1988

Process and Quality Characteristics of Ocean Pout Surimi

Paul Akeng'o
University of Rhode Island

PROCESS AND QUALITY CHARACTERISTICS OF OCEAN POUT SURIMI

BY

PAUL AKENG'O

A THESIS SUBMITTED IN PARTIAL FULFILLMENT

OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

IN

FOOD SCIENCE AND TECHNOLOGY

UNIVERSITY OF RHODE ISLAND

1988

MASTER OF SCIENCE THESIS

OF

PAUL AKENG'O

Approved:

Thesis Committee:

Major Professor .....

.....

.....

.....

Dean of the Graduate School

UNIVERSITY OF RHODE ISLAND

1988

THESIS ABSTRACT

Experiments were conducted to utilize ocean pout (Macrozoarces americanus) for the production of surimi, a washed fish mince made stable for frozen storage by incorporation of cryoprotectants. Principal factors affecting gel forming properties, freeze-thaw stability and sensory quality of ocean pout surimi were examined alone, as well as, in combination with either red hake or turkey meat under various conditions. Parameters studied were: i) moisture and salt levels, ii) thermal gelation in a single as well as a two-stage heating process, iii) optimization of gel formimg properties and freeze-thaw stability of blended surimi, iv) texture-modifying effect of different nonfish proteins in the ocean pout surimi and its applicability as a binder in formed products, and v) use of ocean pout in the turkey as an extender. Compressive force (cohesiveness) and penetration force (rigidity) were measured for the evaluation of gel forming properties of surimi, and expressible moisture for water binding ability as well as freeze-thaw stability of surimi gel. Sensory quality of ocean pout incorporated turkey roll was also evaluated.

The 74% moisture level produced the most cohesive gel while NaCl progressively increased cohesiveness and rigidity, accompanied by a general decrease in expressible moisture.

Thermal gelation was best demonstrated on a single-stage heating at 90 C by maintaining the integrity of the gel; regardless of the length of time of heating as compared to a two-stage heating, heat-setting at different temperatures and subsequent cooking at 90 C. Blending ocean pout surimi with red hake surimi resulted in increases in all measured physical characteristics as the red hake surimi level increased. At the 5% level, egg albumin outperformed the rest of nonfish proteins in improving the texture as well as reducing the amount of expressible moisture. The gel strengthening ability of egg albumin reached a maximum at a 2% level above which significant decrease in all parameters were observed. The development of a turkey roll from a blend of ocean pout surimi and turkey at different combinations, showed that the product was acceptable up to a 50% replacement with ocean pout surimi; regardless of whether a nonfish protein was incorporated or not.

ACKNOWLEDGMENT

The author extends valued recognition and gratitude to his advisor, Dr. C.M. Lee for the academic assistance and guidance throughout the author's stay at the University and especially in his organization of the various facts into the meaningful patterns presented in the text.

Special appreciation are due to the author's committee members, Dr. J.A. Dain, and Dr. H.J. Dymsza for their useful suggestions in completing this thesis.

Most of all, the author wishes to express his special appreciation to his parents who gave him the opportunity and encouragement to study.

PREFACE

This thesis was written to conform to the manuscript plan approved by the University of Rhode Island Graduate School. The first portion is a manuscript which has been written in a form suitable for publication in the Journal of Food Science. The second portion includes appendices which present in detail the procedures and information referred to in the manuscript.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF FIGURES

MANUSCRIPT I

LIST OF FIGURES (continued)

LIST OF FIGURES (continued)

Page

APPENDIX

MANUSCRIPT I

PROCESS AND QUALITY CHARACTERISTICS OF OCEAN POUT SURIMI

ABSTRACT

Gel forming properties and freeze-thaw stability of ocean pout (Macrozoarces americanus) surimi, with and without red hake surimi blend, were determined by evaluating physical and other sensory parameters under various formulation and processing conditions. Paramaters studied were: i) moisture and NaCl levels, ii) thermal gelation in a single- and a two-stage heating process, iii) optimization of gel forming properties and freeze-thaw stability of blended surimi, and iv) texture-modifying effect of different nonfish proteins in the ocean pout surimi and its applicability as a binder in formed products, and v) suitability of ocean pout surimi in a turkey roll as an extender. The sensory quality of the ocean pout surimi was evaluated alone and in combination with turkey meat as it was formed into a turkey roll.

The 74% moisture level produced the most cohesive gel while NaCl levels from 0 to 3% progressively increased cohesiveness and rigidity accompanied by a general decrease in expressible moisture. Thermal gelation was best demonstrated on a single-stage heating at 90 C by maintaining the integrity of the gel; regardless of the length of time of heating as compared to a two-stage heat setting at various temperatures followed by cooking at 90 C. Blending ocean pout with red hake surimi resulted in increases in all

measured physical characteristics as the level of red hake surimi increased. At the 5% level, egg albumin outperformed the rest of nonfish proteins in improving the texture as well as in reducing the amount of expressible moisture. The strengthening ability of egg albumin reached a maximum at 2% level above which significant decreases in all measured parameters were observed. The development of a turkey roll from ocean pout surimi and turkey chunks at different combinations showed that the product was acceptable up to a 50% replacement with ocean pout regardless of whether a nonfish protein was incorporated or not.

Introduction

The revolutionary discovery of the process of preserving fish mince during freezing in the cryostabilized form has spawned a whole new field of research as scientists investigate ways of producing a mass of cryostable raw materials from fish. Specialists studying the mechanism of cryoprotection are fascinated by what they have already learned and are using this process to exploit fishery resources to a fruitful advantage.

Surimi, a crude form of myofibrillar proteins is the Japanese term for mechanically deboned fish that has been washed with water and mixed with cryoprotectants for a good frozen shelf-life. It is used as an intermediate product in the manufacture of a variety of fabricated seafoods. Since the introduction of surimi in the U.S. markets in 1978, consumer acceptance of fabricated seafood products has increased dramatically. Two million pounds were sold in 1979, increasing to 29 million pounds in 1983 (Lee, 1984). In 1984 alone, 75 million pounds of surimi-based products were sold wholesale (King, 1985). U.S. seafood processors have since then expressed interests in sharing the the world surimi market, which has been dominated by the Japanese (King, 1985).

The importance of fabricated seafoods in supplementing and substituting for conventional sources has been reflected

in the past and present market growth. Chronic shortages of raw materials, increasing costs and increased per capita consumption has forced seafood processors to focus on fabricated products such as shrimp, lobster, and fish portions to improve the market share. The process of fabrication and extrusion offers the process or an opportunity to utilize a variety of cheap supply of raw materials to produce profitable products.

Institutional acceptance of fabricated seafoods was first recognized in 1973 (Katz, 1974). Retail acceptance is evident from the already growing number of new products appearing on supermarket frozen food shelves. Fabrication usually involves combining the suitable matrix agents at an appropriate level to retain the desired texture when the mixture is passed through an extruder. The primary matrix agent, myofibrillar proteins, is the major component of surimi and is responsible for the textural characteristics of a wide variety of surimi-based products. When the washed fish mince is mixed with cryoprotectants and frozen, a condition which is less conducive to freeze deterioration is created. Much research on this subject has focused on the effect of various cryoprotectants on the proteins functional stability as well as on gelation, a process invariably linked to the success in the manufacture of finished products.

The gel forming ability of surimi is known to vary with the functional characteristics of these proteins which is

species-dependent (Lanier et al., 1982; Hashimoto, 1985; Shimizu, 1974). Processing technology coupled with quantitative monitoring of the gelation process is important in the prediction of end product characteristics with respect to such variables as temperature, NaCl, moisture and other formulation additives.

As a result of an expanding surimi market, coupled with a growing sign of shortage of Alaskan pollock, securing stable supplies of additional sources of raw materials are being actively sought. This would not only lead to development of new sources of surimi, but also reduce the dependency on Alaskan pollock.

Initial preliminary studies indicated that the surimi made from ocean pout possessed unique textural and flavor characteristics and can be processed into a product that cannot be produced by red hake or Alaskan pollock which is conventionally being used. Presently, use of ocean pout is limited to fillets and nobody has explored its potential application for production of surimi and surimi-based products. For any species to be used for producing a good quality surimi, one must understand the species-dependent thermal gelation behavior of myofibrillar proteins, the relationship of moisture to freeze-thaw stability, and the effect of ingredients incorporated in formulation.

With respect to the supply of surimi, a continued decline in the stock of Alaskan pollock has been noted

(Lee, 1986). Blending of surimi from different sources is expected to reduce the production costs as well as improve the supply problem (Lanier, 1985). It is therefore proposed in this study to evaluate ocean pout for its suitability for surimi production, and to determine how effectively ocean pout can be used in blended products as well as its applicability as a binding material in the production of formed meat products.

Materials and Methods

Fresh fish, ocean pout (Macrozoarces americanus) and red hake (Urophycis chuss) used for preparing surimi, were obtained from local fishermen at Point Judith, R.I. They were about 2-3 days post-harvest upon arrival and appeared to be in good condition. They were transported on ice to the pilot plant facility at the University of Rhode Island where they were immediately filleted skinned before processing into surimi.

Preparation of surimi was done in a pilot plant. The surimi pilot plant was equipped with a production line having a throughput capacity of 500 lbs. The production line consisted of meat-bone separator (Baader 694, Baader North America, New Bedford, MA), washing tank (500 gallon capacity with a paddle agitator, rotary rinser, strainer (Bibun SUM 420, Bibun Manufacturing Co., Japan), and screw press dehydrator (Bibun SR 1000).

The prepared surimi was mixed with cryoprotectants and stored frozen until tested. The preparation of surimi gel was done at the preparation laboratory equipped with a silent cutter (Model #84142, Hobart Manufacturing Co., Troy, Ohio), extruder with different sizes of nozzles, water bath, electronic scale (50 kg capacity), and Instron testing machine (Model 1122, Instron Corp., Canton, MA). The cryoprotectants, namely, sucrose, sorbitol and polyphosphates were commercial grade, and proteins used were wheat gluten (WG) from Ogilvie Mills (Minnetonka, MN); soy protein isolate (SPI) from Grain Processing Corporation (Muscatine, Iowa); milk protein isolate (MPI) from New Zealand Milk Products (Petaluma, CA); egg white (EW) from Hydrate Egg Products (Elizabeth, NJ); and lactoalbumin (LA) from New Zealand Milk Products (Pelaluma, CA).

Preparation of surimi and surimi gels

As outlined in Fig 1, the ocean pout or red hake flesh was separated from belly flaps to avoid incorporating protease and black skin, and run through a deboner (Baader 694) equipped with a drum having 3-4 mm perforations. The mince was washed for 2 min in ice chilled water (5 C) at a meat to water ratio of 1:4 and pumped into a washing tank (500 gallon capacity equipped with a paddle agitator) and agitated for additional 10 min. The slurry was discharged

into a rotary rinser and the meat was collected. Washing and rinsing was repeated. In the second washing 0.2% (w/v) NaCl was used to aid in dewatering. It was then passed through a strainer (Bibun SUM 420) having 2 mm perforations to separate the flesh from dark connective tissue, black skin, bone and scale, and was dewatered by a screw press (Bibun SR 1000). Cryoprotectants were incorporated into dewatered mince at 4%, 4% and 0.2% sucrose, sorbital and polyphosphates, respectively, on a minced meat weight basis while chopping in a Hobart silent cutter for 2 min. The average weight of each batch chopped was 15 kg. Special care was taken not to exceed the temperature of the mince over 10 C. The surimi prepared was then wrapped in aluminum foil, packaged in heat sealable cryobags, vacuum sealed and frozen at -20 C for a period of 2 weeks before conversion into gels for laboratory testing.

Frozen surimi from a single production lot was thawed overnight in the walk-in refrigerator at 4 C. The half-thawed surimi was chopped into paste in a silent-cutter (Hobart Manufacturing Co., Troy, Ohio) for 10 min with 2.0% NaCl (Morton plain salt, Morton Thiokol, IL), keeping processing temperature of paste below 10 C in order to prevent any possible changes in gel forming properties of myofibrillar proteins as a result of increase in temperature (Lee, 1984). Surimi gels were prepared by stuffing the paste into 25mm cellulose casings using an extruder. The extruder

worked on the principle of volumetric displacement from a hopper to an appropriate shaping spout by the action of a water powered piston. Volume and speed were adjusted to produce uniformity of the extrudate. The extrudate in casings was then immersed into a water bath at 90 C and heat set for 40 min for further gel testing or steam cooked for 20 min for sensory evaluation, removed, cooled in running tap water for 5 min and placed at room temperature for 24 hr before testing. Following the procedures for gel testing proposed by Lee (1984a), compressive force (cohesiveness), penetration force (rigidity) and expressible moisture were measured using an Instron testing machine.

Effects of moisture levels

After a storage period of two weeks, surimi was thawed overnight at 4 C and chopped for 10 min into paste by adding 2.0% NaCl and enough water to bring moisture level to 72%, 75%, 76%, 78% and 80%, respectively. The paste was stuffed into 25mm cellulose casings, cooked at 90 C for 40 min, cooled in running tap water for 5 min, and left at room temperature for 24 hr before testing for gel properties. Results were used to determine the moisture-dependent gel setting behavior of ocean pout surimi.

Effects of two stage heating process

Heat-induced gel setting behavior was determined by subjecting the extruded paste to a single-stage as well as two-stage heating. The half-thawed surimi was chopped with 2.0% NaCl on a surimi weight basis and enough water to adjust moisture level to 78%. The paste was divided into two lots and treated as follows. The first lot was subjected to a single-stage cooking at 90 C for 30, 40, 50 and 60 min to determine the cooking time dependency of gel setting. The second lot was heat-set in a two-stage heating process for 20 min at 40 C, 50 C and 60 C, followed by cooking for 30 min at 90 C to determine the temperature-dependency of gel setting. The resulting gels were tested as described previously.

Effects of NaCl concentration

Ocean pout surimi were thawed overnight at 4 C and chopped with varying amounts of NaCl and enough water to adjust moisture level to 78%. NaCl was added at 1%, 1.5%, 2.0%, 2.5% and 3% on a surimi weight basis. The paste was extruded into 25mm cellulose casings and cooked at 90 C for 40 min. After equilibrating to room temperature overnight, the gels were tested for the textural properties.

Formulation optimization in blended surimi

Frozen surimi of ocean pout and red hake each obtained from a single production lot under the same processing conditions were used as a principal source of the matrix forming protein. The combinations consisted of the following ratios 0:100, 20:80, 40:60, 60:40, 80:20 and 100:0 ocean pout to red hake, respectively, on a weight-to-weight basis. Surimi gels were prepared in the usual manner and were divided into two groups. Group one was immediately subjected to Instron testing following a 24 hr period of equilibration at room temperature. Group two was subjected to three freeze-thaw cycles before testing in order to evaluate freeze-thaw stability in terms of changes in the expressible moisture and physical parameters of the gels (Lee, 1984). For each parameter, a set of duplicate gels were tested before and after freeze-thaw storage. Each cycle consisted of three days in the freezer at -20 C and one day thawing at 4 C. The final thawing was accomplished at room temperature in order to equilibrate gels to room temperature.

Evaluation of texture modifying effects of different proteins

Samples for evaluating the texture-modifying effect of different nonfish proteins in ocean pout surimi were prepared in the following manner. The frozen surimi was thawed

overnight at 4 C in the walk-in refrigerator. A 600g portion of surimi was chopped for 10 min in a Hobart silent cutter with addition of proteins (soy protein, milk protein concentrate, gluten, egg albumin and lactoalbumin) at a 5% level on a surimi weight basis. Two per cent NaCl and enough water to achieve 78% moisture level were added during chopping. The texture-modifying effect was then assessed from the Instron data. The additive protein which produced the best result in terms of gel cohesiveness and water binding was reformulated into surimi at levels of 0%, 2%, 4%, 6% and 8% to test for the effect of the protein levels on textural properties of ocean pout surimi gels and was treated in the same manner as described previously.

Binding ability of ocean pout surimi

In preparing a turkey roll, seven blends, each 500 g, were formulated to contain 0:100, 10:90, 20:80, 30:70, 40:60, 50:50 and 100:0 of ocean pout surimi paste to turkey chunks. The ocean pout surimi paste was prepared in the same manner as previously described with addition of 2% egg albumin on a surimi weight basis. The turkey chunks were prepared by appropriately dicing the lean portion obtained from the thigh and breast after hand deboning. The chunks were put in a bowl and mixed to give a uniform mix. The dressed whole turkey was purchased from a local supermarket. All

formulations were mixed in a Hobart bowl mixer for for 3 min at a constant speed with addition of enough NaCl and sodium tripolyphosphate to achieve a level of 1.5% and 0.2%, respectively. The 2% level resulted in a maximum gel strength in the ocean pout surimi. All blends were stuffed into 30mm cellulose casings and steam cooked for 20 min in the autoclave. Comparisons for visual and sensory parameters were made for albumin and non-albumin extended formulations. Samples for testing were cut approximately 10mm long and served as cold to a panel of six members who were acquainted with the evaluation of surimi-based products. Each member independently evaluated samples for hardness, cohesiveness, chewiness, moistness, appearance and overall acceptability. The scores used by the panelists were 1 = low and 9 = high for all sensory parameters. Analysis of variance were used to analyze the effect of treatment according to SAS (1982). The significance of the differences in means was determined according to Duncan's multiple range test at a predetermined level of probability of 5% for all analysis throughout the experiment.

Evaluation of gel forming properties and freeze-thaw stability

For each test condition, quadruplicate preparations of samples were used. Textural properties of gels from each

treatment including cohesiveness (compressive force), rigidity (penetration force), tensile strength (tensile force) and expressible moisture were tested using Instron testing machine. Textural properties were evaluated at 90% deformation of a cylindrical sample (length 25mm, diameter 30mm). The cross head and chart speeds were adjusted to 50mm and 100mm per minute, respectively. Compressive force at failure was measured as an index of gel cohesiveness using 90% deformation at a deformation rate of 50mm/min. The peak compressive force in kg at failure was defined as cohesiveness of the sample. Penetration force was measured using a 5mm diameter probe. Tensile strength was measured by measuring the tensile force required to break a 2mm thick extrudate (25mm wide X 70mm long) which was partially heat-set at 50 C for 15 min. These properties are generally used to elucidate the force-deformation relationship and the physio-chemical behavior of the gel in relation to the processing or treatment conditions. Under the same testing conditions expressible moisture was also measured during compression test by placing samples on two pieces of Whatman filter paper (fast speed, 12cm diameter). The weight of the expressed moisture after compression was used as expressible moisture. This was then expressed as a percentage of the sample moisture content. The expressible moisture was also measured before and after three freeze-thaw cycles and was used as an indication of freeze-thaw stability.

The total moisture content of the samples was determined by drying approximately 5 grams of gel in the drying oven (Model OV-12, Modern Electric Laboratory, Chicago, IL).

Sensory evaluation

Sensory textural properties of the ocean pout surimi incorporated turkey roll were evaluated at different combinations of ocean pout surimi and turkey chunks by a group of six taste panelists composed of graduate students and faculty of the Department of Food Science. They were well acquainted with the products and had previous experience in evaluation of surimi-based products and therefore were familiar with technical terms used in the procedure. Evaluation was done for cohesiveness, hardness, chewiness, moistness, appearance and overall acceptability. Each panelist was asked to score the intensity of each textural characteristic measured on a 9-point scale. Hardness was described as the ease by which a sample was cut by front teeth; cohesiveness as the extent to which material was deformed before it ruptures when compressed between the fingers; chewiness as the number of chews required to masticate a solid food to a steady state for swallowing; moistness as the ability of a sample to give juice when it is compressed with a finger. Two experimental trials were prepared for each matrix agent level by mixing in a bowl

mixer for 3 min a 500 g portion of the combined matrix of surimi paste chopped for 5 min in a Hobart silent cutter and chunks obtained by hand deboning of breast and thigh meat. Trial No. 1 was formulated using surimi paste and turkey chunks, while Trial No. 2 contained 2% egg albumin formulated on a surimi weight basis. NaCl and polyphosphates were adjusted to 1.5% and 0.2%, respectively, by weight of the mixture for each combination. The mixture was extruded in the usual manner into 30mm cellulose casings, labeled, and cooked in the autoclave at 90 C for 20 min and kept in the refrigerator until served to the panelist.

Statistical Analysis

The data were analyzed using the Statistical Analysis System (SAS, 1982). The instrumentally measured textural properties and sensory characteristics were analyzed for the significance of difference and degree of variations among different treatments. Duncan's Multiple Range Test was used to determine significance differences within the treatment and simple correlation coefficients between parameters were calculated using the Proc Corr program. The degree of variation was determined using the analysis of variance.

Figure 1. PROCESS SCHEME FOR SURIMI PREPARATION

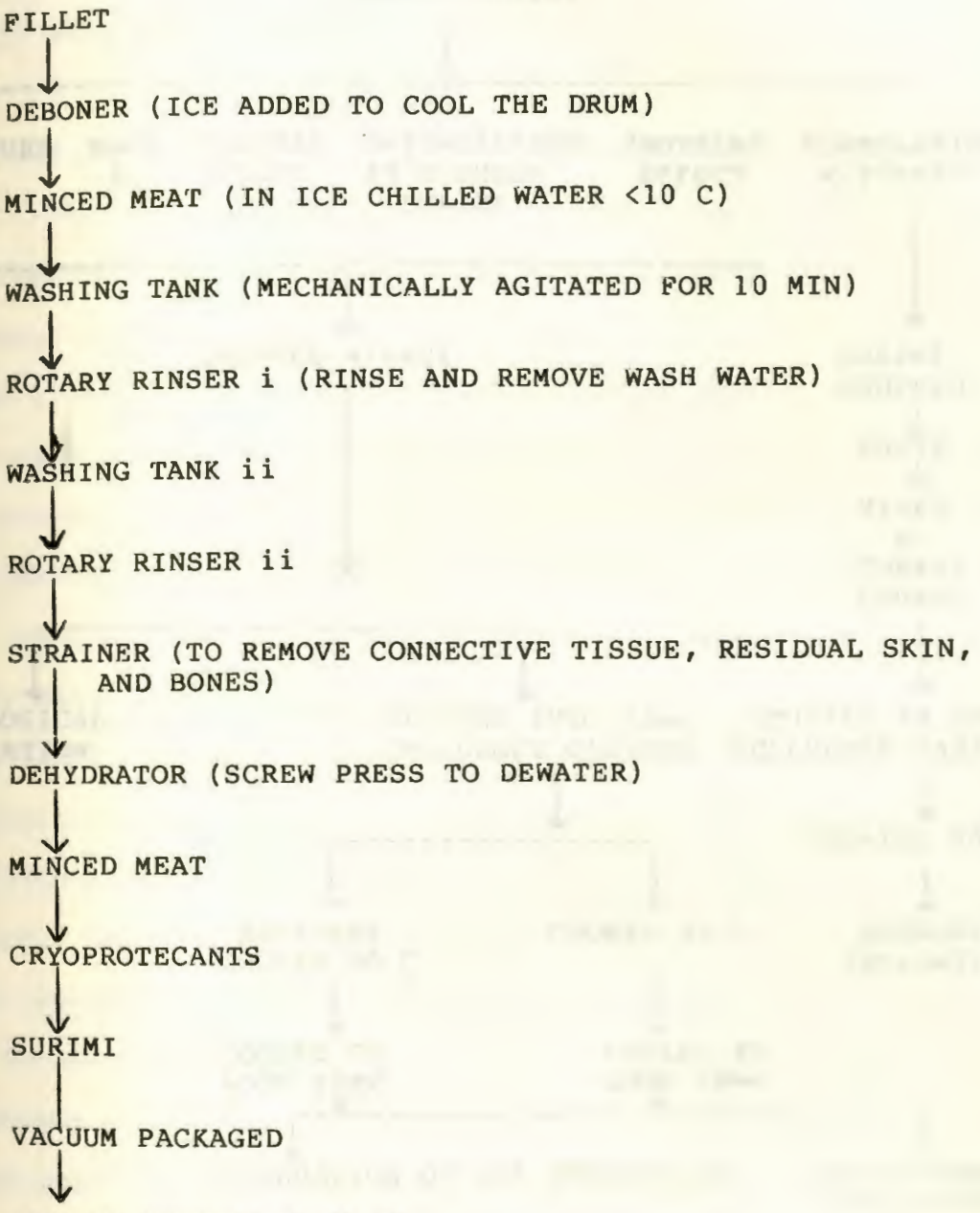
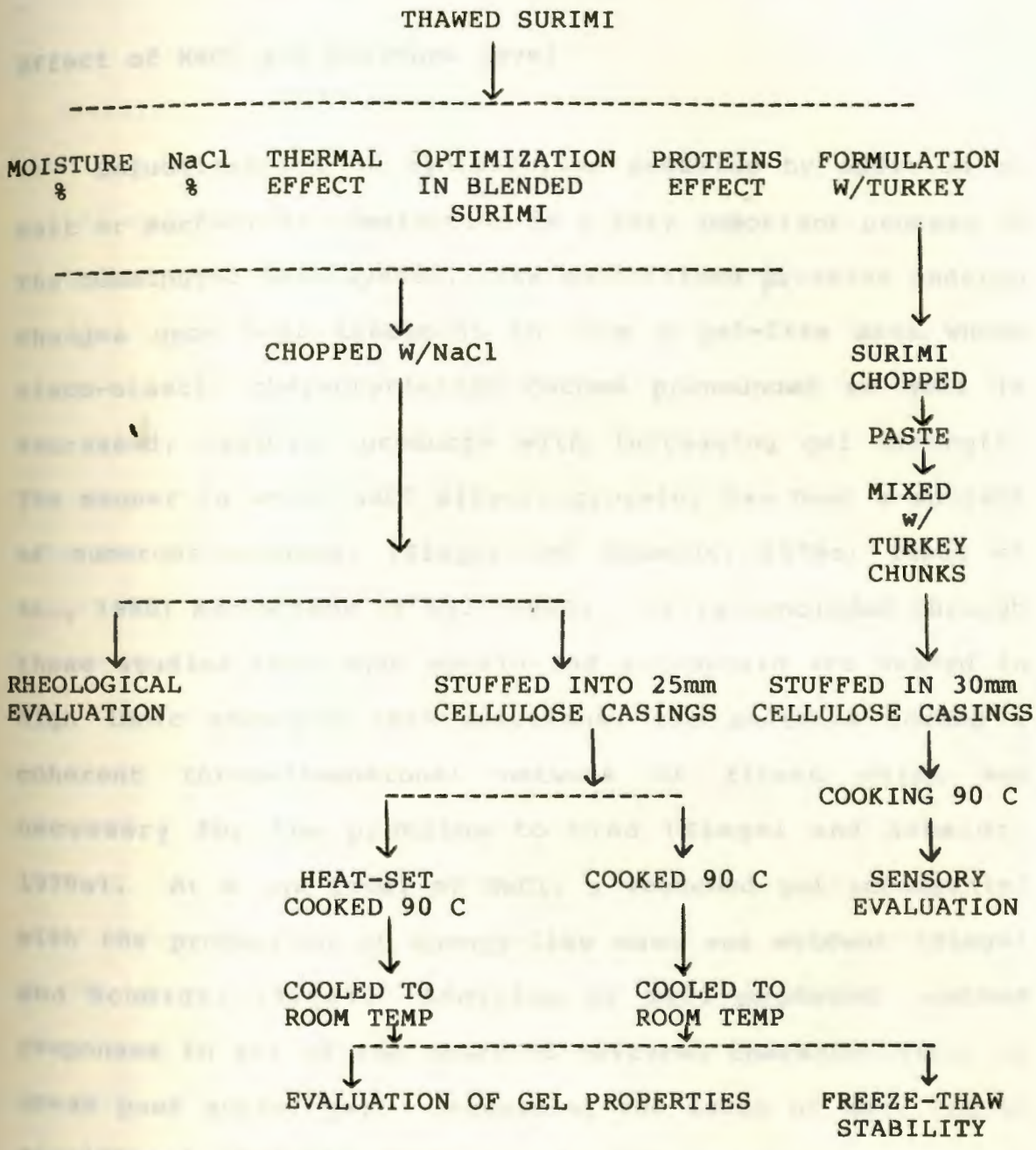


Figure 2. PROCESS SCHEME FOR PREPARATION OF SURIMI GELS



RESULTS AND DISCUSSION

Effect of NaCl and Moisture level

Solubilization of myofibrillar proteins by addition of salt or mechanical comminution is a very important process in the comminuted meat system. The solubilized proteins undergo changes upon heat treatment to form a gel-like mass whose visco-elastic characteristics become pronounced as NaCl is increased, yielding products with increasing gel strength. The manner in which NaCl affects proteins has been a subject of numerous studies. (Siegel and Schmidt, 1979a; Yasui et al., 1980; MacFarlene et al., 1986). It is concluded through these studies that when myosin and actomyosin are heated in high ionic strength salt solutions, the proteins formed a coherent three-dimensional network of fibers which was necessary for the proteins to bind (Siegel and Schmidt, 1979a). At a low level of NaCl, a weakened gel accompanied with the production of spongy-like mass was evident (Siegel and Schmidt, 1979a). Addition of NaCl produced marked responses in all of the observed textural characteristics of ocean pout surimi gel. Increasing the level of NaCl led to significant ($P<0.05$) decreases in the expressible moisture (Fig. 3). Ambient NaCl levels of 2% and 2.5% were not significantly different in their effect on the moisture of the paste, expressible moisture, cohesiveness and rigidity.

An inverse relationship was obtained between expressible moisture and the NaCl level. The cohesiveness of ocean pout surimi was markedly affected by salt concentration (Fig. 4). A positive response was observed by increasing NaCl level with the most cohesive gels produced at the 3% level on a surimi weight basis (Fig. 4). Rigidity (Fig. 5) as a measure of gel strength also increased with increased NaCl, peaking at 3%, though the changes were less sensitive to Instron textural analysis as was obtained with expressible moisture and cohesiveness. There was no statistical significance in rigidity at salt concentrations of 1.5%, 2% and 2.5%. This suggests that penetration test is not as discriminative as compression test and is in agreement with the previous report by Lee and Chung (1988).

The changes in cohesiveness, rigidity, and expressible moisture of ocean pout surimi after salt treatment were observed to differ in the mode of action between red hake and Alaskan pollock (Douglas-Schwarz and Lee, 1988). The cohesiveness of ocean pout gel linearly increased and peaked at 3%; whereas red hake and Alaskan pollock showed maximum cohesiveness at 2% and 1.5%, respectively, and declined as the NaCl level increased.

Solubilization of myofibrillar proteins is greatly affected by the salt concentration (Lee and Toledo, 1976; Quinn et al., 1980). Nakayama and Sato, (1971ab); Samejima et al., (1969); Fukazawa et al., (1961) have studied model

systems containing isolated protein components of the myofibrillar fraction. More importantly was their conclusion that myosin and actomyosin were more important in binding. Their findings contrasted with those of MacFarlene et al. (1980), and Siegel and Schmidt, (1979b) as to the ability of each individual component to form stronger bonds. Yasui et al., (1980) observed that actin, alone, could not form a stronger gel, but when myosin was added, the gel produced was much stronger. Along with the difference in gel forming properties between ocean pout and red hake/Alaskan pollock surimi (Douglas-Schwarz and Lee, 1988), observations of these isolated model systems may lead us to theorize that one of the factors accounting for the differences may probably be found in the relative amounts of individual protein fractions of the myofibrils and their effectiveness to bind or interact with other proteins in the system, besides the species specificity. Okada (1973) reported that commercial surimi gel from Atlantic pollock is produced at a salt level between 2.5%-3.5% above which textural characteristics are drastically reduced. This level is much higher than 1.5% that was reported as an optimal level by Douglas-Schwarz and Lee (1988). The loss in texture at a high salt level attributed to the salting out phenomena (Lehninger, 1970) which is accompanied by increasing salt concentration.

Figures 6 and 7 illustrate the effect of increasing moisture level on textural integrity of ocean pout surimi

gel. Gel cohesiveness and rigidity were best demonstrated at a moisture level of 74% and significantly ($P<0.05$) decreased beyond or below this level. Expressible moisture increased with an increase in moisture level and this corresponded well with a weakening of the gel. During the formation of proteins, amino acids condense through peptide bonds causing partial double bond formation resulting in partial dipole of the peptide backbone which should hydrate when placed in water (Busk, 1984). The degree of polarity of the side groups when in a basic solution enhances hydration (Kuntz and Kauzmann, 1974).

Effect of heat-induced gel setting

Douglas-Schwarz and Lee (1988) examined the effect of heating time at 90 C on red hake and Alaskan pollock surimi gels. Cohesiveness was significantly affected by cooking time showing an inverse relationship.

Heat-induced gel setting behavior of ocean pout surimi as affected by cooking time on a single as well as a two-stage thermal treatment as investigated by varying cooking times at 90 C between 30 to 60 min for a single-stage heating, and varying setting temperature at 40 C, 50 C and 60 C for 20 min followed by cooking for an additional 30 min at 90 C for a two-stage heating.

There were no significant differences ($P<0.05$) in the cohesiveness, rigidity and expressible moisture of surimi gels cooked at different times when subjected to a single stage heating. Thermally heat-set and cooked gels were significantly different from each other and from the gels which were subjected to a single stage heating process. Results in Table 1 show that the strength of ocean pout surimi was marginally affected by cooking time, being at a maximum at 40 min which corresponded very well to the reported standard cooking time (Lee, 1984). The Japanese Ministry of Welfare recommended that an internal cooking temperature of 75 C should be reached (Suzuki, 1981). Tournas (1984) found that cooking for 30 min at 90 C was able to bring the internal temperature of the gel to the recommended level. Cooking ocean pout surimi for 40 min, therefore, appears to be sufficient to allow internal temperature to reach the recommended level.

Katoh et al., (1986) observed that when myofibrillar proteins are subjected to a prolonged heating, myosin heavy chains disappeared. This would decrease the gel forming ability of myofibrillar proteins in model systems. Gel cohesiveness of ocean pout surimi slightly decreased with cooking time, but not significantly in a single-stage heating. Minimal textural changes occurred as a result of prolonged heating time, showing these gels were significantly superior to the gels which were prepared in a two-stage

heating. This study is in contrast with the previous report in which a two-stage heating resulted in formation of a stronger gel (Lanier et al., 1983). Such a discrepancy could be due to lack of gel-network forming ability of ocean pout during a partial heat-setting process. The latter showed significant ($P<0.05$) changes in all measured physical parameters and expressible moisture at all temperatures (Figures 8-11). The strength of the gels diminished as heat setting temperature increased from 40 C to 60 C and an inverse relationship was observed between the quantity of expressible moisture and both cohesiveness and rigidity. Acton and Dick (1984) noted that the syneresis of proteins occurred when heating temperature was increased, resulting in changes in texture. Syneresis follows formation of increased interprotein bonds causing the protein matrix to contract into a more stable state as the number of loci available for bonding water decreased. This consequently reduces the amount of the intermolecular space available for immobilization of water. This finding was supported by the work of Deng et al. (1976) who found that higher temperature increased the protein-protein interactions causing aggregations of the protein and the eventual removal of water. Lanier et al. (1983, 1985) noted through differential scanning calorimeter (DSC) studies that changes in texture may arise due to conformational or structural transitions which occur in the gelling protein matrix under changing temperatures.

As to heat-induced gel setting behavior of ocean pout surimi, it exhibited a maximum gel strength when subjected to a two-stage heating at 40 C/90 C (Table 1). The progressive weakening of the gel as heat set temperature increased to 60C is in agreement with the findings of Lee and Toledo (1976), Makinodan et al. (1986); Lanier et al. (1981); and Su et al. (1981). They attributed the gel weakening to heat stable alkaline proteases remaining in the muscle tissue. The combined effect of heat setting and cooking are summarized in Table 1. Marked differences in cohesiveness, rigidity and expressible moisture among samples incubated at 40 C, 50 C and 60 C for 20 min before cooking for 30 min at 90 C were observed. Samples processed at 40 C setting temperature demonstrated greater gel strength. The setting of solubilized fish proteins at about this temperature is known to involve unfolding of protein structure and noncovalent hydrophobic interactions (Lanier et al., 1982), while losses in sulfhydryl groups are thought to occur at temperatures above this level.

Formulation Optimization in Blended Surimi

The optimization of formulation with respect to the production of surimi-based products has been examined (Lee et al., 1986). Subsequent to the establishment of a target specification, it is recommended that functionality testing

be carried out to find the degree of flexibility from the target functionality at which we can deviate without sacrificing product quality.

In order to assess the changes in gel forming properties due to blending of ocean pout and red hake surimi, the textural properties of surimi gel and subsequent freeze-thaw stability were compared at the following formulations, 100:0, 80:20, 60:40, 40:60, 20:80 and 0:100 (%) ocean pout to red hake, respectively. Results presented in Figures 12 through 15 show textural properties along with expressible moisture. As was expected, surimi prepared from ocean pout alone had a low gel strength when compared to red hake. The gel properties were all significantly ($P<0.05$) affected before and after freeze-thaw cycles according to the analysis of variance. Rigidity, cohesiveness, elasticity, chewiness were highly inversely correlated with expressible moisture over all treatments as the amount of ocean pout surimi in the matrix increased.

Before freeze-thaw cycles, a significant ($P<0.05$) difference in the initial gel strength was shown between 100:0 and 0:100 formulations. The expressible moisture was higher for ocean pout surimi than red hake surimi and progressively decreased as the ocean pout content was reduced in the formulations. This trend was also evident after three freeze-thaw cycles. During frozen storage, Connell (1959), Buttkus (1970, 1971), and Matsumoto (1977) have supported

the theory that aggregation of protein molecules occur in a side-to-side fashion, caused by the dehydrated protein molecule when water is displaced from the hydrating sites of the protein. The aggregated molecules increase the probability of intermolecular crosslinking. A redistribution of water occurs due to changes in water vapor pressure, giving rise to ice crystal formation. When the system is thawed, some of the water leaves the tissue as drip (Noguchi, 1974), and the protein-water affinity is reduced. Lee and Kim (1985) noted that higher expressible moisture was manifested by freeze-thaw instability. Sone et al. (1983) noted that some relationship existed between water holding capacity and protein-water interactions, whereby a strong protein-water interaction would endow a more elastic nature to the gel. From the textural property data obtained in this experiment, usage of ocean pout surimi in blended products would be recommended at the 20% level, though much work is needed to establish the proper processing factors.

The effect of different nonfish proteins on ocean pout surimi gel

Nonfish proteins have been incorporated into surimi to enhance textural strength of surimi-based products. The manner by which these additives influence texture has been described (Lee and Kim, 1985), as primarily their

texture-modifying effect upon thermal treatment. Appropriate protein additives that can maximize texture must be carefully selected. Egg white, lactoalbumin, soy protein, and egg albumin, among others, have been used in surimi (Lee and Kim, 1985).

The texture-modifying effect of some of the above proteins, along with gluten and milk protein, in ocean pout surimi was investigated at a 5% level. Among the additives there were significant differences ($P<0.05$) on the cohesiveness, rigidity and expressible moisture. The order of gel strengthening effect of nonfish proteins on cohesiveness was egg albumin > gluten > soy protein = milk protein > lactoalbumin > control (ocean pout) (Fig. 17). Rigidity followed a similar pattern: soy, milk protein and lactoalbumin were not significantly different ($P<0.05$) (Fig. 18). As to expressible moisture, the control and lactoalbumin had the highest and this significantly differed from the rest (Fig. 16). This clearly supports the previous observation of an inverse relationship between gel strength and expressible moisture. When egg albumin was added at varying levels ranging from 0% to 8%, gels showed a maximum strength at 2% and increasing above this level produced linear decreases in the cohesiveness and rigidity (Fig. 18). Overall, egg albumin outperformed the rest in all measured textural characteristics. This is in agreement with the findings of Lee and Kim (1985). Slight increases in the

texture at an additive level of 5% were attributed to the loss of water from the network possibly due to the absorbtive effect of the protein. Iso et al. (1984) and Bugarella et al. (1985a, b) observed that the additive protein absorbed water and became swollen and merely filled the interstitial spaces of the protein network rather than contributing to the network structure itself. Decreases in texture above the 2% level, as in the case with egg albumin, indicates that a proper amount of the solid content between the surimi and the additive protein must be reached for the filler effect to be optimal. The negative interaction observed, when the level of the protein additive is increased, has been reported (Bugarella et al., 1985; Acton and Dick, 1984; Lanier et al., 1982; Lee, 1986; Chang, 1982; Peng and Nielsen, 1986). It has also been noted that myosin-albumin mixtures proceed with formation of stronger gels at temperatures above 80 C (Foegeding et al., 1986), thus thermal conditions necessary for the albumin to interact with myosin is an important consideration.

Surimi as a binder

Restructured and formed meat systems share one basic but fundamental characteristic, that is, the ability to bind their constituent meat pieces together into a cohesive product that simulates intact muscle. These products often

contain from 10% to 15% fine ground meat or mechanically deboned meats (Field, 1976) used as extenders. Currently, there is a need for the meat industry to use extenders that are of economic advantage. At the present moment, there is a growing tendency to turn to seafoods, which provides resources of functional superiority. Because of the kamaboko forming property, surimi could provide the potential binding characteristics needed in the success of the restructuring process.

The binding potential of seven blends formulated from ocean pout surimi to contain 0, 10, 20, 30, 40, 50 and 100% turkey meat chunks, were compared with and without incorporating 2% egg albumin. The ability of the surimi to bind chunks of turkey meat was determined by evaluating sensory and visual properties of gels which were prepared from the combined matrix agents. Results showed that all sensory and visual properties were affected as the level of surimi increased (Tables 2 and 3). The firmness, cohesiveness, appearance, overall acceptability, moistness desirability scores decreased as surimi content increased. Turkey extended with surimi up to 40% level were rated as being equal to the control (turkey), though the 10% surimi formula appeared to be superior. However, when egg albumin was added at a 2% level, the gel cohesiveness of ocean pout-turkey meat mixture decreased for all combinations tested. There was no added advantage of using surimi

formulated with 2% egg albumin. Overall acceptability ratings (Fig. 20 and 22) show that all restructured turkey extended with surimi, or surimi-albumin formula were rated good-to-fair, with no significant difference ($P<0.05$) among formulas.

Cohesiveness of the blended surimi gel did not significantly change up to the 40% surimi level without egg albumin (Table 2). Cohesiveness of the mixture decreased with increased surimi in the formula with the most cohesive mixture produced from a 10% surimi combination without added albumin. Firmness, moistness and appearance followed the same patterns (Fig. 23). Moistness desirability was rated as good to fair in all formulations with or without egg albumin except for 100% surimi with or without the added protein. A comparison of data obtained with and without the added egg albumin indicated that in almost all of the sensory and visual attributes, egg albumin had a slightly negative effect (Tables 2 and 3).

Results presented in the same figures show that sensory and visual scores (firmness, cohesiveness, moistness, appearance and overall acceptability) were found to increase as the amount of turkey in the formulation was increased. There were numerical increases in the desirability of visual and sensory parameters as the percentage of ocean pout decreased. The pooled means of the mixtures, however, indicate that sensory scores of the turkey mixtures

containing 40% to 100% turkey meat were not significantly different from each other in almost all the parameters. These results are comparable with those from experiments comparing beef-turkey patties (Novakofski et al., 1987) in which there were no significant differences in textural scores. Positive correlations between sensory firmness ($r = 0.81$), sensory cohesivenss ($r = 0.69$), appearance ($r = 0.81$), and overall acceptability scores ($r = 0.83$) with increasing turkey suggests that the product increased binding as a result of increased turkey in the formulation. The product became less moist as the level of turkey (75%) increased. Considered that the moisture content of turkey meat and ocean pout surimi (76%) were not significantly different, such a change reflect the poor water binding ability of ocean pout surimi. A reduction in the turkey meat as a result of increasing surimi in the formula contributed to a reduction in the muscle fiber content of the matrix. Theno et al., (1978) postulated that if this is the case, myofibrils and muscle fibers which are normally tightly packed would separate after mechanical treatments. This opened structure would allow the solubilized proteins of the exudate to be worked into the loose fiber structure allowing a more cohesive bond to form between the protein matrix and meat surface. The differences noted would therefore have arisen from increased fiber content of turkey, since surimi contains less fibers.

Slightly better sensory acceptability were scored in mixtures without added albumin. The added albumin may interfere with the formation of a rigid matrix (Lee, 1984) which is believed to be due to retardation of cross-linkage formation of actomyosin (Okada, 1964; Shimizu and Nishioka, 1974). Furthermore, biological dissimilarities in the sources of raw materials may show differences in the inherent proteins composition and functionality.

The binding properties of surimi of different qualities in meat systems has been reported (AFDP, 1984). A synergistic effect was observed between meat and surimi proteins which improves the binding between surimi and meat protein, though no significant differences were observed among surimi of different quality (low versus medium versus high gel strength surimi). This relationship supports the use of ocean pout surimi in the turkey meat system and thus proves the economic advantage that would be gained by use of underutilized resources of low market value should such products be acceptable for consumption.

CONCLUSION

The results of this investigation (of the process characteristics of ocean pout surimi and its application in processed meat products) indicated that ocean pout produced a surimi of low gel strength. However, there does exist a potential for ocean pout surimi to be incorporated into a surimi of higher gel strength at a level which does not significantly alter the required gel strength. The texture forming ability was comparatively lower to red hake, but in conjunction, indicated a considerable use as a protein ingredient up to the 20% level. This finding was consistent with other reports indicating the efficacy of low gel-strength surimi for application in processed meat products.

The results obtained with NaCl and moisture levels could be useful in defining the process parameters and indicated that surimi continued to show improved textural characteristics with increasing salt level. The 3% NaCl was best in improving gel-strength and greatest water binding ability, while the 74% moisture level showed the best gel characteristics.

In comparison of a single-stage and a two-stage heating, the best results were obtained in a single-stage heating at 90 C for 40 min, while a two stage heating showed a steady loss of textural firmness reaching its lowest at 60 C. This

study is in contrast with the previous report in which a two-stage heating resulted in formation of a stronger gel (Lanier et al., 1983). Such a discrepancy could be due to the lack of gel network forming ability of ocean pout during a partial heat-setting process. While the effects of low temperature setting (<30 C) was not investigated, this result is consistent with other reports which show marked textural degradation of gels at 60 C, indicative of the presence of alkaline protease (enzyme) activities. A sequential study of enzyme activity in ocean pout surimi would therefore require a future study.

The gel strength effect of nonfish protein added at a 5% level and the order of such an effect of different nonfish proteins was egg albumin, wheat gluten, soy protein, milk protein, lactoalbumin and control (ocean pout). This could be attributed to the filler effect rather than having an impact on the network structure. Incorporation of surimi into a turkey meat system was agreeable up to 40%, being rated equal to the turkey (100%) in almost all sensory parameters, though the 10% surimi formula was rated higher in overall acceptability with no added advantage when egg albumin protein was incorporated.

The fact that ocean pout forms a low gel-strength surimi would limit its usage primarily as a binder or matrix for protein based products. However, its unique flavor and textural characteristics, highly compatible to those of

turkey meat, would allow ocean pout surimi to be used as a prime extender in a turkey meat system. This was the reason why turkey meat was chosen as a meat system in the first place. Continued research would establish its proper processing guidelines and should sufficient demand be created for a properly processed product, the landings of ocean pout is likely to increase for the purpose of human consumption.

TABLE 1 MEANS STANDARD DEVIATIONS AND SIGNIFICANCE OF HEAT INDUCED GEL SETTING BEHAVIOR OF OCEAN POUT SURIMI GELS ON EXPRESSIBLE MOISTURE RIGIDITY AND COHESIVENESS

HIGH-TEMP HEAT-SET	COOKING 90 C	MOISTURE GEL(%)	EXPRESSED MOISTURE	RIGIDITY	COHESIVENESS (KG)
	30 min	77.20a ±0.20	5.20b ±0.25	870.ab ±31.62	7.1a ±0.41
	40 min	75.70c ±0.30	5.27b ±0.22	890. a ±21.69	7.0 a ±0.42
	50 min	77.40a ±0.30	5.25b ±0.24	870. ab ±16.30	6.75 ±0.29
	60 min	77.30a ±0.30	5.07b ±0.17	880. a ±16.30	6.45b ±0.33
20 min (40 C)	30 min	76.70b ±0.20	5.73a ±0.27	852. c ±16.20	5.13c ±0.25
20 min (50 C)	30 min	76.10b ±0.30	7.02a ±0.45	698. d ±20.62	3.95d ±0.10
20 min (60 C)	30 min	77.30a ±0.20	7.60a ±0.34	560. e ±29.44	3.13e ±0.25

a Average of 4 observations

abcde Means followed by different letters in the same column are significantly different ($P<0.05$).

TABLE 2 MEANS, STANDARD DEVIATIONS AND SIGNIFICANCE OF SENSORY PANEL EVALUATION OF OCEAN POUT AND TURKEY COMBINATION WITHOUT EGG ALBUMIN

Sensory	Percentage Combinations						
NOTE Turkey O.Pout	100 0	90 10	80 20	70 30	60 40	50 50	0 100
Firmness	6.60 ±1.67 a	7.20 ±1.30 a	6.60 ±0.84 a	5.40 ±1.34 ab	4.60 ±1.82 b	3.89 ±1.48 b	1.00 ±1.23 c
Cohesiveness	6.80 ±1.30 a	7.00 ±1.73 a	6.40 ±1.52 ab	5.60 ±1.52 ab	5.60 ±2.12 ab	4.00 ±2.00 b	1.40 ±2.07 c
Moistness/ Acceptability	6.40 ±2.19 a	6.80 ±1.64 a	6.20 ±1.30 a	5.60 ±1.67 ab	5.00 ±1.87 ab	4.80 ±1.92 ab	3.40 ±2.19 a
Appearance/ Color	6.80 ±1.79 a	7.00 ±1.41 a	6.20 ±1.48 a	5.40 ±1.95 ab	4.80 ±2.17 ab	4.20 ±1.92 b	1.80 ±1.48 c
Overall/ Acceptability	6.20 ±2.17 a	6.60 ±1.95 a	6.40 ±1.34 a	5.20 ±2.17 a	5.00 ±2.00 a	4.40 ±2.07 a	1.80 ±1.48 b

a Average of 6 observations

abcd Means followed by different letters in the same row are significantly different ($P<0.05$).

TABLE 3 MEANS, STANDARD DEVIATIONS AND SIGNIFICANCE OF SENSORY EVALUATION OF TURKEY - OCEAN POUT SURIMI IN COMBINATION WITH 2% EGG ALBUMIN.

Sensory	Percentage Combinations						
NOTE: Turkey	100	90	80	70	60	50	0
O. Pout	0	10	20	30	40	50	100
Firmness	6.00 ±1.41 a	5.75 ±0.96 a	5.00 ±1.16 ab	4.25 ±1.50 ab	4.00 ±1.83 ab	3.50 ±1.29 ab	2.00 ±0.82 c
Cohesiveness	6.00 ±0.82 a	5.50 ±1.00 ab	5.30 ±1.50 ab	4.50 ±1.30 b	4.30 ±2.20 b	4.30 ±2.60 b	2.0 ±0.80 c
Moistness	6.25 ±1.30 a	6.00 ±0.80 a	5.00 ±0.80 a	4.50 ±0.60 ab	4.00 ±1.60 ab	3.50 ±0.80 c	3.00 ±2.1 c
Appearance	5.50 ±1.00 a	5.50 ±1.00 a	5.50 ±1.00 a	4.80 ±1.70 a	4.80 ±1.70 a	4.50 ±2.10 b	1.80 ±0.50 c
Acceptability	5.80 ±1.00 a	5.80 ±1.00 a	5.50 ±1.30 a	5.00 ±1.80 ab	5.00 ±1.80 ab	4.80 ±1.70 ab	2.30 ±1.00 c

a Average of 6 observations.

abcd Means followed by different letters in the same row are significantly different ($P<0.05$).

Fig. 3 Effect of Nacl on Expressible Moisture of Ocean Pout Surimi Gels

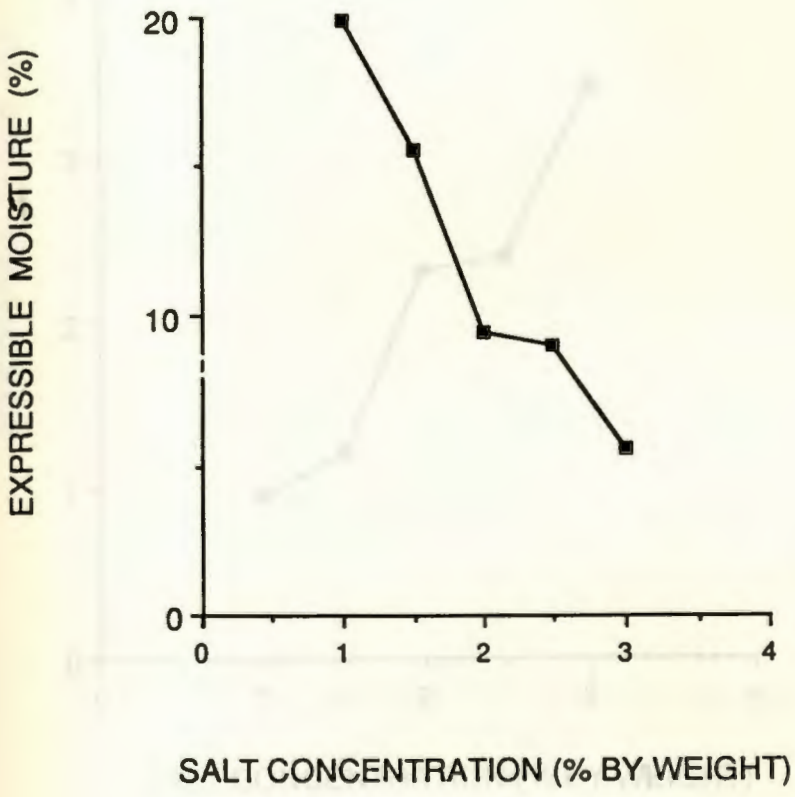


Fig.4 Effect of NaCl on Compressive Force of Ocean Pout Surimi Gels.

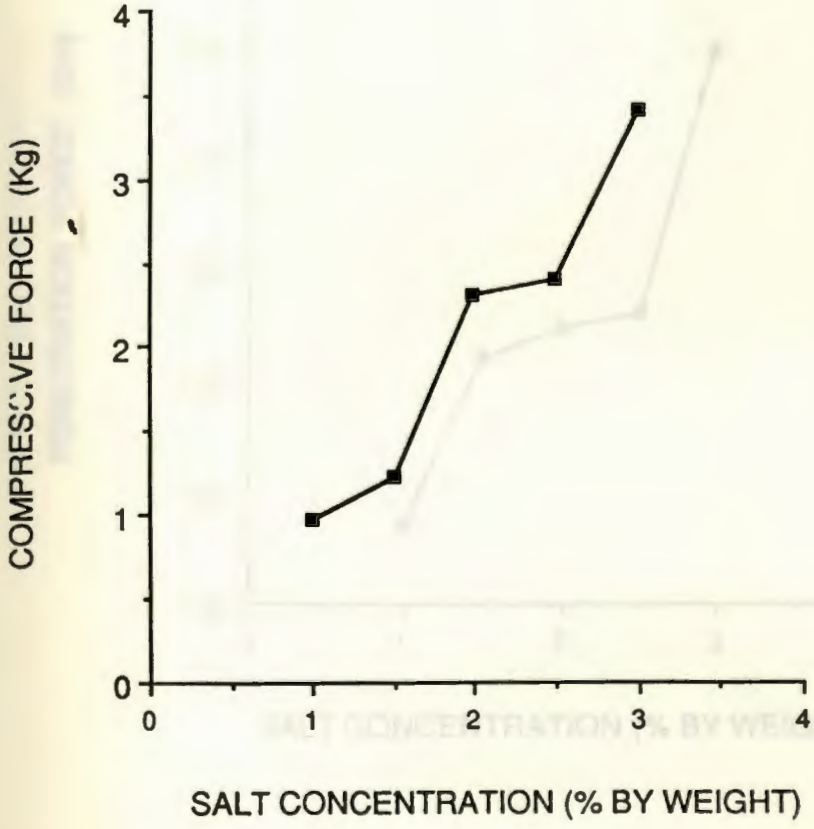


Fig.5 Effect of NaCl on Penetration Force of Ocean Pout Surimi Gels.

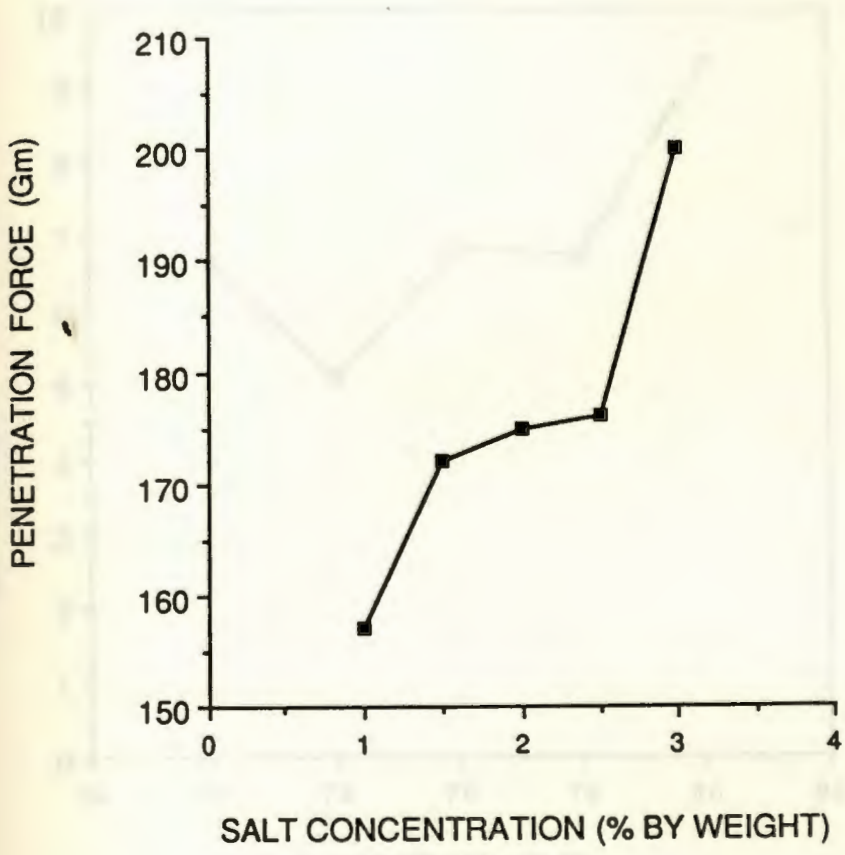


Fig.6 Effect of Moisture Level on Expressible Moisture of Ocean Pout Surimi Gels

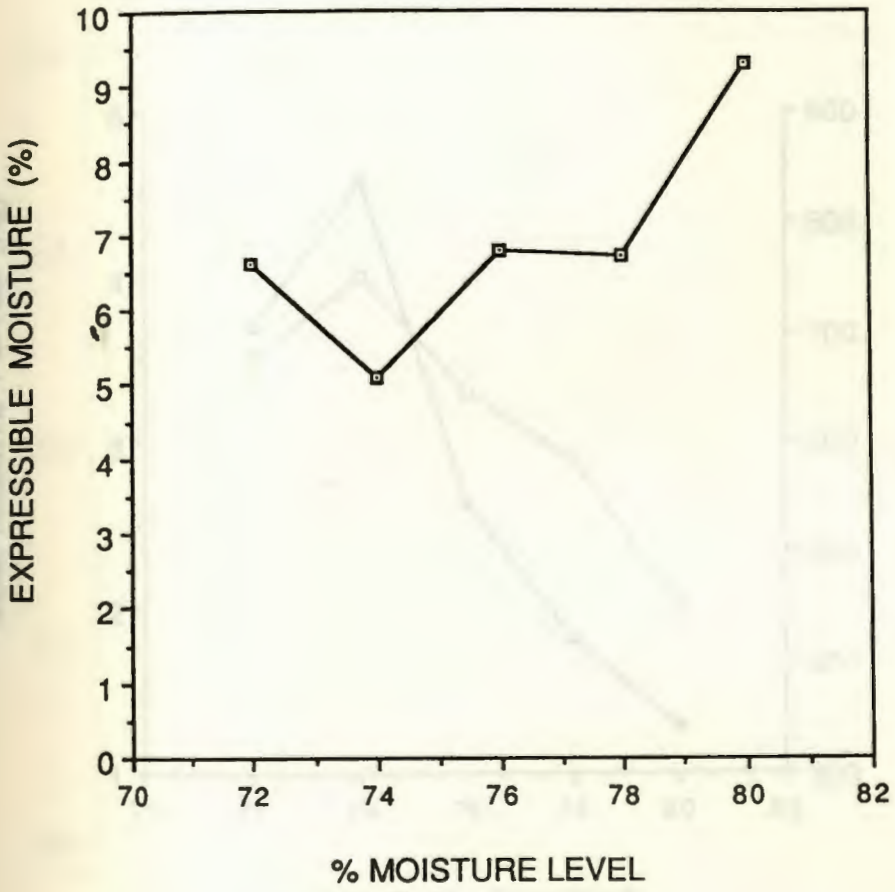


Fig.7 Effect of Moisture Level on Compressive Force and Penetration Force Of Ocean Pout Surimi Gels.

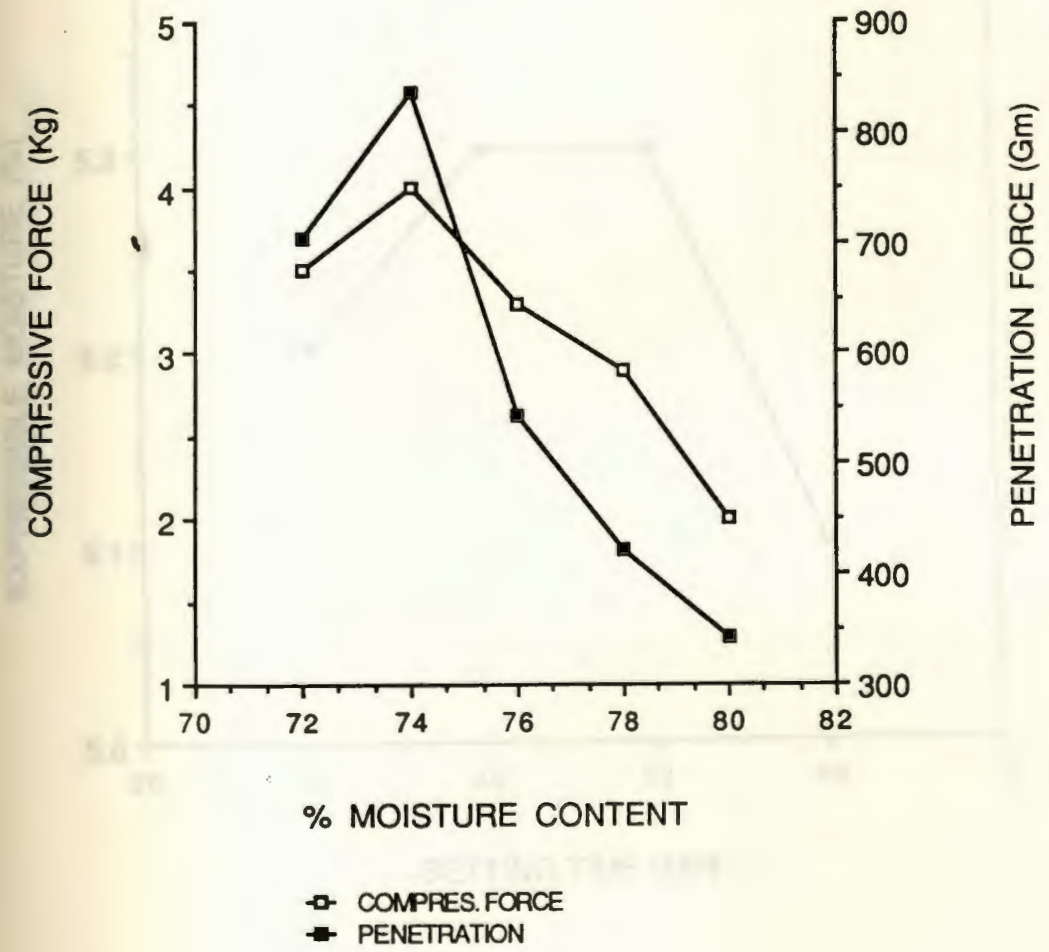


Fig.8 Effect of Setting Time on Expressible Moisture of Ocean Pout Surimi Gels.

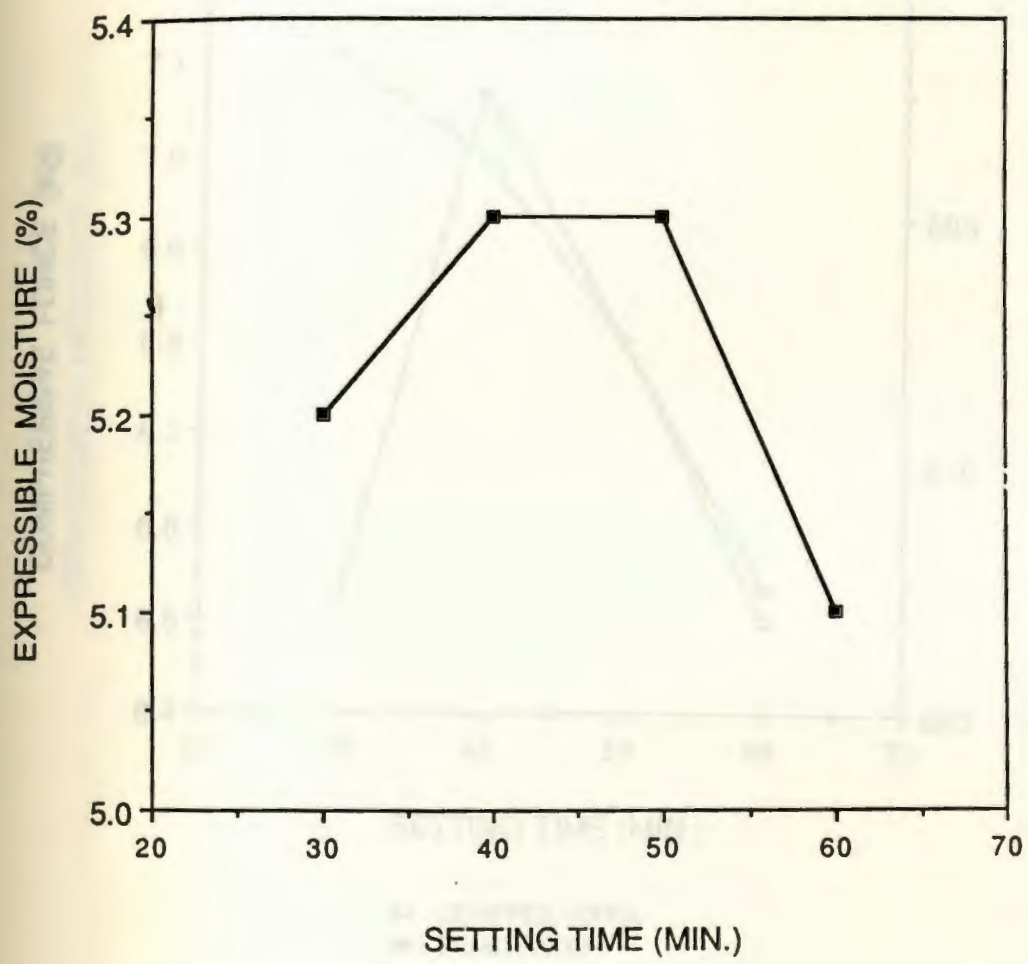


Fig.9 Effect of Setting Time on Compressive Force and Penetration Force of Ocean Pout Surimi gels.

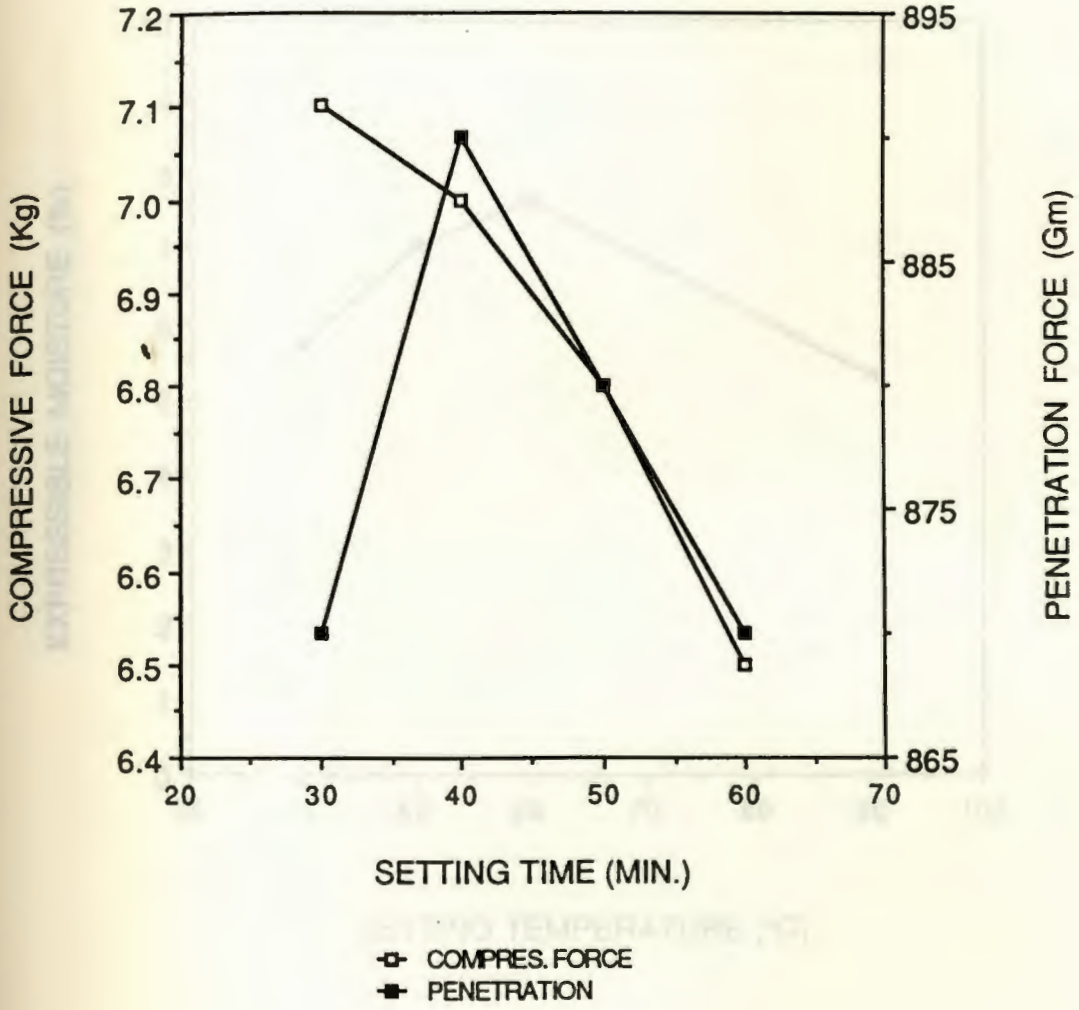


Fig.10 Effect of Setting Temperature on Expressible Moisture of Ocean Pout Surimi Gels.

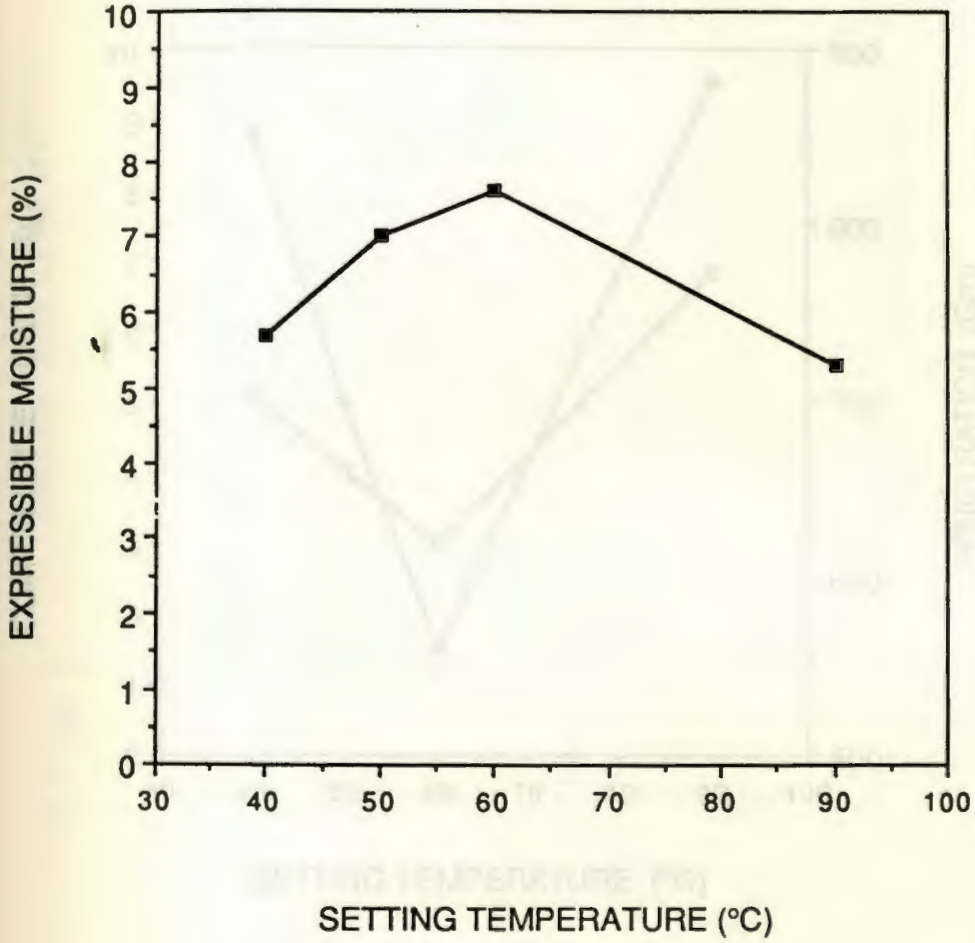
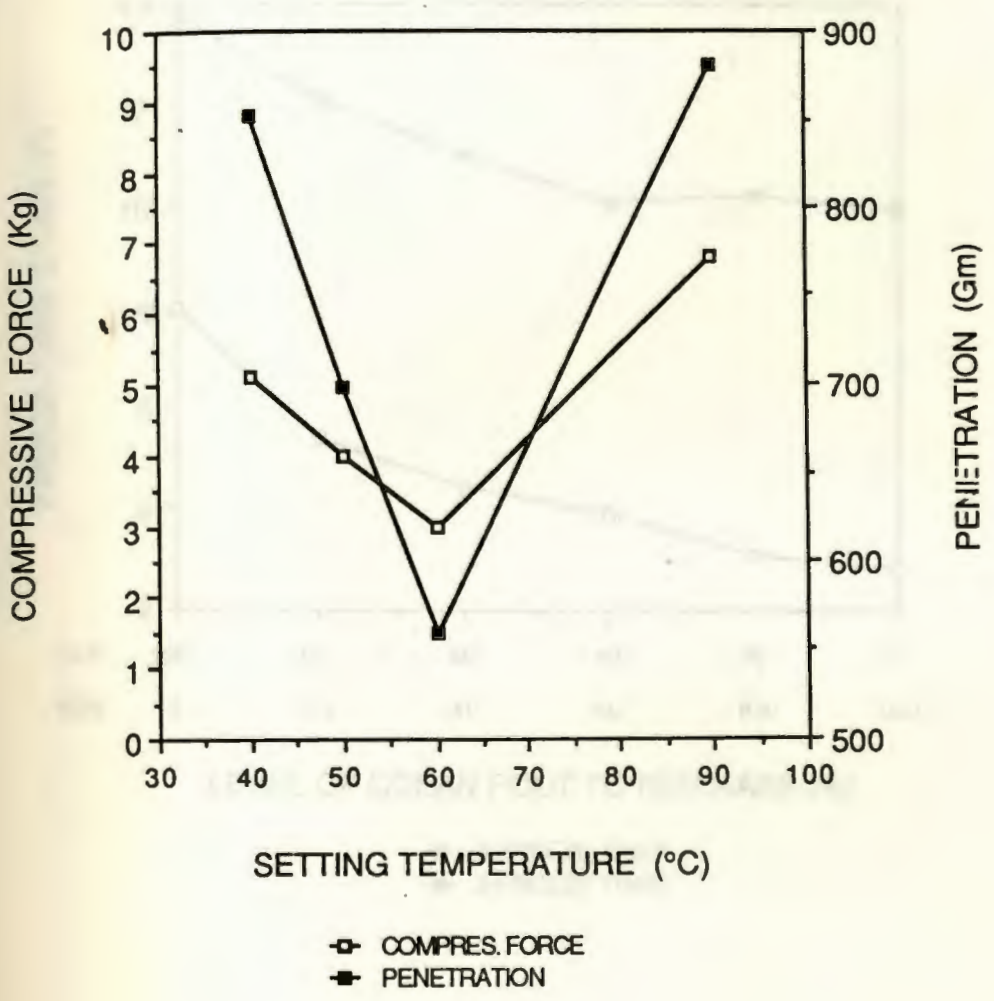
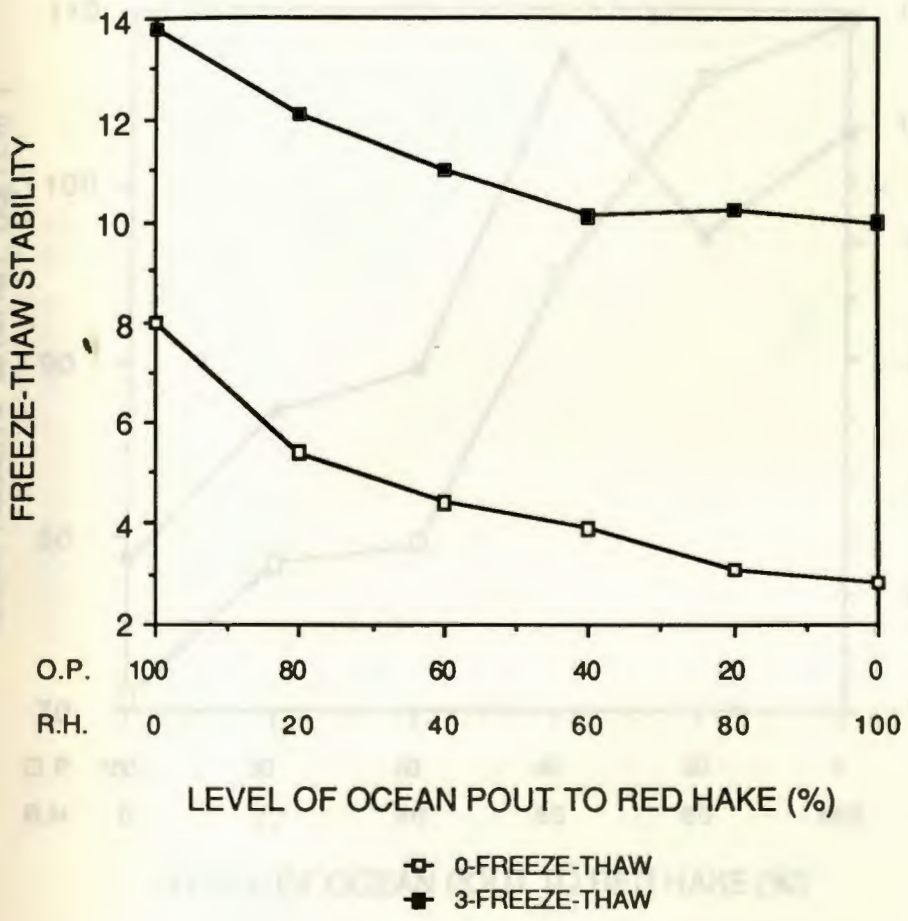


Fig.11 Effect of Setting Temperature on Compressive Force and Penetration Force of Ocean Pout Surimi Gels.




FREEZE-THAW STABILITY
14
12
10
8
6
4
2
O.P. 100 80 60 40 20 0
R.H. 0 20 40 60 80 100
LEVEL OF OCEAN POUT TO RED HAKE (%)
0-FREEZE-THAW
3-FREEZE-THAW

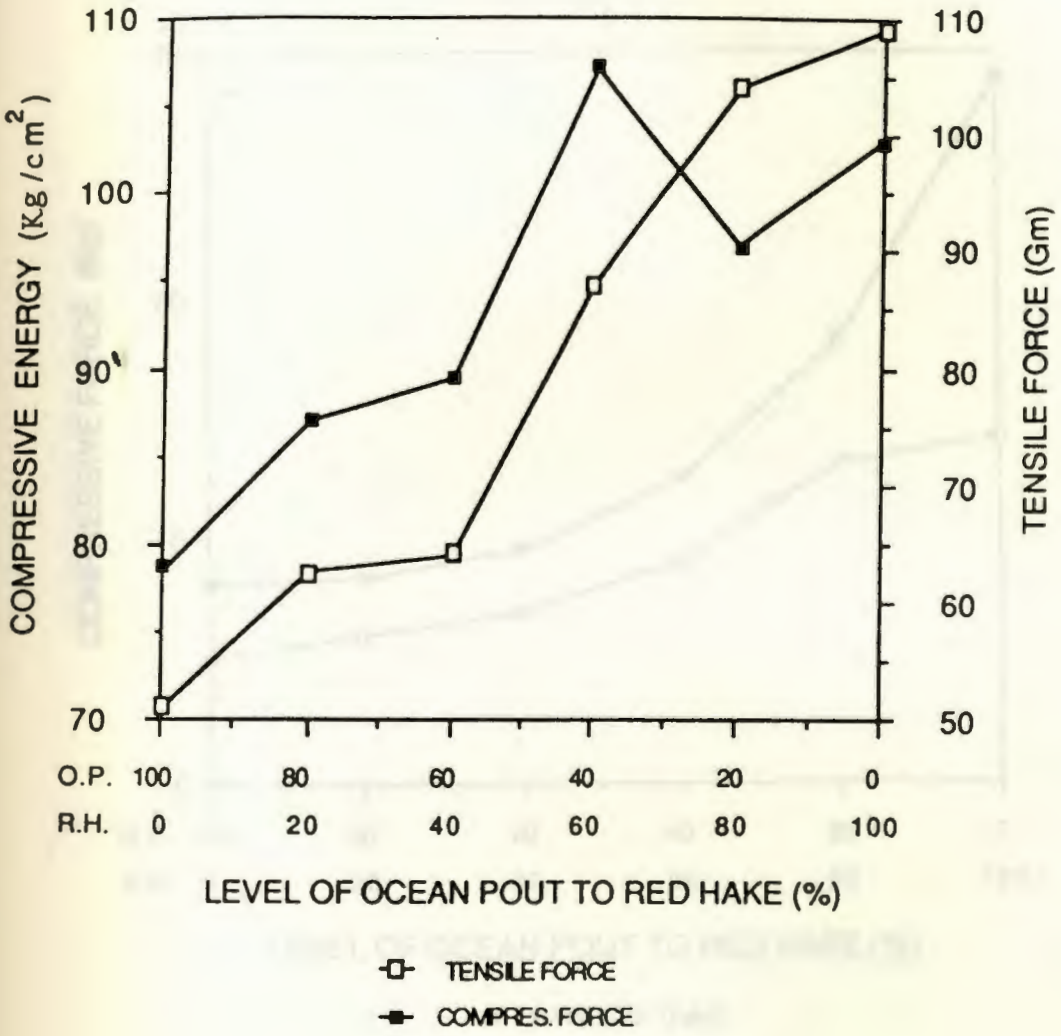

110
100
90
80
70
COMPRESSIVE ENERGY (Kg/cm²)
110
100
90
80
70
60
50
TENSILE FORCE (Gm)
O.P. 100 80 60 40 20 0
R.H. 0 20 40 60 80 100
LEVEL OF OCEAN POUT TO RED HAKE (%)
TENSILE FORCE
COMPRES. FORCE

Fig.14 Effect of Combinations of Ocean Pout and Red Hake on Compressive force before and after 3-Freeze-Thaw Cycles.

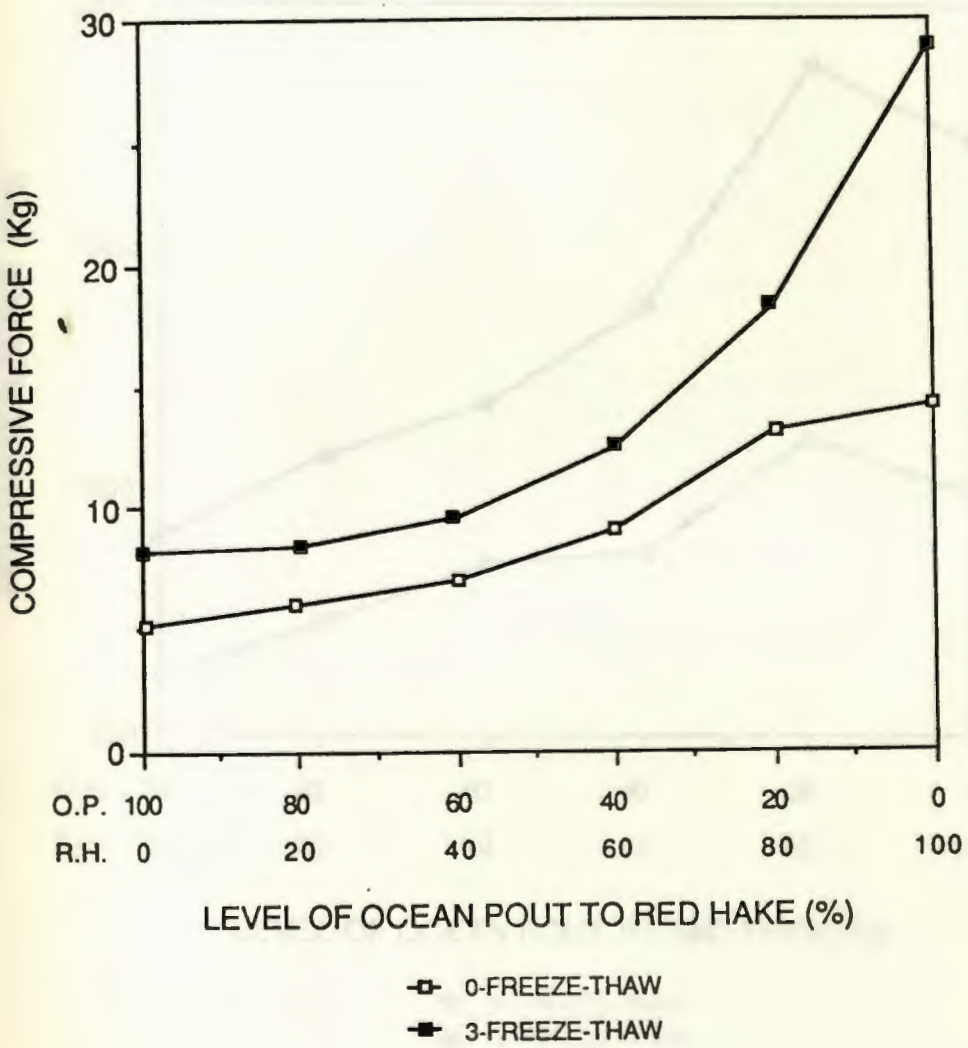


Fig.15 Effect of Combinations of Ocean Pout and Red Hake on Penetration Force before and after 3-Freeze-Thaw Cycles.

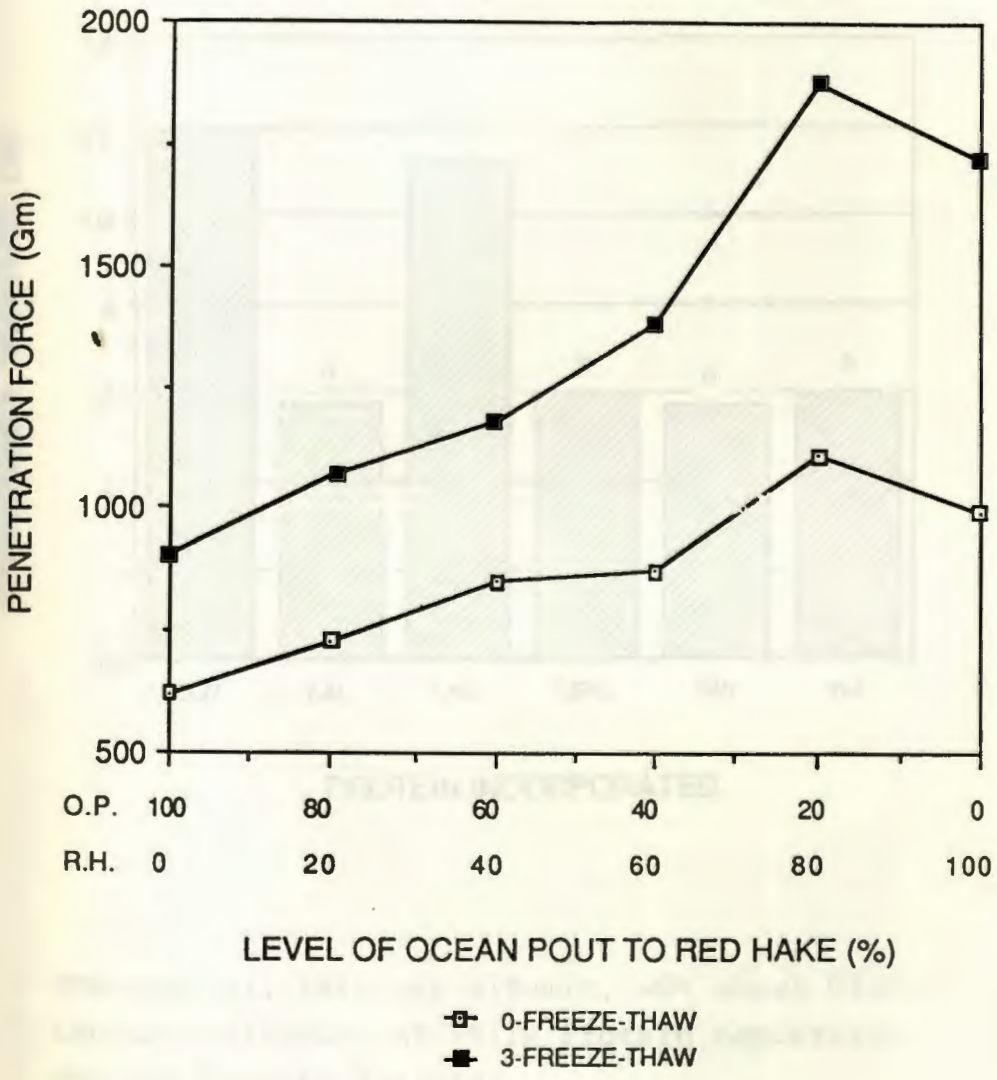
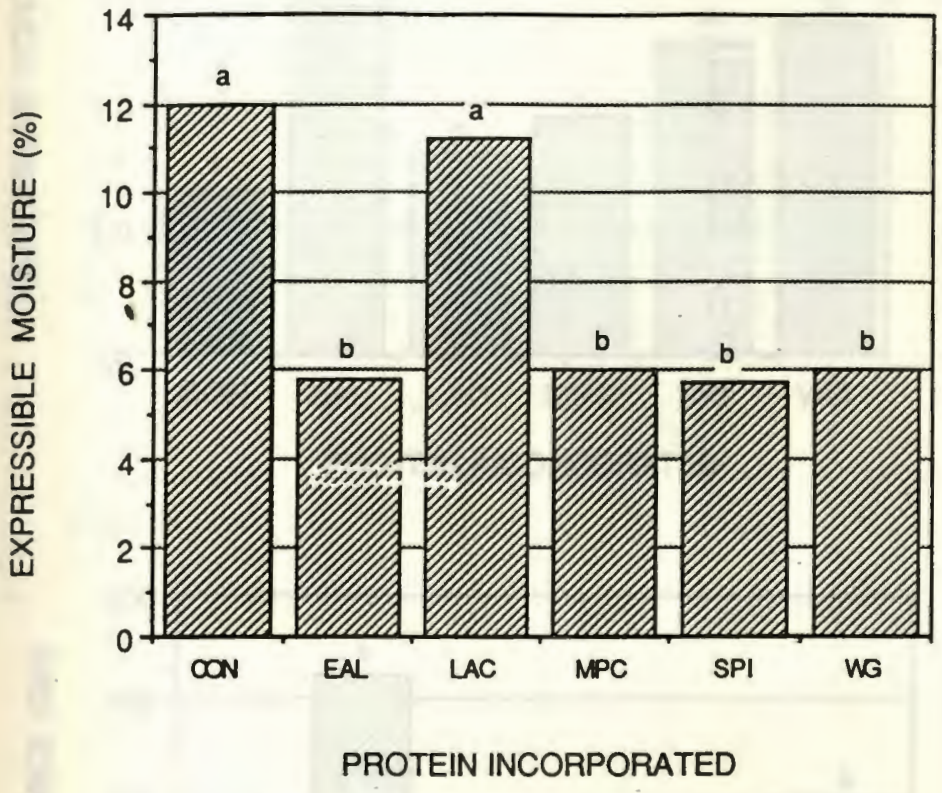


Fig.16 · Effect of Nonfish Proteins on Expressible Moisture of Ocean Pout Surimi Gels.



CON=control, EAL= egg albumin, WG= wheat Gluten
LAC=Lactoalbumin, MPC=Milk Protein concetrate,
SPI=Soy protein Isolate.

Fig.17&18 Effect of Nonfish Proteins on Compressive and Penetration Force of Ocean Pout Surimi Gels.

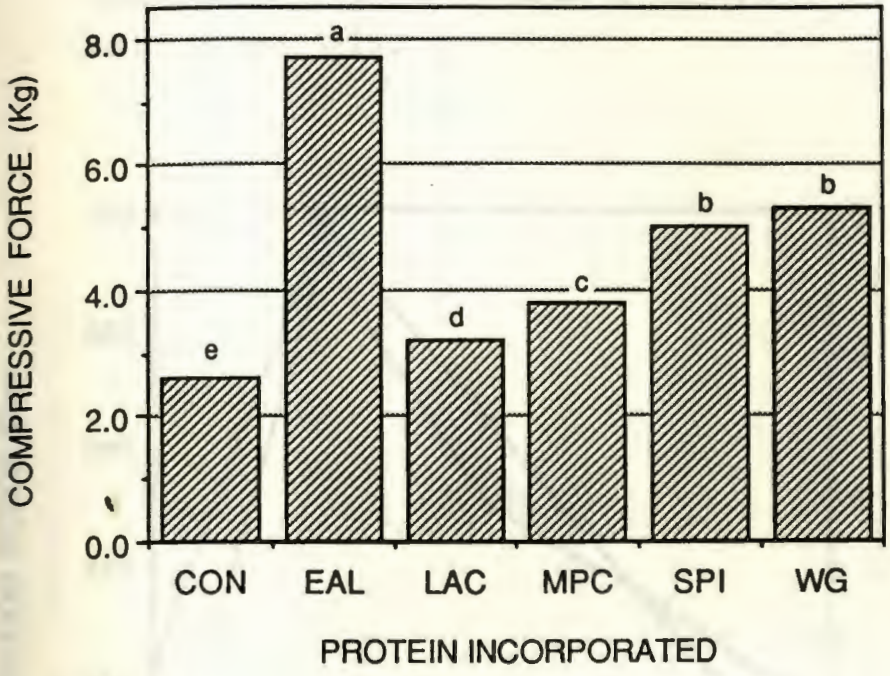


Fig.18

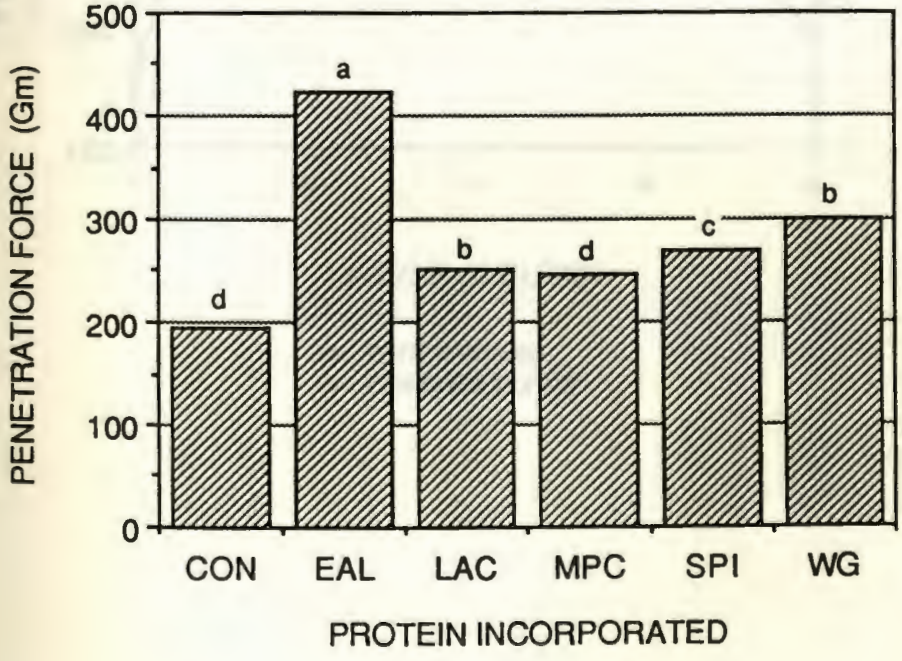


Fig.19 Effect of Different Levels of Egg albumin on Compressive Force and Penetration Force of Ocean Pout Surimi Gels.

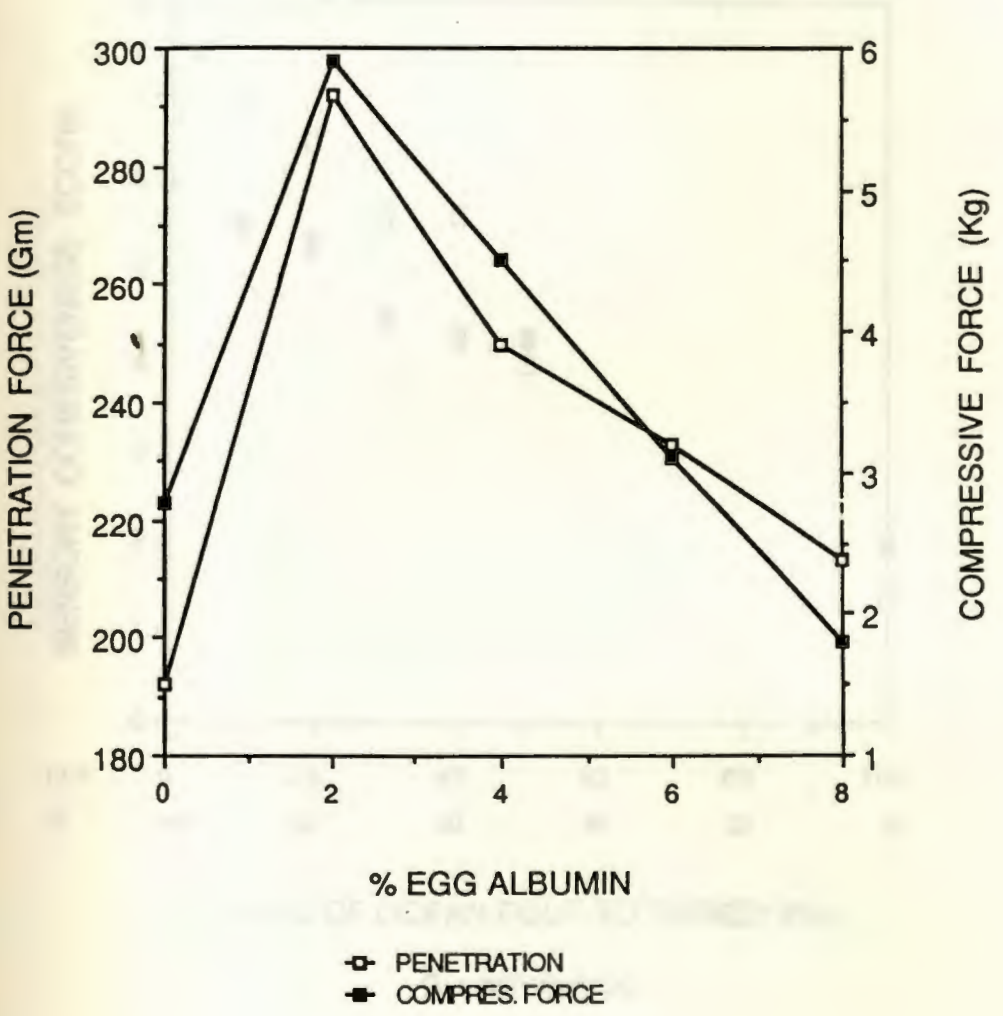


Fig.20 Sensory Evaluation of Ocean Pout-Turkey meat Combination with and without 2% Egg albumin on cohesiveness.

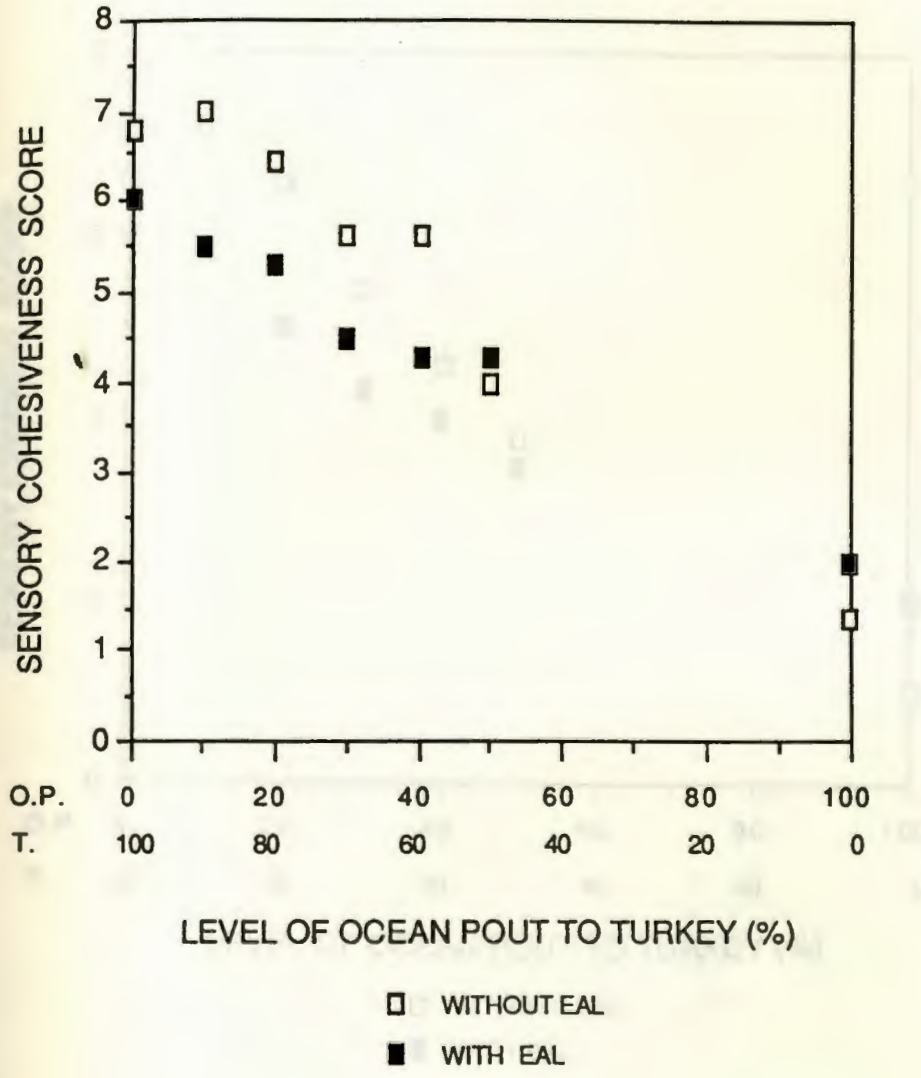


Fig.21 Sensory Evaluation of Ocean Pout-Turkey meat Combination with and without 2% Egg albumin on Firmness.

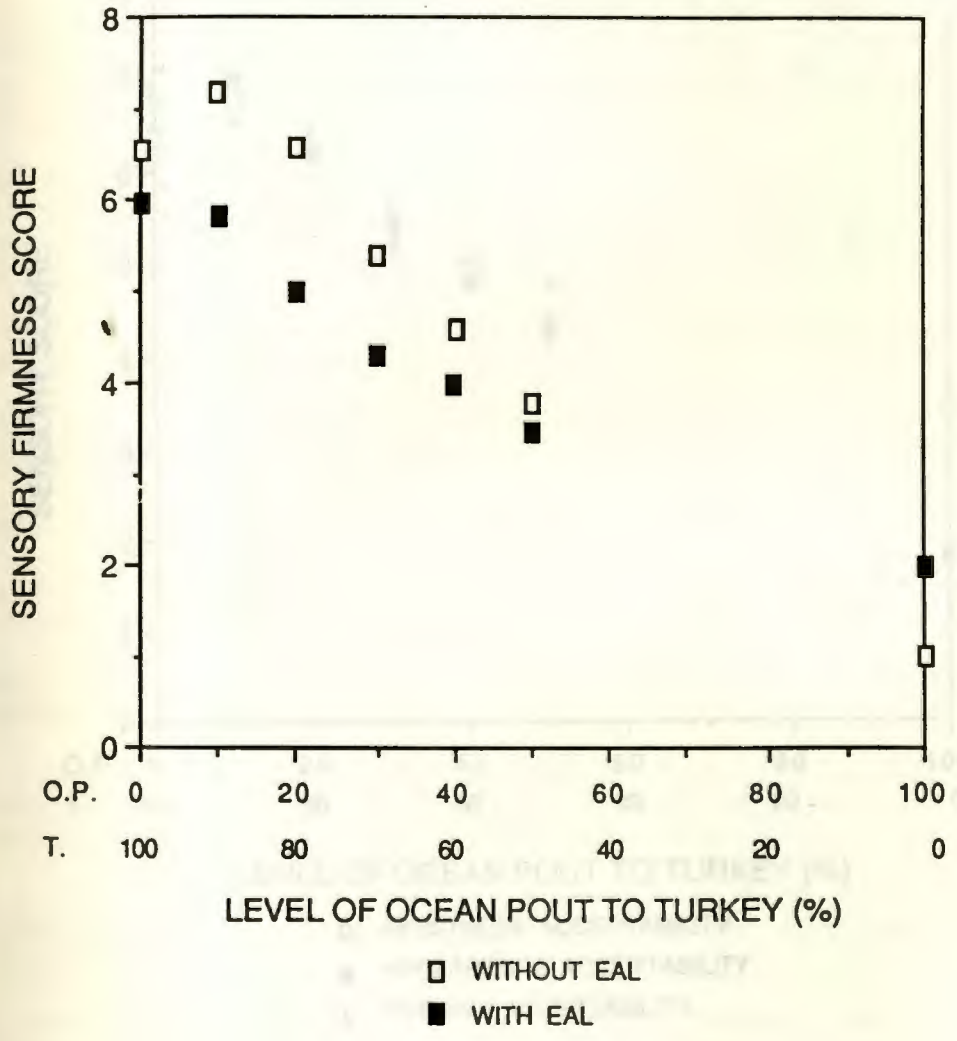
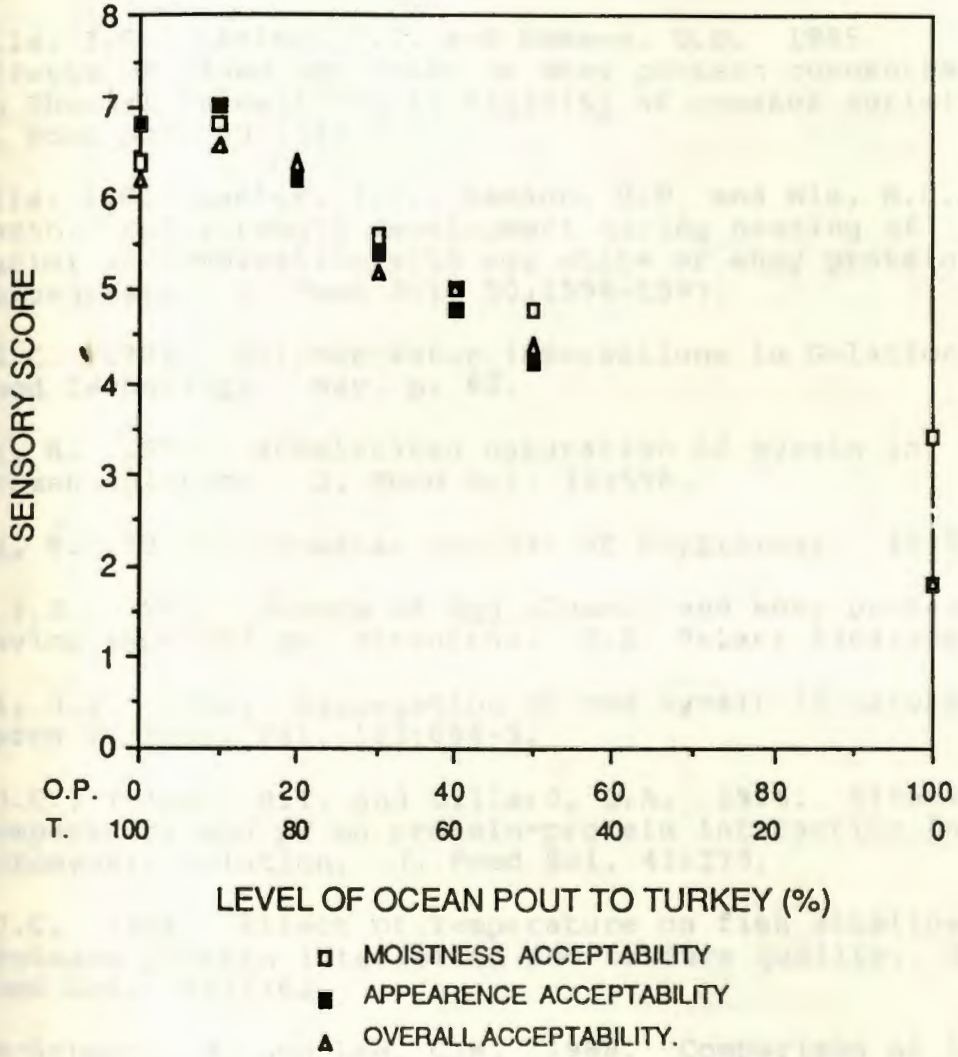


Fig.22 Sensory Evaluation of Ocean Pout-Turkey Combination on Expressible Moisture, Appearence, and Overall Acceptability.



REFERENCES

Acton, J.C. and Dick, R.L. 1984. Protein - Protein interactions in processed meats. Proceedings Reciprocal Meats Conference. Vol 37.

Bugarella, J.C., Lanier, T.C. and Hamann, D.D. 1985. Effects of added egg white or whey protein concentrate on Thermal Transitions in rigidity of croaker surimi. J. Food Sci. 50:1594.

Bugarella, J.C., Lanier, T.C., Hamann, D.D. and Wie, M.C. 1985b. Gel strength development during heating of surimi in combination with egg white or whey protein concentrate. J. Food Sci. 50:1596-1597.

Busk, G.C. 1984. Polymer-water interactions in Gelation in Food Technology. May, p. 62.

Buttkus, H. 1970. Accelerated naturation of myosin in frozen solution. J. Food Sci. 32:558.

Buttkus, H. 1971. Canadian Journal of Physiology. 49-97.

Chang, P.K. 1982. Blends of egg albumin and whey protein having improved gel strengths. U.S. Patent 4364:966.

Connell, J.J. 1959. Aggregation of cod myosin in nature, March 7, 1959, Vol. 183:664-5.

Deng, J.C., Toledo, R.T. and Lillard, D.A. 1976. Effect of temperature and pH on protein-protein interaction in actomyosin solution. J. Food Sci. 41:273.

Deng, J.C. 1984. Effect of Temperature on fish alkaline protease protein interaction and texture quality. J. Food Sci. 46(1)62.

Douglas-Schwarz, M. and Lee, C.M. 1988. Comparison of the thermostability of red hake and Alaskan pollock surimi during processing. J. Food Sci. (in press).

Field, R.A. 1974. New restructured meat products food service and retail. In Proceeding International Symposium on Meat Science and Technology. p. 290.

Foegeding, E.A., Dayton, W.R. and Allen, C.E. 1986. Interaction of myosin-albumin and myosin-fibrinogen to form protein gels. J. Food Sci. 51(1):109-110.

Fukazawa, T., Hashimoto, Y. and Yazui, T. 1961. Effect of some proteins on the binding quality of an experimental sausage. J. Food Sci. 26:541.

Hashimoto, A., Katoh, N., Nozaki, H. and Arai, K. 1985. Effects of storage temperature on deterioration of salted meat paste from three fish species. Bull. Jap. Soc. Sci. Fish 51(5)847.

Iso, N., Mizuno, H., Saito, T., Lin, C.Y., Fujika, T., Nagahisa, E. 1984. Effects of additives (egg white, soy protein) on the rheological properties of kamaboko. Bull. Jap. Soc. Sci. Fish 5(3):485-88.

Katoh, N., Hashimoto, A., Nozaki, H., Marnyama, T., Arai, K. 1986. Change in myofibrillar protein of salted meat past from Alaskan pollock and tilapia during salting. Bull. Jap. Soc. Sci. Fish. 52(5):875.

King, R.W. and Dunkin, A. 1985. Surimi could become the hot dog of the fish business. Bus. Wk. Feb. 25, 1985. 106.

Kuntz, I.D. and Kauzmann, W. 1974. Hydration of proteins and polypeptides. In "Advances in Protein Chemistry". C.B. Anfinses, J.T. Edsall, and F.M. Richards, eds, Vol. 28, p. 239. Academic Press.

Lanier, T.C., Lin, T.S., Hamann, D.D. and Thomas, F.B. 1981. Effects of alkaline protease in minced fish on texture of heat-processed gels. J. Food Sci. 46:1644-45.

Lanier, T.C., Liu, Y.M. and Hamann, D.D. 1982. Heat gelation properties of actomyosin and surimi prepared from Atlantic croaker. J. Food Sci. 47:1921.

Lanier, T.C., Montejano, J.G., Hamann, D.D. 1983. Final strengths and rheological changes during processing of thermally induced fish muscle. J. of Rheology. 27(6):567.

Lanier, T.C., Wis, M.D. and Hamann, D.D. 1985. Rigidity and viscosity changes of croaker actomyosin during thermal gelation. J. Food Sci. Vol. 50:16-18.

Lanier, T.C. 1985. Application of functionality measurements to the least-cost linear programming of surimi-based product formulations. Paper #24, presented at the International Symposium on Engineered Seafood including surimi. Washington. Nov. 19-21.

Lee, C.M., and Toledo. 1976. Factors affecting textural characteristics of cooked comminuted fish muscle. J. Food Sci. 4(2)391.

Lee, C.M. 1984. Surimi process technology. Food Tech.

Lee, C.M. and Kim, J.M. 1985. Texture and freeze-thaw stability of surimi gel in relation to ingredient and formulation. In proceedings of International Symposium on Engineered Seafood including surimi.

Lee, C.M. 1986. Surimi manufacturing and fabrication of surimi-based products. Food Tech. 40(3)124.

Lee, C.M. and Chung, K.H. 1988. Analysis of surimi gel properties by compression in punch tests (submitted to J. Food Sci.).

Lehninger, A.L. 1970. in "Biochemistry" Worth Publishers Inc. and Ed. p.162.

Makinodan, Y., Takeshi, T., Toyohara, H. and Shimizu, Y. 1986. Participation of muscle alkaline protease in Himodori of Kamaboko. Bull. Jap. Soc. Sci. Fish 53(1) 99.

MacFarlene, J.J., Schmidt, G.R. and Turner, R.H. 1977. Binding of meat pieces: A comparison of myosin, actomyosin and sucoplasmic proteins as binding agents. J. Food Sci. 42:1603.

MacFarlene, J.J., Turner, R.H. and Jones, P.N. 1986. Binding of meat pieces: Influence of some processing factors on binding strength and cooking losses. J. Food Sci. 51(1) 740-41.

Nakayama, T and Sato, Y. 1971a. Relationship between binding quality of meat and myofibrillar proteins. Part EE. The contribution of native tropomyosin and actin to the binding quality of meat. Agri. BioChemistry 35(2):208.

Nakayama, T. and Sato, Y. 1971. Relationship between binding quality of meat and myofibrillar proteins. Part II. The contributor of myosin A and actin to rheological properties of heat induced minced meat gel. J. Fex. Studies 2:75.

Novakofski, S.P.J., McKeith, F.K., and Betchell, P.J. 1987 Effect of mixture and storage on the palatability of beef-turkey patties. J. Food Sci. 52:1161.

Okada, M. 1964. Effect of washing in gelly forming ability of fish meat. Bull. Jap. Soc. Sci. Fish 30:255.

Okada, M. 1973. Kamaboko the giant among Japanese processed fishery products. Marine Fish. Rev; 35(12)1-6.

Park, S., Novakofski, J. McKeith, F.K. and Betchel, P.J. 1987. Effects of mixture and storage on the palatability of beef-turkey patties.

Peng, I.C. and Nielsen, S.S. 1986. Protein-protein interactions between soybean beta-conglycinin (B^1B^6) and myosin. J. Food Sci. 51(3):589-590.

Quinn, J.R., Raymond, D.R. and Harwalker, V.R. 1980. Differential scanning calorimetry of meat proteins as affected by processing treatment. J. Food Sci. 45:1146-49.

SAS. 1982. "SAS user's guide: statistics". SAS Institute, Inc., Cary, N.C.

Samejima, K., Hashimoti, Y., Yasui, T., and Fukazawa, T. 1969. Heat gelling properties of myosin, actin, actomyosin and myosin subunits in a saline model system. J. Food Sci. 34:242.

Shimizu, Y. and Nishioka, F. 1974. Interactions between horse mackerel actomyosin and sarcoplasmic proteins during heat coagulation. Bull. Jap. Soc. Sci. Fish 40:231.

Shimizu, Y. 1974. Species variation in gel-forming ability of fish meat paste. Bull. Jap. Soc. Sci. Fish 40(2) 175-179.

Siegel, D.G. and Schmidt, G.R. 1979a. Ionic; pH and temperature effects on the binding quality of myosin. J. Food Sci. 44:1686.

Siegel, D.G. and Schmidt, G.R. 1979b. Crude myosin as meat binders. J. Food Sci. 44:1129.

Sone, T., Dosako, S. and Kimura, T. 1983. Microstructure of protein gels in relation to their rheological properties. In Instrumental Analysis of Foods. Vol 2. Academic Press, Inc.

Soo, H.M. and Sander, E.H. 1977. Prediction of sensory response to textural parameters of breaded shrimp shapes using Instron texture profile analysis. F. Food Sci. 42:163.

Su, T.S., Lin, and Lanier, T.C. 1981. Investigation into potential sources of heat stable alkaline protease in mechanically separated Atlantic croaker (micropagan undulatus). J. Food Sci. 46:1955-56.

Syzuki, T. 1981. Fish and krill protein processing technology. Applied Science Publishers, London.

Theno, D.M., Siegel, D.G. and Schmidt, G.R. 1978. Meat messaging: Effects of salt and phosphate on the microstructural composition of the muscle exudate. J. Food Sci. 43:483.

Tournas, V. 1984. Protease and heat setting in fish gel structure. Masters Thesis, University of Rhode Island.

Yasui, T., Ishioroshi, M., and Samejima, K. 1980 Heat induced gelation of myosin in the presence of actin. J. Food Biochemistry 4:61:78.

Ziegler, G.R. and Acton, J.C. 1984. Mechanism of gel formation by proteins of muscle tissue. Food Tech. May. p.77.

APPENDIX A

LITERATURE REVIEW

Surimi, a crude form of myofibrillar protein is the Japanese term for mechanically deboned fish that has been washed with water and mixed with cryoprotectants for a good frozen storage life. It is used as an intermediate product for the manufacture of a variety of seafood products. Since the introduction of surimi in U.S. markets in 1978, consumer acceptance of fabricated seafood products has increased dramatically. Two million pounds were sold in 1979, increasing to 29 million pounds in 1983 (Lee, 1984). In 1984, alone, 75 million pounds of surimi-based products were sold wholesale (King, 1985). U.S. seafood processors have since then expressed interest in sharing the Japanese dominated market which produces 90% of the world's surimi (King, 1985).

In 1975, the U.S. Accounting Office suggested that one of the most promising strategies to revitalize and strengthen the fishing industry is through the development of underutilized fishery resources (Constantinides, et al, 1977). These generally discarded or considered as trash fish make up to 80% of the fish caught, are presumed to be inedible primarily because of lack of information regarding their nutritional status, methods of preservation and processing.

Current fishery statistics show that the New England area provides approximately 11% of total U.S. commercial landings contributing to an average of 16% of the dollar

value (Constantinides et al, 1985). These statistics are vital to the fishery industry should there be need to develop new fishery resources or products. And because the need is already existing as a result of intensified exploration of an already declining stock abundance of traditionally accepted commercial species, appropriate acceleration in the supply of new resources should be made to parallel the increasing need. Therefore, the importance of the seafood industry to the economy of this area can not be underestimated. Increasing competition with imported fish products necessitates research into utilization of nontraditional fish species.

The dependency on Alaskan pollock for the supply of fish paste material which is thought to lead to the development of a variety of products with only one distinctive flavor (Komatsu, 1981) is presumably dangerous to the seafood industry. In the absence from New England waters of traditional resource (Alaskan pollock) used by the Japanese for the manufacture of surimi, interest in identifying regionally and abundantly available species continues to grow. Researchers at the University of Rhode Island and North Carolina State University have established the suitability of red hake (Urophycis chuss) an underutilized species for surimi production (Lee, 1984; Douglas, 1986). Ocean pout (Macrozoarces americanus) is abundant from the Gulf of St. Lawrence to Delaware and is also available in ample supplies in Southern New England waters

(Constantinides et al., 1979; Orach-Meza, 1975). In 1980, 230 metric tons of ocean pout were landed in the states of Maine, Massachusetts, and Rhode Island, and increased to 408 metric tons in 1983 (Constantinides et al., 1985).

Known to belong to the Zoarcidae family, Macrozoarces americanus, is characterized by such names as ocean pout, ellpout, catfish, yellow eel, muttonfish, conger eel and ling. They are known to be present in ample supplies in Southern New England during winter and spring and migrate into obscurity off Rhode Island in summer and fall. The average length is between 40-71 cm long. It is thought to have been introduced in U.S. markets in 1943, but because of the unattractive names associated with it and the damaging effect of parasitic infestations by microsporidian, plistophora macrozoarcides, a cessation in their consumption was apparent after World War II. Exhaustive efforts by biologists, food technologists and marketing groups at the University of Rhode Island culminated in reestablishing its consumption in 1975 (Sheely et al., 1977; Alton, 1978). From a nutritional point of view, ocean pout is a very lean fish whose fillets contain an average of 81.9% moisture, 16.64% protein, 0.91% lipid and 1.13% ash (Constantindes et al., 1977), which is favorably compared to red hake 82.2% moisture, 16.5% protein, 0.75% lipid and 0.86% ash (Kelleher et al., 1981).

Fabricated foods are of great potential in the supplementation and substitution for conventional sources. This has been reflected in the past and present with expected future market growth. But chronic shortages in the supply of raw materials, increasing costs accompanied by limited per capita consumption has driven seafood processors to turn to fabricated seafood products such as shrimp, lobster and fish portions in an effort to improve shrinkage in the profit margins. The process of fabrication and extrusion, therefore, offers the processor an opportunity to utilize an abundance of cheap supply of raw materials to produce profitable products.

Institutional acceptance of fabricated seafood was first recognized in 1973, (Katz, 1974) and a surmounting evidence of retail acceptability is seen from the already growing number of new products appearing on supermarket frozen food shelves.

Surimi, the functional "essence" in fabricated seafood products, is primarily composed of 76% water, 16% protein, 4% sucrose, 3.5% sorbitol, 0.3% polyphosphate, 0.2% fat and 0.0038% calcium (Anonymous, 1985). Myofibrillar proteins, the major component protein of surimi is of primary importance in the physiochemical properties seen in a wide variety of surimi-based products. When comminuted with cryoprotectants and frozen, a condition which is less conducive to deterioration of surimi is created. This

factor has enabled researchers to focus on the protein's functionality and stability during gelation, a process invariably linked to the success in the manufacture of these products.

Properties of Meat Proteins

The muscle protein consists of myofibrillar, sarcoplasmic and connective tissue proteins. The proteins in the myofibrillar are made of myosin, tropomyosin and actin. Sarcoplasmic proteins are composed of myogen, globulins, myoglobin, hemoglobin, and enzymes while connective tissue includes collagen, elastin and reticulum. It is believed that some or all of these proteins, particularly myofibrillar proteins and to a lesser extent connective tissue, are involved in binding.

Myosin molecules, when cleaved by the action of papain or trypsin, result in a heavy meromyosin (HMM) fraction which is soluble into low ionic strength solutions and light meromyosin (LMM) that is not soluble at low ionic strength solutions. The difference in solubility has been attributed to the differences in their content of alpha helix, where HMM contains lower alpha helix than LMM (Lowey et al., 1961; Matsumoto, 1980). At physiological pH, myosin is expected to be negatively charged due to its content of a large amount of aspartic, glutamic acid residues and a fair amount of

histidine, lysine and arginine basic residues, besides its ATPare activity.

Actin represents the second most abundant protein of the myofibrillar unit. Actin is the globular form (G-actin) when ATP is attached to it and it polymerizes under the influence of neutral salts into F-actin. In muscle, myosin and F-actin can be found more or less in completed form called actomyosin, a structural component which performs contraction and relaxation in muscle of living animals. Actomyosin may also be formed from actin and myosin at high salt concentrations to give a highly viscous solution. Actomyosin forms various aggregated states during frozen storage (Noguchi, 1977; Buttkus, 1970, 1971; Connell, 1968; Noguchi et al., 1970; Matsumoto et al., 1971; Oguni, et al., 1975), that account for changes in viscosity. During frozen storage, actomyosin filaments are thought to aggregate side to side and dissociation of F-actomyosin into F-actin and myosin do occur. Changes in sulfhydryl (-SH) groups, titrable acid groups, net changes and salting out profiles are known to occur during frozen storage with significant changes occurring mostly during salting out.

Tropomyosin and troponin are located in the grove of the actin filament and are important in the control of muscular contraction under influence of calcium ions (Murray and Weber, 1974).

Connective tissue proteins consists of collagen and elastin. Collagen which contains the highest amount of hydroxyproline than any other meat protein shorten significantly when heated to about 70 C. Elastin which contains desmosine and isodesmosine amino acids is not decomposed by heat and is resistant to acid and heat treatment (Bendall, 1964). Because of its amino acid content, it is thought to be highly involved in crosslinking of polypeptide to give its elastic characteristics.

Factors affecting the binding strength of meat protein matrix

The efficacy of binding of meat proteins is complex and is dependent on the amount of interrelationships that exist among processing factors and the inherent proteins. Schmidt et al. (1982); Seidman (1982); Breindestein (1982); Mandingo (1982); Smith (1982); Schness et al. (1970); Siegel et al. (1979); MacFarlene et al. (1977, 1986) and Vadehra et al. (1970) have identified among others, protein extraction, mechanical treatment, the presence and concentration of added salts and heating temperature as factors which affect binding of meat proteins in model systems.

The extractability of salt soluble proteins is influenced by temperature, extraction time, prerigor meat and salt concentration (Bard, 1965; Gillet et al., 1977). These researchers found that maximum extraction temperature

to be 7.2 C with a marked decrease in extractability at 0 C. Solomon and Schmidt (1980) found that the extraction of crude myosin increased linearly with time , and was compounded by use of prerigor meat than postrigor meat which is in agreement with Saffle and Galbreath (1964) and Acton and Saffle (1969). Solubilized meat proteins bind to the insoluble components in a protein matrix forming a stable, coherent combination and much research has been done to augment this concept. With increase in protein extraction, concurrent increases in binding strength and the relationship between them has been found to be significant and highly correlated but there appears to be a maximum messaging time by which extraction reaches a constant (Theno et al., 1978) beyond which binding strength levels off which is explained by the fact that muscle fiber is disrupted and weakening of the bind strength is evident.

A prerequisite to effective binding is the mechanical treatment applied to most meat systems. Chopping, mixing, messaging, tumbling and mechanical tenderization are among the most common mechanical treatments employed in meat industries to increase the binding strength. The importance of mechanical treatment has been explained by Koo (1980) and Therno et al. (1978b) who found that cell disruption and the amount of myofibrillar protein solubilized increased. Using scanning electron microscopy, Theno et al. (1978b) showed that myofibrils and muscle fibers which are normally tightly

packed separate after messaging causing the solubilized proteins of the exudate to be worked on the loose fiber structure allowing a more cohesive bond to form between the protein matrix and meat surface. Extended mechanical treatment excessively disrupted the muscle fibers and the protein matrix system looses its integrity. A certain degree of mechanical treatment is therefore recommended with respect to the product being manufactured.

The two most widely used salts are sodium chloride and sodium salts of polyphosphoric acids. Salts contribute to the ionic strength of the system. The effects of alkaline polyphosphates is to increase the pH, while neutral salts tend to reduce pH with the resultant increase in the amount of proteins extracted as well as alteration in the ionic and pH environment so that the resultant heat-set protein matrix forms a coherent, three-dimensional structure. Several researchers have studied the effects of changing salt concentrations on gel strengths of washed fish myofibrils and extracted fish myofibrillar proteins (Turner et al., 1979; Ishioroshi et al., 1979). Salt, when added from 0 to 5% produced increasing gel strength up to 3%, after which salt concentration had little effect. By using scanning electron microscopy, Siegel and Schmidt (1979) concluded that myosin and actomosin, when heated in high ionic strength salt solutions, formed a coherent, three dimensional network of fibers which was necessary to produce a satisfactory bind.

The absence of salt led to the formation of a spongy structure with little strength. In addition, Swift and Ellis (1957) found that addition of 0.5% polyphosphate used in conjunction with 2% salt greatly improved the binding strength of bologna and was considerably greater than when 2% salt was used alone.

Binding of meat is a heat-initiated reaction and it does not occur in the raw state (Schnell et al., 1970). The previously dissolved proteins, when heated, undergo rearrangement in order to facilitate an interaction with the insoluble components on the meat surface to form a coherent structure. This process is thought to be initiated at temperatures around 45 C and has been described by Hamm and Deatherage (1960) as a noncovalent process based on the fact that even heating to 70 C did not cause any observable formation of intermolecular bonds leading to the conclusion that hydrogen and ionic interactions were the main forces behind stabilized bonds when heat is applied. The increase in gel strength of fish myofibrils was found to start at 30 C and continued until a temperature of 80 C (Quinn et al., 1980). The above conclusions and the work of Wright et al. (1977) have indicated that denaturation temperatures of different protein components was a characteristic of the species of animal from which the protein came, pH and ionic strength which explains why results by researchers in this area differ.

Roles of specific meat proteins in binding

Of the three groups of proteins found in muscle, myofibrillar, sarcoplasmic and stromal, myofibrillar is the one that has been implicated as being the most important in binding. However, there is evidence that sarcoplasmic and stromal proteins do contribute to a significant extent on the binding characteristics. MacFarlene et al. (1977), Ford et al. (1978) investigated the ability of extracted myosin to bind meat pieces. The general conclusion drawn from this group of workers is that when the ionic strength of the binding matrix is low (below 0.4), the sarcoplasmic proteins make a significant contribution to the binding ability of the system. But when the ionic strength is increased beyond this level, sarcoplasmic proteins have little beneficial effect on binding ability and in some cases the effect is detrimental. Not much research has been done to determine the contribution of sarcoplasmic proteins. Current research indicates that this protein does contribute to the binding in meat systems and their ability to do so is influenced by ionic environment and the presence of other meat proteins.

The salt extractable myofibrillar proteins have been shown to be necessary for satisfactory binding in both emulsion and restructured meat products, as a group or individual component proteins. Acton et al. (1981), Siegel et al. (1979) have demonstrated the effectiveness of binding

myofibrillar proteins in sectioned and formed meats while most of the work on individual proteins of the myofibrillars have been done by Fukazawa et al. (1961a, b); Samejima et al. (1969) and Nakayama and Sato (1971a, b) and through these studies it has generally been concluded that myosin and actomyosin were the proteins that produced the greatest gel strengths and so were the most important in binding. In certain cases, actomyosin was found to be a more effective binding agent than myosin. Yasui et al. (1980) produced a much stronger gel when myosin was added to actomyosin than either myosin or actomyosin alone. The binding quality of heat set gel increased when F-actin was present in an appropriate ratio to myosin and this increased further when tropomyosin was added to the myosin/F-actin model system. The presence of tropomyosin was found to be effective in increasing the water holding capacity.

Products made without stromal proteins are known to be soft, jelly-like and lack cohesion (Schut, 1976), but model systems with high connective tissue have yielded products which were poor in binding and so it is thought that a certain level of this protein must be present to produce acceptable binds. Very little work has therefore been undertaken in finding out proper processing levels of stromal proteins that can produce optimal binding quality. Up to now, the most common approach has been to limit the connective tissue to an economic minimum. Researches that

have been carried out have not been conclusive. Randall and Voisey (1977) showed that stromal and myofibrillar proteins increased binding in a meat emulsion when added separately, but the effect was synergistic when added together, which explains why isolated protein systems cannot always be extrapolated to more complex systems, such as meat products, due to possible interactions. Gelatin is formed on heat processing and can liquefy if the product is reheated above a certain critical temperature which, in the case of beef, is 49 C. The liquification of gelatin above critical temperature can result in collapse of product structure and loss of moisture and fat (Poulanne and Ruusunen, 1981). Difficulties arise as to the extraction and quantification of collagen (Sato et al., 1986). Very often, the denatured and insolubilized myofibrillar proteins are included during extraction of collagens. On the basis of hydroxyproline content of muscles, variations from species to species of fish is a major factor.

Significant information has been obtained as to the effect of using Alaskan pollock surimi in red hake meat and poultry gelation in ground meat products (AFDF, 1985). Of great importance is their conclusion that increased binding potentials of meat blends can easily be obtained by adding relatively low levels of lower-cost surimi. In addition, the level of surimi added does not appear to contribute as

significantly to the possible binding potential as does the actual inclusion of surimi into the formula.

Protein gel and physical properties

The potential of a protein to form heat-induced gel depends on its ability to interact with other proteins in the system. This interaction, which involves protein-water and protein-protein aggregations are important contributors to the functional properties of gel-type products, such as hot dogs, fabricated shellfish meat and kamaboko (Kinsella, 1976; Acton et al., 1983). In order to achieve the desired functional properties in these systems, it is necessary to control the composition of the product from its initial processing history, formulation through thermal treatment.

Myofibrillar proteins which are more responsive for the functionality of comminuted meat products (Okada, 1963; Li-Chan et al., 1984; Hashimoto et al., 1983 & 1985; Kinney et al., 1986; Hickson et al., 1982; Jiang et al., 1986) undergo an initial heat denaturation (unfold) and aggregate when heated to form a three dimensional, crosslinked protein network in which polymer- polymer, polymer solvents interactions occur. The network formed is responsible for the texture and waterbinding characteristics of the finished products (Kijowski et al., 1978; Acton et al., 1983; Ziegler and Acton, 1984) and may vary among animal species (Lanier et

al., 1982; Makinodan et al., 1971; Shimizu, 1974 & 1981; Douglas, 1986; Katoh et al., 1986).

The effects of temperature, pH, salt, and protein concentration on gelation of myofibrillar proteins have previously received wide attention (Ishioroshi et al., 1979; Yasui et al., 1980 & 1982; Lanier, 1982; Wu et al., 1985; Foegeding et al., 1986; Montejano et al., 1983; Iso et al., 1984; Hickson et al., 1982; Seki et al., 1985) and it is apparent that rheological changes occurring during gelation correlate well to the texture and visco-elastic measurements of the products (Smith et al., 1988). Myosin and actomyosin are the major proteins involved in gelations. Factors accounting for the differences in gelation among fish species have been attributed to differences in hydrophobic interactions on the surface of the protein molecules (Niwa et al., 1971 & 1982; Liu et al., 1982), thermal stability of actomyosin (Shimuzu et al., 1983 & 1981), protein-protein interaction (Acton et al., 1981). Therefore it is generally concluded that the level of functional actomyosin which is measured as extractable actomyosin or ATPase activity is a measure of gel-forming ability of surimi as determined by the water binding capacity and correlates well with the gel strength. With an increase in the number of washing cycles the level of actomyosin increases, but is greatly affected by the freshness of the fish (Lee, 1984). Loss in protein functionality and in particular, the gel forming ability is

due to freeze denaturation and aggregation of the myofibrillar proteins (Sikorsky et al., 1976; Matsumoto, 1980 & Suzuki, 1981) which decreases the stability of actomyosin and increases the susceptibility for rapid denaturation during thawing and/or subsequent storage (Scott et al., 1988). In addition, the quality of surimi during frozen storage is also affected by storage temperature, storage period, the level of moisture and cryoprotectants used (Lee, 1984; Okada & Iwata, 1969; Shimuzu and Fujike, 1985). Thus, gel forming ability of surimi will be maintained significantly with extended storage time for up to one year at a constant temperature of -20 C (Iwata et al., 1968 & 1971). Reports (Iwata et al., 1971) also indicate gradual decrease in gel forming ability at a storage temperature of -10 C rendering the surimi useless after three months.

The adjustment of moisture content of kamaboko while being a convenient way of altering the protein content is considered a critical factor in assessing the gel forming ability. The breaking force, deformation and gel strength can be altered by the moisture level in surimi and it is important that when comparing different surimis, the moisture should be made constant. Consequently, the moisture tolerance level of different species must be assessed, since it plays an important role in the freeze thaw stability. The higher moisture level increases the susceptibility to freeze

destabilization (Yoon, 1986). Addition of cryoprotectants such as starch (for products which are to be cooked and frozen, and sorbitol for uncooked products to be frozen), has been suggested as the best approach to overcome freeze-thaw instability without reducing the myosin level.

The application of heat for cooking of further process products and addition of salt, however, are the two major factors in denaturation and gelation of muscle proteins. The solubized surimi paste gels rapidly upon heating at 80-90 C, but slowly at 40-50 C. Okada (1963) reported that slow setting of the gel at 40-50 C resulted in stronger gel than cooking without a slow set. This was not the case with ocean pout surimi and the phenomenon may be attributable to the species differences (Makinodan & Ikeda, 1971; Shimuzu & Nishioka, 1974; Shimuzu et al., 1981). Gel setting occurs at temperatures up to 50 C. Increasing temperature to 60-70 C causes a softening phenomena (Madori). In contrast, reports for surimi prepared from red hake (Urophycis chuss) and Alaskan pollock (Theragra chalcogramma) or the ocean pout appears to be affected by the softening phenomena. Makinodan and Ikeda (1971), Deng et al. (1979) and Lanier et al. (1982) have attributed this to the presence of alkaline protease enzyme that has maximum activity at 60-70 C. In the latter case, a theory of temperature-dependent gel setting was proposed. At a faster heating rate, a tight cohesive network with a large number of small aggregate is formed, whereas at

a slow heating rate a loose network with a small number of large aggregate is found.

Some loss of gel forming potential may be acceptable for products manufactured for western tastes where a less rubbery texture may be acceptable (Lanier, 1986). This would require a dilution of high quality with low quality surimi or use of other less functional ingredients. In the manufacture of frozen products, both molded and fiberized, a combination of wheat gluten and wheat starch has a beneficial rubbery-texture reducing ability and better freeze-thaw stabilizing effect while a combination of wheat gluten and modified potato starch will produce a more acceptable texture in fresh products (Lee, 1987).

Figure 1

CONSENT FORM

I, the undersigned, do hereby acknowledge that I am voluntarily participating in the below described sensory analysis of surimi produced at the surimi-making facility of the University of Rhode Island. Further, I have read the statement below and understand what I am expected to do as a participant and the risks outlined below.

This sensory panel is being conducted to evaluate the desirable combination of ocean pout and red hake and their combination with sugar and sorbitol in surimi extruded products. Surimi and extruded products are prepared using fresh ocean pout and red hake, and various processing techniques. The newly extruded surimi and extruded products are steam cooked and cooled before being presented to the panel. Those which are obviously unacceptable after treatment are eliminated. The desirability will be tested and rated on a numerical scale according to how desirable the taster finds them for compensation.

Any individual with allergy to surimi or fish should be removed from the study.

The information obtained in this panel will be used to determine optimum levels of ocean pout and red hake with desirable qualities. The names of the individual participants in the panel will not be associated in any way with the results of the panel, and will not appear in any publication which may result from the information gathered.

Finally, participation in the panel does not obligate the panelist in any way to participate in subsequent panels unless they wish to do so, and a panelist may remove himself from the survey at any time by simply returning the form to the individual conducting the panel and stating he or she does not wish to continue with the taste testing.

Your participation in this project is appreciated. Please read the above statement carefully and if you wish to participate in the panel, sign and date this form below. If you have further questions regarding involvement in the panel, or the nature of the research, please feel free to contact me at 792-4022 or in Quinn Hall, Room 209.

Thank you,

Paul Akengo

Signature of Participant Date

Figure 2

EXAMPLE FORMAT FOR SENSORY EVALUATION REPORTS

Questionnaire:

Evaluate these samples or texture and desirability. Taste each one and use appropriate scale to show your evaluation and check the point that best describes your feelings about the sample.

Firmness

Sample #	V. Poor	Poor	Fair	Good	V. Good	Excellent
601						
602						
603						
604						
605						
606						
607						
608						

Desirability

Sample #	V. Poor	Poor	Fair	Good	V. Good	Excellent
601						
602						
603						
604						
605						
606						
607						
608						

APPENDIX

B

ORIGINAL DATA

TABLE 1 EFFECT OF NaCl ON OCEAN POUT SURIMI GELS

NaCl (%)	MOISTURE OF PASTE a 0.0014	MOISTURE OF GEL	EXPRESSIBLE MOISTURE % a 0.0001	RIGIDITY (GMS) a 0.0323	COHESIVENESS (KGM) a 0.0001
1%	78.45 a +0.13	76.03	19.92 a ±0.38	157. b ±6.45	0.98 d ±0.15
1.5%	78.27 a +0.23	76.46	15.56 b ±0.57	172. b ±15	1.23 c ±0.05
2%	77.43 b +0.21	77.90	9.53 c ±0.31	175. ab ±17.32	2.28 b ±0.1
2.5%	77.78 b +0.22	77.58	9.0 c ±0.22	176. ab ±20.56	2.38 b ±0.05
3%	77.40 b +0.42	77.34	5.61 d ±0.67	100. a ±18.26	3.35 a ±0.13

a Probability of error that the gels were not significantly affected by salt level. Values are means of three determinations for moisture of surimi gel, moisture of paste and four determinations for expressible moisture, rigidity and cohesiveness

abcd Means followed by the same letters in the same column are not significantly different ($P<0.05$).

TABLE 2 MEANS, STANDARD DEVIATIONS AND SIGNIFICANCE OF MOISTURE LEVEL ON EXPRESSIBLE FLUID, COHESIVENESS AND RIGIDITY OF OCEAN POUT SURIMI GELS

MOISTURE LEVEL (%)	EXPRESSIBLE FLUID (%)	COHESIVENESS (KG)	RIGIDITY GMS
	a 0.0001	0.0001	0.0001
	MEANS + STANDARD DEVIATIONS b		
72	6.59± 0.46 b	3.5± 0.0 b	702.5± 38.6 b
74	5.11± 0.47 c	4.0± 0 a	835. ± 83.86a
76	6.78± 0.29 b	3.25± 0.29b	422.5± 17 d
78	6.73± 0.41 b	2.88± 0.25 c	422.5± 17.1 d
80	9.34± 0.23 a	2.0 ± 0 d	342. ± 18.1 e

a Probability of error that the gels were not significantly affected by the moisture level

b Average of 4 observations

abcd Means followed by the same letter in the same column are not significantly different ($P<0.05$).

TABLE 3 MEANS STANDARD DEVIATIONS AND SIGNIFICANCE OF HEAT INDUCED GEL SETTING BEHAVIOR OF OCEAN POUT SURIMI GELS ON EXPRESSIBLE MOISTURE RIGIDITY AND COHESIVENESS

HIGH-TEMP HEAT-SET	COOKING 90 C	MOISTURE GEL(%)	EXPRESSED MOISTURE	RIGIDITY	COHESIVENESS (KG)
	30 min	77.20a ±0.20	5.20b ±0.25	870.ab ±31.62	7.1a ±0.41
	40 min	75.70c ±0.30	5.27b ±0.22	890. a ±21.69	7.0 a ±0.42
	50 min	77.40a ±0.30	5.25b ±0.24	870. ab ±16.30	6.75 ±0.29
	60 min	77.30a ±0.30	5.07b ±0.17	880. a ±16.30	6.45b ±0.33
20 min (40 C)	30 min	76.70b ±0.20	5.73a ±0.27	852. c ±16.20	5.13c ±0.25
20 min (50 C)	30 min	76.10b ±0.30	7.02a ±0.45	698. d ±20.62	3.95d ±0.10
20 min (60 C)	30 min	77.30a ±0.20	7.60a ±0.34	560. e ±29.44	3.13e ±0.25

a Average of 4 observations
abcde Means followed by different letters in the same column are significantly different ($P<0.05$).

TABLE 4 MEANS, STANDARD DEVIATIONS AND SIGNIFICANCE OF COMBINATIONS OF OCEAN POUT SURIMI AND RED HAKE SURIMI ON EXPRESSIBLE MOISTURE OF SURIMI GELS

Combinations (%)		Expressible Moisture	
Pout	Red Hake	Day 0 0.0001	After 3 F-T 0.0001
		Means + Standard Deviations	
100	0	7.99 ± 6.70 a	12.80 ± 0.26 a
80	20	5.44 ± 0.74 b	12.10 ± 0.48 b
60	40	4.44 ± 0.32 c	10.98 ± 0.81 c
40	60	3.9 ± 0.37 c	10.08 ± 0.33 d
20	80	3.11 ± 0.29 d	10.21 ± 0.37 d
0	100	2.79 ± 0.15 d	10.00 ± 0.59 d

a Probability of error that the gels were not significantly affected by different combinations.

b Average of 4 observations.

abcd Means followed by the same letter in the same column are not significantly different ($P<0.05$).

TABLE 5 MEANS STANDARD DEVIATIONS AND SIGNIFICANCE OF COMBINATIONS OF OCEAN POUT SURIMI AND RED HAKE SURIMI ON ELASTICITY AND CHEWINESS OR SURIMI GELS

Combinations (5) Ocean Pout/Red Hake		Elasticity	Chewiness 0.0001	
		Means + Standard Deviations		
100	0	50.87 ±6.81d	78.4 ±10.14	c
80	20	62.87 ±9.2 c	87 ± 4.33	c
60	40	63.87 ±6.79c	89.39± 5.21	c
40	60	86.87 ±4.73b	106.61± 4.23	a
20	80	103.75±14.93a	97.34± 1.01	b
0	100	109.3 ± 8.69a	102.58± 3.51	a

a Probability of error that the gels were not significantly affected by combinations.

b Average of 8 observations.

abcd Means followed by the same letter in the same column are not significantly different ($P<0.05$)

TABLE 6 MEANS STANDARD DEVIATION AND SIGNIFICANCE OF DIFFERENT COMBINATIONS OF OCEAN POUT AND RED SURIMI ON COHESIVENESS

Combinations (%)		Surimi Gel 0.0001 a Means + standard deviation b	
Ocean Pout	Red Hake	Day 0	3 F - T
100	0	5.09 ± 0.60 d	8.13 ± 0.85 d
80	20	6.11 ± 0.31 cd	8.5 ± 0.58 d
60	40	6.99 ± 0.39 c	9.63 ± 0.75 d
40	60	8.99 ± 0.61 b	12.5 ± 1.92 c
20	80	13.05 ± 1.47 a	18.25 ± 0.96 b
0	100	14.19 ± 2.15 a	29.13 ± 1.18 a

a Probability of error that the gels were not affected by different combinations.

b Average of 8 observations.

abcd Means followed by the same letter in the same column are not significantly different ($P<0.05$).

TABLE 7 MEANS STANDARD DEVIATIONS AND SIGNIFICANCE OF DIFFERENT COMBINATIONS OF OCEAN POUT AND RED HAKE SURIMI ON RIGIDITY OF SURIMI GELS.

RIGIDITY

Combinations (%)		Surimi Gel 0.0001 a Means + Standard Deviation b	
Ocean Pout	Red Hake	Day 0	After 3 F - T
100	0	623.75 ± 66.9 e	912 ± 87.7 e
80	20	728.25 ± 56.9 c	1875 ± 20.4 a
60	40	853.12 ± 42.4 c	1068.7 ± 47.3 d
40	60	873.5 ± 59.8 c	1181.2 ± 85.1 d
20	80	1110.75± 103.7 a	1382.5 ±154 c
0	100	992 ± 95.2 b	1722 ± 48.6 b

a Probability of error that the gels were not significantly affected by different combinations.

b Average of 8 observations

abcde Means followed by the same letter in the same column are not significantly different ($P<0.05$).

TABLE 8 MEANS, STANDARD DEVIATIONS AND SIGNIFICANCE OF SENSORY PANEL EVALUATION OF OCEAN POUT AND TURKEY COMBINATION WITHOUT EGG ALBUMIN

Sensory	Percentage Combinations						
NOTE Turkey	100	90	80	70	60	50	0
O.Pout	0	10	20	30	40	50	100
Firmness	6.60 ±1.67 a	7.20 ±1.30 a	6.60 ±0.84 a	5.40 ±1.34 ab	4.60 ±1.82 b	3.89 ±1.48 b	1.00 ±1.23 c
Cohesiveness	6.80 ±1.30 a	7.00 ±1.73 a	6.40 ±1.52 ab	5.60 ±1.52 ab	5.60 ±2.12 ab	4.00 ±2.00 b	1.40 ±2.07 c
Moistness/ Acceptability	6.40 ±2.19 a	6.80 ±1.64 a	6.20 ±1.30 a	5.60 ±1.67 ab	5.00 ±1.87 ab	4.80 ±1.92 ab	3.40 ±2.19 a
Appearance/ Color	6.80 ±1.79 a	7.00 ±1.41 a	6.20 ±1.48 a	5.40 ±1.95 ab	4.80 ±2.17 ab	4.20 ±1.92 b	1.80 ±1.48 c
Overall/ Acceptability	6.20 ±2.17 a	6.60 ±1.95 a	6.40 ±1.34 a	5.20 ±2.17 a	5.00 ±2.00 a	4.40 ±2.07 a	1.80 ±1.48 b

a Average of 6 observations

abcd Means followed by different letters in the same row are significantly different ($P<0.05$).

TABLE 9 MEANS, STANDARD DEVIATIONS AND SIGNIFICANCE OF SENSORY EVALUATION OF TURKEY - OCEAN POUT SURIMI IN COMBINATION WITH 2% EGG ALBUMIN.

Sensory	Percentage Combinations						
NOTE: Turkey	100	90	80	70	60	50	0
O. Pout	0	10	20	30	40	50	100
Firmness	6.00 ±1.41 a	5.75 ±0.96 a	5.00 ±1.16 ab	4.25 ±1.50 ab	4.00 ±1.83 ab	3.50 ±1.29 ab	2.00 ±0.82 c
Cohesiveness	6.00 ±0.82 a	5.50 ±1.00 ab	5.30 ±1.50 ab	4.50 ±1.30 b	4.30 ±2.20 b	4.30 ±2.60 b	2.0 ±0.80 c
Moistness	6.25 ±1.30 a	6.00 ±0.80 a	5.00 ±0.80 a	4.50 ±0.60 ab	4.00 ±1.60 ab	3.50 ±0.80 c	3.00 ±2.1 c
Appearance	5.50 ±1.00 a	5.50 ±1.00 a	5.50 ±1.00 a	4.80 ±1.70 a	4.80 ±1.70 a	4.50 ±2.10 b	1.80 ±0.50 c
Acceptability	5.80 ±1.00 a	5.80 ±1.00 a	5.50 ±1.30 a	5.00 ±1.80 ab	5.00 ±1.80 ab	4.80 ±1.70 ab	2.30 ±1.00 c

a Average of 6 observations.

abcd Means followed by different letters in the same row are significantly different ($P<0.05$).

TABLE 10 COMPARISON OF MEAN SENSORY SCORES OF TURKEY-SURIMI SYSTEM WITH AND WITHOUT 2% EGG ALBUMIN (SURIMI - WEIGHT BASIS)

Formulation (%)		Firmness(after cooking)		Cohesiveness	
		Without	With	Without	With
Turkey	Ocean Pout				
100	0	6.60 ±1.67a	6 ±1.41a	6.80 ±1.30a	6 ±0.82a
90	10	7.20 ±1.30a	5.75 ±0.96a	7.0 ±1.73a	5.5 ±1.00ab
80	20	6.60 ±0.84	5.0 ±1.16ab	6.4 ±1.52ab	5.3 ±1.50ab
70	30	5.40 ±1.34ab	4.25 ±1.5b	5.6 ±1.52ab	4.5 ±1.30b
60	40	4.60 ±1.82b	4.00 ±1.83b	5.6 ± 2.12ab	4.3 ± 2.20b
50	50	3.80 ±1.48b	3.5 ±1.29b	4.0a ±2.00b	4.3a ±2.6b
0	100	1.00 ±1.23	2.00 ±0.82	1.4 a ±2.07c	2.0a ±0.8c

a Means are an average of 6 observations.

abcd Means in the same column followed by the same letter are not significantly different ($P<0.05$).

TABLE 11 COMPARISON OF MEAN SENSORY SCORES OF TURKEY-SURIMI SYSTEM WITH AND WITHOUT 2% EGG ALBUMIN (SURIMI WEIGHT BASIS) ON MOISTURE, APPEARANCE, AND OVERALL ACCEPTABILITY

Formulation		Moisture		Appearance		Overall Acceptability	
Tur-key	Ocean-Pout	With (mean)	Without (mean)	With (mean)	Without (mean)	With (mean)	Without (mean)
100	0	6.25 ±1.30a	6.4 ±2.19a	5.5 ±1.0a	6.8 ±1.79a	5.8 ±1.0a	6.2 ±2.17a
90	10	6.00 ±0.80a	6.8 ±1.64a	5.5 ±1.0a	7.0 ±1.41a	5.8 ±1.0a	6.6 ±1.95a
80	20	5.0 ±0.80ab	6.2 ±1.3a	5.5 ±1.0a	6.2 ±1.48a	5.5 ±1.3a	6.4 ±1.34a
70	30	4.5 ±0.60b	5.6 ±1.67ab	4.8 ±1.7ab	5.4 ±1.95ab	5.0 ±1.8ab	5.2 ±2.17a
60	40	4.0 ±1.6b	5.0 ±1.87ab	4.8 ±1.7ab	4.8 ±2.19ab	5.0 ±1.8ab	5.0 ±2.0a
50	50	3.5 ±0.80c	4.8 ±1.92ab	4.5 ±2.1b	4.2 ±1.92b	4.8 ±1.7b	4.4 ±2.07a
0	100	3.0 ±2.1c	3.4 ±2.19b	1.8 ±0.5c	1.8 ±1.48c	2.3 ±1.0c	1.8 ±1.48b

a Means are average of 6 observations.

abcd Means in the same row followed by the same letter are not significantly different ($P<0.05$).

TABLE 12 EFFECT OF INCORPORATING DIFFERENT PROTEINS ON THE PROPERTIES OF OCEAN POUT SURIMI GELS (5% PROTEINS)

Proteins (5%)	Moisture of gel	Expressible Moisture	Rigidity (GMS)	Cohesiveness (KGM)
Control (c)	78.24 a ±0.20	11.98 a ±0.29	196 d ±25	2.56 e ±0.08
Milk Protein (MLP)	75.36 bc ±0.17	6.04 b ±0.50	246 c ±8.94	3.75 c ±0.37
Soy Protein (SOP)	75.67 b ±0.24	5.70 b ±0.32	268 c ±8.35	4.95 b ±0.19
Egg Albumin (EA)	75.52 b ±0.12	5.78 b ±0.69	422 a ±42	7.68 a ±0.26
Gluten (GL)	75.06 cd ±0.18	5.97 b ±0.47	300 b ±10	5.33 b ±0.47
Lactalbumin (LAC)	74.86 d ±0.28	11.18 a ±1.12	250 c ±20	3.15 d ±0.17

a Probability of error that the gels were not significantly affected by the protein incorporated.

b Average of 4 observations.

abcde Means followed by the same letter in the same column are not significantly different ($P<0.05$).

TABLE 13 EFFECT OF INCORPORATION OF EGG ALBUMIN ON OCEAN POUT SURIMI GELS.

Instron TPA Parameters	Percent Egg Albumin 0	2	4	6	8
Moisture of paste a = 0.1073	78.30 a ±0.1	78.23 a ±0.13	78.12 a ±0.17	78.18 a ±0.13	77.03 b ±1.26
Expressible moisture % a = 0.0001	13.44 b ±0.30	9.47 d ±0.48	11.58 c ±0.37	14.94 b ±0.63	20.41 a ±1.67
Rigidity a = 0.0001	192 d ±11.67	292 a ±11.69	250 b ±17.89	233 b ±16.33	213 c ±16.33
Cohesiveness a = 0.0001	2.78 d ±0.13	5.90 a ±0.08	4.50 b ±0.26	3.08 c ±0.22	1.83 e ±0.17

b Average of 4 observations

abcd Means followed by the same letter in the same row are not significantly different ($P<0.05$).

APPENDIX C

BIBLIOGRAPHY

BIBLIOGRAPHY

Acton, J.C. and Saffle, R.L. 1969. Preblended and prerigor meat in sausage emulsions. Food Technol. 23(3):367.

Acton, J.C., Hanna, M.A. and Satterlee, L.D. 1981. Heat induced gelation and protein - protein interactions of natural actomyosin. J. Food Biochem. 5:101.

Acton, J.C., Ziegler, G.R. and Burge, D.L. Jr. 1983. Functionality of muscle constituents in the processing of comminuted meat products. Crit. Rev. Food Sci. Nutri. 18(2):99.

Bard, J.C. 1965. Some factors influencing extractability of salt-soluble proteins. In: Proceedings of Meat Industry Research Conference. pp. 96-98. American Meat Institute Foundation, 1600 Wilson Blvd., Arlington, VA.

Bendall, J.R. 1964. Meat products. In Symposium on Foods: Protein and their reactions, eds. Shultz, H.W. and Anglemier, A.F. Avi Publishing Company, Westport, CT. p. 225.

Breidenstein, B.C. 1982. Industry's view - Short term research priorities in restructured meat area. In Proceedings Int. Symp. on Meat Science and Technology. Nov. 1-4.

Buttkus, H. 1970. Accelerated denaturation of myosin in frozen solution. J. Food Sci. 32:558.

Catsimpoolas, H. and Myere, E.W. 1970. Cereal chemistry. 48:559.

Catsimpoolas, N. and Meyer, E.W. 1971. Cereal chemistry. 48:159.

Cheng, C.S., Hamann, D.D. and Webb, N.B. 1979. Effect of thermal processing on minced fish gel texture. J. Food Sci. 44:1080.

Connell, J.J. In "Low Temperature Biology of Foodstuffs," (Hawthorn, J., Rolfe, E.F., Eds.), Pergamon Press: Oxford, 1968, p. 429.

Constantinides, S.M., Sheely, D.J., Shenonda, S.Y.K., Alton, A.A., Saita, S.B. 1977. The Ocean Pout: An example of underutilized Fishery Resource Development. M.F.R. Vol. 39(6):5.

Constantinides, S.M., Shenonda, S.Y.K., Montecalvo, J. and Jhaveri, S. 1979. Technological studies on ocean pout, an unexploited fish species for direct human consumption. J. Food Sci. 44(1):64.

Constantinides, S.M., Jhaveri, S.N., Karakohsidis, P.A., Shenonda, Y.K. 1985. Ocean pout (Macrozoarces Americanus): Nutrient analysis and utilization. J. Food Sci. 50:719-722.

Douglas, M.A. 1986. Thermostability of surimi gel and subsequent freeze-thaw stability. Masters Thesis. URI

Foegeding, E.A., Allen, C.E., Dayton, W.R. 1986. Effect of heating rate on thermally formed myosin, fibrinogen and albumin gels. J. Food Sci. 51(1):104.

Ford, A.L., Jones, P.N., MacFarlane, J.J., Schundtz, G.R. and Turner, R.H. 1978. Binding of meat pieces: Objective and subjective assessment of restructured steakettes containing added myosin and sarcoplasmic proteins. J. Food Sci. 43:815.

Fukazawa, T., Hashimoto, Y. and Yasui, T. 1961a. Effect of some proteins on the binding quality of experimental sausage. J. Food Sci. 26:541.

Fukazawa, T., Hashimoto, Y. and Yasui, T. 1961b. The relationship between the components of myofibrillar protein and of the effect of various phosphates that influence the binding quality of sausage. J. Food Sci. 26:550.

Gillet, T.A., Meibing, D.E., Brown, C.L. and Simon, S. 1977. Parameters affecting meat protein extraction and interpretation of model system data for meat emulsion formation. J. Food Sci. 42:1606.

Hamm, R. and Deatherage, F.E. 1960. Changes in hydration, solubility and charges of muscle proteins during heating of meat. Food Res. 25:587.

Hashimoto, A., Katoh, N., Nozak, H., Marnyama, T. 1983. Effect of preservation temperature on the quality of defrosted surimi. Bull. Jap. Soc. Sci. Fish. 49(9):1443.

Hashimoto, A., Kator, N., Nozaki, H., Arai, K. 1985. Effect of temperature on denaturation of salted meat paste from three fish species. Bull. Jap. Soc. Sci. Fish. 51(5):847.

Hermansson, A.M. 1986. Soy protein gelatin. JACCS. Vol. 63(5).

Hickson, D.W., Dill, C.W., Morgan, R.G., Stewart, V.E., Suter, D.A. and Carpenter, Z.L. 1982. Rheological properties of two-stage heat-induced protein gels. J. Food Sci. 47:783.

Ishioroshi, M., Samejima, K. and Yasui, T. 1979. Heat-induced gelation of myosin: Factors of pH and salt concentrates. J. Food Sci. 44:1280.

Iso, N., Mizuno, H., Saito, T., Ohzeki, F., Kirihara, N. 1984. The changes of the rheological properties of surimi (minced fish meat) by heating. Bull. Jap. Soc. Sci. Fish. 50(6):1045.

Iwata, K., Okada, M., Fujii, Y. and Mimoto, K. 1968. Influence of storage temperature in quality of frozen Alaska pollock surimi. Reito [Refrigeration] 43:1145.

Iwata, K., Kanna, K., Umemoto, S., and Ikada, M. 1971. Study of the quality of frozen stored Alaskan pollock surimi. 1. The influence of freshness of the material and changes in storage temperature. Bull. Jap. Soc. Sci. Fish. 52(5):875.

Jiang, S.T., Lan, C.C., Tsao, C.Y. 1986. New approach to improve the quality of minced fish products from freeze-thawed cod and mackarel. J. Food Sci. 51(2):310.

Katoh, N., Hashimoto, A., Nozaki, H., Marnyama, T., Arai, K. 1986. Change in myofibrillar protein of salted meat past from Alaskan pollock and tilapia during salting. Bull. Jap. Soc. Sci. Fish. 52(5):875.

Katz, A. 1974. Frozen fish and seafood. Quick frozen foods. Jan. 18. Szczesniak, A.S. 1975. General food texture profile revised. Ten years perspective. J. Texture Studies. 6:5.

Kelleher, S.D., Buck, E.M., Hultin, H.O., Parkin, K.L., Licciarello, J.J. and Damon, R.A. 1981. Chemical and physical changes in red hake blocks during frozen storage. J. Food Sci. 47(1):65.

King, R.W. and Dunkin, A. 1985. Surimi could become the hot dog of the fish business. Bus. Wk. Feb, 25, 1985. 106.

Kinney, P.B., Henrickson, R.L., Claypool, P.L., Rao, B.R.. 1986. Influence of temperature, time and solvent on the solubility of coriam collagen and meat proteins. J. Food Sci. 51(2):277.

Kinsella, J.E. 1976. Functional properties of proteins in foods: A survey Crit. Rev. Food Sci. Nutri. 8:219.

Kijowski, J. and Niewigrowicz, A. 1978. Effect of initial pH in broiler breast muscles on gel forming capacity of meat proteins and on rheological characteristics of frankfurter stype sausage. J. Food Tech. 13:461.

Komatsu, K. 1981. Recent developments and future progress in Japanese fish parts products. In Recent Advances in Food Sci. and Tech. Vol.II. p.77.

Koo, K.H. 1980. Determination of myofibrillar proteins binding strength, yield and TBA effected by mechanical treatment, salt and micro-organisms in a pre-cooked (uncured) chunked and formed beef product. Dissertation Abstracts International. B40(10):4726.

Kotter, L. and Fisher, A. 1975. The influence of phosphates on polyphrophates on the stability of forms and emulsions in meat technology.

Lanier, T.C., Lin. T.S., Hamann, D.D. and Thomas, F.B. 1981. Effects of alkaline protease in minced fish on texture of heat-processed gels. J. Food. Sci. 46:1643.

Lanier, T.C., Lin, T.S., Lin, Y.M. and Haman,, D.D. 1982. Heat gelation properties of actomyosin and surimi prepared from Atlantic croaker. J. Food Sci. 47:1921.

Lanier, T.C. 1986. Function properties of surimi. Food Technol. 40(3):107.

Lee, C.M. and Toledo, R.T. 1984. Comparison of shelf life and quality of mullet stored at zero and subzero temperature. J. Food Sci. 49:317.

Lee, C.M. 1984. Surimi process technology. Food Technol. 38(11):69

Lee, C.M. 1987. Evaluation of texture modifying effect of wheat gluten in surimi-based analog product. Technical Report to International Wheat Gluten Association. June 15, 1987.

Li-Chan, E., Nakai, S., Wood, D.F. 1984. Hydrophobriety and solubility of meat proteins and their relationship to emulsifying properties. J. Food Sci. 49:345.

Liu, Y.M., Lin. T.S. and Lanier, T.C. 1982. Thermal denaturation and aggregation from Atlantic croaker. J. Food Sci. 47:1916.

Lowey, S., Goldstein, L., Cohen, C. and Luck, S.M. 1967. Proteolytic degradation of myosin and the meromyosin by a water-insoluble polyanionic derivatiave of trypsin. Properties of a helical subunit isolated from heavy meromyosin. J. Mol. Biol. 23:287.

MacFarlane, J.J., Turner, R.H. and Jones, P.N. 1986. Binding of meat pieces. Influence of some processing factors on binding strength and cooking losses. J. Food Sci. 51(1):740-741.

MacFarlane, J.J., Schmidt, G.R. and Turner, R.H. 1977. Binding of meat pieces - A comparison of myosin, actomyosin and sarcoplasmic proteins as binding agents. J. Food Sci. 41:1603.

Makinodan, Y. and Ikeda, S. 1971. Studies on fish muscle protease. IV. Relations between himodori of Kamaboko and muscle protease. Bull. Jap. Soc. Sci. Fish. 37:518.

Makinodan, Y., Hirotsuka, M. and Ikeda, S. 1980. Autolysis of carp muscle. Bull. Jap. Soc. Sci. Fish. 46:1507.

Mandingo, R.W. 1982. Processing systems-mixing, temperature control and raw materials. In Proceedings Int. Symp. on Meat Science and Technol. Lincoln, Nebraska, Nov. 1-4.

Matsumoto, J.J. 1980. Chemical deterioration of muscle proteins. Ch.5. In "Chemical deterioration of proteins". J.R. Whitaker and Fujimaki (Ed), p.95. ACS Symposium Series, 123 ACS, Washington, D.C.

Montejano, J.G., Hamann, D.D., Lanier, T.C. 1983. Final strengths and rheological changes during processing of thermally induced fish muscle. J. Rheology. 27(6):557.

Murray, J.M. and Webber, A. 1974. The cooperative action of muscle proteins. J. Scientific America. d230(2):59.

Nakayama, T. and Sato, Y. 1971a. Relationship between binding quality of meat and amyofibrillar proteins. Part II. The contribution of native tropomyosin and actin to the binding quality of meat. Agri. Biol. Chem. 35(2)208.

Nakayama, T. and Sato, Y. 1971b. Relationship between binding quality of meat and myofibrillar proteins. Part III. Contribution of myuosin A and actin to rheological properties of heat minced meat gel. J. Text. Studies. 2:75.

Niwa, E. and Miyake, M. 1971. Physico-chemical behavior of fish meat proteins. 1. Behavior of polypeptide chains of proteins during setting of fish meat paste. Bull. Jap. Soc. Sci. 37:877.

Niwa, E., Matsubara, Y. and Hamada, I. 1982. Hydrogen and other polar bondings in fish flesh and setting gel. Bull. Jap. Soc. Sci. Fish. 48:667.

Noguchi, S. and Matsumoto, J.J. 1970. Studies on the control of the denaturation of the fish muscle proteins during the forzen storage. I. Prevention effect of na-glutamate. Bull. Jap. Soc. Sci. Fish. 36(10):1078.

Noguchi, S. In "Proteins of Fish Muscle," Jap. Soc. Sci. Fish. 1977, 99.

Oguni, M., Kubo, T. and Matsumoto, J.J. 1975. Studies on denaturation of fish muscle proteins, I. Physichochemical and electron microscopic studies of freeze-denatured carp actoymosin. Bull. Jap. Soc. Sci. Fish. 41(11):1113-1123.

Okada, M. 1963. Studies of elastic property of kamaboro. Bull. Tokai. Reg. Fish. Res. 36:21.

Okada, M. and Iwata, K. 1969. Relationship between freshness before freezing and cold storage deterioration in the North Pacific Alaska pollock. III. Bull. Tokai. Reg. Fish. Res. Lab. 60:179.

Oracho Meza, F.L. 1975. Distribution and abundance of ocean pout (Macrozoarces Americanus) (Block and Sneider) in the Western North Atlantic Ocean. M.S. Thesis. U.R.I., Kingston.

Poulanne, E. and Ruusunen, M. 1981. The properties of connective tissue membrane and pig skin as raw materials for cooked sausage. Meat Science. 5:371-382.

Quinn, J.R., Raymond, D.P. and Herwalker, V.R. 1980. Differential scanning calorimetry of meat proteins as affected by processing treatment. J. Food Sci. 1146-1148.

Randall, C.J. and Voisey, P.W. 1977. Effect of meat protein fractions on textural characteristics of meat emulsions. J. Inst. Can. Sci. Technol. Alinment. 10(2):88.

Saffle, R.L. and Galbreath, J.W. 1964. Quantitative determination of salt-soluble protein in various types of meat. Food Technol. 18:1943.

Samejima, K., Hashimoto, Y., Yasim T., and Fukazawa, T. 1969. Heat gelling properties of myosin, actin, actomyosin and myosin - subunites in a saline model system. J. Food Sci. 34:242.

Sato, K., Yashinaka, R., Sato, M. and Shizunori, I. 1986. A simplified method for determing collagen in fish muscle. Bull. Jap. Soc. Sci. Fish. 52(5):889-893.

Schmidt, G.R. and Trout, G.R. 1982. Chemistry of meat binding. In "Proceedings Inter. Symposium on Meat Science and Technology. Lincoln, Nebraska. Nov. 14. pp. 265-275.

Schnell, P.G., Vadehra, D.V., and Bakes, R.C. 1970. Mechanism of binding chunks of meat. I. Effect of physical and chemical treatments. 2. Can. Inst. Food Technol. 3(2):44. Alinment).

Schut, J. 1976. Meat emulsions. In "Food Emulsions". Ed. Friberg, S., Marcel Dekker, Inc., New York.

Scott, D.N., Porter, R.W., Kudo, G., Miller, R. and andf Koury, B. 1988. Effect of freezing and frozen storage of Alaska pollack on the chemical and gel-forming properties of surimi. J. Food Sci. 53(2):353.

Seidman, S.C., Smith, G.C., Carpenter, Z.L., Diu, C.W. 1979 Plasma protein isolate and textured soy protein in ground beef formulations. J. Food Sci. 44:1032-1034.

Siegel, D.G. and Schmidt, G.R. 1979. Crude myosin fractions as meat binders. J. Food Sci. 44:1129.

Selci, N., Matsubara, H., Yanagisawa, H., Arai, K. 1985. Changes in water holding capacity of carp myofibrillar during heat induced-denaturation. Bull. Jap. Soc. Sci. Fish. 51(5):793.

Sikorski, Z., Olley, J. and Kostuch, S. 1976. Protein changes in frozen fish. Crit. Rev. Food Sci. Nutri. 8(1):97.

Shimizu, Y. and Nishioka, F. 1974. Interactions between horse mackarel actomyosin and sarcoplasmic during heat coagulation. Bull. Jap. Soc. Sci. Fish. 40:231.

Shimiza, Y. Machida, R. and Takenami, S. 1981. Species variations in the gel forming characteristics of fish meat paste. Bull. Jap. Soc. Sci. Fish. 47:95.

Shimiza, Y., Nishioka, F., Machida, R. and Shine, C.M. 1983. Gelation characteristics of salt added myosin gel. Bull. Jap. Soc. Sci. Fish. 49:1239.

Shimiza, Y. and Fujika, T. 1985. Stability of unwashed and washed fish mince during frozen storage. Bull. Jap. Soc. Sci. Fish. 51:1187.

Smith, J.J. 1982. Functionality of ingredients in restructured meats. In "Proceedings Int. Symposium on Meat Science and Technology. Lincoln, Nebraska. Nov. 1-4, 1982.

Smith, D.M., Alvarex, V.B. and Morgan, R.G. 1988. A generalized model for predicting heat induced chicken myofibrillar protein gel strength. J. Food Sci. 53(2):359.

Solomon, L.W. and Schmidt, G.R. 1980. Effect of vacuum and mixing time on the extractability and functionality of pre and post-rigor beef. J. Food Sci. 45:283.

Suzuki, T. 1981. "Fish and Krill Protein Processing Technology". Applied Science Pub., Ltd., London.

Theno, D.M., Siegel, D.G. and Schmidt, G.R. 1978a. Meat messaging effect of salt and phosphate on the microstructural composition of the muscle exudate. J. Food Sci. 43:483.

Theno, D.M., Siegel, D.G. and Schmidt, G.R. 1978b. Meat messaging: Effect of salt and phosphate on the microstructure of binding functions in sectioned and formed hams. J. Food Sci. 43:493.

Turner, R.H., Jones, P.N., and MacFarlane, J.J. 1979. binding of meat pieces. An investigation of the use of myosin-containing extracts from pre- and post-rigor bovine muscle as meat binding agents. J. Food Sci. 44:1443.

Vadehra, D.V. and Baker, R.C. 1970. The mechanism of heat-initiated binding of poultry meat. Food Technol. 24:766.

Wright, D.J., Leach, I.B. and Wilding, P. 1977. Differential scanning calorimetry studies of muscle and its constituent proteins. J. Sci. Food Agri. 28:557.

Wu, M.C., Lanier, T.C., Hamann, D.D. 1985. Rigidity and viscocity changes of croaker actomyosin during thermal gelation. J. Food Sci. 50:14.

Yasin, T., Ishivooshi, M. and Samejima, K. 1980. Heat-induced gelatin of myosin in the presence of actin. J. Food Biochem. 4:61-78.

Yoou, K.s. 1986. Assessment of the cryoprotectability of liquid sorbitol. Master Thesis. U.R.I.

Ziegler, G.R. and Acton, J.C. 1984. head-induced transitions in the protein-protein interaction of bovine natural actomyosin. J. Food Biochem. 8:25.