50
Lactose[b] (%)		35.54	24.45	7.65
Lipids (%)		4.37	5.09	6.75
Ash (%)		4.97	3.29	5.60
Moisture (%)		2.94	2.95	3.5
Minerals (mg/100 g):				
	Ca	595	364	395
	P	586	326	875
	Na	381	274	1130
	K	1295	860	610
pH		5.80	4.53	6.85

[a] Data from supplier.
[b] Calculated by difference.

Preparation of Turkey Rolls

Turkey rolls were made at ratio 90:10 of skinless turkey breast fillets and skinless/boneless thigh meat. Partially frozen breast meat was coarsely ground with a Hobart grinder (Koch Supplies, Inc., Kansas City, MO) through a 2.5-cm plate, and thigh meat was finely ground through a 0.31-cm plate. Four and half kilograms of ground meat and other ingredients were blended in a Hobart mixer bowl (Koch Supplies, Inc., Kansas City, MO) for 3-5 minutes to obtain a sticky mixture. The emulsions were then stuffed into 12-cm diameter, water impermeable, plastic casings (Cryovac, Salt Lake City, UT), using a manual stuffer (Koch, Kansas City, MO). Two rolls were prepared for each treatment. Control rolls were prepared in a similar manner. Rolls were then placed in the smokehouse (Model TR2-1700, Vorton, Inc., Beloit, WI) and cooked at 82^0 C, 100% relative humidity (dampers closed) to an internal temperature of 74^0 C. Total cooking time was 8-10 hours. Rolls were then removed from the smokehouse, cooled and held at 3^0 C until sensory evaluation.

Bind Measurements

Bind measurements were made using the penetrometer described by Dobson *et al.* (1993). The cooked rolls were sliced (Berkel slicer, Koch Supplies, Inc., Kansas City, MO) into 1.5 cm thick X 10 cm diameter slices. Slices were mounted on a plexiglass cylinder, similar to that described by Field *et al*. (1984). The slices were held in place by tapered needles, 0.4 cm apart and protruding 1.25 cm above the surface of the cylinder. The circle formed by the needles was 9 cm in diameter. The cylinder + meat slice was placed on a top-loading balance with digital readout and 1-g readability (Sartorius PT 6, 6000 g capacity, Baxter Scientific Products, Salt Lake City, UT), centered under the penetrometer rod, and tared to zero. The balance programmable menu code settings were set to "Unstable Ambient Conditions," and the data output parameter was set to "Automatic Output Synchronous with Display Regardless of Stability." The rod was advanced at maximum speed (2 cm/min) and force (g) was recorded in 0.4 sec intervals until the polished steel ball (1.9 cm diameter) on the end of the rod penetrated through the meat slice. Note that the term "force" is defined as "applied weight to penetrate the sample," measured in grams. The balance was connected to an IBM-compatible computer by a standard RS 232 cable. We developed a Quick-Basic program to collect data and specify the time interval between recorded values. The Microsoft Excel 4.0 program (Anon., 1992) was used to plot the data and to determine peak bind strength values.

Taste Panels

Potential panelists were asked to participate in a training session where they were given three samples to evaluate based on their own standards. This was followed by a group discussion where standards for each attribute were established. The most consistent panelists were selected to be on the trained panel. The attributes evaluated by the trained panel were flavor, texture, cohesiveness, juiciness, color uniformity, pink color intensity and overall acceptability. The attributes were evaluated using a seven-point scale, where 7 was high and 1 was low for each attribute. Flavor, texture, cohesiveness, juiciness and overall acceptability were evaluated on samples of 2.5 x 2.5 x 1.5-cm thick. Eight samples were coded, randomly arranged on partitioned plates and served at room temperature. Cold tap water was provided for mouth rinsing between samples. Pink color intensity and color uniformity were evaluated on 1.5-cm thick slices immediately after slicing. The 13 trained panelists were required to attend all experimental sessions in order to evaluate all three replications. All samples were evaluated within one week of cooking.

Statistical Analysis

Experimental data were analyzed using the StatView program (Anon., 1992b) for the Macintosh. Two-way ANOVA, multiple comparison Fisher's LSD values and correlation coefficients were computed for physico-chemical and sensory data. Correlations were based on nine means for physico-chemical and sensory data. Significance was accepted at the 5% confidence level.

RESULTS AND DISCUSSION

Mean values of relative bind strength of turkey rolls are presented in Table 3. Rolls made with phosphate had significantly higher bind strength than all other rolls. Addition of 1% WPC-60 decreased bind strength lower than most of the other treatments. All of the WPC treatments were not significantly different from the controls without phosphate.

Table 3 - Influence of whey protein concentratess on bind strength of turkey rolls

Treatment	Number of observations	Penetrometer bind strength mean ± SD (g)
No phosphate	9	748 ± 258[bc]
Phosphate	9	1217 ± 278[a]
3% WPC-50	9	873 ± 147[b]
3% WPC-60	9	728 ± 179[bc]
3% WPC-75	9	804 ± 103[b]
1% WPC-50	9	781 ± 78[b]
1% WPC-60	9	652 ± 163[c]
1% WPC-75	9	886 ± 191[b]

[a-c] Values within columns with the same superscript letter are not significant different ($p<0.05$).

Mean bind strength values (Figs. 1-3) varied over time with peaks at about 70-75 sec for rolls with 1 or 3% WPC. Time was about 45 sec for controls without phosphate and 85 sec for control with phosphate. Peak bind strength values sometimes differed in Table 1 versus Figs. 1-3 (e.g., for rolls with 1% WPC-75, mean peak bind strength was 886 g in Table 1 and 806 g in Fig. 3). In Table 1, peak values were averaged for each of the nine runs, regardless of time. In Figs. 1-3, peak values versus time were lower since the peak did not occur at the same time point for each run. The absence of any significant effect of WPC's pH on binding ability may be explained by buffering effects of the muscle. Therefore, the buffering capacity of the muscle could have eliminated any differences in pH (Siegel and Schmidt, 1979). According to Hamm (1970) and Knipe *et al.* (1985), phosphates increase bind strength due to their ability to dissociate actomyosin into actin and myosin, increasing the protein extraction from postrigor meats. This action of phosphate was probably more important for developing bind strength in turkey rolls than for formation of WPC-meat gels.

Results of sensory evaluation of turkey rolls are presented in Table 4. Rolls containing phosphate had the highest sensory scores. Among WPC treatments, rolls made with 1% WPC-75 were rated highest, and rolls made with 3% WPC-50 were rated lowest for intensity of turkey flavor.

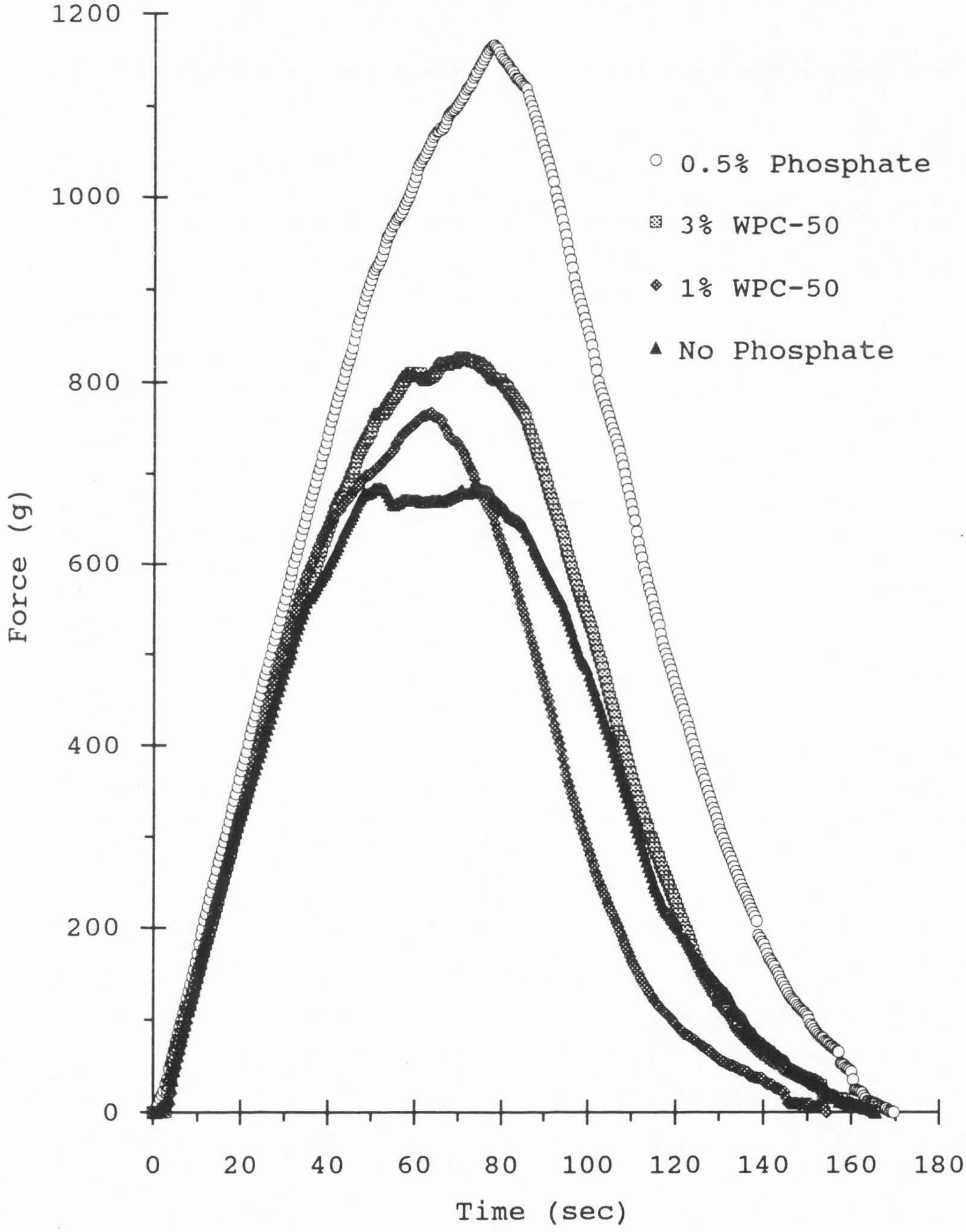

Fig. 1. - Penetrometer mean bind strength values with time for turkey rolls with WPC-50. For each point, n=9.

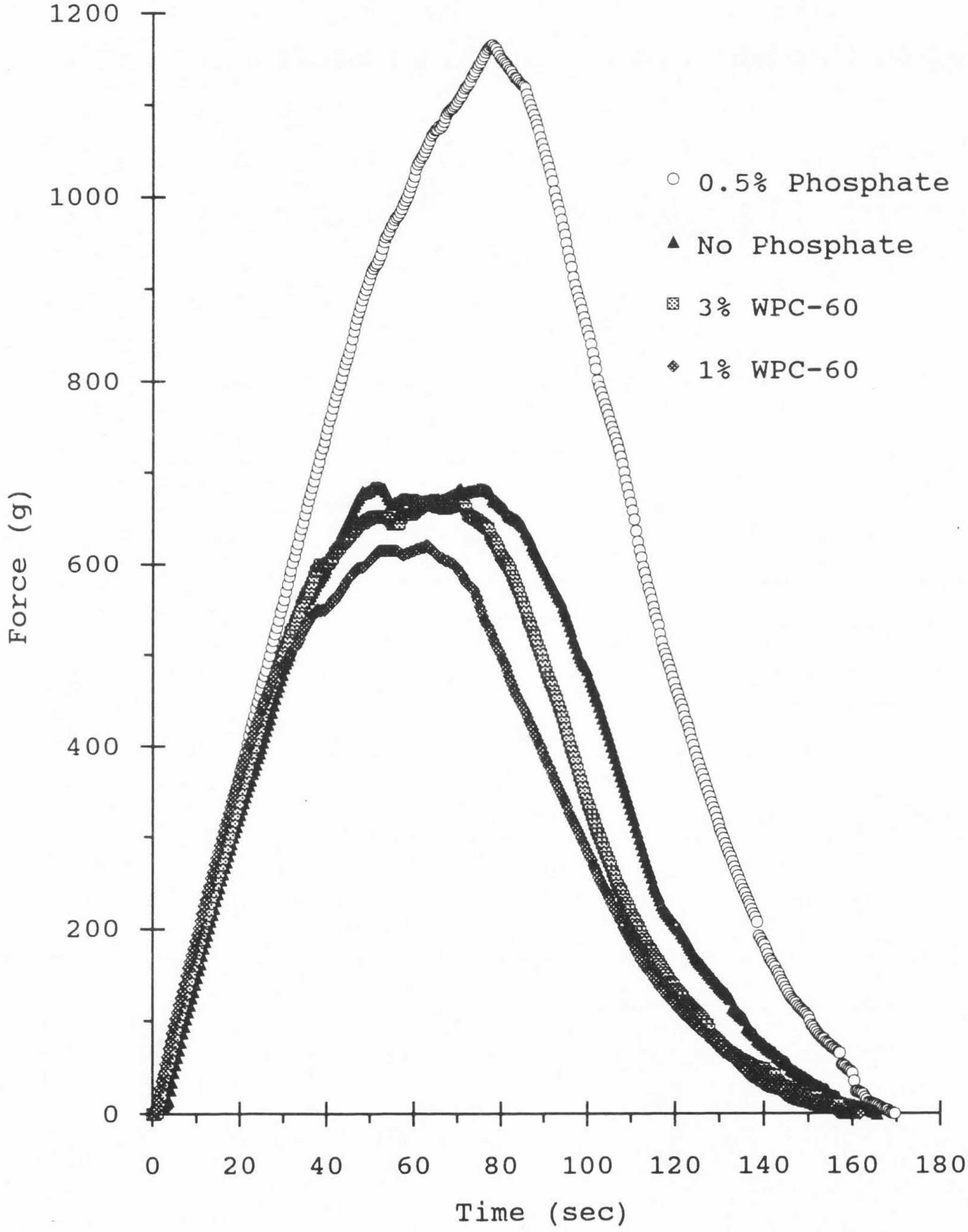

Fig. 2. - Penetrometer mean bind strength values with time for turkey rolls with WPC-60. For each point, n=9.

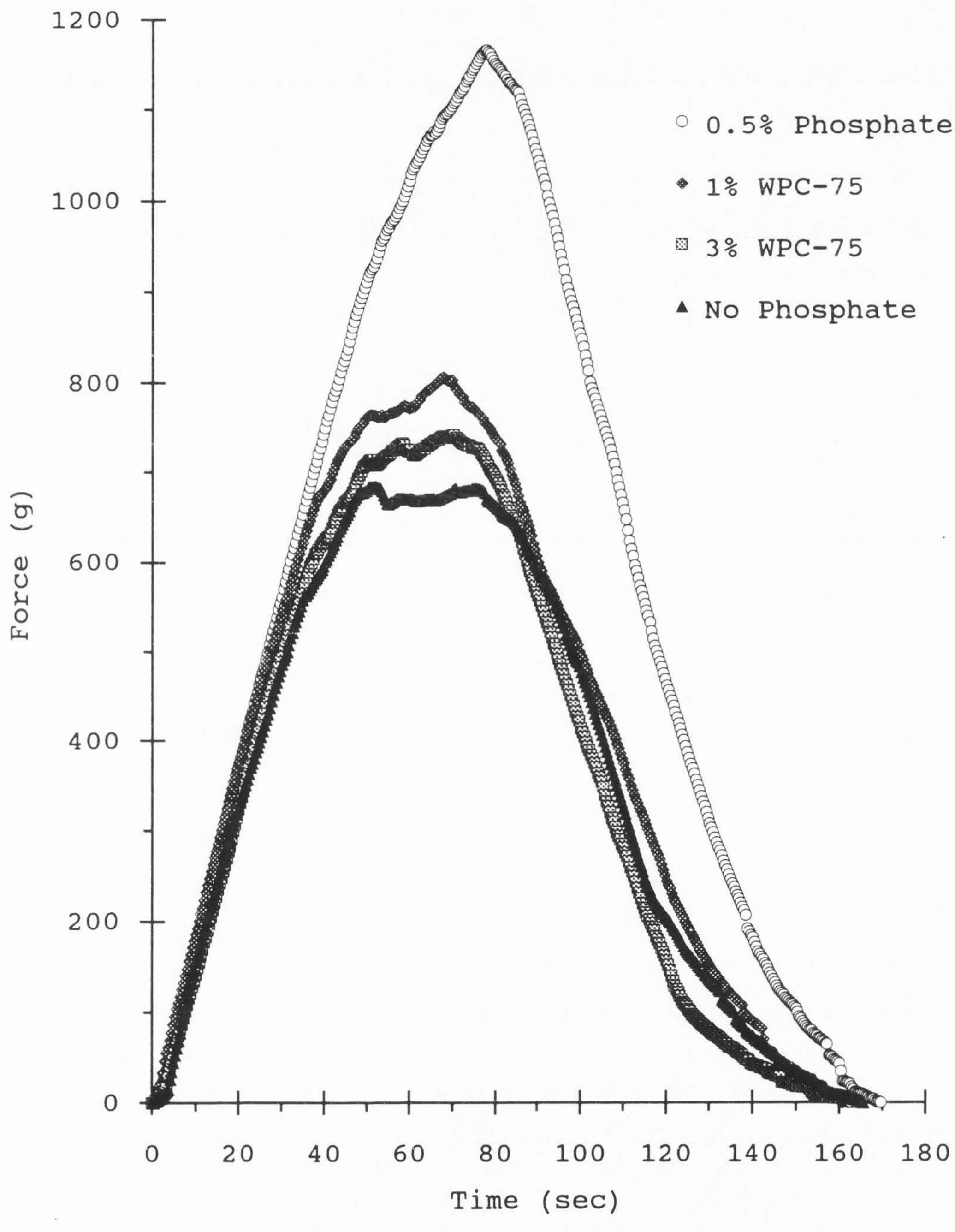

Fig. 3. - Penetrometer mean bind strength values with time for turkey rolls with WPC-75. For each point, n=9.

Table 4 - Sensory evaluation of turkey rolls[c]

Treatment	Flavor	Texture	Cohesive-ness	Juiciness	Color unifor-mity	Pink color	Overall
No phosphate	4.5 ±1.2^{a}	4.0 ±1.3^{a}	4.2 ±1.3^{b}	3.1 ±1.3^{bc}	4.2 ±1.4^{b}	4.0 ±1.1^{bc}	4.3 ±1.1^{b}
Phosphate	4.7 ±1.4^{a}	4.5 ±1.0^{a}	5.0 ±1.1^{a}	4.5 ±1.3^{a}	5.0 ±1.0^{a}	5.2 ±1.1^{a}	5.3 ±1.0^{a}
3% WPC-50	3.5 ±1.5^{b}	3.8 ±1.2^{ab}	4.0 ±1.1^{b}	3.0 ±1.2^{bc}	3.4 ±1.4^{bc}	3.7 ±1.1^{c}	4.0 ±1.3^{bc}
3% WPC-60	3.9 ±1.7^{ab}	3.6 ±1.2^{ab}	4.2 ±1.4^{b}	3.1 ±1.4^{bc}	3.7 ±1.5^{bc}	3.3 ±1.4^{c}	3.9 ±1.4^{bc}
3% WPC-75	4.5 ±1.6^{a}	4.2 ±1.0^{a}	4.4 ±1.2^{b}	3.0 ±1.3^{bc}	3.8 ±1.3^{b}	4.3 ±1.1^{b}	4.4 ±1.2^{b}
1% WPC-50	4.7 ±1.1^{a}	3.5 ±1.1^{b}	4.0 ±1.3^{b}	3.7 ±1.3^{b}	3.8 ±1.3^{b}	4.6 ±1.3^{ab}	4.4 ±1.1^{b}
1% WPC-60	4.4 ±1.4^{a}	3.8 ±1.0^{ab}	3.8 ±1.1^{bc}	3.3 ±1.3^{b}	3.7 ±1.0^{bc}	3.8 ±1.2^{bc}	4.2 ±1.2^{bc}
1% WPC-75	4.9 ±1.4^{a}	3.8 ±0.9^{ab}	4.3 ±1.2^{b}	3.7 ±1.2^{b}	4.3 ±1.2^{b}	5.0 ±1.2^{a}	4.8 ±1.2^{b}

[a-d] Values within columns with the same superscript letter are not significantly different ($p<0.05$).
[c] Values are mean ± SD.

Texture scores were higher for rolls made with phosphate; rolls made with 3% WPC-75 were the second highest. Also, rolls with phosphate had higher cohesiveness than rolls made with WPC. Color uniformity and intensity of pink color scores were lower for all WPC rolls than for rolls with phosphate. The pink color that sometimes develops during refrigerated storage of turkey rolls is usually considered undesirable since the product may be considered by some to be undercooked (Dobson and Cornforth, 1992). Thus, the lower incidence of pink color in rolls made with 3% WPC-60 would be considered a positive attribute. Among WPC treatments, rolls made with 1% WPC-75 were rated highest for overall acceptability.

Bind strength was lower for all treatments in the third trial, apparently because the turkey meat was obtained from a different source than for the first two trials (Appendix A). However, in all trials, treatment effects were similar. For taste panel results, no significant differences were observed among trials.

CONCLUSIONS

Rolls made with 0.5% phosphate had the highest bind strength and sensory evaluation scores. WPC-75 (1%) was acceptable as a binding agent and flavor enhancer. WPC-60 reduced pink discoloration of rolls, but flavor, bind and cohesiveness scores were unacceptably low. WPC-50 was not an effective binding agent. Also, 3% WPC-50 lowered the intensity of turkey flavor. In general, rolls made with 3% WPC had lower scores for intensity of turkey flavor. Thus, only WPC-75 at the 1% usage level has potential as an additive to processed turkey rolls.

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CHAPTER IV

EFFECTS OF SODIUM HYDROXIDE AND SODIUM TRIPOLYPHOSPHATE ON BIND STRENGTH AND SENSORY CHARACTERISTICS OF BEEF ROLLS

ABSTRACT

Bind strength and sensory characteristics were compared for restructured beef rolls formulated with 1% salt, 0.375% sodium tripolyphosphate (STPP) or 0.07% sodium hydroxide (NaOH), and 5, 10 or 20% added water. Controls also had 1% salt, but no STPP or NaOH. Relative bind strength of rolls was STPP > NaOH > controls. Addition of 20% water reduced bind strength. Cooked yield, moisture content, beef flavor and texture of NaOH rolls were similar to STPP rolls. Bind strength and cohesiveness of NaOH rolls were lower than STPP rolls, but still acceptable.

INTRODUCTION

Phosphates are widely used to increase bind strength, water binding and yield of cooked, restructured meat products (Siegel and Schmidt, 1979). Product acceptability is largely dependent upon the degree of bind developed among meat particles. Phosphate action is attributable to the increase of both pH and ionic strength in meat products (Schmidt and Trout, 1982). Phosphates are permitted up to 0.5% of final product weight (de Holl, 1981). However, phosphates are expensive and insoluble in salt brines, and may impair absorption of zinc, calcium and iron (Zemel and Bidari, 1983; Mahoney and Hendricks, 1978). Thus, there is interest in alternatives to phosphates in cooked meats.

It is permissible to use sodium hydroxide (NaOH) in combination with food grade phosphates in ham and bacon processing (Long *et al.*, 1982). Both NaOH and alkaline inorganic phosphates raise the pH of meat products. Increasing meat pH above its isoelectric point significantly enhances water-holding capacity, emulsifying capacity and protein solubility (Knipe *et al.*, 1985a). Little has been published about the use of NaOH in meat products. Knipe *et al.* (1985b) studied effects of NaOH, separately or in combination with various inorganic phosphates, on meat emulsion characteristics. Addition of 0.075% NaOH increased raw emulsion pH and solubilized protein more than did addition of 0.30% tetrasodium pyrophosphate (NaPP), but NaPP resulted in more stable emulsions. NaOH also reduced product yields below that of the control. Anjaneyulu *et al.* (1990) evaluated sodium hydroxide and polyphosphate blends on the physico-chemical properties of buffalo meat and patties. Increasing the pH by NaOH incorporation improved ($p<0.01$) emulsifying capacity, emulsion stability and patty yield while decreasing cooking loss and shrinkage, compared to controls. Thus, pH adjustment with NaOH can improve some physico-chemical parameters of meat products.

The purpose of this study was to compare the effects of sodium hydroxide (NaOH) and sodium tripolyphosphate (STPP) on bind strength, cooked yield, moisture, pH and sensory characteristics of beef rolls.

MATERIALS AND METHODS

Experimental Design

The experiment was a 3 x 3 factorial design with three types of non-meat ingredients: a) 1% salt + 0.07% sodium hydroxide; b) 1% salt + 0.375% sodium tripolyphosphate; c) 1% salt (control without sodium hydroxide or sodium tripolyphosphate), and with three levels of added water (5, 10, 20%). Three trials were performed. All percentage values were calculated as percent of meat weight.

Meat Formulation and Processing

Choice beef inside rounds were trimmed of fat and passed once through a 2.5-cm grinder plate of a Hobart grinder (Koch Supplies, Inc., Kansas City, MO). Ten percent of the meat was fine ground through a 0.31-cm plate. For each treatment, 4.54 kg of coarse and fine-ground meat in a ratio 90:10 was mixed for 2 min in Hobart mixer bowl (Koch Supplies, Inc., Kansas City, MO). During mixing, NaCl (1%) was added to all beef rolls. STPP (0.375%) and NaOH (75 ml 1 N NaOH, 0.07%) were added as appropriate, based on meat weight. STPP was dissolved in a small volume of hot water to ensure complete phosphate solubility. Enough cold water was added to give

5, 10 or 20% added water based on meat weight. Meat was manually stuffed (Koch Supplies, Inc., Kansas City, MO) into 15-cm diameter water impermeable plastic casings (Cryovac Division, W.R. Grace, Simpsonville, SC). Two rolls were made per treatment. Rolls were cooked (about 7 hrs) to 74^0C internal temperature in a smokehouse (Model TR2-1700, Vorton, Inc., Beloit, WI) at 82^0C with closed dampers (100% relative humidity). Cooked beef rolls were cooled by cold water shower for 2 min and stored at 3^0C for 3-4 days before evaluation.

pH Measurement

pH was measured after blending 10 g sample with 90 ml deionized water for 1 min with a Polytron homogenizer (Brinkmann Instruments, Westbury, NY). The pH of filtered homogenate was measured with an Orion pH meter model 420A (Orion Inc., Cambridge, MA).

Moisture Content

Moisture content was determined as weight loss after samples were dried in a convection oven at 100^0 C for 16 hrs (AOAC, 1990).

Cooked Yield

After removal from the oven and cooling to approximately 3^0 C, beef rolls were weighed. One end of the casing was opened. The broth was drained and the rolls were reweighed.

Yield of cooked beef rolls was determined as broth-free weight/initial weight x 100%.

Bind Measurements

Bind measurements were made using the penetrometer described by Dobson *et al.* (1993). The cooked rolls were sliced (Berkel slicer, Koch Supplies, Inc., Kansas City, MO) into 1.5 cm thick X 10 cm diameter slices. Slices were mounted on a plexiglass cylinder, similar to that described by Field *et al.* (1984). The slices were held in place by tapered needles, 0.4 cm apart and protruding 1.25 cm above the surface of the cylinder. The circle formed by the needles was 9 cm in diameter. The cylinder + meat slice was placed on a top-loading balance with digital readout and 1 g readability (Sartorius PT 6, 6000 g capacity, Baxter Scientific Products, Salt Lake City, UT), centered under the penetrometer rod, and tared to zero. The balance programmable menu code settings were set to "Unstable Ambient Conditions," and the data output parameter was set to "Automatic Output Synchronous with Display Regardless of Stability." The rod was advanced at maximum speed (2 cm/min), and force (g) was recorded at 1 sec intervals until the polished steel ball (1.9 cm diameter) on the end of the rod penetrated the meat slice. Note that the term "force" is defined as "applied weight to penetrate the sample," measured in grams. The balance was connected to an IBM compatible computer by a standard RS 232 cable. We developed a Quick-Basic program to collect data and specify the time interval between recorded values. The Microsoft Excel 4.0 program (Anon., 1992) was used to plot the data and to determine peak bind strength values.

Taste Panels

Taste panelists evaluated beef rolls in partitioned booths with red lighting to reduce color bias. Segments (1/8 slice) of control, alkali- and phosphate-treated rolls with the same level of added water (5, 10 or 20%) were coded, randomly arranged on partitioned plates and served at room temperature. Panelists (n>34 per panel) evaluated samples using a seven-point descriptive scale for flavor (1 = no beef flavor and 7 = strong beef flavor); texture (1 = mushy and 7 = very hard); cohesiveness (1 = not cohesive and 7 = very cohesive); juiciness (1 = dry and 7 = very juicy) and overall acceptability (1 = very unacceptable and 7 = very acceptable). Cold tap water was provided for mouth rinsing between samples. Nine sessions were held. All treatments and replicates were evaluated within one month after cooking.

Statistical Analysis

Experimental data were analyzed using the Statistica program (Anon., 1991) for the Macintosh. Two-way ANOVA, multiple comparison Fisher's LSD values and correlation coefficients were computed for physico-chemical and sensory data. Correlations were based on nine means for physico-chemical and sensory data. Significance was accepted at the 5% confidence level.

RESULTS AND DISCUSSION

Mean values of physico-chemical characteristics for beef rolls are presented in Table 5. At all levels of added water, peak bind strength was higher for rolls prepared with STPP, compared to NaOH. Similarly, rolls with NaOH had stronger bind than controls had. The addition of 20% water reduced the bind strength of all treatments. Cooked yield of both STPP and NaOH rolls was higher than for controls. Moisture content was not affected by STPP or NaOH, but was higher at 20% added water than for rolls with only 5% added water. pH was about 6.07 for controls to pH 6.25 for rolls with STPP or NaOH. Mean bind strength values (Figs. 4-6) varied over time, with peaks at about 55-65 sec for rolls with STPP or NaOH, and at about 30-40 sec for controls. Peak bind strength values differed in Table 1 versus Figs. 4-6 (e.g., for rolls with STPP and 5% added water, mean peak bind strength was 1532 g in Table 1 and 1438 g in Fig. 4). In Table 1, peak values were averaged for each of the nine runs, regardless of time. In Figs. 4-6, peak values versus time were lower since the peak did not occur at the same time point for each run.

The improvement in bind strength associated with STPP was apparently not due to simply an increase in pH because

Table 5 - Physico-chemical characteristics of beef rolls[a]

H_2O[b]	Sample	Bind[c] strength (g)	Cooked yield (%)	Moisture (%)	pH
		n=9	n=6	n=6	n=6
5%	Salt[d]	733 ± 185	78.9 ± 1.7	67.3 ± 1.2	6.05 ± 0.04
5%	NaOH + Salt	1126 ± 359	83.3 ± 1.3	67.8 ± 0.9	6.29 ± 0.05
5%	STPP + Salt	1532 ± 495	84.8 ± 4.4	68.1 ± 1.2	6.21 ± 0.02
10%	Salt[d]	552 ± 158	75.8 ± 5.0	69.3 ± 1.8	6.10 ± 0.05
10%	NaOH + Salt	939 ± 250	81.4 ± 2.2	69.9 ± 1.3	6.26 ± 0.05
10%	STPP + Salt	1663 ± 466	83.5 ± 1.2	69.2 ± 0.9	6.21 ± 0.10
20%	Salt[d]	393 ± 129	73.6 ± 0.9	69.5 ± 2.2	6.07 ± 0.07
20%	NaOH + Salt	653 ± 254	77.6 ± 2.5	71.1 ± 1.5	6.30 ± 0.04
20%	STPP + Salt	1036 ± 458	79.6 ± 1.9	70.6 ± 0.8	6.25 ± 0.04
	Fisher's $LSD_{0.05}$	318	3.2	1.6	0.06

[a] Values are mean ± SD.
[b] Added water (%).
[c] Peak value.
[d] Control.

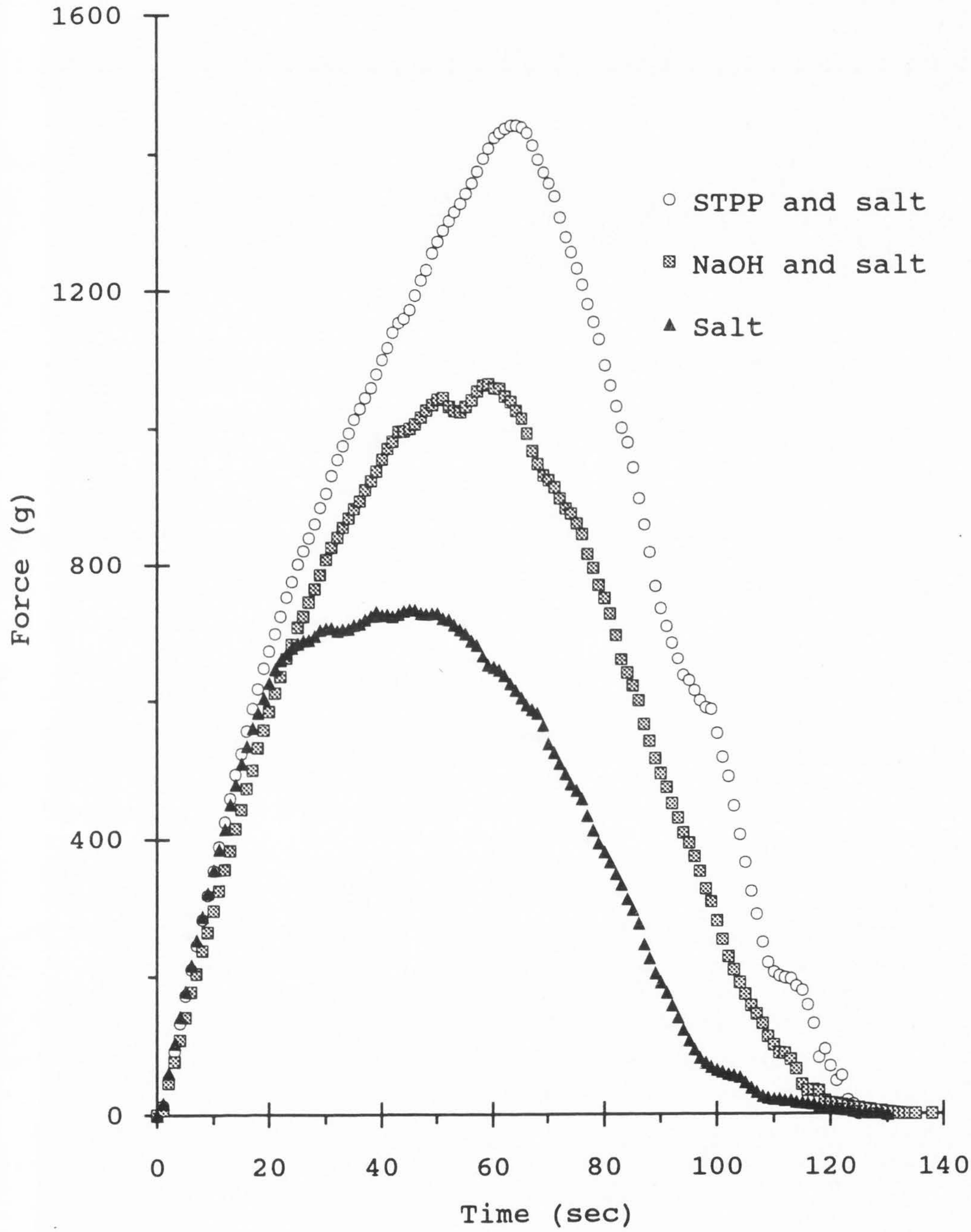

Fig. 4. - Penetrometer mean bind strength values with time for beef rolls with 5% added water. For each point, n=9.

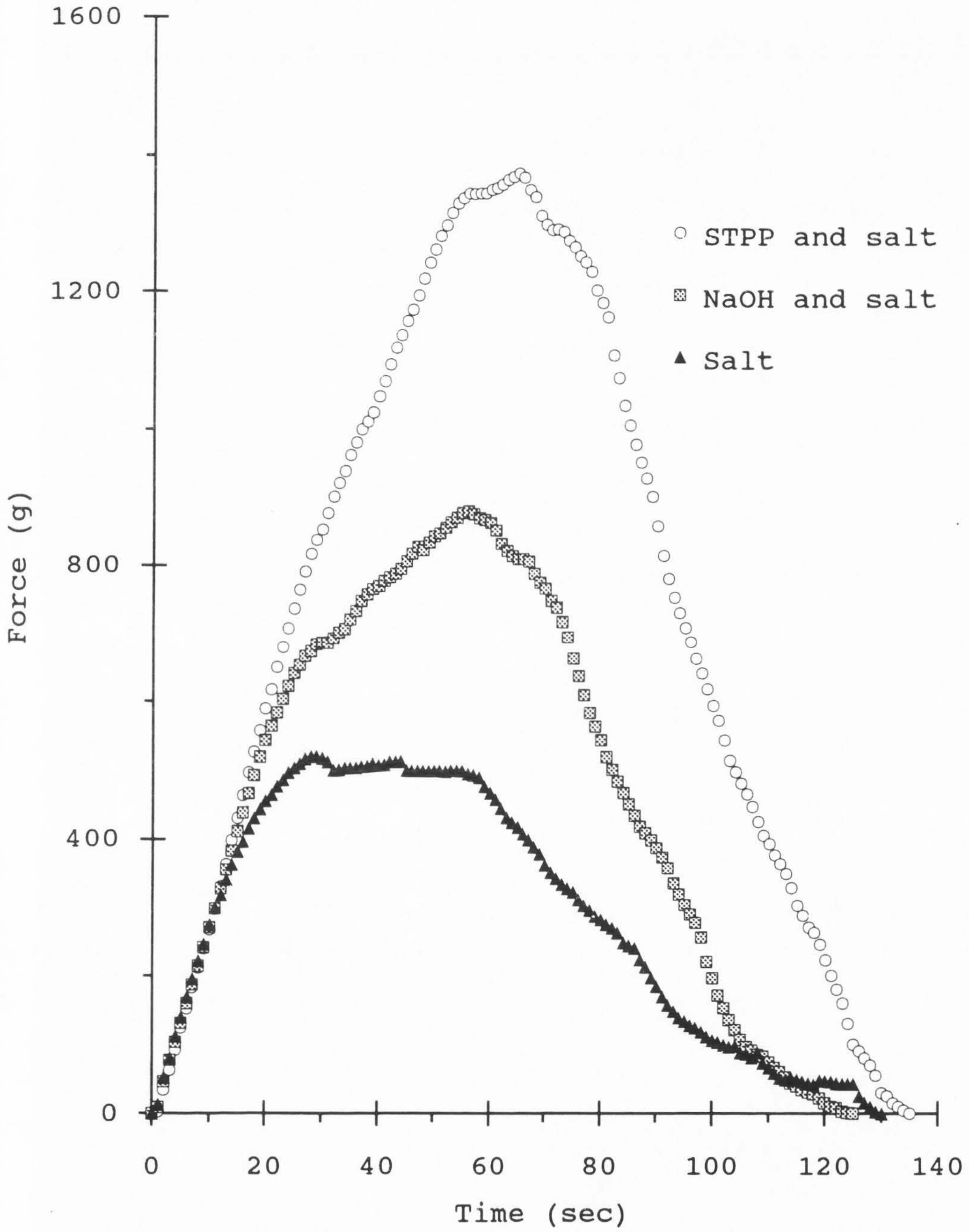

Fig. 5. - Penetrometer mean bind strength values with time for beef rolls with 10% added water. For each point, n=9.

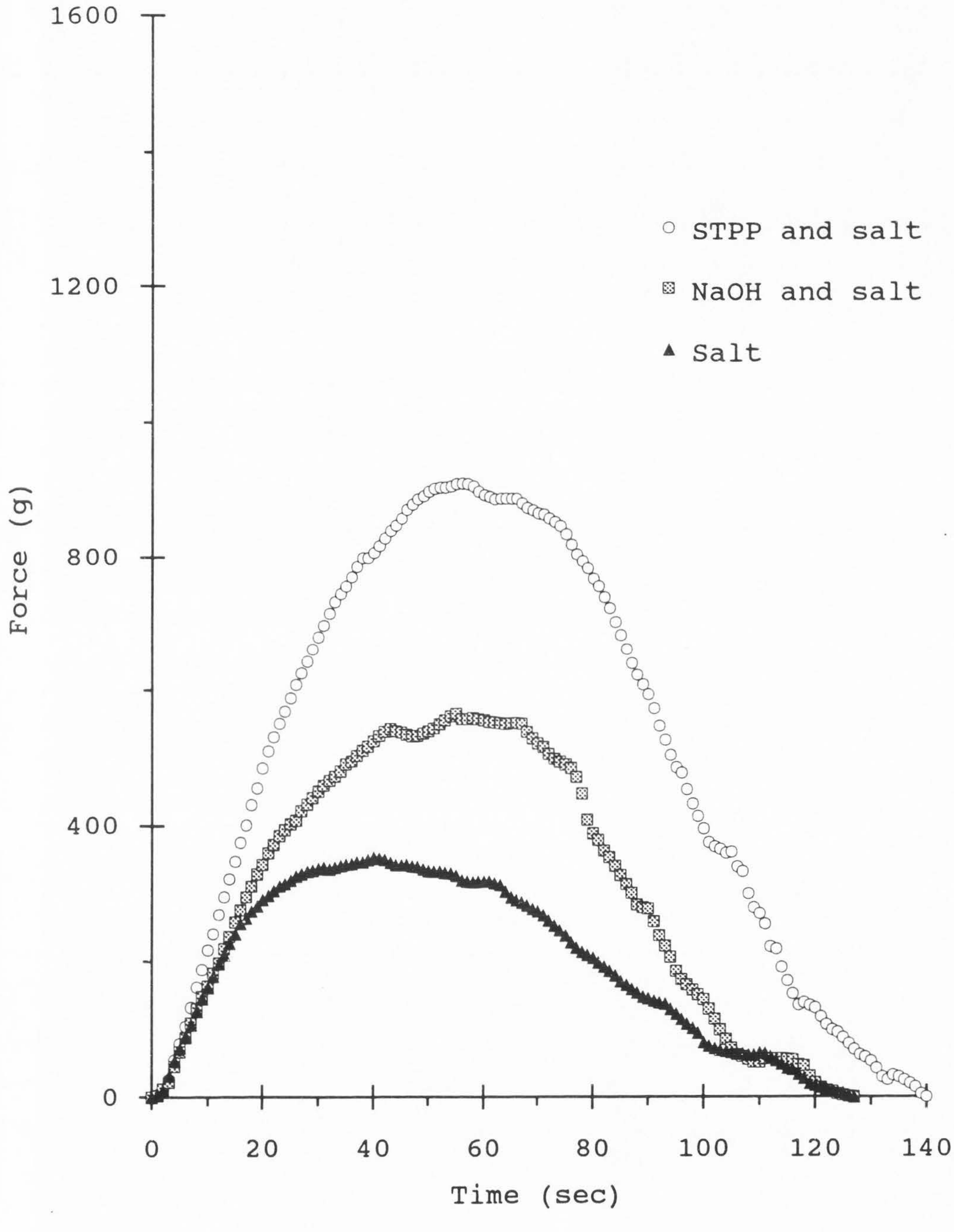

Fig. 6. - Penetrometer mean bind strength values with time for beef rolls with 20% added water. For each point, n=9.

rolls with NaOH had a similar pH, but a lower bind strength. According to Hamm (1970), phosphates also increase bind strength due to their ability to dissociate actomyosin into actin and myosin, increasing the protein extraction from post-rigor meats. The degree of extraction of myofibrillar proteins (particularly myosin) in meat products is related to both cooking yield and bind strength (Acton, 1972; Theno *et al.*, 1978; Turner *et al.*, 1979) and may in large part explain why the bind strength of rolls with STPP was higher than rolls with NaOH. In the present study, however, NaOH and STPP were equally effective in increasing the cooked yield.

Results of sensory evaluation of beef rolls are presented in Table 6. Rolls containing STPP had the highest cohesiveness and overall acceptability at all levels of added water. There were no differences in the juiciness of NaOH and STPP rolls, but both were juicier than controls. Rolls prepared with STPP had the highest scores for most sensory characteristics, but treatment did not affect texture scores. Only when rolls contained 10% added water were flavor scores of NaOH or STPP rolls higher than controls.

Table 6 - Sensory evaluation of beef rolls[d]

H_2O[e]	Sample	Flavor	Texture	Cohesiveness	Juiciness	Overall
		n>34	n>34	n>34	n>34	n>34
5%	Salt[f]	4.8 ± 1.6	3.8 ± 1.1	4.0 ± 1.4[c]	4.1 ± 1.7	4.5 ± 1.5[c]
5%	NaOH + Salt	4.5 ± 1.5	3.9 ± 1.1	4.7 ± 1.3[b]	4.6 ± 1.7	4.9 ± 1.6[b]
5%	STPP + Salt	4.8 ± 1.4	4.0 ± 1.1	5.4 ± 1.2[a]	4.6 ± 1.5	5.3 ± 1.3[a]
10%	Salt[f]	4.3 ± 1.6[b]	4.1 ± 1.2	3.9 ± 1.3[c]	3.4 ± 1.6[b]	4.1 ± 1.5[b]
10%	NaOH + Salt	4.8 ± 1.4[a]	3.8 ± 1.1	4.3 ± 1.5[b]	5.2 ± 1.3[a]	5.2 ± 1.4[a]
10%	STPP + Salt	4.9 ± 1.3[a]	3.9 ± 1.0	5.3 ± 1.2[a]	5.0 ± 1.4[a]	5.4 ± 1.2[a]
20%	Salt[f]	4.6 ± 1.6	3.8 ± 1.5	3.8 ± 1.6[c]	4.1 ± 1.7[c]	4.1 ± 1.5[c]
20%	NaOH + Salt	4.5 ± 1.6	3.7 ± 1.1	4.4 ± 1.4[b]	4.8 ± 1.5[b]	4.8 ± 1.4[b]
20%	STPP + Salt	4.8 ± 1.5	3.8 ± 1.2	5.0 ± 1.4[a]	5.3 ± 1.4[a]	5.5 ± 1.2[a]

[a-c] Mean values within each level of added water with different letter superscripts are significantly different ($p<0.05$).
[d] Values are mean ± SD.
[e] Added water (%).
[f] Control.

CONCLUSIONS

Although rolls with STPP had highest bind strength and cohesiveness at all levels of added water, the cohesiveness ratings of rolls with NaOH were in the acceptable range (4.3-4.7; Table 6). Compared to rolls prepared with STPP, rolls with NaOH had similar cooked yield, moisture content, beef flavor and texture. Thus, in situations where phosphate reduction is desired, NaOH may be a reasonable alternative.

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CHAPTER V

AN INSTRUMENT FOR MEASURING BIND STRENGTH OF RESTRUCTURED MEAT PRODUCTS[1]

ABSTRACT

A sensitive and inexpensive penetrometer is described, consisting of a mounted rod and polished steel ball that may be advanced downward at variable speed. Meat slices were mounted on a plexiglass cylinder. The slice + mounting cylinder was placed on a top-loading balance, tared to zero, and centered under the penetrometer rod. Bind strength was measured as the peak force (g) required for the steel ball advancing at 2.0 cm/min to penetrate the meat slice. Data points (grams force vs time) were collected and plotted using an IBM-compatible personal computer and printer. Since the balance collected gram values continuously, a Quick-Basic program was developed, allowing the user to specify the time interval (1, 2, 5 sec, etc.) between recorded values. Penetrometer bind strength and taste panel cohesiveness ratings of turkey and beef rolls were highly correlated (r=0.89 and r=0.93, respectively).

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[1]Coauthored by Dobson, B.N., Moiseev, I.V., Cornforth, D.P., Savello, P., Wood, R.J., and Andersen, R. 1993. Instrument for measuring bind strength of restructured and emulsion-type meat products. J. Texture Studies 24: 303-310. Portions of the article are reprinted here.

INTRODUCTION

Restructured meat products, including boneless ham, roast beef and poultry rolls are a large and growing segment of the processed meat industry. Typically, boneless meat pieces are massaged or tumbled at about 0^0 C with salt-containing brines to facilitate meat protein extraction, thus enhancing adhesion of the meat pieces after cooking (Siegel and Schmidt, 1979; Booren *et al.*, 1981; Coon *et al.*, 1983). Product acceptability is largely dependent upon the degree of bind developed among meat particles. Bind, texture, and yield of cooked meat products is also influenced by phosphate (Siegel and Schmidt, 1979), soy proteins (Siegel *et al.*, 1979; Ensor *et al.*, 1987; Bater *et al.*, 1992), milk proteins (Siegel *et al.*, 1979; Ensor *et al.*, 1987), and a number of polysaccharides, including alginate (Trout, 1989), carrageenan and starch (Bater et al., 1992). Texture and cohesiveness may be evaluated by taste panelists or by instrumental measurement of bind strength. Results of instrumental procedures are valid only when they are positively correlated with results of certain sensory procedures. An Instron Universal Testing Machine equipped with a penetrometer head has been recommended for bind measurements on restructured meats (Field *et al.*, 1984). The Instron and similar commercially available instruments are very versatile when equipped with the proper accessories, but they are also prohibitively expensive for many industrial and university laboratories. This study describes a sensitive and inexpensive penetrometer that may be assembled from commercially available components, and its application in the measurement of bind strength of turkey rolls and beef rolls formulated with whey protein concentrate (WPC) and sodium hydroxide (NaOH), respectively. Using a descending rod rather than a ball, this instrument has been used to measure mechanical properties of whey protein films (Mahmoud and Savello, 1992).

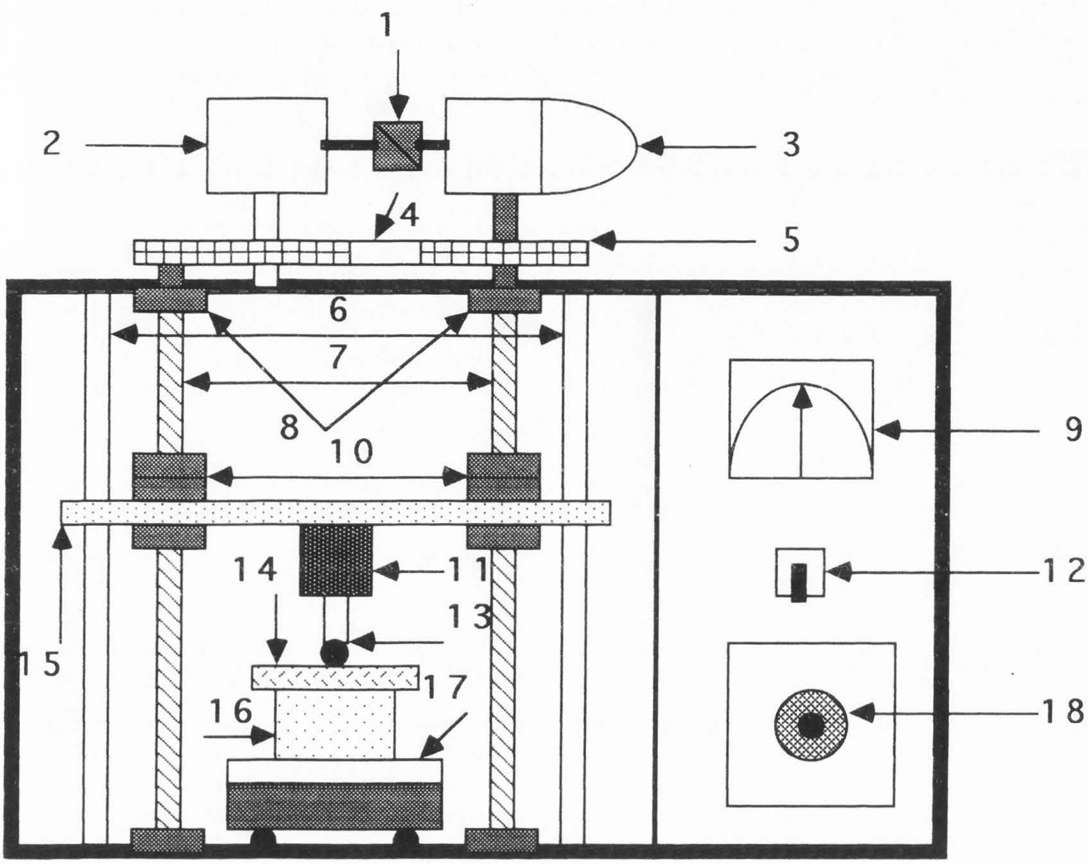
MATERIALS AND METHODS

Plexiglass Cylinder for Holding Meat Slices

Meat slices (1.5 cm thick, 10 cm diameter) were mounted on a plexiglass cylinder as described by Field *et al.* (1984), with modifications. We used a larger cylinder to accommodate the large diameter turkey roll slices and placed the tapered needles holding the meat slice 4 mm, rather than 2 mm, apart to minimize tearing between needles when the penetrometer ball was advanced. The cylinder had an inside diameter of 75 mm, an outside diameter of 100 mm, a height of 75 mm, and the circle formed by the needles was 90 mm in diameter. Each needle protruded 12.5 mm above the surface of the plexiglass cylinder and measured 1 mm at the base.

Penetrometer Assembly

Bind strength was measured as the peak force (g) required for a polished steel ball advancing at 2.0 cm/min to penetrate a sliced meat sample. The ball (high carbon chrome alloy grade 25, 19 mm diameter) was welded to a rod (9 mm diameter x 75 mm long) and mounted to a standard 1/16 - 3/8" (2-10 mm) adjustable drill bit chuck (Fig. 7). The drill bit chuck was attached to the center of an aluminum crossbar (2.5 x 10 x 51 cm). The crossbar was in turn mounted on two precision-ground threaded shafts (1.27 x 40.6 cm, 5 threads/inch, 35.6 cm apart), using a right-handed, standard-ground, threaded-ball and screw assembly (Utah Bearing, Logan, UT). Both threaded shafts were attached to the top and bottom plates of the penetrometer by 1.27 cm standard self-aligning pillow block bearings (Utah Bearing, Logan, UT). The top of the right-side threaded shaft was connected directly to the drive shaft of a DC step motor (Dayton Permanent Magnet DC Gear Motor, model 4Z723A, Dayton Electric Manufacturing Company, Chicago, IL; distributed by Granger Industrial and Commercial Equipment and Supplies, Salt Lake City, UT). Sprockets (26 tooth) were welded near the top of both threaded shafts, connected by a chain # RS 35 (Utah Bearing, Logan, UT), so that both threaded shafts rotated at the same rate. Uniform vertical motion was facilitated by installation of stabilizer rods (1.27 x 43.2 cm polished steel) at either end of the aluminum crossbar



1. Linkage rod
2. Speed control reduction converter.
3. Dayton 12 volt DC model 2M197 step motor
4. Chain idler (to tighten the chain)
5. 14 inch chain number 50 on a 10 tooth sprocket
6. Stabililizer rod
7. Precision ground threaded shaft
8. Standard ball bearing housing
9. DC microammeter
10. Standard ground thread-ball and screw assembly (right)
11. Drill bit chuck attachment
12. Double pole toggle switch (up/down direction)
13. 19 mm polished steel ball welded to a rod
14. Meat slice 12 cm X 1.5 cm
15. Aluminum mounting bar (000 Kaiser precision plate)
16. Plexiglass ring for mounting of meat slices
    (OD 10 cm, ID 7.7 cm, height 7.5 cm)
17. Top loading balance, RS 232 serial port, capasity 6000 g,
    dimensions W x D X H = 18.5 X 21.5 X 5.5 cm
18. Dayton SCR variable speed control

Fig. 7. - Schematic diagram of the penetrometer.

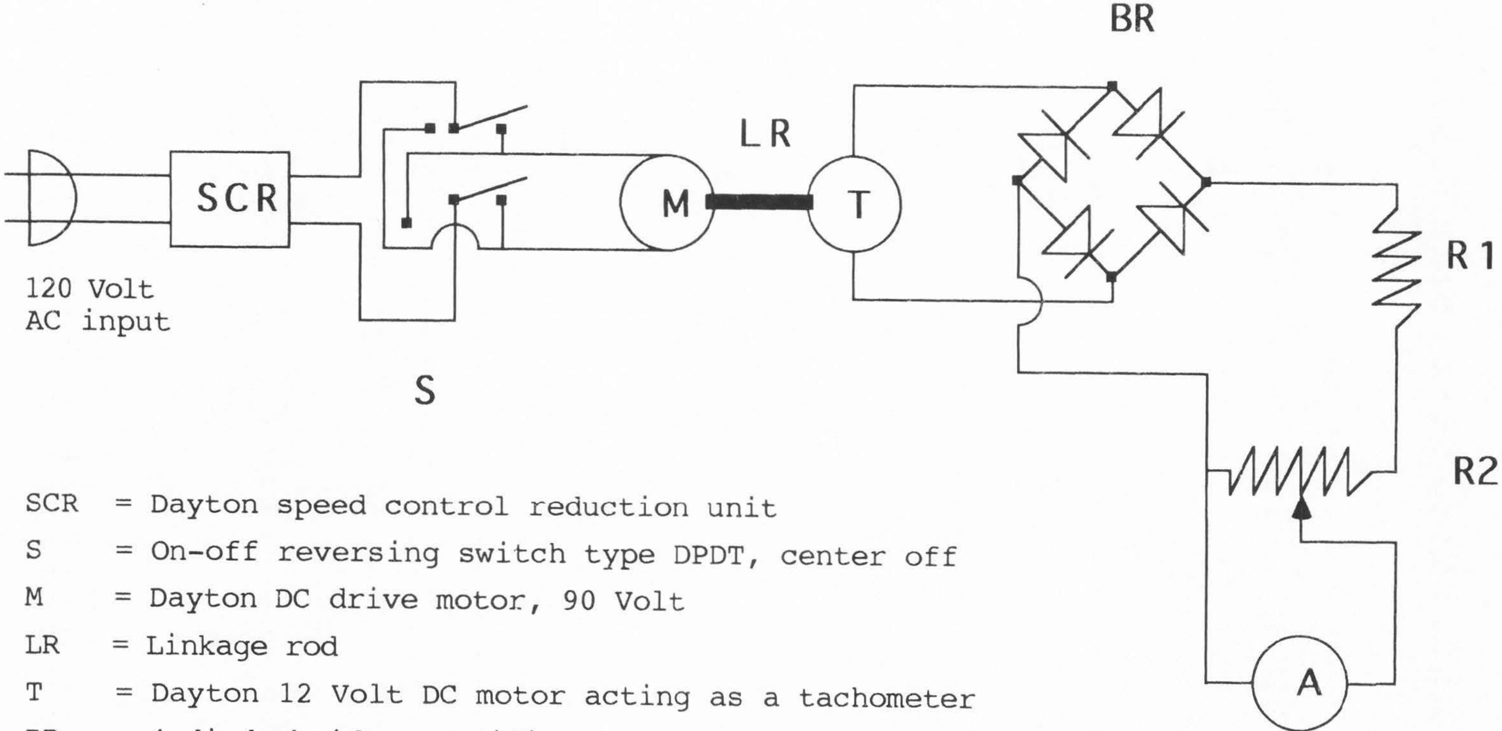
(Fig. 7). Dimensions of aluminum base, cover and mountingplates included in Appendix D.

Rate Control of the Penetrometer

The penetrometer rod and ball could be raised or advanced downward at variable speed (0 - 2.0 cm/min) by manually holding the toggle switch (double-pole, double-throw, center-return switch, Granger Industrial and Commercial Equipment and Supplies, Salt Lake City, UT) in the up or down position, respectively. Speed control was achieved by adjustment of a SCR (speed control reduction) unit (model 5 x 412, Dayton Electric Manufacturing Co., Chicago, IL), which converted AC to DC current and regulated DC current flow to the step motor. An ammeter (0-10 microamps DC, Dayton Electric Manufacturing Co., Chicago, IL) was installed to monitor the step motor, making it possible to advance the penetrometer at the same rate for each sample. In order to generate DC current to the ammeter, the step motor was linked to a 12-volt DC motor (Dayton model 2M197, Dayton Electric Manufacturing Co., Chicago, IL) by a 0.64 cm diameter flex-coupling rod.

Electrical Wiring of the Penetrometer

The penetrometer was powered by standard 110 V connection to the SCR speed control unit (Fig. 8). As mentioned previously, a DC motor linked to the step motor served as a tachometer, generating DC current to the ammeter.



SCR = Dayton speed control reduction unit

S = On-off reversing switch type DPDT, center off

M = Dayton DC drive motor, 90 Volt

LR = Linkage rod

T = Dayton 12 Volt DC motor acting as a tachometer

BR = 4 diode bridge rectifier

R1 = 340,000 Ohm resistor

R2 = 5,000 Ohm resistor

A = Microammeter, 10 Amp

Fig. 8. - Schematic electrical wiring diagram of the penetrometer.

The bridge rectifier was included so that the ammeter read positively, whether the penetrometer rod was advanced or withdrawn.

Bind Measurements

For bind measurements, the cooked rolls were sliced (Berkel slicer, Koch Supplies, Inc) into 1.5 cm thick x 10 cm diameter slices. The slices were mounted on the plexiglass cylinder, and the cylinder + meat slice was then placed on a top-loading balance (18.5 cm W x 21.5 cm L x 5.5 cm H) with digital readout (Sartorius PT 6, 6000 g capacity, 1 g readability, Baxter Scientific Products, Salt Lake City, UT). The balance programmable menu code settings were set to "Unstable Ambient Conditions" (code 43), and the data output parameter was set to "Automatic Output Synchronous with Display Regardless of Stability" (code 83). The balance output port was modified (Sartorius Interface Kit YDO 01 PT, Baxter Scientific Products, Salt Lake City, UT) to accept a standard RS 232 cable for data transmission to an IBM-compatible PC (CUI Advantage 386, CUI, Santa Clara, CA). The balance with mounted meat slice was centered under the penetrometer rod. The rod was advanced until it was nearly in contact with the meat slice, and the balance was then tared to zero. The penetrometer was then turned to maximum speed (2.0 cm/min), and force (g) was recorded with time until the ball penetrated through the meat slice (1.5 - 2.0 min). Note that the term "force" is defined as "applied weight to penetrate the sample," measured in grams. Initially, all data points were collected using Terminal, the communications application that was included with the Microsoft Windows 3.1 (Anon., 1992a). Using the "paste" function, values were transferred to the Microsoft Excel 4.0 (Anon., 1992b) spreadsheet, then plotted. Continuous data transmission generated 2.5 values per second, or about 400 data points per sample. To reduce the number of data points collected per run, the following Quick-Basic program was developed. This program allows the user to specify the time interval between recorded values. Commercial software packages are also available (LabTech Notebook, National Instruments, Austin, TX; Mettler BalanceTalk™, Mettler Instrument Corporation, Hightstown, NJ).

Quick-Basic Program for the Penetrometer

```
DIM SHARED weights (1000)
OPEN"com2:1200,o,7,1,cd,ds,cs,RB32768",FOR RANDOM AS #1
INPUT "Number of seconds to take data", sec
INPUT "Time interval between data points", inter
totpoints = sec / inter
IF totpoints > 1000 THEN GOTO toomany
ON TIMER (inter) GOSUB timerloop
TIMER ON
timepoint = 1
WHILE totpoints > 0
```

```
LINE INPUT #1, dummy$
WEND
TIMER OFF
INPUT "File name for output: ", file$
OPEN file$ for OUTPUT AS #2
FOR i = 1 TO timepoint - 2
Print #2, weights (i)
NEXT
CLOSE #1
CLOSE #2
SYSTEM
END

toomany:
PRINT "Too many data points for DIMENSION, try less
points"
SYSTEM
END

timerloop:
GOSUB getdata
RETURN

getdata:
LINE INPUT #1, a$
gram = VAL (MID$ (a$, 5, 6))
```

```
34    PRINT gram
35    weights (timepoint) = gram
36    timepoint = timepoint + 1
37    totpoints = totpoints - 1
38    RETURN
```

Line 1 sets the maximum number of data points at 1000. Line 2 opens communication between the balance and the computer and sets the RB (receive buffer) to 32,768 bytes, a large binary number allowing about 16 minutes of data collection at 1 point/sec. Line 33 (gram = VAL ...) instructs the computer to read only the gram values of the balance output, disregarding the ± and g symbols. The Microsoft Excel 4.0 program (Anon., 1992b) was used to plot the data and to determine peak bind strength values.

Meat Formulation and Processing

Turkey and beef rolls were formulated and processed according to recipes and cooking procedures described in Chapter III (p. 27) and Chapter IV (p. 42), respectively.

Taste Panels

Procedures for sensory evaluation of turkey and beef rolls are described in Chapter III (p. 28) and Chapter IV (p. 45).

Statistical Analysis

Experimental data of turkey rolls and beef rolls were analyzed using the StatView program (Anon., 1992b) and the

Statistica program (Anon., 1991) for the Macintosh, respectively. Two-way ANOVA, multiple comparison Fisher's LSD values and correlation coefficients were computed for physico-chemical and sensory data. Correlations were based on nine means for physico-chemical and sensory data. Significance was accepted at the 5% confidence level.

RESULTS AND DISCUSSION

Representative plots of bind strength vs time for turkey rolls prepared with 1 or 3% WPC-50, WPC-60, WPC-75 are shown in Figs. 9-10. The device is clearly able to differentiate samples based on the peak force required to penetrate a meat slice. A double peak was observed on some samples. This effect was likely due to tearing of the sample from the supporting needles as the rod advanced, causing a slight decline in force registered on the balance and the appearance of the first peak. The appearance of the first peak might be prevented by using fewer needles in the construction of the supporting plexiglass cylinder. The decline in force registered after the second peak was always associated with total penetration of the sample.

Bind strength values of turkey rolls as measured by penetrometer readings were positively correlated with sensory panel ratings of cohesiveness (r=0.89, Table 7). Overall acceptability of turkey rolls was positively correlated with cohesiveness (r=0.79), juiciness (r=0.89), uniformity

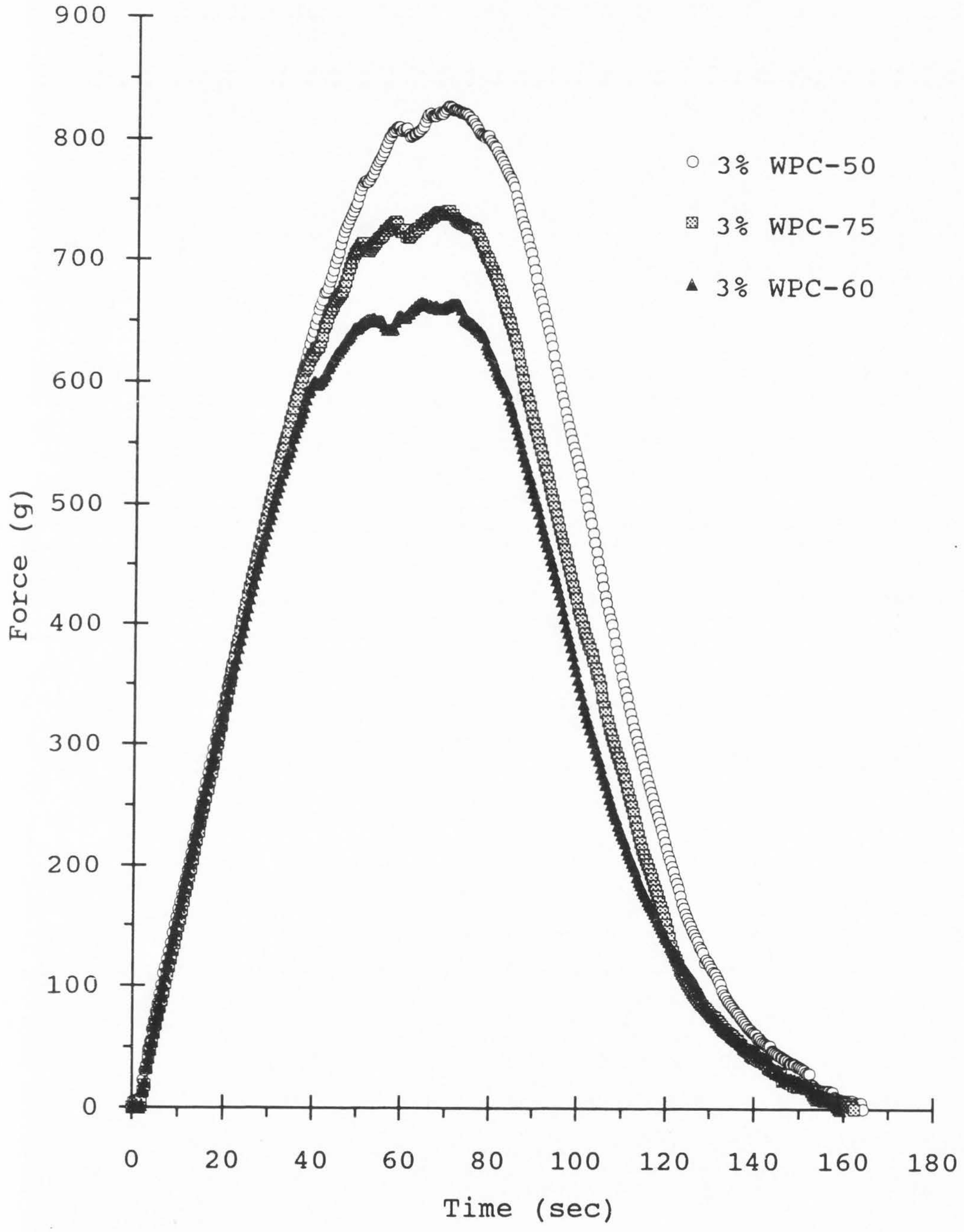


Fig. 9. - Penetrometer mean bind strength values with time for turkey rolls formulated with 3% whey protein concentrates. For each point, n=9.

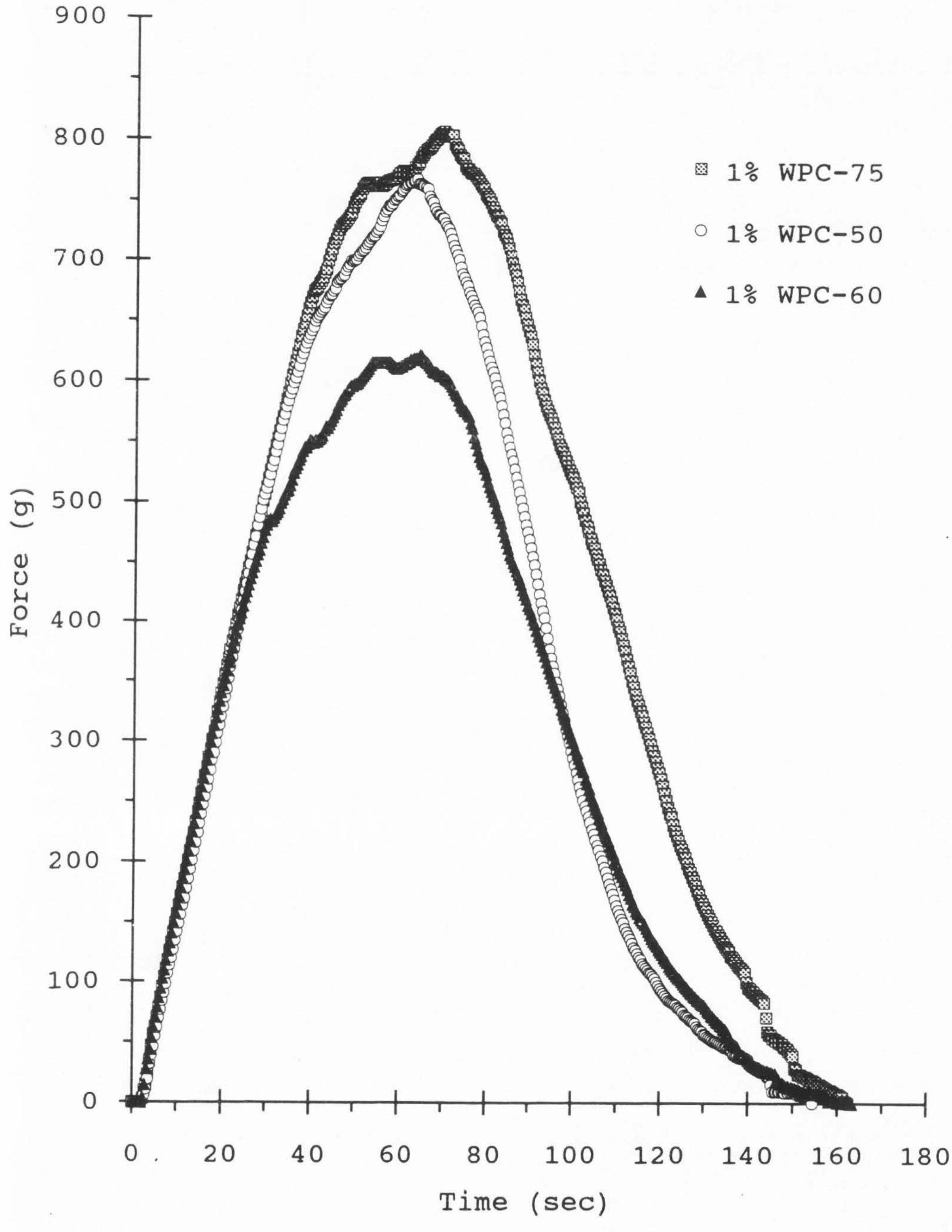


Fig. 10. - Penetrometer mean bind strength values with time for turkey rolls formulated with 1% whey protein concentrates. For each point, n=9.

Table 7 - Correlation between bind strength and sensory characteristics of turkey rolls

Parameter	Bind[a]	Flavor	Texture	Cohesi- veness	Juici- ness	Color unifor- mity	Pink Color	Overall
Bind[a]	1.00	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Flavor	0.26	1.00	. . .	. . .	. . .	. . .	. . .	. . .
Texture	0.69	0.28	1.00	. . .	. . .	. . .	. . .	. . .
Cohesiveness	0.89	0.32	0.78	1.00	. . .	. . .	. . .	. . .
Juiciness	0.78	0.63	0.42	0.64	1.00	. . .	. . .	. . .
Color uniformity	0.77	0.66	0.71	0.82	0.84	1.00	. . .	. . .
Pink color	0.71	0.81	0.46	0.60	0.84	0.76	1.00	. . .
Overall	0.84	0.71	0.70	0.79	0.89	0.93	0.93	1.00

[a] Bind strength peak value.

(r=0.93) and pink color (r=0.93). Bind strength and sensory rating data of turkey rolls are presented in Table 3 (p. 30) and Table 4 (p. 35), Chapter III.

Positive correlation was also found between cohesiveness and overall acceptability (r=0.90) and for juiciness and overall acceptability (r=0.88) of beef rolls (Table 8). Panel cohesiveness and instrumental measurement of peak bind strength were highly correlated (r=0.93). Physico-chemical and sensory rating data are presented in Table 5 (p. 47) and Table 6 (p. 52), Chapter IV.

CONCLUSIONS

The instrument used in this study required about 100 h of labor for assembly, and it cost $9,900 ($1,800 for penetrometer parts, $4,700 for assembly, and $3,400 for top-loading balance, PC, printer and software) compared to $50,000 or more for commercially available instruments capable of making similar measurements.

In conclusion, the instrument used in this study, coupled with a top-loading balance and PC, had the ability to rapidly, sensitively and inexpensively measure bind strength of cooked meat products.

Table 8. Correlation coefficients among physico-chemical and sensory characteristics of beef rolls

Parameter	Bind	Yield	Moisture	pH	Flavor	Texture	Cohes.	Juiciness	Overall
Bind[a]	1.00	...	...	...	...	...	...	...	...
Yield[b]	0.92	1.00	...	...	...	...	...	...	...
Moisture	-0.26	-0.37	1.00	...	...	...	...	...	...
pH	0.45	0.56	0.41	1.00	...	...	...	...	...
Flavor	0.67	0.54	0.09	0.27	1.00	...	...	...	...
Texture	0.26	0.19	-0.33	-0.20	-0.30	1.00	...	...	...
Cohes.[c]	0.93	0.85	-0.05	0.59	0.65	0.18	1.00	...	...
Juiciness	0.54	0.55	0.39	0.75	0.78	-0.51	0.63	1.00	...
Overall	0.83	0.81	0.12	0.69	0.80	-0.13	0.90	0.88	1.00

[a] Bind strength peak value.
[b] Cooked yield.
[c] Cohesiveness.

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CHAPTER VI

SUMMARY

Rolls made with 0.5% phosphate had the highest bind strength and sensory evaluation scores. WPC-75 (1%) was acceptable as a binding agent and flavor enhancer. WPC-60 reduced pink discoloration of rolls, but flavor, bind and cohesiveness scores were unacceptably low. WPC-50 was not an effective binding agent. Also, 3% WPC-50 lowered the intensity of turkey flavor. In general, rolls made with 3% WPC had lower scores for intensity of turkey flavor. Thus, only WPC-75 at the 1% usage level has potential as an additive to processed turkey rolls.

Although rolls with STPP had highest bind strength and cohesiveness at all levels of added water, the cohesiveness ratings of rolls with NaOH were in the acceptable range of 4.3-4.7. Compared to rolls prepared with STPP, rolls with NaOH had similar cooked yield, moisture content, beef flavor and texture. Thus, in situations where phosphate reduction is desired, NaOH may be a reasonable alternative.

The penetrometer used in this study required about 100 hrs of labor for assembly and cost $9,900 ($1,800 for penetrometer parts, $4,700 for assembly, and $3,400 for top-loading balance, PC, printer and software), compared to $50,000 or more for commercially available instruments capable of making similar measurements. The penetrometer coupled with a top loading balance and PC had the ability to rapidly, sensitively and inexpensively measure bind strength of cooked meat products.

APPENDICES

APPENDIX A.

SOURCES OF TURKEY MEAT FOR EXPERIMENT WITH WHEY PROTEIN CONCENTRATE

First trial:

a) *Turkey breast tenderloins*
   Individually Quick Frozen (20 Lbs/ea)

   Jerome Foods, Inc.
   Barron, Wisconsin 54812

b) *Turkey thigh meat* (drum sticks)

   Smith's Supermarket
   442 N. 175 E.
   Logan, UT 84321

Second trial:

a) *Turkey breast meat,*
   boneless-skinless (40 Lbs/ea)

   Jerome Foods, Inc.
   Barron,Wisconsin 54812

b) *Turkey thigh meat* (quarters)

   Albertson's Supermarket
   400 N. 49 E.
   Logan, UT 84321

Third trial:

a) *Turkey breast meat,*
   boneless-skinless (40 Lbs/ea)

   Norbest Inc.
   Midvale,UT

b) *Turkey thigh meat,*
   boneless-skinless (40 Lbs/ea)

   Norbest Inc.
   Midvale,UT

Turkey breast meat was ordered from:

   D & M Distributing
   1160 W. 3050 S.
   Ogden, UT 84401
   (801) 392-5533

APPENDIX B.

SENSORY RATING BALLOTS FOR TRAINED TASTE PANEL AND OPEN TASTE PANEL

EVALUATION SHEET FOR TRAINED PANEL (TURKEY ROLLS)

Name _____________________ Date ______________________
Please sample in the order below. Use the following scale for evaluation the sample characteristics:

1. Flavor
7 Strong turkey flavor
6
5 Moderate turkey flavor
4
3 Slight turkey flavor
2
1 No turkey flavor (bland)

2. Texture
7 Very hard
6
5 Hard
4 Neither hard or soft
3 Slightly soft
2
1 Mushy

3. Cohesiveness
7 Very cohesive
6
5 Moderately cohesive
4
3 Slightly cohesive
2
1 Not cohesive

4. Juiciness
7 Very juicy
6
5 Moderately juicy
4
3 Slightly juicy
2
1 Dry

5. Overall Acceptability
7 Very acceptable
6
5 Slightly acceptable
4
3 Slightly unacceptable
2
1 Very unacceptable

Sample code #	*Flavor*	*Texture*	*Cohesive-ness*	*Juiciness*	*Overall*
247					
848					
114					
318					
504					
414					
659					
986					

EVALUATION SHEET FOR TRAINED PANEL (TURKEY ROLLS)

Name ______________________ Date ________________________

Please look at these samples displayed and evaluate color uniformity & pink color intensity using the following scale:

1. Color Uniformity

7 Very spotted
6
5 Moderately spotted
4
3 Slightly spotted
2
1 Not spotted (uniform)

2. Pink Color Intensity

7 Very intensely pink
6
5 Moderately pink
4
3 Slightly pink
2
1 Not pink

Sample Code Number	*Color Uniformity*	*Pink Color Intens.*
247		
848		
114		
318		
504		
414		
659		
986		

Comments:

Thank you for being a taste panel member.

EVALUATION SHEET FOR OPEN PANEL (BEEF ROLLS)

Name ________________________ Date __________________

Please sample in the order below. Use the following scale for evaluation the sample characteristics:

1. Flavor

7 Strong beef flavor
6
5 Moderate beef flavor
4
3 Slight beef flavor
2
1 No beef flavor (bland)

2. Texture

7 Very hard
6
5 Hard
4 Neither hard or soft
3 Slightly soft
2
1 Mushy

3. Cohesiveness *(How meat holds together)*

7 Very cohesive
6
5 Moderately cohesive
4
3 Slightly cohesive
2
1 Not cohesive

4. Juiciness

7 Very juicy
6
5 Moderately juicy
4
3 Slightly juicy
2
1 Dry

5. Overall Acceptability

7 Very acceptable
6
5 Slightly acceptable
4
3 Slightly unacceptable
2
1 Very unacceptable

Sample code #	*Flavor*	*Texture*	*Cohesive-ness*	*Juiciness*	*Overall*
504					
318					
414					

APPENDIX C.

MOISTURE IN MEAT

Air Drying (Procedure 950.46, AOAC, 1990)

With lids removed, dry sample containing about 2 g dry material 16-18 hr at 100-102^{0} C in air oven (mechanical convection preferred). Use covered aluminum dish $\geq$ 50 mm diameter and $\leq$ 40 mm deep. Cool in desiccator and weigh. Report loss in weight as moisture.

APPENDIX D.

DIMENSIONS OF ALUMINUM BASE, COVER, AND MOUNTING PLATES

Item	Dimensions
Base Plate	1.3 x 35.6 x 56 cm
Top Plate - drilled to allow	1.3 x 20.3 x 56 cm threaded rods to pass through
Left Side Plate	1.3 x 20.3 x 56 cm
Right Side Plate	1.3 x 20.3 x 56 cm
Top Cover - over step motor and chain	0.16 x 21.6 x 21.3 x 69 cm (with welded seams)
Left Front Cover	0.16 x 15.2 x 44.8cm (with 4.4 cm lip bent at 90^0 for a smooth inside corner, and another 2.5 cm lip bent at 90^0 for mounting to base
Left Rear Cover	Same as left front
Right Front Cover	Same as left front
Right Rear Cover	Same as left front
DC Motor Mounting Plate (Mounted parallel to sides)	1.3 x 13.7 x 15 cm (with 2.9 x 10 cm port to allow chain to pass)
Step Motor Mounting Plate (mounted parallel to front)	1.3 x 10 x 13.7 cm
SCR Mounting Plate	0.6 x 13 x 15 cm
Toggle Switch & Ammeter	0.6 x 13 x 25.4 cm
Mounting Plate (front) Toggle Switch & Ammeter Cover (right side and rear)	0.16 x 13 cm deep x 25.4 cm high, bent at 90^0, then 13 cm wide, then bent 90^0 for a 2.5 cm lip to mount to the right cover

Bridge Rectifier Mounting Plate	0.6 x 2.5 x 5 cm

The screws attaching cover plates to the base were 0.6 cm long x 0.5 cm diameter hex head (Allen-wrench) screws. Front and rear face plates were attached to side plates with 0.5 cm diameter, 2 cm long hex head screws, with washers. Mounting plates were attached to side or top plates with Phillips-type screws.

APPENDIX E.

ANALYSIS OF VARIANCE TABLES

Table 9 - Analysis of variance for bind strength of turkey rolls

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	553368	42.2	<0.0001
Treatment (T)	7	264943	20.2	<0.0001
R X T	14	34786	2.6	0.0061
Residuals	48	13098		
Total	71			

Table 10 - Analysis variance for flavor of turkey rolls

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	3.817	1.826	0.1629
Treatment (T)	7	8.870	4.243	0.0002
R X T	14	1.814	0.868	0.5947
Residuals	288	2.090		
Residuals	311			

Table 11 - Analysis of variance for texture of turkey rolls

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	1.628	1.451	0.2361
Treatment (T)	7	3.432	3.058	0.0040
R X T	14	2.606	2.322	0.0048
Residuals	288	1.122		
Total	311			

Table 12 - Analysis of variance for cohesiveness of turkey rolls

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	0.561	0.397	0.6724
Treatment (T)	7	5.451	3.862	0.0005
R X T	14	1.696	1.202	0.2729
Residuals	288	1.411		
Total	311			

Table 13 - Analysis of variance for juiciness of turkey rolls

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	1.436	0.834	0.4352
Treatment (T)	7	11.087	6.442	<0.0001
R X T	14	2.048	1.190	0.2823
Residuals	288	1.721		
Total	311			

Table 14 - Analysis of variance for overall acceptability of turkey rolls

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	1.946	1.342	0.2628
Treatment (T)	7	8.252	5.694	<0.0001
R X T	14	1.304	0.900	0.5591
Residuals	288	1.449		
Total	311			

Table 15 - Analysis of variance for color uniformity of turkey rolls

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	6.292	4.369	0.0135
Treatment (T)	7	9.545	6.628	<0.0001
R X T	14	5.054	3.509	<0.0001
Residuals	288	1.440		
Total	311			

Table 16 - Analysis of variance for pink color of turkey rolls

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	2.446	1.797	0.1676
Treatment (T)	7	16.291	11.974	<0.0001
R X T	14	2.262	1.663	0.0628
Residuals	288	1.361		
Total	311			

Table 17 - Analysis of variance for bind strength of beef rolls

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	220326	3.95783	0.02489
Treatment (T)	8	1452786	26.09712	<0.0001
R X T	16	231559	4.15961	0.00004
Residuals	54	55668		
Total	80			

Table 18 - Analysis of variance for yield of beef rolls

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	4.77475	0.81356	0.45385
Treatment (T)	8	85.0764	14.49601	<0.0001
R X T	16	10.4122	1.77411	0.09160
Residuals	27	5.86895		
Total	53			

Table 19 - Analysis of variance for moisture of beef rolls

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	7.87187	22.4924	<.00001
Treatment (T)	8	9.83490	28.10150	<.00001
R X T	16	3.90913	11.16967	<.00001
Residuals	27	0.34997		
Total	53			

Table 20 - Analysis of variance for pH of beef rolls

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	0.02000	80.6269	<.00001
Treatment (T)	8	0.05490	221.2456	<.00001
R X T	16	0.00578	23.3274	<.00001
Residuals	27	0.00025		
Total	53			

Table 21 - Analysis of variance for flavor of beef rolls at 5% water added

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	0.55716	0.24322	0.78424
Treatment (T)	2	2.85667	1.247037	0.28878
R X T	4	2.50397	1.093070	0.35998
Residuals	312	2.29077		
Total	320			

Table 22 - Analysis of variance for texture of beef rolls at 5% water added

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	0.22967	0.19434	0.82347
Treatment (T)	2	1.53973	1.302874	0.27324
R X T	4	1.09745	0.928632	0.44748
Residuals	312	1.18179		
Total	320			

Table 23 - Analysis of variance for cohesiveness of beef rolls at 5% water added

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	1.02749	0.59156	0.55408
Treatment (T)	2	52.2348	30.07333	<.00001
R X T	4	2.10952	1.21452	0.30453
Residuals	312	1.73691		
Total	320			

Table 24 - Analysis of variance for juiciness of beef rolls at 5% water added

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	5.05911	1.95112	0.14384
Treatment (T)	2	6.95544	2.682470	0.06997
R X T	4	5.39516	2.08072	0.08317
Residuals	312	2.59292		
Total	320			

Table 25 - Analysis of variance for overall acceptability of beef rolls at 5% water added

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	2.31970	1.07531	0.34245
Treatment (T)	2	18.4146	8.536268	0.00024
R X T	4	2.65155	1.22914	0.29836
Residuals	312	2.15722		
Total	320			

Table 26 - Analysis of variance for flavor of beef rolls at 10% water added

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	2.58107	1.29966	0.27406
Treatment (T)	2	12.2055	6.145970	0.00240
R X T	4	8.39083	4.225102	0.00239
Residuals	318	1.98594		
Total	326			

Table 27 - Analysis of variance for texture of beef rolls at 10% water added

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	6.42418	5.40109	0.00493
Treatment (T)	2	3.41226	2.799457	0.06234
R X T	4	3.41226	2.868842	0.02330
Residuals	318	1.18942		
Total	326			

Table 28 - Analysis of variance for cohesiveness of beef rolls at 10% water added

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	39.0188	24.5937	<.00001
Treatment (T)	2	50.8415	32.04564	<.00001
R X T	4	1.52627	10.96201	0.42852
Residuals	318	1.58653		
Total	326			

Table 29 - Analysis of variance for juiciness of beef rolls at 10% water added

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	0.0194	0.01107	0.98899
Treatment (T)	2	108.401	61.7875	<.00001
R X T	4	30.7017	17.4995	<.00001
Residuals	318	1.75442		
Total	326			

Table 30 - Analysis of variance for overall acceptability of beef rolls at 10% water added

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	1.76860	1.06534	0.34583
Treatment (T)	2	49.7713	29.98055	<.00001
R X T	4	16.7645	10.0983	<.00001
Residuals	318	1.66012		
Total	326			

Table 31 - Analysis of variance for flavor of beef rolls at 20% water added

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	2.72256	1.13525	0.32625
Treatment (T)	2	3.45368	1.440122	0.23842
R X T	4	4.93637	2.058378	0.08605
Residuals	321	2.39818		
Total	329			

Table 32 - Analysis of variance for texture of beef rolls at 20% water added

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	3.96395	2.45659	0.08733
Treatment (T)	2	0.22216	0.137684	0.87142
R X T	4	3.94271	2.443434	0.04660
Residuals	321	1.61359		
Total	329			

Table 33 - Analysis of variance for cohesiveness of beef rolls at 20 % water added

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	2.02949	0.94842	0.38843
Treatment (T)	2	44.0017	20.56288	<.00001
R X T	4	4.05463	1.89481	0.11107
Residuals	321	2.13986		
Total	329			

Table 34 - Analysis of variance for juiciness of beef rolls at 20% water added

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	16.0606	7.09010	0.00097
Treatment (T)	2	42.4114	18.72293	<.00001
R X T	4	11.6614	5.14804	0.00049
Residuals	321	2.26521		
Total	329			

Table 35 - Analysis of variance for overall acceptability of beef rolls at 20% water added

Source of variance	DF	MS	F-value	P-value
Replicate (R)	2	0.41571	0.21390	0.80754
Treatment (T)	2	48.0825	24.73993	<.00001
R X T	4	3.57236	1.83809	0.12123
Residuals	321	1.94352		
Total	329			

APPENDIX F.

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Permission Letter

May 9, 1994

Mr. J. O'Neil
Food & Nutrition Press, Inc.
2 Corporate Drv., P.O. Box 374
Trumbull, CT 06611

Dear Mr. O'Neil:

I am in the process of preparing my thesis in the Nutrition and Food Sciences Department at Utah State University. I want to complete in May of this year.

I am writing to request copyright permission to reproduce my article "B.N. Dobson, I.V. Moiseev, D.P. Cornforth, P. Savello, R.J. Wood, and R. Andersen. 1993. *Instrument for measuring bind strength of restructured and emulsion-type meat products*. Journal of Texture Studies, 24(3): 303-310." I want to include this article as a chapter of my thesis.

Please indicate your approval of this request by signing in the space provided, attaching any other form or instruction necessary to confirm permission. If you have any questions, please call me at the number above.

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John J. O'Neil May 10, 1994

Permission Letter

May 24, 1994

Dobson, B.N.
Golden Cheese Company of California
1138 West Rincon St.
Corona, CA 91720
Ph.(909) 737-9260

Dear Mr. Dobson:

I am in the process of preparing my thesis in the Nutrition and Food Sciences Department at Utah State University. I want to be completed by May of this year.

I am writing to request copyright permission to reproduce portions of the article "B.N. Dobson, I.V. Moiseev, D.P. Cornforth, P. Savello, R.J. Wood, and R. Andersen. 1993. *Instrument for measuring bind strength of restructured and emulsion-type meat products*. Journal of Texture Studies, 24(3): 303-310." I want to include some information from this article as a chapter of my thesis.

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Brent N. Dobson

Permission Letter

May 26, 1994

Savello, P.
Department of Nutrition and Food Sciences
Utah State University,
Logan,UT 84322-8700

Dear Dr. Savello:

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Paul E. Savello May 26, 1994

Permission Letter

May 25, 1994

Wood, R.J.
Computer Science Department
Utah State University
Logan, UT 84322-4205

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Robert J Wood May 25, 1994

Permission Letter

May 24, 1994

Andersen, R.
Technical Services,
Utah State University
Logan, UT 84322-1200

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