1987

Effect of isolated soy protein and canning on physical, chemical, microbiological and sensory properties of extended cured beef

Arno Enrique Sandoval
Iowa State University

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Effect of isolated soy protein and canning on physical, chemical, microbiological and sensory properties of extended cured beef

Sandoval, Arno Enrique, Ph.D.
Iowa State University, 1987
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Effect of isolated soy protein and
canning on physical, chemical, microbiological and
sensory properties of extended cured beef

by

Arno Enrique Sandoval

A Dissertation Submitted to the
Graduate Faculty in Partial Fulfillment of the
Requirements for the Degree of
DOCTOR OF PHILOSOPHY
Department: Animal Science
Major: Meat Science

Approved:

Signature was redacted for privacy.

In Charge of Major Work

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For the Graduate College

Iowa State University
Ames, Iowa

1987
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF ABBREVIATIONS</td>
<td>iv</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>REVIEW OF LITERATURE</td>
<td>3</td>
</tr>
<tr>
<td>Beef Chuck</td>
<td>3</td>
</tr>
<tr>
<td>Meat Color</td>
<td>4</td>
</tr>
<tr>
<td>Cured color</td>
<td>5</td>
</tr>
<tr>
<td>Meat color measurements</td>
<td>7</td>
</tr>
<tr>
<td>Sectioned and Formed Products</td>
<td>7</td>
</tr>
<tr>
<td>Whole Muscle Extended Products</td>
<td>11</td>
</tr>
<tr>
<td>Properties of Isolated Soy Proteins</td>
<td>15</td>
</tr>
<tr>
<td>Objectives</td>
<td>18</td>
</tr>
<tr>
<td>MATERIALS AND METHODS</td>
<td>19</td>
</tr>
<tr>
<td>Experiment 1</td>
<td>19</td>
</tr>
<tr>
<td>Meat and formulation</td>
<td>19</td>
</tr>
<tr>
<td>Production</td>
<td>19</td>
</tr>
<tr>
<td>Experiment 2</td>
<td>22</td>
</tr>
<tr>
<td>Meat and formulation</td>
<td>22</td>
</tr>
<tr>
<td>Production</td>
<td>22</td>
</tr>
<tr>
<td>Physical Measurements</td>
<td>24</td>
</tr>
<tr>
<td>Product yield</td>
<td>24</td>
</tr>
<tr>
<td>Percentage extension</td>
<td>25</td>
</tr>
<tr>
<td>Purge</td>
<td>25</td>
</tr>
<tr>
<td>Color</td>
<td>26</td>
</tr>
<tr>
<td>Color stability</td>
<td>26</td>
</tr>
<tr>
<td>Toughness</td>
<td>27</td>
</tr>
<tr>
<td>Chemical Analysis</td>
<td>27</td>
</tr>
<tr>
<td>Proximate analysis</td>
<td>27</td>
</tr>
<tr>
<td>pH</td>
<td>27</td>
</tr>
</tbody>
</table>
# List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>Celsius</td>
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<td>CFU</td>
<td>Colony-forming units</td>
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<td>ISP</td>
<td>Isolated soy protein</td>
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INTRODUCTION

According to the American Meat Institute (1986), 2,912,072,727 kilograms of beef chuck (27% of the beef carcass) were produced in 1985. The retail cuts from the beef chuck vary widely in palatability and especially in value. According to Parrish et al. (1986), the conventional method of beef chuck fabrication is to make blade and arm chuck roasts, or steaks, stew meat and ground chuck. These cuts are usually low priced to help in their sale, sometimes resulting in an economic loss. New ways to merchandise beef chuck are needed in order to increase its acceptability and profitability.

One approach would be to use the most tender muscles like the infraspinatus, which is removed conventionally from the chuck, as steaks or roasts. A variation in the methods of packaging and cooking cuts from this muscle could represent a definite advantage; for example, a microwave-ready chuck product.

The less tender muscles could be used in restructured products. In these, the particle size is reduced to provide a cut of meat with improved characteristics. Also, products that are battered and breaded, like nuggets or patties, could be made from the less tender chuck muscles. Another restructured product could be a precooked beef cube that would be used as part of the formulation of soups and stews.

Ham is considered an almost universal type of processed meat; for this reason, a ham-like product made out of beef chuck would be a potential new product. This new product would offer alternatives to people that do not consume pork, for either religious or perceived health
reasons. This product could be marketed internationally or domestically.

Beef is darker in color than pork, due to the higher concentration of myoglobin and it has a firmer texture. By extending the product with an essentially colorless extender, it would be possible to dilute the color and also produce a more desirable texture. To make an extended cured beef product, a nonmeat protein is needed. Some examples are: isolated soy protein, blood plasma, wheat gluten, corn gluten, egg albumin, milk protein and others.

Extension would undoubtedly cause changes in the resulting product, so it is important to determine the extent of these changes, if any, and if they are advantageous or disadvantageous. Determination of the level to which a nonmeat protein can be incorporated into a product is likewise important.
REVIEW OF LITERATURE

Beef Chuck

According to the National Association of Meat Purveyors (1976), the chuck from a beef carcass is the portion of the forequarter remaining after removal of the foreshank, brisket, short plate and rib. It is obtained by two straight cuts, the first one passes across the forequarter between the 5th and 6th ribs. The second cut passes through the cartilaginous juncture of the first rib and the sternum continuing in a straight line to the 5th rib perpendicular to the first cut.

According to Parrish et al. (1986), there are about 20 muscles in the chuck that are surrounded by layers of connective tissue and the chuck contains large deposits of subcutaneous and intramuscular (seam) fat. The muscles of the chuck have a wide variation in composition and palatability. They stated that nine muscles make up about 40% of the lean in the chuck, and based on sensory tenderness evaluation and Warner-Bratzler shear values, three muscle groupings of these nine major muscles can be made. First, the infraspinatus is the most tender and palatable. Second, the longissimus, the triceps brachii, the serratus ventralis, the deep pectoral and the complexus are intermediate in tenderness. Third, the supraspinatus, the biceps brachii and the rhomboideus are the least tender. These data agree with data presented by McKeith et al. (1985) and by Ramsbottom and Strandine (1947).

Due to the great number of muscles and the variation in their
composition, different retail cuts can be fabricated. Traditionally, chucks can be cut into the following cuts: chuck eye roast, arm pot roast, cross rib pot roast, blade roast, 7-bone pot roast, boneless top blade steak, boneless shoulder pot roast, mock tender, under blade pot roast, short ribs, flanken style ribs and ground beef. According to Parrish et al. (1986), the usual methods of cookery for many of the roasts are braise or cook in liquid.

Meat Color

According to Setser (1984), color is probably the most important sensory quality of meat, because odor, texture or taste become unimportant if the product is visually unappetizing and is not purchased. Adams and Huffman (1972) claimed that consumers relate the color of the lean to freshness.

Walters (1975) reported that meat color, as perceived by the consumer, is determined by factors of concentration and chemical form of myoglobin, morphology of the muscle structure and the ability of the muscle to absorb or scatter incident light.

Stryer (1981) described myoglobin as a protein in muscle that serves as a reserve supply of oxygen and facilitates the movement of oxygen within the muscle cell. He also stated that the capacity of myoglobin to bind oxygen depends on the presence of a nonpolypeptide unit, the heme group. This heme group and the gas bound to it gives myoglobin its distinctive color. The heme consists of an organic part and an iron atom. The organic part, protoporphyrin, is made up of
four pyrole groups. The iron atom in the heme can be in the ferrous (+2) or in the ferric (+3) oxidation state: ferromyoglobin and ferrimyoglobin, respectively. The ferrimyoglobin is also called metmyoglobin. Only the ferromyoglobin can bind oxygen.

Seideman et al. (1984) stated that when an animal is stunned and bled, myoglobin becomes the principal meat color pigment. He also explained that the color intensity of meat is determined by antemortem factors such as species, stress, sex and age of the animal, and by the postmortem factors of rate of pH decline and ultimate pH.

The color intensity differences due to species are caused by different concentrations of myoglobin. Beef has the highest concentration of myoglobin of all red meats and, therefore, is the darkest in color. Pork has a lower concentration of myoglobin than beef which makes it lighter in color than beef. The differences due to sex and age are also caused by different concentrations of myoglobin.

Walters (1975) explained that a rapid postmortem pH decline caused a denaturation of sarcoplasmic and myofibrillar proteins. Low pH when muscle temperature is near at-death temperature, will cause muscle structure (fibrils) to be more open and scatter light causing the meat to appear pale in color. In addition, a low pH will also cause the myoglobin fraction to be more readily oxidized to metmyoglobin which has a low color intensity.

**Cured color**

Myoglobin can bind not only oxygen, but also other gases; the most important of these, nitric oxide. When this gas combines with
myoglobin or metmyoglobin, a pigment called nitrosomyoglobin is formed, which is not stable and can be converted back to myoglobin or metmyoglobin. Heating meat with nitrosomyoglobin to 55°C to 60°C will form nitrosohemochrome which is the stabilized pigment form in a cured product (Rust and Olson, 1973).

These authors also explained that nitric oxide in high concentration is a toxic gas and is very difficult to handle. For this reason, nitric oxide is added to meat in the form of a nitrite salt, sodium or potassium. These salts are rapidly changed to nitric oxide in the meat. Even though nitrosohemochrome is a stable compound, exposure to light and oxygen will oxidize it, resulting in a grayish-brown color (cured color fading). Therefore, it is important that cured meat be vacuum packaged in oxygen impermeable packages, and kept away from direct intense light. Vacuum packaging is the best way to preserve the color of cured meat and also diminishes the growth of spoilage bacteria.

According to Kropf and Hunter (1984), retail display conditions frequently stress meat products due to rough handling, adverse lighting and variation in temperature. Lighting effects on product appearance can be the result of meat surface temperature elevation, photochemical effects and changes due to different spectral energy distribution patterns. A warmer temperature on the product surface will promote a faster discoloration. He also recommended that between 70-100 foot candles are optimum for effective retail display.
Meat color measurements

Meat color is a surface phenomenon of a nonmetallic, opaque object. Light striking meat is either absorbed or reflected. Meat color measurements involve two basic methods: human visual appraisal and instrumental analysis (Hunt, 1980).

According to Hunt (1980), the color of a meat surface can be described in two different ways. The first is a physical description of the actual perceived color of the meat sample. This description is useful in determining color standards, selection criteria, description of consumer response, and research where only color descriptions are made. Several color systems have been developed for these purposes; for example, Hunter Lab, CIE-tristimulus, Munsell, etc. These systems provide information about how color is perceived or the stimulus needed to match the meat color. Reflectance and transmission spectrophotometry offer a second approach. They relate directly to myoglobin properties and, therefore, provide extremely important information about how a treatment affects meat pigments and their stability.

Sectioned and Formed Products

Sectioned and formed products are produced by injecting a curing brine into the meat pieces and then tumbling or massaging the product. This mechanical action produces a creamy, viscous protein exudate on the meat surfaces. When heated, this exudate binds the meat pieces resulting in a cohesively formed meat product. The finished product has the texture and appearance of a whole muscle product.
According to Scheid (1986), it has been demonstrated many times that correct pumping of the curing brine into the meat is very important. By correct, he meant that brine is pumped as close as possible to the desired level and that it is distributed as evenly as possible. Rust and Olson (1973) agreed with him and suggested that forcing the brine into the meat would be an advantage. Without brine injection, rapid curing would not be possible. They discussed various methods of injection and concluded that continuous brine injection machines, due to the large number of needles that inject the brine at hundreds of points, produced a relatively uniform brine distribution throughout the meat.

Scheid (1986) discussed a technique that he called a squeeze technique. In it, the pieces of meat are put through two rollers in such a way that the surface is severely altered. The alteration to the surface of the meat increased the surface area, thus helping to absorb the brine quickly and homogeneously. It has also been suggested that this technique will improve protein extraction, which on the other hand, will improve binding of the meat pieces upon heating. This technique could be applied prior to injection.

The mechanical action needed to produce the creamy viscous protein exudate can be achieved in several ways, but the procedures most commonly used are massaging and tumbling. Massaging accomplishes its work by rubbing the meat pieces against each other by rotating paddles (Knipe, 1982). According to Theno et al. (1977), tumbling imparts "impact energy" to the meat pieces. This is accomplished by rotating a drum which causes the meat to fall from the upper portion of the drum
on to the meat in the lower part of the drum. Many tumblers are equipped with a vacuum system to minimize introduction of air into the exudate and facilitate protein extraction. Tumbling is relatively a more severe physical treatment than massaging, which makes it more effective when applied to firmer muscles like beef, turkey and mutton (Knipe, 1982).

Rahelic et al. (1974) studied the effect of tumbling on canned hams. He found that tumbling for 320 min. decreased the amount of released juice in the cans, but tumbling for more than 460 min. increased the released juice. Offer and Trinick (1983) explained that in the processing of large pieces of meat, the presence of the sarcolemma and endomysium inhibited swelling of the myofibrils by blocking the ingress of ions or by mechanical restraint. They concluded that the effect of tumbling was to disrupt those structures and remove those constraints. According to Schmidt (1978), after extensive tumbling, the sarcomere structure was completely degraded and actin filaments and Z discs were the structures most rapidly degraded.

Theno et al. (1978), after analyzing samples of meat that had been massaged during different periods of time and with various levels of salt and phosphate, concluded that the effects of the mechanical action were more pronounced in the presence of salts and phosphates at all time intervals. They also showed that as massaging time increased, the amount of fat and protein in the exudate also increased.

Krause et al. (1978) determined that tumbling significantly improved canned ham external appearance, color, sliceability, taste, aroma and yield. Three hours of continuous tumbling resulted in
less improvement in product quality and yield than 18 hours intermittent tumbling. Scheid (1986) explained that during the rest period, meat filaments were allowed to swell and immobilized water was therefore deposited in the structure of the muscle. He also stated that this swelling could not be achieved in a continuous tumbling cycle of 3 to 4 hours.

According to Knipe (1982), binding of meat pieces occurs during heat treatment. Theno et al. (1977) stated that the binding of the meat pieces in sectioned and formed products was due to the salt soluble proteins present in the exudate. These proteins underwent a structural rearrangement during processing. The new structure was then stabilized by the application of thermal energy. Siegel et al. (1978) explained that the protein exudate was composed primarily of actin and myosin and to a lesser degree, tropomyosin, C-protein and alpha-actinin. In 1977, MacFarlane et al. concluded that myosin was required for satisfactory binding of meat pieces.

The structural rearrangements that occur to myofibrillar proteins during processing is also known as aggregation, and this term is used to describe many types of protein-protein interactions. According to Acton and Dick (1984), a clear difference exists between protein aggregations named coagulation and gelation. Coagulation is the random protein to protein interaction, which does not lead to an ordered structural assembly of the final aggregate. Contrarily, gelation is the orderly interaction of proteins, which leads to the formation of a three-dimensional structural matrix. One of the best examples of protein to protein interaction involvement in meat processing is the binding of
two meat pieces in sectioned and formed products.

Acton and Dick (1984) stated that the protein to protein interaction that leads to the formation of a three-dimensional matrix by myosin and actin was heat induced and could be divided into two stages; the first one was between 30°C and 50°C, which involves aggregation of the globular head of myosin, and the second stage was from a temperature of 50°C to 71°C and was associated with structural change of the helical rod of myosin, which culminates with a network formation due to cross-linking of these segments. He concluded that binding strength development at the junction between adjacent pieces of meat was temperature dependent, particularly above 50°C.

In 1982, Knipe discussed different factors that affect binding strength. One of the factors he thought to be important was muscle pH. Binding of meat pieces was improved with higher pH because myosin is optimally solubilized at pH 6.5. He also stated that binding strength was increased with decreasing meat particle size because more exudate was produced as meat surface area increased. External fat on meat pieces had detrimental effects on bind strength and yield.

Whole Muscle Extended Products

The use of nonmeat proteins, such as soy proteins, milk proteins, etc., in meat products has increased in recent years. Consumers accept these products not only for economic reasons, but because the technology has reached a point where it is possible to produce
extended products with appealing taste. Even though this technology is in its primary stage of development, it has reached the point where it is possible to produce combination meat and nonmeat protein products from traditional pieces of meat like ham, beef round, etc. Preliminary information indicates that these products will eventually be accepted by the consumer. It is of vital importance that the products used to extend meat have a high nutritive content, so that they do not substantially reduce the nutritive characteristics of the combination products as compared to products that do not contain such nonmeat extenders (Federal Register, 1976).

Hawley and Tuley (1977) described a method that used the addition of nonmeat proteins to curing brines commonly utilized in the production of ham and corned beef. This method permitted the injection of a protein and water solution to meat, obtaining cooked yields of at least 130%, and maintaining a protein content of at least 17%. This was possibly due to the utilization of isolated soy protein, which has the ability to form gels in water. He recommended that to have full benefit from this extension system, the isolated soy protein had to be fully hydrated before the addition of the other ingredients. Rust (1980) agreed and recommended that the isolated soy protein should be combined with all the water except that needed for solubilization of the phosphate. After the soy protein had been fully hydrated, all of the remaining ingredients could be added to this protein brine in the normal way. He also suggested that the mixture be blended for at least 30 min.

Hawley and Tuley (1977) stated that due to the viscous nature of the
protein brine, it tended to form brine pockets in the seam and seam fat areas of the hams. To avoid this, he suggested that hams should be skinned and defatted prior to injection and that after injection, hams should be tumbled or massaged to obtain good distribution and equilibration of the brine.

In 1980, Rust explained that it was very important to carefully select the isolated soy protein to be used. The isolated soy protein should be easy to disperse in the brine without complicated and expensive equipment and should have the capability of being pumped through conventional injectors without plugging needles and screens. He suggested a 20-hr massage cycle after injection with 15 min. work and 45 min. rest. Longer massage cycles insure uniform distribution of isolated soy protein. After massaging, hams can be stuffed in fibrous casing using conventional equipment or can be canned. He concluded that even though no comparisons with normal water added ham were made, all of the sensory tests on this product indicated good acceptance.

Siegel et al. (1979a) reported that combination hams were manufactured by injecting soy brines to ham muscles. The meat was injected by 30%, 45% and 60%. Two tumbling times were used (0 hr. and 18 hr.) of intermittent massaging. Massaging and isolated soy protein had beneficial effects on binding strength and cooking yield. Increased levels of injection decreased binding strength and cooking yield. Massaging improved uniformity of the products, texture and overall acceptability, but decreased tenderness and had no effect on juiciness and flavor. Injection level, on the other hand, had a detrimental effect on uniformity, texture and overall acceptability. They concluded
that binding strength and cooking yields showed that the effect of isolated soy proteins on those types of products was related to its ability to bind water. This binding of water promotes the binding of meat pieces by minimizing the effect of excess water on the functionality of the extracted myofibrillar proteins.

Siegel et al. (1979b) compared the microstructure of combination ham and water added to determine the location of the isolated soy protein. The results showed that isolated soy protein fills primarily the perimysial spaces, but mechanical action by means of massaging or tumbling incorporates those proteins into the endomysial spaces and mixes them with the extracted myofibrillar proteins. Scanning electron microscopy showed that the gel formed by the isolated soy protein was denser than the one formed by a crude myosin preparation. The gel formed by the mixture of myosin and isolated soy protein was similar in structure to the one formed by crude myosin.

In 1978, Tybor et al. evaluated regular hams, water added hams and three different combination hams. The products were prepared by injection, massaging, canning and water cooking. The brines used to prepare the combination hams had 10% isolated soy protein or more which made the final ham content of the finished products of 76%, 71% and 66%. The protein efficiency ratios (PER) of the combination hams were statistically equivalent to the regular and to the water added hams. They concluded that extension of hams with isolated soy protein resulted in a product with similar nutritional quality to traditional ham products.

There are several nonmeat proteins like isolated soy protein, wheat
gluten, blood plasma, egg white, etc. that can be used in extended whole muscle products. Siegel et al. (1979c) studied the binding ability of some of them and compared the results with the binding ability of crude myosin. They found that the binding ability of the proteins studied was inferior to that of crude myosin. They also compared the binding abilities of the nonmeat proteins in presence of 8% salt and 2% tripolyphosphate and ranked them from highest to lowest as follows: wheat gluten, egg white, corn gluten, calcium-reduced dry skim milk, bovine blood plasma, isolated soy protein and sodium caseinate. In the absence of salt and tripolyphosphate bovine blood plasma, wheat gluten and isolated soy protein ranked the highest.

Properties of Isolated Soy Proteins

Soy isolates are prepared from minimum heat-treated soy flour by dissolving the protein in dilute alkali (pH 8.0) removing the insoluble materials by centrifugation or filtration and precipitation of protein at pH 4.5. This curd is usually neutralized with sodium hydroxide (potassium and calcium may also be used) and spray dried (Kinsella, 1979).

Isolated soy protein contains approximately 92% protein and is used in comminuted meat and dairy products where emulsifying, thickening and gelling properties are required. Isolates are composed of two main fractions: 7S (35%) that contains lipoxgenase, amylase and globulins; and 11S (52%) which are mainly globulins. Other minor components are 2S (trypsin inhibitor) and 15S (polymers).
Proteins that are intended to be used as ingredients in formulation of food products should have acceptable flavor, texture and color; good nutritional value and appropriate functional properties for the intended use. According to Kinsella (1979), functional properties affect the behavior of proteins in foods during preparation, storage and consumption.

In 1979, Wilcke et al. discussed the contribution of soy products to texture of foods. They stated that flours, concentrates and isolates will contribute in some degree to the texture of products in which they are incorporated. For example, in the production of emulsified or comminuted meat products like frankfurters, mortadella and bologna, the fiber structure has been destroyed, the characteristic texture is provided by a meat gel. Spray dried isolated soy protein, rehydrated in water at the proper concentration, mixed and heated will form a gel very similar to the one formed by meat proteins. This makes isolated soy proteins very desirable for use in emulsified meat products.

Soluble proteins are easier to incorporate in foods. Normally, proteins with low solubility have low functionality and limited application. According to Kinsella (1979), methods of preparation of soy proteins affect their solubility. Heat treatment, although necessary to desolventize, to inactivate the antinutrient compounds and to improve flavor (by inactivating the lipoxygenase activity) will decrease the solubility of soy proteins. There are soy proteins with different degrees of solubility; therefore, care must be taken while selecting the appropriate one for a particular use.

Soy proteins form gels upon heating and cooling. This charac-
teristic is useful in food applications because it provides a structural matrix that holds water, flavors, sugars and other ingredients. Temperatures above 60°C are necessary to induce dissociation of the quaternary structure causing unfolding of the polypeptides of the protein subunits. During cooling, the unfolded polypeptides reassociate via hydrophobic bonds, hydrogen bonds, ionic interactions and possibly disulfide links to form a stable gel (Kinsella, 1979).

It was reported by Siedeman et al. (1977) that soy proteins are useful in the manufacture of many kinds of meat products like sausage and beef patties in which soy proteins are used to bind meat particles together. Peng et al. (1982) reported that the soy 11S component interacts with myosin at temperatures between 85-100°C. They also explained that the basic subunit of the 11S component interacted with the myosin heavy chain and the acidic subunit showed no interaction. King (1977) stated that myosin and the 7S component associated at a temperature range of 75-100°C. Lin and Ito (1985) concluded that the nature of the interaction between myosin and soy proteins was determined by hydrogen bonds, hydrophobic bonds and van der Waal's forces. Haga and Ohashi (1984) suggested from the findings of gel filtration and SDS polyacrylamide gel electrophoresis of the mixture of myosin and soy protein that the interaction between them occurs even before heating.

According to Kinsella (1979), the limiting factor in the use of soy proteins is the strong "beany" flavor associated with them. Even though proteins have no flavor, they may modify flavor by their capacity to bind flavors and off flavors. Many off-flavor components
in soy proteins originate via enzymatic (lipoxigenase) or chemical oxidation of the lipid components. It has also been suggested that 2-pentyl furan, 3-cis-hexenal and ethyl-vinyl-ketone are the key off-flavor compounds; these are formed from the lipohydroperoxides generated by lipoxigenase.

Objectives

This research project had the following objectives:

1. Produce a cured beef product with the quality characteristics of ham;
2. Determine the effect of isolated soy protein on extended cured beef; and
3. Compare the effect of canning on soy extended cured beef, cured beef and ham.
MATERIALS AND METHODS

Experiment 1

Meat and formulation

No roll (less than USDA choice grade), three-piece beef chucks were purchased from a commercial source. Muscles were separated and defatted at the Iowa State University Meat Laboratory. The resulting pieces of meat were passed through a membrane skinner model 720 (Townsend Engineering, Inc., Des Moines, IA) to remove as much connective tissue (epimysium) as possible.

Isolated soy protein (Pro-fam S-646) was obtained from Grain Processing Corporation (Muscatine, IA). Four treatments were formulated; one control having no isolated soy protein added and three with isolated soy protein approximately 1.85%, 2.60% or 3.35%. These percentages are approximations of the content of ISP in the products after cooking and are based on results obtained in the preliminary work. These percentages are used throughout this dissertation to identify the various treatments containing ISP in Experiment 1. All treatments were injected to 50% of the original meat weight. Formulas for each treatment, including all the curing ingredients, are shown in Table 1.

Production

The meat was injected to 150% of original weight using a Townsend 1400 injector (Townsend Engineering, Inc., Des Moines, IA). After injection, the meat was tumbled intermittently under vacuum (15 min. work, 45 min. rest) at a speed of 22 rpm for 22 hr. in a Globus VMS 77 vacuum tumbler (Globus Laboratories, Inc., Vienna, Austria). Meat corresponding to each
Table 1. Brine formulation for 50% injection in Experiment 1

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Control</th>
<th>1.85% ISP&lt;sup&gt;a&lt;/sup&gt;</th>
<th>2.60% ISP&lt;sup&gt;a&lt;/sup&gt;</th>
<th>3.35% ISP&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>89.96</td>
<td>84.96</td>
<td>82.96</td>
<td>80.96</td>
</tr>
<tr>
<td>Isolated soy protein</td>
<td>0.00</td>
<td>5</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Salt</td>
<td>6.21</td>
<td>6.21</td>
<td>6.21</td>
<td>6.21</td>
</tr>
<tr>
<td>Sugar</td>
<td>2.29</td>
<td>2.29</td>
<td>2.29</td>
<td>2.29</td>
</tr>
<tr>
<td>Phosphate&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.35</td>
<td>1.35</td>
<td>1.35</td>
<td>1.35</td>
</tr>
<tr>
<td>Sodium erythorbate</td>
<td>0.1485</td>
<td>0.1485</td>
<td>0.1485</td>
<td>0.1485</td>
</tr>
<tr>
<td>Sodium nitrite</td>
<td>0.0421</td>
<td>0.0421</td>
<td>0.0421</td>
<td>0.0421</td>
</tr>
</tbody>
</table>

<sup>a</sup>Isolated soy protein.

<sup>b</sup>Blend of 75% sodium tripolyphosphate/25% sodium polyphosphate glassy (formerly sodium hexametaphosphate).
treatment was tumbled separately in identical tumblers.

After tumbling, the meat was stuffed into 147 mm by 900 mm prestuck fibrous casings (Teepak, Chicago, IL) with a Vemag Robot 1000s 116, vacuum stuffer (Robert Reiser and Co., Boston, MA) and placed in a Deltec model d-7-3237 ham press (Deltec, Inc., Batavia, OH).

After stuffing and pressing, the meat was heat processed in a Maurer and Sohne allround system oven (H. Maurer and Sons, Riechenau, West Germany). It was cooked to an internal temperature of 68°C using the following schedule:

<table>
<thead>
<tr>
<th>Time</th>
<th>Program</th>
<th>Dry bulb (°C)</th>
<th>Wet bulb (°C)</th>
<th>Moisture impulse (°C)</th>
<th>Core temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>45 min.</td>
<td>Hot air</td>
<td>82</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>15 min.</td>
<td>Drying</td>
<td>82</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>45 min.</td>
<td>Hot smoke I</td>
<td>82</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>1 hr.</td>
<td>Intensive smoke</td>
<td>82</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Hot air finish</td>
<td>82</td>
<td>74</td>
<td>75</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td>Cooking/steam</td>
<td>85</td>
<td>--</td>
<td>--</td>
<td>68</td>
</tr>
</tbody>
</table>

After cooking, the extended beef product was transferred to a 2°C cooler, and the smoke truck was covered with a plastic bag to avoid excessive product weight loss due to surface overdrying and stored overnight. The next day each product was weighed, casings were peeled and the product packaged in high-oxygen barrier pouches (O₂ permeability < 1 ml/645 cm²/24 hr. at 22.8°C and 0% RH) of nylon/saran/surlyn laminate (Curwood, Inc., New London, WI) using a Multivac chamber machine AG800 (Sepp Haggenmuler
KG, West Germany) at 530 nm of Mercury (3 setting) and 3 seconds sealing impulse. This experiment was replicated three times for chemical, physical and sensory measurements and four times for the microbiology studies.

Experiment 2

Meat and formulation

No roll, three-piece chucks similar to those used in Experiment 1 were purchased from a commercial source; boneless pork legs were obtained from the Iowa State University Meat Laboratory. All the meat was separated and defatted at the Iowa State University Meat Laboratory. Beef was passed through a membrane skinner model 720 (Townsend Engineering, Inc., Des Moines, IA) in order to remove as much connective tissue (epimysium) as possible.

Isolated soy protein (Pro-fam S-646) was obtained from Grain Processing Corporation (Muscatine, IA). Three treatments were formulated, one with pork ham and two with beef. The pork meat was injected to 10% of the original weight with no isolated soy protein added. With the two beef treatments, one was injected to 10% of the original weight with no isolated soy protein added and the other was injected to 50% of the original weight containing 1.85% isolated soy protein. Formulas including all the curing ingredients are shown in Table 2.

Production

The meat was injected with a Townsend 1400 injector (Townsend Engineering, Inc., Des Moines, IA). After injection, both pork and
Table 2. Brine formulation for ham, cured beef, and soy extended cured beef

<table>
<thead>
<tr>
<th>Ingredient (%)</th>
<th>Ham (10% injection)</th>
<th>Cured beef (10% injection)</th>
<th>Soy extended cured beef (50% injection)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>63.17</td>
<td>63.17</td>
<td>84.96</td>
</tr>
<tr>
<td>Isolated soy protein</td>
<td>0.00</td>
<td>0.00</td>
<td>5</td>
</tr>
<tr>
<td>Salt</td>
<td>22.77</td>
<td>22.77</td>
<td>6.21</td>
</tr>
<tr>
<td>Sugar</td>
<td>8.41</td>
<td>8.41</td>
<td>2.29</td>
</tr>
<tr>
<td>Phosphate&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.95</td>
<td>4.95</td>
<td>1.35</td>
</tr>
<tr>
<td>Sodium erythorbate</td>
<td>0.5445</td>
<td>0.5445</td>
<td>0.1485</td>
</tr>
<tr>
<td>Sodium nitrite</td>
<td>0.1544</td>
<td>0.1544</td>
<td>0.0421</td>
</tr>
</tbody>
</table>

<sup>a</sup> All products are formulated to contain the same amount of ingredients except water and isolated soy protein. Brine formulations vary to reflect the different levels of injection and cooking loss.

<sup>b</sup> Blend of 75% sodium tripolyphosphate/25% sodium polyphosphate glassy (formerly sodium hexametaphosphate).
beef were ground through a Biro grinder model 7.5 (The Biro Manufacturing Company, Marblehead, OH) fitted with a kidney plate. After injecting, the meat was tumbled under vacuum, intermittently (5 min. work, 55 min. rest), at a speed of 22 rpm for 22 hr. in a Globus VMS 77 vacuum tumbler (Globus Laboratories, Inc., Vienna, Austria). Each treatment was tumbled separately in identical tumblers.

After tumbling, the meat was stuffed into 100 mm by 100 mm by 150 mm cans (Continental Can Co., Omaha, NE), with a Vemag Robot 1000s 116 vacuum stuffer (Robert Rieser and Co., Boston, MA) fitted with a square stuffing horn. The filled cans were vacuum sealed using a No. 1 PUV Closing Machine (American Can Co., Greenwich, CT).

The sealed cans were water cooked in a Korimat cooker model KA120/1,6/R (Christian Wagner, West Germany) to an internal temperature of 70°C. After cooking, the cans were transferred to a 2°C cooler. Three replications of this experiment were made.

Physical Measurements

Product yield

Product yield calculations were made for both experiments. The products were weighed before and after heat processing using a Fairbanks electronic scale model H90-7601. It was assumed that casings and cans do not change in weight during cooking, so for practical reasons, they were included with the product weight before and after cooking. Product yield was calculated by the following formula:
Cooked weight \[\frac{\text{cooked weight}}{\text{raw weight}} \times 100 = \text{percent product yield}\]

**Percentage extension**

Percentage extension calculations were made for both experiments. The products were weighed before and after heat processing using a Fairbanks electronic scale model H90-7601. Degree of extension was calculated by the following formula:

\[\frac{\text{cooked weight}}{\text{raw weight}} \times \text{degree of injection} \times 100 = \text{percentage extension}\]

**Purge**

Percent purge (the free liquid in the package) was calculated in both experiments. In Experiment 1, nine 10 mm slices per treatment per replication were weighed using an Ohaus balance (Model 1500D) and vacuum packaged individually (530 mm of mercury) in a high oxygen barrier pouch (O\(_2\) permeability < 1 ml/645 cm\(^2\)/24 hr. at 22.8°C and 0% RH) nylon/saran/surlyn laminate. The packages were stored in a 2°C cooler. After 2 weeks, 4 weeks and 8 weeks, three packages from each treatment were opened, the slices were dried with paper towels and weighed using the same balance.

In Experiment 2, two cans per treatment per replication were weighed and stored in a 2°C cooler. After 6 weeks of storage, the cans were opened and the product dried with paper towels and weighed. An average cooking loss, calculated from other cans, was subtracted from the weight loss at 6 weeks to determine the amount of purge after 6 weeks. Percent purge was calculated by the following formula:
Color readings were made in both experiments using a Hunter Labscan Spectrocolorimeter (Hunter Associates Laboratory, Inc., Reston, VA). "L," "a" and "b" (opponent color scales) were measured with illuminant F (light from a cool white fluorescent source) as the light source and a 10° observer was selected. A 50 mm port insert was used in order to cover as much surface area as possible. The instrument was standardized with a standard plate (x = 81.60, y = 86.68 and z = 91.18).

Three slices 3 mm thick of each treatment were randomly selected. The slices were vacuum packaged, covered and color readings recorded within 1 hr. after packaging.

Color stability

Color stability of unpackaged slices was determined in Experiment 1 in the following manner: Ten 3 mm slices per treatment were put on display under cool white fluorescent lamps at room temperature. The light intensity at the surface of the product was 180 foot-candles. Hunter Lab color readings were taken in triplicate on a different slice every 10 min. during 90 consecutive minutes. This test was performed after production and again after 4 weeks of storage at 2°C.
**Toughness**

The Warner-Bratzler shear measure was used to determine toughness of the product in Experiment 1. Samples 50 mm in length by 26 mm in diameter were used in this test. A 50 mm core sampler was used to cut these samples from the center of the ham-like product. Peak force was measured.

**Chemical Analysis**

**Proximate analysis**

Moisture, fat and protein percentages were determined in both experiments using A.O.A.C. procedures (A.O.A.C., 1975).

**pH**

The pH of the extended cured beef product was determined in Experiment 1 by homogenizing 10-gram samples in a Waring blender with 90 ml of deionized distilled water for 60 seconds. The pH was determined using a Corning pH meter model 125 fitted with a combination pH electrode.

**TBA**

Thiobarbituric acid (TBA) test, which measures formation of malonaldehyde (Tarladgis et al., 1960), was used to indicate rancidity development in Experiment 1. TBA number was determined immediately after production and at 4 weeks, 8 weeks and 12 weeks of storage at 2°C.
Salt

The Volhard procedure for determination of salt in foods (A.O.A.C., 1975) was used to determine salt content of products in Experiment 1.

Residual nitrite

Residual nitrite, after production and at 4 weeks, 8 weeks and 12 weeks of storage at 2°C, was determined using the A.O.A.C. procedure (A.O.A.C., 1975).

Sensory Evaluation

Hedonic scale

Extended cured beef product from Experiment 1 was evaluated on a seven-point facial scale (Figure 2) for flavor, texture, juiciness and overall acceptability. The results were analyzed by giving numerical values to the answers (7 = like extremely, 1 = dislike extremely). The test was conducted three weeks after production and repeated three weeks later.

Sample preparation

Half an hour prior to the presentation of samples to the sensory panel, 3 mm thick slices of extended cured beef product were taken from each treatment. The slices were cut into six pieces, placed on plates with a random identification number, and served.
SENSORY EVALUATION FORM

The taste panel for which you have volunteered will involve your evaluation of various meat products. Samples, identified by only a random number, will be presented to you for your tasting and scoring on the evaluation form provided. All samples are entirely wholesome and safe for consumption. Differences occur only in palatability characteristics with no personal risks or discomforts involved in tasting the samples. If you so desire, you may discontinue your participation on the panel at any time. We will also be available at any time to answer questions that you may have.

I have read this document and I consent to participation on the taste panel described.

DATE ____________________ SIGNATURE __________________________

-----------------------------------------------------------------

PLEASE FILL OUT THE QUESTIONNAIRE ABOUT YOURSELF, THEN USE THE FOLLOWING PAGES TO EVALUATE THE CODED SAMPLES.

CONSUMER SURVEY

Please answer the following questions about yourself:

1. SEX: _____ Male _____ Female

2. Age group
   _____ 1-20
   _____ 21-30
   _____ 31-40
   _____ 41-50
   _____ over 50

3. How often do you eat ham?
   _____ Several times a week
   _____ Once a week
   _____ Several times a month
   _____ Once a month
   _____ Several times a year
   _____ Never

PLEASE TAKE A WARM-UP SAMPLE FIRST FOLLOWED BY A DRINK BETWEEN EACH SAMPLE.

Figure 1. Consent-survey form for the sensory evaluation of extended cured beef
<table>
<thead>
<tr>
<th>Sample Code</th>
<th>Flavor</th>
<th>Texture</th>
<th>Juiciness</th>
<th>Overall Acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Like extremely</td>
<td>![Smiley]</td>
<td>![Smiley]</td>
<td>![Smiley]</td>
<td>![Smiley]</td>
</tr>
<tr>
<td>Neutral</td>
<td>![Neutral]</td>
<td>![Neutral]</td>
<td>![Neutral]</td>
<td>![Neutral]</td>
</tr>
<tr>
<td>Dislike extremely</td>
<td>![Sad]</td>
<td>![Sad]</td>
<td>![Sad]</td>
<td>![Sad]</td>
</tr>
<tr>
<td>Comments:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 2. Hedonic scale evaluation form
Microbiological Analysis

The day after production, the extended cured beef product was sliced into 2 mm thick slices. Three slices per bag were placed in high oxygen-barrier bags \( \text{O}_2 \text{ permeability} < 1 \text{ ml/645 cm}^2/24 \text{ hr. at } 22.8^\circ\text{C and 0% RH} \) of nylon/saran/surlyn laminate (Curwood, New London, WI) and vacuum sealed to 530 mm of mercury with a Multivac chamber packaging machine (AG800, Sepp Hagenmuller KG, West Germany). Packages were placed in cardboard boxes and stored at 2-4°C in a walking cooler or placed in display cases at 5±2°C or 7±2°C.

Samples were taken from the display cases on day 0 (day of preparation) and every 2 days thereafter for microbiological examination, whereas the samples stored at 2-4°C were only examined on Day 0 and Day 30. Portions of product weighing 30g were taken from the slice in the center of the package, macerated with 270 ml of sterile 0.1% peptone water by using a Stomacher Lab blender 400 (Tekmar Company, Cincinnati, OH), and serial dilutions were prepared according to standard procedures. Bacterial types enumerated were total aerobic mesophiles and psychrotrophs, lactic acid bacteria, total anaerobes and total viable spores. Trypticase soy agar (TSA, BBL) was used to plate mesophilic \((30^\circ\text{C, 48 hr.})\) and psychrotrophic \((5^\circ\text{C, 10 days})\) microorganisms while TSA with 1% added soluble starch (Fisher Scientific, Fair Lawn, NJ) and Anaerobic Gas Pack Systems (BBL) were used to enumerate total anaerobic bacteria \((30^\circ\text{C, 48 hr.})\) and total viable spores (heat-shocked at 80°C for 20 min. followed by 30°C, 48 hr. incubation). Lactic acid producing bacteria were determined
with lactobacilli specific medium (LBS, BBL) after incubating at
30°C for 72 hr.

For inoculated studies, slices of product corresponding to each
treatment were immersed in a dilution of ca. $10^5$ spores of Clostridium
sporogenes PA3679/ml of sterile distilled water, withdrawn immediately,
allowed to drain 1 min. over a sterile stainless steel grill, vacuum
packaged as before, and held at room temperature for 24 or 48 hr.
Inoculum preparation was as described by Molins et al. (1985, 1986).
Inoculated samples were examined after 24 and 48 hr. of abuse
temperature holding (24-25°C) before and after heat shocking (80°C,
20 min.) a 10 ml aliquot of the initial macerate in order to determine
clostridial vegetative cells and viable spores, respectively.
C. sporogenes PA3679 vegetative cells and viable spore counts were
determined by counting typical rhizoid colonies characteristic of
the culture used as inoculum (Food Technology Department collection,
Iowa State University, Ames, IA).

Statistical Analysis

The Statistical Analysis System (Helwig and Council, 1979) was
used to determine means, standard errors and analysis of variance.
Both experiments used a randomized complete block design and were
replicated three times. Least significant difference was used as the
method of mean separation. Sensory panel data were averaged over all
panelists before analysis. For the microbiological measurements,
a fourth repetition was made; plate count data were transformed to
logarithms and comparison of means was accomplished by using a Duncan's multiple range test.
RESULTS AND DISCUSSION

Preliminary Study

The main objective of this research project was to produce a cured beef product with the quality characteristics of ham. To deal with the inconveniences of beef being darker and firmer than pork, an extended product was made. This product, due to the increased level of water and to the nonmeat protein present, had a diluted color and a more desirable texture.

To produce the best possible product, the manufacture and evaluation of prototype products is needed in order to make the necessary adjustments in formulation and processing.

Injection levels of 50%, 60% and 70% were tested. These injection levels produce differences in extension that range from 30% to 52%. Even though the products are comparable in composition and color, they present differences in manufacture. In our conditions, it is very difficult to pump over 50% brine in the meat even after two runs through the injector. The remaining brine has to be added as liquid to the tumbler. This is time consuming and will slow the speed of a commercial plant. Results of this preliminary study show that product with 70% injection presented extensive areas of soy gel between different pieces of meat. These areas were detrimental for the overall texture of the product. A fifty injection level was determined to be the best level.

Levels of isolated soy protein in the brine ranging from 5% to 10% were tested. It was concluded that it is not possible to add
more than 9% isolated soy protein to the brine because it becomes too thick, almost like a paste and would not go through the needles of the injector. The lower levels of isolated soy protein produced more foam during mixing than the higher ones, but this was overcome by mixing the isolated soy protein with the water the night before so that when the rest of the ingredients were added, the isolated soy protein was fully hydrated and went into solution much faster with a more gentle mixing that did not produce much foam but was enough to dissolve the other curing ingredients.

Considerable quality improvement was accomplished by running the meat through a membrane skinner. This treatment removes most of the connective tissue present in chuck. The finished product had better eating characteristics and improved binding.

With the purpose of conditioning the connective tissue, two internal cooking temperatures were compared (68°C and 72°C). No noticeable differences were found in this respect, but at 72°C, a reduction in cooking yield was found.

Experiment 1

Introduction

The objective of this experiment was to compare different levels of isolated soy protein (ISP) in a 50% injection brine used to inject beef chuck and to determine the effect that the level of ISP had on selected characteristics of extended cured beef.
Proximate analysis

Mean values for percentage of moisture, fat and protein for each treatment are shown in Table 3. No significant (P > 0.05) difference in percent moisture and fat was found between treatments, even though there was a reduction in moisture content as the level of ISP increased. This was expected since in the formulation, water was substituted by ISP.

For protein percentage, the product made with 3.35% ISP was significantly (P < 0.05) higher than the control and the product made with 1.85% ISP, but it was not significantly (P > 0.05) higher than the product made with 2.60% ISP, which at the same time was not significantly (P > 0.05) higher than the control (no ISP) and the product made with 1.85% ISP. The data showed that the protein percentage increased as the ISP was increased in the formulation. No significant (P < 0.05) differences in the moisture protein ratio of the products containing ISP were found, but they were significantly (P < 0.05) different than the control.

pH

Initial pH values are presented in Table 3. No significant (P > 0.05) difference was found between treatments. There was a significant (P < 0.05) decrease in pH over the 12-week storage period studied. This was probably due to lactic acid producing bacteria growth; however, no significant (P > 0.05) differences between treatments were found in the rate of pH decline. The pH decline is presented in Figure 3.
Table 3. Effect of isolated soy protein on extended cured beef proximate analysis, pH and salt values

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Moisture (%)</th>
<th>Protein (%)</th>
<th>Moisture/protein</th>
<th>Fat (%)</th>
<th>pH</th>
<th>Salt (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>75.02</td>
<td>15.73(^b)</td>
<td>4.78(^b)</td>
<td>3.84</td>
<td>6.37</td>
<td>2.55</td>
</tr>
<tr>
<td>1.85% ISP</td>
<td>74.97</td>
<td>16.68(^b)</td>
<td>4.50(^c)</td>
<td>3.27</td>
<td>6.43</td>
<td>2.47</td>
</tr>
<tr>
<td>2.60% ISP</td>
<td>75.20</td>
<td>16.91(^b,c)</td>
<td>4.45(^c)</td>
<td>3.66</td>
<td>6.45</td>
<td>2.52</td>
</tr>
<tr>
<td>3.35% ISP</td>
<td>74.19</td>
<td>17.97(^c)</td>
<td>4.13(^c)</td>
<td>3.21</td>
<td>6.40</td>
<td>2.50</td>
</tr>
<tr>
<td>SE</td>
<td>0.72</td>
<td>0.3</td>
<td>0.31</td>
<td>0.36</td>
<td>0.033</td>
<td>0.07</td>
</tr>
</tbody>
</table>

\(^a\) = 3 per treatment mean.

\(^b,c\) Means within each column having different letters are significantly different (P < 0.05).
Figure 3. Effect of isolated soy protein on pH of extended cured beef during storage at 2°C
Salt

No significant (P > 0.05) difference was found between treatments for salt content (Table 3). The salt content was used to check the formulation and the results indicated that the targeted injection levels were achieved.

Cooking yield and percentage extension

Cooking yield mean values are presented in Table 4. Results indicated that no significant (P > 0.05) differences were found between treatments. Cooking yield data was similar to that presented by Siegel et al. (1979a).

Percentage extension mean values are presented in Table 4. Even though these data showed that extension increased as the level of ISP increased, it was not significant (P > 0.05). It is important to remember that the protein content increased as the ISP increased. This will account for the differences in extension level because there was more protein available for water binding.

It is interesting to note that the control product had a relatively high cooking yield and extension level without added protein. It is obvious that the meat proteins are able to retain much of the water when pumped to 150% of the original weight.

Purge

Purge is the water released from the product when vacuum packaged and stored expressed a percent of the weight loss. As shown in Figure 4, the control (no ISP) had a significantly (P < 0.05) greater purge than the treatments that contained ISP. The addition of ISP was probably responsible for the differences in purge, but it is interesting to note that addition of ISP over 1.85% was not capable of producing significant (P < 0.05)
Table 4. Effect of isolated soy protein on extended beef percentage extension and cooking yield

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Percentage extension</th>
<th>Cooking yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>30.31</td>
<td>87.54</td>
</tr>
<tr>
<td>1.85% ISP</td>
<td>32.89</td>
<td>88.59</td>
</tr>
<tr>
<td>2.60% ISP</td>
<td>33.78</td>
<td>89.19</td>
</tr>
<tr>
<td>3.35% ISP</td>
<td>34.80</td>
<td>89.63</td>
</tr>
<tr>
<td>SE</td>
<td>1.10</td>
<td>0.73</td>
</tr>
</tbody>
</table>

aN = 3 per treatment mean.
Figure 4. Effect of isolated soy protein on purge values of extended cured beef during storage at 2°C.
reduction of purge as would have been expected. It was concluded that the reduction of the purge in this case was due to an improvement in the water holding capacity of the combined proteins (myofibrillar and ISP) rather than to the small increase in protein content.

**Toughness**

Warner-Bratzler shear mean peak values are shown in Table 5. No significant ($P > 0.05$) difference between treatments was found. This was probably due to the higher level of moisture in the product and to the tumbling which, as presented by Knipe (1982) and Offer and Trinick (1983), disrupts the internal tissue of the meat.

During tumbling, a mixture of various muscles with different degrees of tenderness occurred. As a consequence, the final product was composed of different muscles, and due to varying degrees of tenderness of those muscles, variation in tenderness within the finished product results. These variations were present in all the treatments but were not significant ($P > 0.05$).

**TBA**

The TBA value is a colorimetric measurement of malonaldehyde. Malonaldehyde is a breakdown product of fatty acids as they become rancid. The results of the test are reported as mg of malonaldehyde per 1000 g of meat sample. A TBA of 1 is generally considered to denote a detectable rancid flavor in a fresh ground beef.

TBA values over the 12-week storage period are shown in Figure 5 and showed no significant ($P > 0.05$) difference between treatments. There were significant ($P < 0.05$) increases in the TBA values over storage time. This
Table 5. Effect of isolated soy protein on extended cured beef Hunter Lab color and shear force values

<table>
<thead>
<tr>
<th>Treatment</th>
<th>&quot;L&quot;</th>
<th>&quot;a&quot;</th>
<th>&quot;b&quot;</th>
<th>Shear force (Kg/26 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>41.71&lt;sup&gt;b&lt;/sup&gt;</td>
<td>10.71</td>
<td>6.18</td>
<td>2.16</td>
</tr>
<tr>
<td>1.85% ISP</td>
<td>43.21&lt;sup&gt;b,c&lt;/sup&gt;</td>
<td>10.57</td>
<td>5.87</td>
<td>2.13</td>
</tr>
<tr>
<td>2.60% ISP</td>
<td>44.47&lt;sup&gt;c&lt;/sup&gt;</td>
<td>10.61</td>
<td>6.21</td>
<td>2.05</td>
</tr>
<tr>
<td>3.35% ISP</td>
<td>41.47&lt;sup&gt;b&lt;/sup&gt;</td>
<td>10.46</td>
<td>5.70</td>
<td>2.27</td>
</tr>
<tr>
<td>SE</td>
<td>0.67</td>
<td>0.19</td>
<td>0.16</td>
<td>0.22</td>
</tr>
</tbody>
</table>

<sup>a</sup>N = 3 per treatment mean.

<sup>b,c</sup>Means within each column having different letters are significantly different (P < 0.05).
Figure 5. Effect of isolated soy protein on thiobarbituric acid (TBA) number of extended cured beef during storage at 2°C.
is expected in most food products; however, all TBA values were well below 1 which suggests absence of detectable rancidity, which was probably due to the products containing sodium nitrite and phosphate, compounds known for their capabilities to retard rancidity development.

Residual nitrite

No significant (P > 0.05) difference for residual nitrite was found between treatments. A significant (P < 0.05) decrease in residual nitrite was found over storage time; the depletion of nitrite follows the pattern presented by Nordin (1969). Figure 6 shows the change in residual nitrite level over the 12 weeks of storage time studied.

Hunter Lab color values and color stability

The Hunter Lab color, which is an objective system to measure color, uses three values to describe color. "L" measures lightness (higher readings indicate a lighter product). Positive "a" values measure redness and positive "b" values indicate yellowness. As shown in Table 5, no significant (P > 0.05) difference between treatments was found for Hunter Lab "a" and "b" color values. Even though it was not significant (P > 0.05), a decreasing trend was observed in Hunter "a" color value as the ISP level increased. This effect was probably due to the light color of the ISP and, thus, if the amount of ISP added to the product was higher, the difference might become significant.

For Hunter "L" value, the control (no ISP) was significantly (P < 0.05) lower than the product containing 2.60% ISP, but it was not significantly (P > 0.05) different from the treatment containing
Figure 6. Effect of isolated soy protein on residual nitrite of extended cured beef during storage at 2°C.
3.35% ISP. An increase in the "L" value would be expected with an increase in the ISP; this was observed in the first three treatments. However, it was not expected that the "L" value for the treatment with the highest level of ISP (3.35%), although not significant ($P > 0.05$) was even darker than the control. No reasonable explanation at this point can be given for this phenomenon.

During the preliminary work, it was observed that the cured color of the extended cured beef faded rapidly when slices were exposed to air. The possibility that the ISP, a difference in pH or residual nitrite could be factors responsible for this accelerated fading. A color stability test was designed. The results of the changes in "L," "a," "b" and "a/b" are presented in Figures 7, 8, 9 and 10, respectively. No significant ($P > 0.05$) differences between treatments was found in the deterioration rate of color values. Also, it is interesting to note that storage time had no significant ($P > 0.05$) effect on Hunter Lab color value rate of deterioration after 4 weeks storage as compared to initial readings. Data presented in Tables 7, 8, 9 and 10 are averaged over storage time.

These results indicate that ISP did not influence color stability and since no significant ($P > 0.05$) differences were found for pH and residual nitrite, it can be concluded that the color of extended cured beef was not actually fading faster, but it only appeared to be so because it has a more intense color than other products like ham.
Figure 7. Effect of isolated soy protein on Hunter Lab "L" value of extended cured beef held at room temperature under 180 foot candles of cool white fluorescent light
Figure 8. Effect of isolated soy protein on Hunter Lab "a" value of extended cured beef held at room temperature under 180 foot candles of cool white fluorescent light.
Figure 9. Effect of isolated soy protein on Hunter Lab "B" value of extended cured beef held at room temperature under 180 foot candles of cool white fluorescent light.
Figure 10. Effect of isolated soy protein on Hunter Lab "a/b" value of extended cured beef held at room temperature under 180 foot candles of cool white fluorescent light.
Sensory evaluation

Sensory scores tended to decrease during storage (3, 6 weeks); however, this decrease was not significant (P > 0.05); therefore, means presented in Table 6 were averaged over storage time.

No significant (P > 0.05) difference between the control and the product containing 1.85% ISP was found for flavor, texture, juiciness and overall acceptability. There was no significant (P > 0.05) difference for flavor and overall acceptability between the products containing 1.85% ISP and 2.60% ISP, but they were significantly (P < 0.05) different for texture and juiciness. No significant (P > 0.05) difference was found for all sensory attributes for the products containing 2.60% ISP and 3.35% ISP.

In general, it can be concluded that higher levels of ISP reduced the sensory scores of extended cured beef.

Microbiology

No treatment differences (P > 0.05) were observed in terms of mesophilic, psychrotrophic or lactic bacterial growth in extended cured beef throughout the 3-week refrigerated storage in a display case at 5°C (Table 7). However, total anaerobic counts in product containing 1.85% ISP were significantly (P < 0.05) higher than corresponding numbers when the product contained 3.35% ISP, but no higher (P > 0.05) than the numbers presented by the control (no ISP) or in samples containing 2.60% ISP. No explanation was found for that result since no pH or residual nitrite differences (P > 0.05) between treatments were recorded. It may be that the highest level of ISP added
Table 6. Effect of isolated soy protein on extended cured beef sensory panel measurementsa,b

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Flavor</th>
<th>Texture</th>
<th>Juiciness</th>
<th>Overall acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>4.83c</td>
<td>4.71c</td>
<td>5.17c</td>
<td>4.82c</td>
</tr>
<tr>
<td>1.85% ISP</td>
<td>4.74c,d</td>
<td>4.83c</td>
<td>5.00c</td>
<td>4.72c,d</td>
</tr>
<tr>
<td>2.60% ISP</td>
<td>4.37d,e</td>
<td>4.42d</td>
<td>4.66d</td>
<td>4.33d,e</td>
</tr>
<tr>
<td>3.35% ISP</td>
<td>4.00e</td>
<td>4.22d</td>
<td>4.61d</td>
<td>4.04e</td>
</tr>
<tr>
<td>SE</td>
<td>0.17</td>
<td>0.19</td>
<td>0.08</td>
<td>0.17</td>
</tr>
</tbody>
</table>

aScore for all traits: 1 = dislike extremely; 4 = neutral; 7 = like extremely.

bN = 6 per treatment mean.

c,d,e Means within each column having different letters are significantly different (P < 0.05).
Table 7. Mesophilic, psychotrophic and lactic bacterial counts in extended cured beef stored at various temperatures

<table>
<thead>
<tr>
<th>Storage temperature (°C)</th>
<th>Weeks</th>
<th>Treatment</th>
<th>Mesophiles Log$_{10}$ colony forming units/g$^a$</th>
<th>Psychotrophs Log$_{10}$ colony forming units/g</th>
<th>Lactic acid bacteria Log$_{10}$ colony forming units/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>5±2</td>
<td>0</td>
<td>Control</td>
<td>2.89</td>
<td>2.75</td>
<td>1.54</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.85% ISP</td>
<td>3.13</td>
<td>2.72</td>
<td>1.35</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.60% ISP</td>
<td>3.17</td>
<td>3.13</td>
<td>1.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.35% ISP</td>
<td>2.64</td>
<td>2.78</td>
<td>1.15</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Control</td>
<td>3.33</td>
<td>3.47</td>
<td>2.76</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.85% ISP</td>
<td>3.57</td>
<td>3.57</td>
<td>2.93</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.60% ISP</td>
<td>3.40</td>
<td>3.52</td>
<td>2.83</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.35% ISP</td>
<td>3.21</td>
<td>3.48</td>
<td>2.68</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Control</td>
<td>6.06</td>
<td>5.29</td>
<td>4.49</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.85% ISP</td>
<td>7.73</td>
<td>6.12</td>
<td>5.54</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.60% ISP</td>
<td>5.78</td>
<td>5.56</td>
<td>4.73</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.35% ISP</td>
<td>5.21</td>
<td>4.98</td>
<td>4.17</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Control</td>
<td>6.72</td>
<td>6.83</td>
<td>6.66</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.85% ISP</td>
<td>6.73</td>
<td>6.47</td>
<td>6.66</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.60% ISP</td>
<td>7.00</td>
<td>7.25</td>
<td>7.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.35% ISP</td>
<td>5.94</td>
<td>5.54</td>
<td>6.08</td>
</tr>
<tr>
<td>2-4</td>
<td>4</td>
<td>Control</td>
<td>3.26</td>
<td>3.84</td>
<td>2.08</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.85% ISP</td>
<td>3.81</td>
<td>4.07</td>
<td>2.22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.60% ISP</td>
<td>3.74</td>
<td>3.86</td>
<td>2.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.35% ISP</td>
<td>3.73</td>
<td>4.07</td>
<td>2.03</td>
</tr>
</tbody>
</table>

$^a$Standard error: Mesophiles: 0.14  
Psychotrophs: 0.15  
Lactic acid bacteria: 0.15.
(3.35%) contributed high enough levels of some undetermined inhibitor of anaerobic bacteria to the product. Under retail display conditions at approximately 5°C, the extended cured beef had a shelf-life greater than 3 weeks on the basis of a spoilage level of $10^7$ colony-forming units (CFU)/g determined by Kraft and Ayres (1952). When the display temperature was raised to 8°C to 10°C, however, the product spoiled shortly after 2 weeks, regardless of the level of ISP added. In contrast, samples stored in cardboard boxes held at 2°C to 4°C under conditions similar to those found during wholesale distribution did not exceed $10^4$ CFU/g after 4 weeks for any of the bacterial types examined. That time would be considered enough to allow products of the type studied to go to the commercial wholesale distribution chain.

No significant ($P > 0.05$) treatment effects were observed in samples inoculated with Clostridium sporogenes PA3679 and temperature abused at 24°C to 25°C for 24 and 48 hr. Although no clostridial vegetative cells were detected by phase-contrast microscopy performed on spore suspensions used to inoculate the product, total anaerobic count in inoculated samples on day 0 yielded an average of $10^5$ clostridial CFU/g, whereas the corresponding mean viable PA3679 spore numbers were only $10^3$/g. That observation indicated that C. sporogenes spores germinated very rapidly after product inoculation. Most samples contained no viable clostridial spores after 24 hr. of elevated temperature holding (24°C to 25°C) suggesting that inoculated spore germination was nearly 100%. However, no C. sporogenes growth after germination was observed in the product even after 48 hr. of temperature abuse regardless of treatment. During exposure to
abuse temperatures, PA3679 numbers decreased in all inoculated samples, whereas other anaerobic microorganisms reached numbers as high as $10^7/g$ and brought about slime formation and off-odors within 24 hr. Consequently, spoilage bacterial growth during simulated product mishandling was rapid enough to render it inedible before any possible clostridial growth could be demonstrated.

**Experiment 2**

**Introduction**

The objective of this experiment was to compare the effect of canning on ham, cured beef and soy extended cured beef.

**Proximate analysis**

Percentage moisture, fat and protein mean values for ham, cured beef and soy extended cured beef are shown in Table 8. No significant ($P > 0.05$) difference for moisture was found between ham and cured beef, but soy extended cured beef was significantly ($P < 0.05$) higher. This was probably due to the difference in injection level. Significant ($P < 0.05$) differences for protein content were found between the products studied with the soy extended cured beef having the lowest value. Due to the physical restraint provided by the can, the moisture migration during cooking was limited. In the soy extended cured beef, because the injection level was higher, it was possible to retain much of the water injected that otherwise would have been lost by the product. This circumstance produced a reduction of the percentage protein content.
Table 8. Proximate analysis of ham, cured beef and soy extended cured beef^a

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Moisture (%)</th>
<th>Protein (%)</th>
<th>Fat (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ham</td>
<td>71.97^b</td>
<td>19.21^c</td>
<td>3.85^b</td>
</tr>
<tr>
<td>Cured beef</td>
<td>72.10^b</td>
<td>17.84^b</td>
<td>5.78^c</td>
</tr>
<tr>
<td>Soy extended cured beef</td>
<td>76.22^c</td>
<td>14.26^d</td>
<td>4.44^b,c</td>
</tr>
<tr>
<td>SE</td>
<td>0.49</td>
<td>0.22</td>
<td>0.42</td>
</tr>
</tbody>
</table>

^aN = 3 per treatment mean.

^b,c,d Mean values within each column having different letters are significantly different (P < 0.05).
Ham and cured beef were significantly ($P < 0.05$) different in fat content. Muscle location and species probably account for this difference. Soy extended cured beef was not significantly different ($P > 0.05$) from either ham or cured beef in fat content.

**Cooking yield and percentage extension**

Cooking yield and percentage extension mean values are presented in Table 9. No significant ($P > 0.05$) difference was found between ham and cured beef. However, soy extended cured beef was found to be significantly ($P < 0.05$) higher in cooking yield than ham or cured beef, even though it had a lower protein content. The difference is probably due to the high water binding capacity of the ISP.

Soy extended cured beef was significantly ($P < 0.05$) higher in percentage extension than ham and cured beef which was due to the difference in injection level. It cannot be expected to have the same amount of weight gain with 10% injection as with a 50% injection. Something very important to look at was the increase of percentage extension due to canning. This can be noted if a comparison of the soy extended cured beef of this experiment and the soy extended cured beef containing 1.85% ISP of Experiment 1 (Table 4) is made. Both products used the same type of meat and brine formulation. It can be concluded that canning is advantageous in this experiment and extended products.
Table 9. Effect of canning on ham, cured beef and soy extended cured beef, percentage extension, cooking yield and percent purge values

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Percentage extension</th>
<th>Cooking yield</th>
<th>% purge at 6 weeks of storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ham</td>
<td>5.45&lt;sup&gt;b&lt;/sup&gt;</td>
<td>95.87&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.49</td>
</tr>
<tr>
<td>Cured beef</td>
<td>5.41&lt;sup&gt;b&lt;/sup&gt;</td>
<td>95.83&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.28</td>
</tr>
<tr>
<td>Soy extended cured beef</td>
<td>44.86&lt;sup&gt;c&lt;/sup&gt;</td>
<td>96.58&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.42</td>
</tr>
<tr>
<td>SE</td>
<td>0.18</td>
<td>0.16</td>
<td>0.22</td>
</tr>
</tbody>
</table>

<sup>a</sup>N = 3 per treatment mean.

<sup>b</sup>,<sup>c</sup>Means within each column having different letters are significantly different (P < 0.05).
**Purge**

Purge is the water released from the product during storage. Means presented in Table 9 show no significant (P > 0.05) difference between treatments during the 6 weeks of storage period studied. It can be concluded that the soy extended cured beef followed the same pattern in purge release as ham, the product that was used as an overall model for the entire research project.

**Hunter Lab color values**

Hunter Lab color values are presented in Table 10. The "L" value was significantly (P < 0.05) different between treatments, with ham being the lightest and cured beef the darkest. Soy extended cured beef was in between. This shows that the lightening effect in soy extended cured beef is due to a dilution of the color produced by the high level of injection and not to other factors. Ham was significantly (P < 0.05) less red (lower "a" value) than the beef products because pork has a lower myoglobin concentration.

A product that is lighter and less red normally presents a higher "b" value (measure of yellowness). Our results confirm this observation. Ham had a significantly (P < 0.05) higher "b" value than the beef products.
Table 10. Effect of canning on ham, cured beef and soy extended cured beef Hunter Lab color values

<table>
<thead>
<tr>
<th>Treatment</th>
<th>&quot;L&quot;</th>
<th>&quot;a&quot;</th>
<th>&quot;b&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ham</td>
<td>52.82^b</td>
<td>8.07^c</td>
<td>6.28^b</td>
</tr>
<tr>
<td>Cured beef</td>
<td>37.29^d</td>
<td>11.22^b</td>
<td>5.35^c</td>
</tr>
<tr>
<td>Soy extended cured beef</td>
<td>42.06^c</td>
<td>10.32^b</td>
<td>5.48^c</td>
</tr>
<tr>
<td>SE</td>
<td>1.18</td>
<td>0.32</td>
<td>0.16</td>
</tr>
</tbody>
</table>

^ = 3 per treatment mean.

^aN = 3 per treatment mean.

^b,c,d Means within each column having different letters are significantly different (P < 0.05).
SUMMARY

Two experiments were performed to determine the effect of isolated soy protein and canning on the physical, chemical, microbiological and sensory properties of extended cured beef. Each experiment was replicated three times.

In the first experiment, four treatments with varying levels of isolated soy protein were made: a control with no isolated soy protein added, one with 1.85% isolated soy protein, one with 2.6% isolated soy protein and one with 3.35% isolated soy protein. Even though isolated soy protein improved product yield, percentage extension, moisture and fat contents, the differences were not statistically significant. Protein content and purge were improved due to isolated soy protein addition. No effect on color stability, residual nitrite, pH, and TBA due to isolated soy protein was found. A lightening effect due to soy level was present but no effect on redness or yellowness was found. Higher levels of isolated soy protein (2.6% and 3.35%) reduced the sensory scores for flavor, texture, juiciness and overall acceptability. No microbiological effect could be attributed to the level of isolated soy protein on the basis of mesophilic, psychotrophic, anaerobic, and lactic bacterial counts. Inoculated Clostridium sporogenes PA3679 did not grow in the product during 24 or 48 hr. of simulated mishandling.

In the second experiment, canned ham, cured beef and soy extended cured beef (1.85% isolated soy protein) were compared. Soy extended cured beef was higher in percentage extension, product yield and
moisture, but it was lower in protein content. This was probably due to differences in injection levels and to the addition of isolated soy protein. No differences in purge between products was found. Soy extended beef color values were found to be in between those of ham and cured beef with ham being the lightest and less red and cured beef being the darkest and more red. The most important finding of this experiment was that canning increases the effects of extending meat over the conventional methods of production.
CONCLUSIONS

1. An extended cured beef product that has similar characteristics to ham with good storage quality and high acceptability to consumers can be produced.

2. Addition of isolated soy protein is needed in order to maintain the moisture/protein ratio of commercial ham with the high injection levels used.

3. Higher levels of isolated soy protein in the product reduced the sensory scores for flavor, texture, juiciness and overall acceptability.

4. No microbiological effect could be attributed to the level of isolated soy protein added to the product.

5. Canning increases the percent extension and cooking yield over the conventional methods of production.

6. The similarity in color between ham and soy extended cured beef was due to a dilution of pigment produced by the high injection level and not to the addition of isolated soy protein.


Siegel, D. G., Church, K. E., and Schmidt, G. R. 1979c. Gel structure of non-meat proteins as related to their ability to bind meat pieces. J. Food Sci. 44:1276.


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