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THE FUNCTIONAL PROPERTIES OF THE MECHANICALLY DEBONED SUCKER (CATOSTOMIDAE FAMILY) FLESH

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Jorge Fuentes Zapata

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THE FUNCTIONAL PROPERTIES OF THE MECHANICALLY DEBONED SUCKER (CATOSTOMIDAE FAMILY) FLESH

By

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ABSTRACT

THE FUNCTIONAL PROPERTIES OF THE MECHANICALLY DEBONED SUCKER (CATOSTOMIDAE FAMILY) FLESH

By

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Sucker fish, an underutilized freshwater species from the Great Lakes area, were mechanically deboned and the cooked minced flesh evaluated for water holding capacity (WHC) and texture by using various techniques. The effect of the handling of the fish prior to freezer storage as well as the freezing conditions throughout a 13 months period were related to the functional properties of the fish.

The centrifuge technique for WHC and the Instron universal testing instrument for texture were found to be the most reliable methods to evaluate the cooked fish matrix.

Severe water losses during cooking resulted in fairly poor texture characteristics for the flesh. However, WHC was improved by the addition of 2% salt or 2% soy protein isolate to the control binder system used in this study.

The best storage procedure for suckers intended for further processing into fabricated fish products seemed to be dressing, washing and storage in blast freezer at -29° C.

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TABLE OF CONTENTS

LIST OF TABLES

Table | Page

LIST OF FIGURES

INTRODUCTION

In the recent few years a significant decrease in the availability of many commercially exploited fish species was noted in several traditional Atlantic fishing grounds. In order to supply the increasing market demands for fish and shellfish attempts are made to utilize several abundant, less valuable species, previously not fished on an industrial scale.

Fish that are underutilized, whether they be of marine or freshwater origin, usually have certain defects in quality which preclude their gaining consumer acceptance when marketed in the conventional forms, such as dressed fish, fillets, breaded sticks, or portions. The defects may be related to the different morphological characteristics of these fish and/or their less appealing sensory properties. The fish may have poor icing and cold storage characteristics, which make marketing difficult. They may be too bony, or their small size or odd shape may make processing technically or economically infeasible.

The advent of deboned (minced) fish flesh and related fishery products on the North American scene in recent years has attracted a considerable amount of attention on the part of many major processors, within government circles and in research-oriented laboratories (Martin, 1972, 1974).

Nevertheless, in spite of the fact that deboned fish technology appeared to offer great processing possibilities and to provide a variety of marketing options which were not readily available for unconventional fish species, many problems have hindered the realization of its full utilization (Nakayama and Yamamoto, 1977). Before underutilized fish can be evaluated for potential use in processed food products, certain basic information on each species is needed to help determine whether the fishery resource is acceptable as human food and can justify the processing equipments and facilities (Miyauchi, 1975). The suckers (Catostomidae family), from the Great Lakes area, have been selected as the target freshwater underutilized species for this study since although it probably has the greatest production potential it is one of the most difficult to market when processed by conventional methods.

It was the purpose of this study to evaluate some of the variables affecting the functional properties of the sucker flesh obtained by mechanical deboning. An attempt was made to assess techniques or methods for measuring texture and water-holding capacity as indicators of the functional behavior of the minced fish flesh. Finally, the influence of the handling of the fish and the freezing storage conditions on the functional parameters of the mechanically deboned sucker flesh was also studied.

LITERATURE REVIEW

Underutilized Freshwater Fish and Mechanical Deboners

In the early 1970's only whitefish and chubs remained as species worth fishing for the Michigan commercial fishery. Economic impact analysis revealed that the commercial fishery had a dollar multiplier of about four making the 1973 catch worth about 16 million dollars to the state of Michigan (Kevern, 1975). For these reasons it was decided to evaluate the potential of the fisheries of underutilized species in the Great Lakes area and an invited symposium on Underutilized Freshwater Fish Species was held at Michigan State University on June 25-26, 1975. Underutilized species that may have potential for commercial development in the upper Great Lakes are the suckers, burbot, rainbow smelt, and alewife (Magnuson, 1975).

The suckers are bottom dwelling freshwater fish. The white sucker (Catostomus commersoni) is the most common sucker found in Michigan. However, the longnose sucker (C. catostomus) can also be found in the Grand Traverse Bay watershed. Suckers are bottom feeders, the characteristic sucking mouth being adapted for picking up and extracting food items from bottom sediments. Suckers provide a sport fishery in some areas during the spring spawning runs.

These fish are excellent eating after a visit to the smokehouse, but because of the many bones in the flesh they are not a popular food fish. Suckers have also been taken commercially in the past, referred to by commercial fishermen as mullet (Price and Kelly, 1976).

Mechanized methods of separating the flesh of fish from skin and bones have been in use for more than 20 years. The Japanese have made extensive use of this technology, especially in the field of fish utilization (Miyauchi et al., 1973, and Okada et al., 1973) but only in recent years has the potential of mechanical flesh separation been recognized by the North American food industry (Miyauchi and Steinberg, 1970). This technique permits greater recoveries of edible flesh than obtained by conventional filleting methods.

At the present time, there are two basic types of machines used to separate raw fish flesh from skin and bones. In one type of machine, the raw material is squeezed between a belt and a perforated metal drum moving at the same or different speeds, and this results in the softer parts such as the flesh being extruded through the holes of the drum, while the harder or tougher parts, like bones and skin, are passed on to discard. In the other type, called a strainer, the material is forced by a worm-feed into a perforated drum, so that the flesh is forced through the holes and unwanted material is discharged through an opening at the end of the drum. The separation of flesh is not perfect in either

machine, and some small pieces of bone and skin will be found in the product, the size and amount depending of the size of the holes in the drum, as well as other operating conditions and on the nature of the raw material. Large bone particles and scales left in the product constitute major quality defects influencing the consumer acceptability of cooked products made from the minced flesh (Dingle et al., 1974).

In species of low muscle lipids, the dark flesh located just under the skin is considerable higher in lipids than the white flesh that forms the bulk of the muscle. It is frequently desirable to collect white flesh separately. The location of the dark flesh permits some control by regulating the belt pressure exerted against the drum. A single pass at low pressure results in a product with virtually all light meat. A second pass of the resultant waste at maximum pressure recovers the balance of the light meat plus a high percentage of the dark meat that was attached to the skin (Patashnik et al., 1973).

Potential source material for deboning may be obtained from 1) racks from a filleting operation, 2) fish which are considered too difficult to fillet efficiently and 3) fish which are diffuclut to market in conventional forms due to their low consumer appeal (Iredale et al., 1974). There are two basic potential uses for deboned fish flesh. The first is the direct substitution of deboned fish blocks for frozen fish fillet blocks to be made into breaded or battered fish

sticks or portions (King, 1973; Teeny and Miyauchi, 1972; Miyauchi et al., 1975). This could be an outlet for the flesh recovered from the racks of well accepted species such as cod and haddock. The second use is in formulated products such as gifelte fish, fish sausages and frankfurters and various types of fish portions where the basic characteristics of the fish have been modified by the addition of other components. This second use is particularly applicable to those species which have low consumer appeal when processed by conventional methods (Iredale et al., 1974).

The Importance of the Structural Proteins of Fish Muscle on the Acceptability of Minced Flesh Products

Based on the differences in their physico-chemical properties fish proteins are broadly categorized as sarcoplasmic and myofibrillar proteins. The sarcoplasmic proteins, forming approximately 15-20% of the total proteins, depending on the fish species, are generally soluble in water or buffers of low ionic strength. The myofibrillar proteins consisting 60-80% of the total proteins are soluble in salt solutions of high ionic strength. These "structural" or "textural" proteins are particularly important as their denaturation, caused by a variety of factors, induces drastic changes in the quality attributes of the product (Warrier et al., 1975).

The drip is defined as the exudate of tissue fluids that

flow free from fish muscle during holding and storage or during thawing of frozen fish or muscle. Drip leaches along with it soluble proteins, vitamins, minerals, and confers an undesirable appearance on thawed fish. Drip has been regarded as occurring as a result of cell damage caused by freezing. The appearance of DNA in the expressible fluid is an indicator of rupture of cell membrane. However, it has been reported by Seagran, (1958) that cell damage alone cannot account for the release of drip, but it is also related to the capacity of muscle proteins to imbibe free liquid.

It is well recongized that the textural qualities associated with muscle such as fibrousness, plasticity, and gel-forming ability are controlled by myofibrillar proteins. Fish muscle contains large proportions of actomyosin, a protein composed of actin and myosin. Investigations carried out by Ueda et al., (1968) on the behavior of the purified actomyosin revealed that there were no species differences in intrinsic viscosity value, electrophoretic mobility, salting-in and salting-out range, etc., while there existed a difference in the temperature of denaturation from species to species. Myosin, actin, and tropomyosin are the other components of the myofibrillar proteins present in fish muscle.

Water molecules combine with polar groups of the contractile proteins. Fish muscle has a minimum ability to combine water molecules around pH 5. On either side of the isoelectric point, the muscle exhibits higher ability to

hold water. Post-mortem changes such as Ca^{++} liberation, influence the amount of bound water. The presence of sodium chloride increases the water holding capacity principally by the effect of Cl^- ions which bring about greater repulsion between the peptide chains (Warrier et al., 1975).

Several salts of weak acids such as sodium pyrophosphate and sodium tripolyphosphate have been recognized by many workers in increasing the water holding capacity of flesh foods. The influence of these phosphates has been related to their effect in promoting the extraction of protein from the fibrils, principally in the presence of high salt concentration and divalent cations. The concept of muscle hydration has now been extensively applied to improve the quality of frozen fish in terms of reduced drip and cooking loss and textural improvement.

The most important biochemical change associated with proteins is denaturation. This structural modification may bring about definite changes in chemical, physical or biological properties of the protein (Warrier et al., 1975). Denaturation mechanism is considered to be a two-step process involving the opening of the peptide followed by the splitting or combination of the molecules. The amount of extractable protein is often taken as a criterion of denaturation. During frozen storage the extractability of the myofibrillar group of proteins is unaffected (Childs, 1973). It is presumed that the proteins of fish can also be damaged as a

consequence of continued exposure to concentrated solutes in the frozen-stored muscle of fish with added salt. The interaction of protein with fatty acids, as well as the tendency of myosin to aggregate have also been reported as situations leading to protein insolubilization (Warrier et al., 1975).

The Effects of Freezing Storage on the Keeping Quality of Fish Flesh

A particular problem associated with unconventional fish species is the relatively poor keeping quality during frozen storage of deboned fish flesh obtained from certain species. This is largely due to the characteristic physical disintegration of the flesh resulting from the deboning process (Miyauchi et al., 1975; Patashnik et al., 1976; and Babbitt et al., 1976). The more drastic changes observed are in the flavor and color of the minced fish flesh as a consequence of lipid oxidation during frozen storage. Washing has been advocated as a means for removing soluble constituents believed to be responsible for such deterioration. The theory proposed to justify this practice is that the hemoproteins, myoglobin and hemoglobin, liberated from either muscle or bone marrow upon deboning catalyze oxidative rancidity, as reported by Lee and Toledo (1977). The same authors demonstrated that iron coming from nonstainless steel parts of the deboning machine accelerated lipid oxidation of the minced fish flesh.

A test based in the reaction of 2-thiobarbituric acid (TBA) with the oxidation products of unsaturated fatty acids to give a red pigment, has been used to determine the oxidative rancidity in minced fish flesh (Sinnhuber and Yu, 1958).

The deterioration of mechanically deboned fish flesh during frozen storage is also manifested by protein denaturation. In sausage formulations such stale raw material induces an undesirable grainy texture of the final product (Grabowska and Sikorski, 1973). This deterioration has been associated with the production of formaldehyde and dimethylamine from the trimethylamine oxide present, mainly in the muscle of marine fishes (Dingle et al., 1977; Hiltz et al., 1976).

Under proper conditions of frozen storage bacterial action is prevented so there is no production of trimethylamine (Mills, 1975). The presence of slime is detrimental to the quality of dead fish because of its ability to support vigorous growth of bacteria. Therefore removal of slime by washing has been strongly suggested to increase storage life of fish (Gillespie and Ostovar, 1971). The technique of washing minced fish muscle followed by incorporation of salt, sodium polyphosphates and sugar has been successfully used in the preparation of "surimi", a japanese fish paste product, to save fish muscle protein from denaturation during cold storage (Iwata and Okada, 1971).

Water Holding Capacity and Texture as Indicators of the Gel-Forming Ability of the Minced Fish Flesh

During the mechanical separation of fish flesh the disruption of tissue integrity allows access of oxygen, the spreading of bacteria and contacts of intracellular and extracellular components. The overall effect is the promotion of a variety of biochemical, physical and chemical reactions at rates greater than occur in fillets or in whole fish (Bremner, 1977). As a result the minced muscle tends to release water and form drip when heated or when frozen and thawed. The degree of drip formation varies with processing procedures and fish species.

The water imbibing power of fish flesh is called either water holding capacity or water binding capacity. These terms are typically used to mean the strength by which water is held in food systems but really are the water content under some given condition. Methods used to measure water-holding capacity (Wierbicki et al., 1957; Wierbicki and Deatherage, 1958; Dagbjartsson and Solberg, 1972; Karmas and Turk, 1975; and Bremner, 1977), are quite arbitrary, and they do not give any physical chemical property to express the immobilized portion of the water. Consequently, water holding capacity should be defined in terms of a particular method of measurement, so that the results obtained in different laboratories may be comparable (Labuza and Lewicki, 1978).

A reason why the leftover parts of fish carcasses, after the fillets have been removed, are underutilized as a source of fish flesh is the poor water binding quality of such minced flesh. Consumer qualities of minced fish products, such as appearance, flavor, as well as drip and skrinkage on cooking depend greatly on the degree of water binding. Therefore, when the water binding of these products is improved, its consumer acceptance is generally increased (Karmas and Turk, 1976).

The moisture content along with the particle size of the mince have a marked influence on the texture of the final cooked fish product. Other important factors determining the texture of cooked minced fish flesh products are the presence of salt and phosphates, the chopping time in emulsion type fish products, and the cooking temperature and rate (Lee and Toledo, 1976). The use of vegetable and milk proteins such as soy protein isolate and sodium caseinate respectively has been suggested to increase the texture characteristics of fish products beyond the intrinsical ability of the natural proteins present in fish muscle (Karmas and Turk, 1976). Textured soy flour has also been successfully used in fish preparations (Daley and Deng, 1978; Daley et al., 1978).

It is obvious that the perception of texture is not solely dependent on the properties of the foodstuff but is strongly influenced by the characteristics of the person

examining or consuming the food. In this respect texture is similar to other physical characteristics such as color and flavor. This dual character of food texture has given rise to attempts to construct a texture classification system based on the impression created on the human sensory system, the texture profile (DeMan, 1975).

Several types of instruments have been used to evaluate the texture of minced fish flesh products in terms of one or more components of the texture profile system. The Instron Universal Testing Machine has been suggested to evaluate texture profile parameters like shear force, hardness, fracturability, springiness. cohesiviness, gumminess and chewiness from the force-deformation curve obtained by the instrument (Peleg, 1976; Soo and Sander, 1977a; Lee and Toledo, 1976; Webb et al., 1976; and Cross et al., 1978). The Kramer Shear Press has been a widely used instrument for food texture measurements. The major use of the shear press is with the universal test cell. It consists of a slotted box through which a set of 10 metal blades is forced down by a hydraulic ram. The action in the cell involves compression, shear and extrusion. With the recording device two types of results can be obtained; maximum force which is indicated by the height of the peak and work which is indicated by the area under the curve (DeMan, 1975). The Universal Penetrometer has been used to measure the consistency (softness) of comminuted fish-matrix agent mixtures

(Soo and Sander, 1977b). The Shear Jaw Press designed by Dassow et al. (1962), has been successfully used for the determination of shear values on fresh and frozen seafood.

There seems to exist a general consensus, among people working in the area of fish processing, that texture characteristics of comminuted fish flesh are important factors affecting acceptability by consumers.

EXPERIMENTAL

Classification of the Experimental Work Into Two Study Sections

In the first section, s study of the variables modifying texture and water-holding capacity of the mechanically deboned sucker flesh, along with the methods used to measure these functional properties, was undertaken.

An examination of the conditions of handling and freezer storage, and their influence on the functional properties of the fish flesh, constituted the work of the second section.

Section One: The Study of the Mechanical Deboning Operations, the Binders, and the Cooking Systems as Related to Texture and Water-holding Capacity Measurements

About 600 lb. of fresh sucker from Lake Huron were purchased at AuGres, Michigan and transported on ice to the Meat Laboratory at Michigan State University. The load was composed of some fish caught 24 hours and some caught 72 hours prior to the time of processing. Species composition consisted of about 50% each: Silver Redhorse sucker, Moxostoma anisurum (Rafinesque), and White sucker, Catostomus commersoni (Lacépède), (Eddy, 1974).

Fish were dressed and passed through a mechanical deboner. The collected minced sucker flesh was then passed one more time through the meat separator to compare the efficiency of the process of separation as well as the chemical, physical and microbiological characteristics of the flesh. Samples of minced flesh were collected after the first and second passes and analyzed for moisture, fat, protein, bone residue, TBA number and microbiological load.

The sucker flesh was then packaged into Cryovac (poly vinylidene chloride) bags and stored in a -29° C blast freezer. The frozen flesh was thawed as needed, with thawing drip determined at this stage. All further operations up until the cooking step were carried out in a cooler room at 2° C. At this point the fish flesh was blended with different binders and cooked by two different ways: water bath cooking and smokehouse cooking, the latter after stuffing and linking the fish paste into frankfurter type casings.

The water-holding capacity was estimated on the smokehouse-cooked fish paste by either the smokehouse shrinkage, filter paper press method or centrifuge technique, and on the water bath-cooked fish paste by either the blotting paper technique, the filter paper press method or the centrifuge technique (see pgs. 28&29). Texture of the smokehouse cooked product was estimated by the shear force obtained from the Kramer Shear Press and from the Instron universal testing instrument, as well as by the softness

measured by using the Universal Penetrometer.

Section Two: The Effect of the Handling and Freezer Storage Conditions on the Functional Properties of the Sucker Flesh

Approximately 350 lb. of fresh sucker from Lake Huron were purchased at Bay Port, Michigan and transported on ice to the Meat Laboratory at Michigan State University. Fish had been caught about 24 hours prior to laboratory processing. Species composition was about the same as that of fish used in the first section.

Fish was handled and frozen according to five treatment groups as follows: A. - Whole fish, fast freezing; B. - Whole fish, slow freezing; C. - Dressed fish, no washing, fast freezing; D. - Dressed fish, washed, fast freezing; E. - Dressed and washed fish, mechanically deboned, fast freezing.

A year earlier a similar study had been conducted wherein one treatment involved exposure for 3 minutes of dressed fish to a severe washing and scrubbing action by placing them in a commercial sand paper-scrubbing type potato peeler (RE-NU open tank, model SAA, Vacuum Filter Mfg. Co., Chicago, Ill.) through which cold water was continuously spraying. Fish treated by this severe washing-scrubbing action were exposed to both fast and slow freezing systems as described in the following.

Fish material was vacuum-packed and freezer stored for 13 months. Fast freezing conditions were accomplished in a -29°C blast freezer. Slow freezing was carried out in a -18° C dead air freezer with an approximate freezing time of 24 hours, at least 16 hours of which occurred in the zone of maximum ice crystal formation.

After this period of storage all fish material was thawed at 2°C. Treatment groups A, B, C and D were either dressed and mechanically deboned or mechanically deboned only. The minced fish flesh from these four treatment groups, along with that of treatment group E, was evaluated for functional behavior according to the following sequence: fish flesh from each treatment group was blended with regular binder into an emulsion type fish paste by chopping and also with regular binder plus 2% salt into a fish paste blended by revolved mixing. The modified flesh was then cooked by water bath and, after being stuffed and linked into frankfurter type casings, in a smokehouse. Water-holding capacity was determined by the centrifuge method on both the smokehouse cooked and the water bath cooked fish flesh. Texture was determined by measuring the shear force on the smokehouse cooked product using the Instron universal testing instrument.

Handling of Fish at Laboratory and Processing Operations

Dressing and Mechanical Deboning

Fish was dressed by separating the head and removing all viscera (along with the kidney tissue) manually. Fish were then washed in cold water and split lengthwise. The mechanical deboning operation was carried out using a Bibun meat separator (Type SDX 13, Bibun Co. Fukuyama Hiroshima, Japan) equipped with a 5mm hole size drum. The machine was fed the split fish with the muscle side facing the drum to facilitate the process of flesh separation. Yields of both the dressing and mechanical deboning operations were calculated from the weight of the fish material before and after each operation.

Packaging of Fish Material for Freezing Storage

The minced fish flesh obtained for the study of section one was packaged into polyvinylidene chloride bags (Cryovac, Dewey and Almy Chemical Co., Cambridge, Mass.). Each bag contained about 25 lbs. of flesh. Whole fish, dressed fish and mechanically deboned fish intended for the study in section two were vacuum packaged into Cryovac bags using a vacuum sealer (Cryovac model FVC-E, Dewey and Almy Chemical Co., Cambridge, Mass.). Each bag contained about 15 lbs. of fish material.

Binders and Blending Operations

The minced fish flesh was modified by using binder mixtures and mechanical agitation as described in Table 3. Regular binder (RB) was established, for the purposes of this study, as a mixture of ingredients used along with the minced fish flesh in the following concentrations:

Salt	1.0 %
Sugar	1.0 %
Corn Oil	1.0 %
Fish Muscle	2.5 %
Ice	5.0 %
Monosodium Glutamate	0.3 %
Sodium Tripolyphosphate	0.15 %
Sodium Ascorbate	0.04 %

Preparation of the regular binder mix was carried out in a 2000 ml bowl capacity Mixmaster (Model 12C, Sunbeam Appliances Mfg., Chicago, Ill.). All ingredients except the corn oil were homogenized for 15 seconds. After the addition of oil the slurry was stirred at maximum speed for 3 minutes.

The proteinaceous substances used as binders in this study were soy protein isolate (Cenpro-P, Central Soya, Chicago, Ill.) and sodium caseinate (Milk Proteins Inc., Detroit, Mich.).

The blending of fish flesh with binders was achieved in either a silent cutter (Model 84181D, Hobart Mfg. Co., Troy, Ohio) for 1, 2 or 4 minutes or in a Kitchen Aid Food Preparer (Model N-50, Hobart Mfg. Co., Troy, Ohio) with a paddle attachment for 15 minutes.

Cooking of the Fish Paste

Fish flesh was cooked in two different ways:

i. - Water bath cooking. Twentyfive grams of fish paste were weighed into open 50 ml plastic centrifuge tubes and cooked in a 70°C water bath for 30 minutes.

ii. - Smokehouse cooking. Fish paste was stuffed into size 22 cellulose casings NoJax (Union Carbide, Films and Packaging Div., Chicago, Ill.) and linked as frankfurter type sausages. The product was then cooked in an Elek-Trol laboratory smokehouse (Drying Systems Inc., Chicago, Ill.) according to the following schedule:

Time (min.)	Temperature (°C)	Relative Humidity (%)
10	54.5	25
20	60.0	35
20	65.5	40
20	71.1	65
15	79.4	65

The cooking process was concluded with a 6 minute cold water shower.

Techniques and Methods of Analysis

Chemical Methods

Moisture Content

The A.O.A.C. (1965, 23.003) procedure for determining moisture was used.

Five grams of fish flesh were accurately weighed into a previously dried and tared aluminum dish (100°C for at

least 1 hour). Sample plus dish were then dried overnight for 18-24 hours in an air convection oven at 100°C. Dry sample was cooled in a dessicator and weighed to four decimal places. Loss in weight was reported as moisture for each hundred grams of meat. Three replicates were run for each sample.

Fat Content

The fat content was determined using the Goldfisch extraction method of the A.O.A.C. (1965, 23.005).

Sample used was the same as for moisture analysis, taken directly from the dessicator. The aluminum dish containing the dried 5 grams sample was carefully folded into a porous thimble and clipped into the Goldfisch apparatus. Fat was extracted with an anhydrous ether for 4-5 hours into a previously dried and tared beaker. The extract was then dried for 30 minutes at 100°C in an air convection oven, cooled in a dessicator and weighed. The percent fat was calculated as grams of fat extracted from each one hundred grams of fish flesh. Three replicates per sample were run.

Protein Content

Protein was determined following the micro Kjeldahl nitrogen determination method (A.O.A.C. 1965, 23.009).

Approximately 0.5g of fish flesh were accurately weighed into a micro Kjeldahl digestion flask followed by

addition of 1 ml $CuSO_4$ 10%, 1 g anhydrous Na_2SO_4, 7 ml H_2SO_4 and several glass beads. This mixture was heated on a rotary Kjeldahl digestion unit under a hood until the boiling mixture turned clear green. The digestion was allowed to continue for 30 minutes. The flask was then cooled, 15 ml deionized water were added and the flask cooled again. Ten ml 2% boric acid and 3 drops Bromcresol green indicator solution were placed into a 125 ml erlenmeyer flask. This was secured under the distillation outlet and raised enough to permit the tip to lie below the surface in the flask. Then enough NaOh 44% solution was added to make the solution strongly alkaline. Steam was allowed to enter the system and the sample was distilled for 7 minutes. After this time the erlenmeyer flask was lowered so the tip was out of the liquid and distillation was run for 3 minutes more. The amonnia boric acid solution was titrated to the Bromcresol green end point with standard H_2SO_4. The percent protein was calculated using the following formula:

$$\% \text{ Protein} = \frac{(\text{ml of } H_2SO_4) \times (\text{Normality of } H_2SO_4) \times (14)(6.25)(100)}{\text{Weight of sample in mg.}}$$

Three replicates were run of each sample.

2 - Thiobarbituric Acid (TBA) Test

The TBA values were determined using the method of Tarladgis *et al.*, (1960).

Four 10 g portions of the minced meat or fish muscle

were homogenized with 50 ml of distilled water at medium speed for one minute in a Virtis homogenizer (Model 6-105-AF, Virtis Co., Gardiner, New York). The homogenized mixture was transferred into a 500 ml distilling flask with the aid of 47.5 ml of distilled water. The pH was lowered to 1.5 using 2.5 ml of 4NHCL. Several drops of Dow Corning Anti-foam A (Dow Corning Corp., Midland, Michigan) and a few glass beads were added to the mixture. The flask was connected to a distilling unit consisting of a 30.5 cm long distilling column connected to the condensor with an elbow joint; a 50 ml graduate cylinder acted as a receiver. After boiling began, the first 50 ml of distillate were collected.

Two 5 ml portions of the distillate were pipetted and transferred to screw top test tubes. Then 5 ml of 0.02 M thiobarbituric acid (Eastman Organic Chemical, Rochester, New York) in 90% redistilled glacial acetic acid were added and the tubes were capped, mixed, and heated in a boiling water bath for 35 minutes. After cooling in cold water for ten minutes the absorbance was determined at 538 nm against a reagent blank in which 5 ml of distilled water were used in place of the distillate. The TBA number was calculated by multiplying the mean absorbance by 7.8, a distillation constant (Tarladgis et al., 1960). The TBA value was reported as mg TBA reactive substance per 1000 grams of fish flesh.

Bone Fragments Content

Bone residue was determined following the method described by Wong and Yamamoto, (1974).

A 100 mg sample of minced fish flesh was added to a 4000 ml erlenmeyer flask containing 2000 ml of 3 M urea and 0.02 M NaOH solution. The suspension was stirred gently overnight at room temperature (28° C) on a Multi-Magnestir (Lab-Line Instruments Inc. Melrose Park, Il.). The suspension was then filtered through a 425 microns sieve (Sargent Welch, No. 40). The retained residue of bone fragments, cartilage and scales was transferred to a dried and tared 100 ml beaker and restirred for 4 hours in 50 ml of 3 M urea and 0.02 M NaOH solution in order to further solubilize small pieces of flesh that still remained with the bone and scale fragments. At the end of this time, fragments were allowed to settle for about half an hour and the urea-NaOH solution again poured off through the sieve. The nearly clean, protein-free residue left in the bottom of the beaker was then washed three or four times with distilled water. The beaker containing the residue was then dried to constant weight in a 105° C oven for 7 hours, cooled in dessicator and reweighed. A separate weight of the scale fraction alone was also recorded.

The percentage of bone fragments was calculated using the following formula:

$$\% \text{ Bones} = \frac{(\text{Dryweight of bones}) \times (100)}{\text{Sample weight}}$$

Six replicates were run on each sample.

Microbiological Method

The bacterial load of the fish material was measured on the surface of the fish and on the minced fish flesh according to methods described by Frazier et al., (1968).

Surface bacterial load was determined by swabbing two fish in each treatment group. Sterile calcium alginate swabs in tubes (Calgitube®) were run over a small area (approximately 4 square cm) midway down on lateral side of each fish. These were held overnight at 34° F in capped tubes containing 10 ml of a 1% $^{w}/v$ sodium citrate solution. A dilution range of 10^{-1} to 10^{-5} was prepared and then samples were plated out on Plate Count Agar. Four replicate plates per dilution and per treatment group were incubated at room temperature (29° C) and counted after 72 hours. Results were expressed as number of bacteria per cm^2 of fish surface.

The bacterial load of the mechanically deboned fish flesh was assessed as follows: Duplicate 11 g samples of the minced fish flesh were weighed into bottles containing 99 ml of sterile water and several glass beads. A dilution range of 10^{-1} to 10^{-5} was prepared and the samples were plated, incubated and counted as described for the surface bacterial

load determination, above. Results were expressed as number of bacteria per gram of minced fish flesh.

Physical Methods

Measurements Related to Water-holding Capacity

Thawing Drip

The thawing drip was determined at room temperature by weighing a 50 g sample of partially frozen fish flesh into a 8.5 cm diameter glass funnel containing a glass wool bed. The liquid was collected into a 10 ml graduated cylinder, and volume measurements were made hourly over a period of 3 - 4 hours. Results were expressed as water losses %.

Smokehouse Shrinkage

The smokehouse shrinkage was calculated by the difference in weight of the fish paste product before and after the smokehouse cooking operation. The results were expressed as water losses %.

Water Losses During Water Bath Cooking

Water losses during water bath cooking of the fish paste were calculated as follows: A 25 g sample of fish paste was cooked in a waterbath as described in Cooking of the Fish Paste, i, above. Following this the centrifuge tubes containing the cooked fish flesh were reversed until

all fluids were completely drained from them (about 15 minutes). Next, the meat pellets were removed from the tubes, blotted on paper toweling and weighed. The weight difference with the original sample of raw fish paste was reported as water losses %.

Expressible Fluids by the Filter Paper Press Method

The water-holding capacity of the cooked fish flesh was determined according to the gravimetric adaptation introduced by Karmas and Turk, (1975) of the original Filter Paper Press method described by Wierbicki and Deatherage, (1958).

A 300 mg sample of cooked fish flesh was weighed onto a 3/4 inch diameter aluminum foil disc. This was placed on the center of a tared piece of filter paper, 7 cm in diameter (Whatman No. 54), stabilized at the laboratory room temperature (29° C) and relative humidity (about 60%) conditions. The sample-liner-filter paper system was then pressed between two plexiglass plates for 1 minute at 500 psi, using a hand operated Carver laboratory press (Fred S. Carver Inc., Hydraulic Equipment, Summit, New Jersey). Then the liner and the meat residue were removed from the filter paper containing the expressible fluids and this was immediately weighed. The weight difference with the original filter paper was reported as water losses %. This determination was run on four repetitions per sample of both the

smokehouse-cooked and the water-bath-cooked fish paste.

Expressible Fluids by the Centrifuge Technique

The water-holding capacity of the cooked fish flesh was also determined using the centrifuge technique reported by Bremner, (1977).

Ten g of cooked fish flesh were weighed into 15 ml Corex® No. 8441 glass centrifuge tubes and centrifugated at 18,000 rpm (39.100 xg) for 1 hour in an automatic refrigerated centrifuge (Sorvall Type RC2B, Rotor S-34, Ivan Sorvall Inc., Norwalk, Conn.). Then the supernatant was drained and tubes were reversed for about 15 minutes on toweling paper to completely drain the remaining fluid. The tubes plus the cooked fish flesh pellets were then weighed. The weight difference of the meat pellet and the original raw paste was expressed as water losses % due to cooking. This technique was applied to both the smokehouse-cooked and the water-bath-cooked products. Three replicates per treatment were run.

Measurements Related to Texture

Shear Force by the Kramer Shear Press

This determination was performed on the smokehouse-cooked fish paste by using a texture test system (TP-2 Texturepress associated with a TR-1 Texturecorder, Food Technology Corp., Reston, VA) equipped with a shear

compression cell. The fish samples were cut into 8 cm long cylinders, weighed and placed within the test cell. Then they were subjected to shear, compression and extrusion. The resistance force was measured by the deformation of a high strength alloy ring and recorded by the texture recorder. The results were expressed as lb-f per gram of cooked fish paste. Five repetitions per sample were recorded.

Shear Force by the Instron, Universal Testing Instrument

This determination was performed on the smokehouse cooked fish paste by using an Instron universal testing machine (Model TTBB, Instron Corp., Canton, Mass.) equipped with a Compression Load Cell, range 1 to 50 kg. A meat shear cell was adapted to the upper moving fixture. The instrument was calibrated with a 1 kg weight for full scale displacement of the recorder pointer. The speed of the drive and the speed of the chart were adjusted both at 20 cm/min. Fish flesh frankfurters were cut into about 10 cm long cylinders and sheared across the section. The resistance force was expressed in kg-f per cm sectional diameter of the fish cores. At least 10 replicate measurements were recorded for each treatment group.

Softness by the Penetrometer

This determination was also performed on the smokehouse-cooked fish flesh by using the Universal Penetrometer

(Micrometer Adjustment Penetrometer, Arthur H. Thomas Co., Philadelphia), equipped with a 35 g penetration cone. Samples of fish frankfurters (1.8 cm average sectional diameter) were cut into 2.6 cm long cylinders and placed vertically (section of the meat cylinder facing the penetration cone) just under the penetration device. This was then released for 10 seconds over the fish cores. The penetration, expressed in mm, was read on the instrument scale. The results were expressed in terms of mm penetration per cm sectional diameter of the fish core. At least 10 repetition measurements per treatment group were recorded.

Statistical Analysis

Statistical analysis were achieved in a TI-59 programmable electronic calculator (Texas Instruments Inc., Lubbock, Texas) equipped with a Solid State software statistics module (STAT-5859).

Correlation Coefficient

Correlation coefficients (r) were obtained by entering row data (average of the repetitions) through the Bivariate Data ST-04 program and then applying the special control operation for correlation coefficient.

Analysis of Variance (AOV)

The one-way AOV was carried out by entering raw data (individual observations) through the one-way AOV ST-06 program and then analyzing the data through the one-way AOV ST-15 program.

The two-way AOV was carried out by entering raw data (single individual observations) through the two-way AOV ST-06 program and then analyzing the data through the two-way ST-16 program.

The Tukey's procedure (Steel and Torrie, 1960) was used to compare the mean values of the treatments each time a significant F value was obtained through the AOV.

RESULTS AND DISCUSSION

Section One

Table 1 shows some of the physical, chemical and microbiological characteristics of the sucker flesh obtained from the mechanical deboner (first-pass flesh) and after passing this flesh through the machine another time (second-pass flesh). The yield of minced sucker flesh from the mechanical meat-bone separator was about 50%. Losses of meat and/or juices by a second pass operation seemed not to affect this yield in a drastic way. This yield figure is expressed as a percent of the initial round weight of fish, however mechanical deboning of dressed suckers yielded about 75% of their dressed weight as minced flesh. The 50% yield seems to be similar to that reported by Morris, (1977) for the same fish species caught through the summer season.

Bone and scale residue showed a slight but significant decrease in the second pass flesh. This was probably due to a considerable dimunution in the scale content rather than a lowering of bone content as shown in Table 1. The chemical technique for isolating bone fragments by Yamamoto and Wong, (1974) proved to be appropriate not only for the separation and determination of the residue (bone, scale, cartilage

TABLE No.1 - Some of the physical, chemical and microbiological characteristics of the sucker flesh obtained by mechanical deboning (mean values*).

Characteristics	First pass flesh	Second pass flesh
Minced flesh yield after mechanical deboning(%)	50.8	48.8
Bone and scale residue(%), N=6	$0.19^{a}\pm0.02$	$0.15^{b}\pm0.03$
Bone residue(%), N=6	$0.13^{a}\pm0.01$	$0.12^{a}\pm0.02$
Scale residue(%), N=6	$0.06^{a}\pm0.01$	$0.03^{b}\pm0.01$
Moisture(%), N=6	$81.23^{a}\pm0.15$	$81.15^{a}\pm0.43$
Fat(%), N=6	$1.42^{a}\pm0.12$	$1.59^{a}\pm0.42$
Protein(%), N=6	$15.98^{a}\pm0.44$	$15.80^{a}\pm0.85$
TBA number as mg TBA/Kg flesh, N=7	$0.3018^{a}\pm0.07$	$0.2709^{a}\pm0.03$
Bacterial load as log No. bacteria/g flesh, N=8	$4.71^{a}\pm0.13$	$4.57^{b}\pm0.09$

* Means in same row not followed by the same superscript are significantly different ($p<0.05$).

and skin fragments) but also for the separation of scales from bone fragments as it was performed in this study. The calcium content of the mechanically deboned sucker flesh has been found to be 0.15 and 0.08% for the first-pass flesh and second-pass flesh respectively (LeBlanc, 1978). These values are well below the proposed 0.75% maximum percent calcium content for mechanically deboned meats (Anonymous, 1976). On the other hand the small size of the bone fragments obtained in this study suggests that the drum hole size and the belt tension used on the mechanical separator permitted good separation of flesh and residue.

Moisture, fat, protein and TBA number (an indicator of the rancidity of the fish lipids) were not significantly different when comparing the first-pass flesh to the second-pass flesh.

The bacterial load on the minced sucker flesh was slightly lower in the second-pass flesh than in the first-pass flesh. However this difference seems not to be of industrial microbiological importance since the change in the number of bacteria was lower than one log unit.

The process of washing the fish after dressing did not affect the bacterial count on the surface of the fish, as can be observed in Table 2. This might be due in part to the poor method of washing used in this study which removed only loose slime from the surface of the fish and in part to the probable diffusion on the skin surface of microorganisms

TABLE No.2 - Mean and standard deviation of the bacterial load on the surface of the suckers, expressed as the log of the number of bacteria / cm^2 fish surface, N=2.

Round fish	Dressed fish (dry way)	Dressed fish (washing way)
4.88 ± 0.21	4.85 ± 0.11	4.99 ± 0.67

coming from the gut cavity. The ability of slime to support bacterial growth has been shown by Gillespie and Ostovar, (1971). These authors also reported a 20-fold lower count on the slime from commercial whitefish washed for 15 minutes under cold water jets compared to that on the unwashed fish. Similar reductions have been obtained in this laboratory by using a potato peeler device to scrub and wash dressed suckers (Price, 1978).

Table 4 shows the results of the water-holding capacity (WHC) studies of the cooked sucker flesh expressed as water losses percent, and measured by four different techniques. The smokehouse shrinkage, the draining and blotting on absorbent paper, the filter paper press method, and the centrifuge technique.

Fourteen different modifications of the minced sucker flesh were carried out in this study as described in Table 3. The sucker flesh with regular binder (RB), (treatment B-5) was considered as the control binder treatment since the washed sucker flesh with binder or without binder (treatments B-3 and B-2 respectively), and the sucker flesh without binder (treatment B-1) showed an extremely soft consistency with very poor textural characteristics. On the other hand 1 and 4 minutes of cutting-mixing (treatments B-4 and B-6 respectively) showed no improvement in the WHC of the sucker flesh when compared to the 2 minute cutting-mixing, the

TABLE No.3 - Modifications of the mechanical deboned sucker flesh by washing, use of binders or by the mechanical stress applied to the flesh during the process of blending with the binders.

Code Identification	Description of the treatment	Mechanical stress applied
B-1	Minced fish flesh (MFF)	2 minutes cutting (meat emulsion)
B-2	MFF and washing	2 minutes cutting (meat emulsion)
B-3	MFF, washing, plus regular binder (RB)	2 minutes cutting (meat emulsion)
B-4	MFF plus RB	1 minute cutting (meat emulsion)
B-5	MFF plus RB	2 minutes cutting (meat emulsion)
B-6	MFF plus RB	4 minutes cutting (meat emulsion)
B-7	MFF plus 2% soy protein isolate (SPI)	2 minutes cutting (meat emulsion)
B-8	MFF plus 2% sodium caseinate (SC)	2 minutes cutting (meat emulsion)
B-9	MFF plus RB plus 2% SPI	2 minutes cutting (meat emulsion)
B-10	MFF plus RB plus 2% SC	2 minutes cutting (meat emulsion)
B-11	MFF plus RB plus 2% salt	2 minutes cutting (meat emulsion)
B-12	MFF plus RB plus 2% salt	15 minutes revolving in paddle mixer
B-13	MFF plus RB plus 2% salt plus 2% SPI	2 minutes cutting (meat emulsion)
B-14	MFF plus RB plus 2% salt plus 2% SC	2 minutes cutting (meat emulsion)

TABLE No.4 - Mean and standard deviations of the water holding capacity of the cooked sucker flesh by four different techniques and expressed as water losses percent.

Method or procedure for the estimation of the WHC	Binder Treatments[2] B-5	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14
Smokehouse shrinkage, N=3	19.6±3.9	21.6±3.8	20.7±4.3	20.0±2.1	19.8±3.1	20.0[3]	20.1±1.6[4]	19.5[3]	18.5[3]
Draining and blotting on absorbent paper, N=4	$19.4^{ab}\pm2.2$	$25.2^{ab}\pm5.0$	$27.0^{b}\pm4.0$	$18.0^{b}\pm1.6$	$23.4^{ab}\pm2.8$	-	-	-	-
Filter paper press on the waterbath cooked flesh, N=4	$51.8^{cde}\pm2.2$	$53.1^{e}\pm2.0$	$52.1^{de}\pm1.6$	$47.5^{abcde}\pm0.5$	$46.5^{abcde}\pm1.9$	$50.7^{bcde}\pm2.5$	$48.5^{abcde}\pm2.8$	$48.8^{abcde}\pm4.8$	$43.1^{a}\pm3.1$
Filter paper press on the smokehouse cooked flesh, N=4	$43.1^{ab}\pm1.5$	-	-	-	-	$38.7^{a}\pm3.4$	$43.8^{b}\pm2.3$	$42.5^{ab}\pm0.9$	$42.5^{ab}\pm2.3$
Centrifuge technique on water bath cooked flesh, N=3	$38.4^{d}\pm0.5$	-	-	-	-	$37.3^{cd}\pm0.5$	$36.0^{bcd}\pm1.7$	$30.3^{a}\pm1.1$	$33.9^{ab}\pm1.0$
Centrifuge technique on smokehouse cooked flesh, N=3	$34.9^{bc}\pm1.3$	-	-	-	-	$33.1^{bc}\pm2.1$	$29.8^{ab}\pm1.2$	$27.3^{a}\pm1.0$	$28.3^{ab}\pm1.0$

[1]Means in same row not followed by the same superscript are significantly different ($p<0.01$), except for the filter paper press on the smoke house cooked flesh which are different at the 5% level of significance.

[2]Binder treatments as described in Table 1.

[3]Single observation.

[4]N=4.

standard procedure used in this study. Thus, nine different binder treatments are compared for WHC and texture characteristics in Tables 4 and 5 respectively. Void spaces in Table 4 are due to the fact that some binders and WHC techniques were tested at the beginning of this experiment and then discarded or replaced by some more advantageous ones. By using any of the reported four techniques the higher the value of water losses percent the poorer was the WHC.

The measurement of the smokehouse shrinkage seemed not to be a good indicator of the WHC of the sucker flesh since no statistical differences were found in this study due to the presence of the various binders used (Table 4).

The WHC determined by the techniques of draining and blotting the fluids from the water-bath-cooked flesh on absorbent paper was found to be subjective and tedious. However, from the results in Table 4 it can be noted that RB imparted to the flesh better WHC than either of the proteinaceous binders, soy protein isolate (SPI) and sodium caseinate (SC) used alone. The 2% SPI produced a greater increase in the WHC of the fish flesh than 2% SC. This effect could be noted in both situations, the proteinaceous binders used alone and in combination with RB. RB plus 2% SPI significantly improved the WHC of the sucker flesh when compared to 2% SC as the sole binder used with the fish flesh.

The determination of the WHC by the filter paper press technique was carried out on the water-bath-cooked flesh and

on the smokehouse-cooked fish flesh, Table 4. The water-bath-cooked flesh had good WHC when 2% SC or 2% SPI was used in combination with RB. No improvement in WHC was noted when these proteinaceous binders were used alone. In this study the results of WHC by the filter paper press technique correlated well with those obtained by using the draining and blotting on absorbent paper technique. They also tend to agree with those reported by Karmas and Turk, (1976) as no significant difference between SPI and SC were detected when used as fish binders alone or in combination with RB. Some improvement in WHC was also detected when RB was used in combination with an additional 2% salt and with 2% added salt plus either of the two proteinaceous binders used in this study. A significant improvement of the WHC was observed in the flesh which had RB plus 2% salt and was subjected to paddle type (Hobart model N-50) mixing for 15 minutes. The incorporation of salt by the paddle-mixing procedure did not reduce the meat particle size and apparently permitted greater retention of water. The gravimetric adaptation of the filter paper press method suggested by Karmas and Turk, (1975) proved to be a good technique for the determination of the WHC of the cooked sucker flesh. In this study, however, it was not possible to obtain good replicates values for each sample due in part to the fact that fish samples were pressed in quadruplicate at the same time between three plates

of plexiglass and the water from the meat continued to diffuse through the filter paper as the liner and meat residue were removed one by one to weigh the filter paper containing the expressed fluids.

The centrifuge technique for the determination of the WHC of the fish flesh was based upon the ability of the meat to retain water as a constant centrifugal force (about 40,000 x g) was applied for one hour to the system. This technique appeared to be more reliable than any other used in this study to assess the WHC of the sucker flesh. Results of WHC by the centrifugation method from the water-bath-cooked flesh and from the smokehouse-cooked flesh correlated very well, $r = 0.91$. Replicate results per sample were fairly easy to reproduce as demonstrated by the low standard deviation values reported in Table 4. An improvement in the WHC of the sucker flesh by this technique was noted by the use of additional 2% salt. The favorable affect of the 15 minute paddle-mixing procedure when compared to the 2 minute cutting-mixing procedure could also be observed. Further improvement in WHC was obtained by using the proteinaceous binders in combination with RB and additional 2% salt. Finally, significant improvement of the WHC was observed when RB was used in combination with 2% additional salt and 2% SPI. In this study SPI tended to perform better than SC as binder for sucker flesh. This might be due to the better swelling and gelation properties of SPI when compared to SC

(Hermansson, 1971).

Table 5 shows the results of various measures of texture of the smokehouse-cooked fish flesh modified by different binder systems. Void spaces in this table are due to the fact that the proteinaceous skin formed on the fish sausage during smokehouse cooking introduced some interference on the texture determination as shear values obtained were due in part to the skin resistance to breaking rather than to the meat resistance to shear; therefore further shear force determinations by both the Instron and Kramer press were carried out on the skinned cores. The higher the shear force value obtained by using these instruments the better the texture or firmness of the product was. By using the Penetrometer to measure the softness of the fish product the higher the penetration length value obtained the poorer the texture or firmness of the product was.

It could be noted, from data in Table 5, that the texture of the unpeeled fish cores determined by the Instron was not improved by using either 2% SPI or 2% SC instead of RB. Fish flesh with RB plus 2% SPI showed the best value of texture although it was significantly higher only than the fish flesh with RB plus 2% SC. Texture by the Kramer shear press on the same product showed higher shear values for the fish with RB plus 2% SPI. Fish with 2% SPI alone as binder showed shear values significantly higher than those with 2% SC or with RB plus 2% SC. Texture values of the unpeeled

TABLE No.5 - Mean[1] and standard deviations of the shear force by the Instron and by the Kramer shear press, and of the softness by the Penetrometer as a measure of texture of the smokehouse cooked sucker flesh.

Procedure and Instrument used to assess texture	Binder Treatments[2]								
	B-5	B-7	B-8	B-9	B-10	B-11	B-12	B-13	B-14
Shear force by Instron[3] on unpeeled fish sausage, N=14	$10.3^{ab}\pm1.3$	$10.3^{ab}\pm1.4$	$8.9^{ab}\pm0.8$	$10.7^{b}\pm2.1$	$8.5^{a}\pm1.3$	-	-	-	-
Shear force by Instron[4] on peeled fish sausage, N=8	$1.9^{a}\pm0.2$	$2.6^{cde}\pm0.8$	$2.4^{bcde}\pm0.1$	$4.1^{b}\pm0.3$	$3.4^{fg}\pm0.1$	$2.2^{abcd}\pm0.2$	$2.6^{de}\pm0.2$	$3.6^{g}\pm0.2$	$2.7^{e}\pm0.2$
Shear force by Kramer[5] on unpeeled fish sausage, N=10	$2.13^{a}\pm0.3$	$3.12^{b}\pm0.8$	$2.05^{a}\pm0.3$	$2.82^{ab}\pm0.8$	$2.11^{a}\pm0.3$	-	-	-	-
Shear force by Kramer[5] on peeled fish sausage, N=5	$.45^{a}\pm0.1$	$.87^{g}\pm0.1$	$.70^{bcdef}\pm0.1$	$1.00^{h}\pm0.1$	$.73^{def}\pm0.1$	$.72^{cdef}\pm0.1$	$.75^{e}\pm0.1$	$1.00^{h}\pm0.1$	$.76^{fg}\pm0.1$
Softness by Penetrometer[6] on unpeeled fish sausage, N=10	$10.7^{g}\pm0.4$	$9.5^{ef}\pm0.6$	$9.5^{ef}\pm0.2$	$7.2^{a}\pm0.2$	$8.7^{cd}\pm0.5$	$9.9^{f}\pm0.6$	$9.9^{f}\pm0.3$	$8.3^{bc}\pm0.7$	$9.2^{def}\pm0.3$

[1]Means in same row not followed by the same superscript are significantly different ($p<0.01$). [2]Binder treatments as described in Table 3. [3]Shear force in Kg-f/1.9 cm sectional Ø. [4]Shear force in Kg-f/1.6 cm sectional Ø. [5]Shear force in lb-f/g of cooked sucker flesh. [6]Softness in mm penetration/1.9 cm sectional Ø.

fish cores by the Kramer shear press tended to be fairly consistent with those obtained by the Instron on the same product and they showed the better binding characteristics of the SPI when compared to the SC.

Shear force measured on the skinned fish cores by the Instron showed that SPI or SC used alone improved the texture of the fish flesh more than the RB. Further improvement in texture was found by using either of these two proteinaceous binders in combination with RB. Texture was also improved by using additional 2% salt in combination with RB. Additional texture improvement was obtained by using 2% salt plus 2% SPI or 2% SC in combination with RB.

Almost the same pattern of texture variation on the skinned fish cores was found by using the Kramer shear press.

The softness of the fish flesh measured by the Penetrometer showed better texture for the treatments with 2% SPI and 2% SC than for the treatment with RB as lower values of penetration were recorded for both proteinaceous binders. Further improvement of texture was obtained by using any of the proteinaceous binders with RB. The use of an additional 2% salt with RB decreased the softness (increase hardness) of the product to levels comparable to those obtained by using the proteinaceous binders alone. The use of 2% salt plus SPI or SC and plus RB showed only slight improvement in texture (lower softness values).

It is important to note from these results that the

textural characteristics of the sucker flesh with RB could be improved by using either the proteinaceous binders or an additional 2% salt. However no further improvement was obtained when the sucker flesh with RB was used in combination with both 2% of any of the proteinaceous binders and 2% additional salt. This might be due in part to the fact that SPI and SC absorb more water in low salt concentration than in high salt concentration systems. Hermansson, (1971) reported that the process of swelling or imbibing water is an intrinsic characteristic of SPI and SC depending on their protein structures and is affected by the ionic strength of the meat system. This author also reported much better gelation characteristics for the SPI than for SC when the system is heated at 70-80° C. From our results, however, there seemed to exist an optimum amount of salt in the system for the swelling and further gelation of the proteinaceous binders. SPI tended to impart better texture characteristics to the sucker flesh when used in combination with RB (1% salt in the system) than when used as the sole binder of the sucker flesh (no salt in the system) or in combination with RB and additional 2% salt (3% salt in the system).

Table 6 shows the simple correlation coefficients obtained among the methods used to assess the functional properties of the cooked sucker flesh in terms of texture (techniques 1 to 5) and WHC (techniques 6 to 11). The Instron and the Kramer shear press methods correlated well

TABLE No.6 - Correlation coeficients (r) obtained by comparing the techniques used to assess the functional properties of the mechanically deboned sucker flesh.

Techniques	1	2	3	4	5	6	7	8	9	10	11
1 Instron shear force on the flesh without skin	-	-	-	-	-	-	-	-	-	-	-
2 Instron shear force on the flesh with skin	2.10	-	-	-	-	-	-	-	-	-	-
3 Kramer shear force on the flesh without skin	0.72**	-	-	-	-	-	-	-	-	-	-
4 Kramer shear force on flesh with skin	0.34	0.50*	-	-	-	-	-	-	-	-	-
5 Softness on the fish flesh by Penetrometer	0.30	-0.49	-0.86**	-0.35	-	-	-	-	-	-	-
6 Smokehouse shrinkage on fish flesh	0.27	-0.34	-0.10	-0.37	0.67**	-	-	-	-	-	-
7 Cooking losses of fish flesh by blotting	0.34	-0.52*	-	-0.18	0.26	0.50*	-	-	-	-	-
8 WHC by filter paper press on smokehouse cooked flesh	0.18	-	0.05	-	-0.02	-0.25	-	-	-	-	-
9 WHC by filter paper press on water-bath cooked flesh	-0.63**	0.01	-0.13	0.36	-0.02	0.26	0.58	-0.50	-	-	-
10 WHC by Centrifugation on smokehouse cooked flesh	-0.90*	-	-.085*	-	0.92**	0.98**	-	-0.30	0.23	-	-
11 WHC by Centrifugation on water-bath cooked flesh	-0.99**	-	-0.86*	-	0.97**	0.81*	-	-0.21	0.10	0.91**	-

*Significant correlation ($p < 0.05$)

**Significant correlation ($p < 0.01$)

($p<0.01$) when used as a measure of the texture on the skinned fish cores. The Penetrometer technique correlated well with the Kramer shear press technique but not with the Instron when used on the same type of cooked fish flesh. Few significant correlations were found among these texture techniques when used on the fish cores with skin. The shear force values obtained in these cases were attributed to the skin resistance rather than to the cooked flesh resistance to shear. The use of the Instron universal testing instrument seemed to have some advantages over the Kramer shear press and the Universal Penetrometer. It is a more automated instrument, is easy to calibrate, and seems to be a more versatile instrument permitting faster determinations and a more complete interpretation of the results in terms of texture profile.

The smokehouse shrinkage as a measure of the WHC correlated well with the penetrometer technique and with the centrifuge technique; it also correlated fairly well with the blotting technique but not with the filter paper press, the Instron and the Kramer shear press techniques.

The blotting method for cooking losses did not show good correlations with the other techniques used in this study.

Values obtained by the filter paper press technique were poorly correlated with most of the values from other methods used to assess the functional properties of the sucker flesh, except when compared to the Instron technique used to assess

texture on the skinned fish cores.

The centrifuge technique for WHC was the most reliable method for WHC of the sucker flesh since it correlated very well with all techniques used for texture (Instron, Kramer press, and Penetrometer). Good correlations were also observed when comparing the WHC on the smokehouse-cooked flesh with that on the water-bath-cooked flesh by using this method.

Section Two

In this section the effect of the handling and freezer storage conditions on the functional properties of the sucker flesh are discussed. Based on results obtained in section one, the binders as well as the methods used to assess the functional properties of the sucker flesh were chosen. Two binder systems were selected to modify the texture of the fish: the RB and the RB plus 2% salt and 15 minute paddle-mixing. The use of proteinaceous binders (SPI and SC) was omitted in this section of the study since although they showed good improvement of the texture characteristics of the sucker flesh they probably represented a texture factor by themselves; independent of the texture role of the fish proteins.

Table 7 shows the yields of processing and mechanical deboning operations as affected by a 13 months freezer storage period of the sucker flesh.

TABLE No.7 - Yields of dressing and mechanical deboning operations (%) as affected by a 13 month freezer storage period.

TREATMENT CODE	DESCRIPTIONS	PERCENT				
		THAWING LOSSES	WASHING LOSSES	YIELD AFTER DRESSING	DRIP DURING MECH. DEBONING	YIELD AFTER MECH. DEBONING
A	Round fish, fast frozen	1.4	1.4	64.0	6.6	51.5
B	Round fish, frozen slow	4.3	0.9	61.4	7.1	48.9
C	Dressed fish, no washing, fast frozen	6.0	-	64.9[1]	7.2	46.8
D	Dressed fish, washed, fast frozen	4.6	0.3	64.8[1]	7.5	43.7
E	Mech. deboned fish, fast frozen	-	-	63.0[1]	0.4[1]	45.4[1]

[1]Operations carried out prior to freezer storage.

The effect of freezing rate could be observed on the stored round fish (treatments A and B). Yields of dressing and mechanical deboning operations were higher for the fish frozen and stored under fast freezing conditions than that for fish under slow freezing conditions. The minced flesh from the fish exposed to fast freezing conditions lost less water (drip during mechanical deboning) than the flesh from the slowly frozen fish. Thawing losses were considerably higher for the fish frozen slowly and stored at -18° C. Washing losses and drip during mechanical deboning were not very different so that the difference in yield after mechanical deboning could be attributed to the difference in thawing losses exhibited by the suckers which was due probably to the freezing rate variation applied.

The dressed suckers frozen quickly and stored at -29° C (treatments C and D in Table 7) showed lower yields of flesh after mechanical deboning than the round fish frozen by either system. They also showed abundant dripping during the mechanical deboning operation and high thawing losses. The process of washing the fish after dressing and before the freezer storage seemed to decrease the losses of fluids during the thawing process, however, it did not improve the final yield of minced flesh after mechanical deboning. The process of mechanical deboning before freezer storage (treatment E in Table 7) showed a very low drip losses at the time of deboning compared to that of the frozen intact fish.

This fact demonstrated the negative effect of freezer storage on the ability of the sucker flesh to retain water.

Table 8 shows the thawing drip of the mechanically deboned sucker flesh at several times throughout the 13 months freezer storage. The minced sucker flesh obtained from fresh fish was considered as the control treatment for this trial. An increase of the drip after 1, 2, and 3 hours was observed after 3, 10, and 13 months of freezer storage respectively. The high drip values obtained for the stored flesh tend to support the finding of Seagran (1958) in that the mere rupture of the cell membrane (during the process of mechanical deboning) does not fully explain the release of large quantities of drip when the same material is frozen and thawed. The most important factor responsible for drip in meat systems has been shown to be the denaturation of the contractil protein actomyosin and the subsequent loss of its power to imbibe water (Dyer, 1953).

Table 9 shows the drip of the mechanically deboned sucker flesh obtained from fish handled and/or frozen in seven different ways.

The effect of the fast and slow freezing conditions could be observed on treatments 1 and 2 with round fish and on treatments 5 and 6 with dressed fish followed by washing in potato peeler. The slow freezing procedure produced slightly lower drip from the minced sucker flesh than the fast freezing procedure. This might be due to the high

TABLE No.8 - Drip values of the mechanically deboned sucker flesh through 13 months of frozen storage.

TIME OF FROZEN STORAGE	DRIP (ml/50g flesh)		
	After 1 hour	After 2 hours	After 3 hours
Control (Fresh fish, no storage)	0.3	0.6	2.5
Three months	5.0	7.8	8.1
Ten months	6.8	8.4	9.0
Thirteen months	8.7	9.5	9.7

TABLE No.9 - Drip of the mechanically deboned sucker flesh obtained from fish handled and freezer stored in seven different ways (ml/ 50g flesh).

HANDLING AND STORAGE CONDITIONS	DRIP		
	After 1 hour	After 2 hours	After 3 hours
1. Round fish, frozen fast	3.5	5.8	6.2
2. Round fish, frozen slow	2.5	5.1	5.4
3. Dressed fish, no washing, frozen fast	5.3	5.5	6.3
4. Dressed fish, washed, frozen fast	5.5	5.6	6.3
5. Dressed fish, washed in potatto peeler, frozen fast	4.3	6.0	-
6. Dressed fish, washed in potato peeler, frozen slowly	3.6	4.5	-
7a. Mechanically deboned flesh, frozen fast (thaw drip)	6.0	8.7	9.0
7b. Mech. deboned flesh, frozen fast (drip after thawing)	8.4	8.7	9.6

thawing losses experienced by the slowly frozen fish (Table 7). Mechanically deboned sucker flesh stored under proper conditions (treatment 7a and 7b in Table 9) produced drip considerably higher than any other processing treatments. The effect of protein denaturation and ice crystal formation seemed to produce a more drastic damage to the minced fish flesh than to the fish stored in the intact muscle fiber form (treatments 1 to 6 in Table 9).

No differences in drip after 2 hours were observed for the minced flesh obtained from the dressed fish either washed or not and stored under fast freezing conditions.

The bacterial load on the mechanically deboned sucker flesh is shown in Table 10. A significant increase in the bacterial load was found during the storage period except for the fish stored as mechanically deboned flesh. A higher bacterial count was found in the flesh from the round fish stored after slow freezing than in that from the round fish stored after fast freezing. No differences in bacterial loads were detected in the dressed fish either washed or not before storage. Although statistical differences were detected in the bacterial counts on the minced fish flesh, freezer storage seemed to inhibit fairly well the bacterial growth throughout the 13 month storage period.

The oxidative rancidity of the sucker lipids after 13 months freezer storage, expressed as TBA values, is shown in Table 11. A significant increase in TBA values was found

TABLE No.10 - Mean values* of the bacterial load in the minced sucker flesh obtained from fish stored in freezer for 13 months (N=2).

HANDLING OF THE FISH PRIOR TO FREEZER STORAGE					
Minced sucker no handling, no storage	Round suckers frozen fast	Round suckers frozen slow	Dressed sucker no washing, frozen fast	Dressed sucker washed, frozen fast	Minced sucker frozen fast
$4.06^{a} \pm 0.14$	$5.04^{cd} \pm 0.04$	$5.65^{e} \pm 0.01$	$4.94^{bcd} \pm 0.01$	$5.33^{de} \pm 0.00$	$3.70^{a} \pm 0.08$

*Means not followed by the same superscript are significantly different ($p < 0.05$)

TABLE No.11 - Means[1] of the TBA values of the mechanically deboned sucker flesh as affected by handling and a 13 month period of frozen storage (N=6).

HANDLING OF THE FISH PRIOR TO FREEZER STORAGE					
Minced sucker no handling, no storage	Round sucker frozen fast	Round sucker frozen slow	Dressed sucker no washing, frozen fast	Dressed sucker washed, frozen fast	Minced sucker frozen fast
$0.24^{a}\pm0.07$	$1.08^{bc}\pm0.11$	$0.99^{ab}\pm0.09$	$10.35^{e}\pm0.67$	$4.78^{d}\pm0.56$	$1.85^{c}\pm0.38$

[1]Means in the same row not followed by the same superscript are significantly different ($p < 0.01$)

for all the processing treatments after 13 months of freezer storage. No differences were observed for round fish frozen under slow or fast freezer conditions. A significantly greater TBA value was observed for the dressed fish frozen without previous washing when compared to the dressed fish frozen after washing. This might be due to the highly unstable fatty tissue along the visceral cavity, the presence of abundant heme proteins and high levels of unsaturated fatty acids in the bone marrow exudate which could be responsible for the high susceptibility of the unwashed fish flesh to lipid oxidation (Lee and Toledo, 1977).

The functional properties of the sucker flesh obtained from the fish material stored in freezer for 13 months are shown in Table 12.

WHC was measured by the centrifuge technique on both the smokehouse-cooked and the water-bath-cooked sucker flesh. No differences in WHC were found due to freezing conditions (slow or fast) or to the washing procedure on the dressed fish before freezing. The suckers mechanically deboned before freezing showed a significantly lower WHC than any of the other processing treatments when measured on the water-bath-cooked meat. They also showed lower WHC than the round fish frozen fast and the dressed fish without washing when measured on the smokehouse-cooked sucker flesh.

No differences were observed in the shrinkage of the smokehouse-cooked sucker flesh. However the high values of

TABLE No.12 - Mean values[1] and standard deviations of the functional properties of the mechanically deboned sucker flesh as affected by handling and freezer storage conditions.

Functional Properties	Handling and Freezer Storage Conditions				
	A[2]	B[3]	C[4]	D[5]	E[6]
WHC on the water bath cooked flesh, expressed as H_2O losses %, (N=6)	$38.6^{a}\pm2.54$	$39.0^{a}\pm3.75$	$38.5^{a}\pm2.45$	$38.7^{a}\pm2.68$	$42.8^{b}\pm3.25$
WHC on the smokehouse cooked flesh, expressed as H_2O losses %, (N=6)	$23.5^{a}\pm4.48$	$24.6^{ab}\pm4.17$	$22.8^{a}\pm5.21$	$25.3^{ab}\pm2.15$	$27.4^{b}\pm4.87$
Shrinkage of the smokehouse cooked flesh, expressed as H_2O losses %, (N=2)	$24.05^{a}\pm0.21$	$24.85^{a}\pm1.06$	$25.20^{a}\pm0.42$	$24.20^{a}\pm0.56$	$25.75^{a}\pm0.35$
Texture on the smokehouse cooked flesh, expressed as Kg-f/1.6cm ø, (N=24)	$2.99^{bc}\pm0.63$	$2.48^{a}\pm0.37$	$3.05^{c}\pm0.81$	$3.94^{d}\pm0.51$	$2.63^{a}\pm0.40$

[1]Means in the same row having different superscripts are statistically different ($p< 0.01$).

[2]Round fish frozen fast.

[3]Round fish frozen slowly.

[4]Dressed fish, no washing, frozen fast.

[5]Dressed and washed fish, frozen fast.

[6]Mechanically deboned fish flesh, frozen fast.

water loss observed during smokehouse-cooking show the poor WHC of sucker flesh stored in freezer for 13 months.

The texture determined by the Instron instrument on the smokehouse-cooked flesh showed the lowest values for the fish stored as mechanically deboned flesh and for the round fish frozen slowly. The best value of texture was obtained for the dressed fish, washed and frozen fast.

Table 13 shows the effect of the binder incorporation to the sucker flesh obtained from the fish material stored for 13 months on the functional properties of the fish flesh.

RB plus 2% salt and 15 minutes paddle-mixing (binder II in Table 13) seemed to impart better characteristics of WHC and texture to the minced sucker flesh than RB alone. No differences due to binder were detected by measuring the smokehouse shrinkage of the sucker flesh. A significant interaction between binders and prefreezing handling effects on the texture of the sucker flesh was found in this study. Figure 1 illustrates this interaction. The overall effect of binder II was better, in terms of texture, than that of binder I. The use of RB plus 2% salt and 15 minutes paddle-mixing permitted a better differentiation of the fish flesh obtained from the 5 prefeezing handling treatments according to their texture characteristics. The best texture was obtained with the flesh from the fish dressed and washed before freezer storage. The poorest texture was for both the fish stored as mechanically deboned flesh and for the

TABLE No.13 - Mean values[1] and standard deviations of the functional properties of the mechanically deboned sucker flesh as affected by the kind of binder incorporated.

Functional Properties	Binder I[2]	Binder II[3]
WHC on the water bath cooked flesh, expressed as H_2O losses %, (N=15)	$41.6^{a}\pm2.77$	$37.4^{b}\pm2.05$
WHC on the smokehouse cooked flesh, expressed as H_2O losses %, (N=15)	$28.2^{a}\pm2.26$	$21.3^{b}\pm2.82$
Shrinkage of the smokehouse cooked flesh, expressed as H_2O losses %, (N=5)	$24.96^{a}\pm0.59$	$24.66^{a}\pm1.02$
Texture on the smokehouse cooked flesh, expressed as Kg-f/1.6cm Ø, (N=60)	$2.58^{a}\pm0.56$	$3.47^{b}\pm0.65$

[1]Means in the same row having different superscripts are statistically different ($p < 0.01$).

[2]Regular binder and 2 minutes of cutting.

[3]Regular binder plus 2% salt and 15 minutes in revolving mixer.

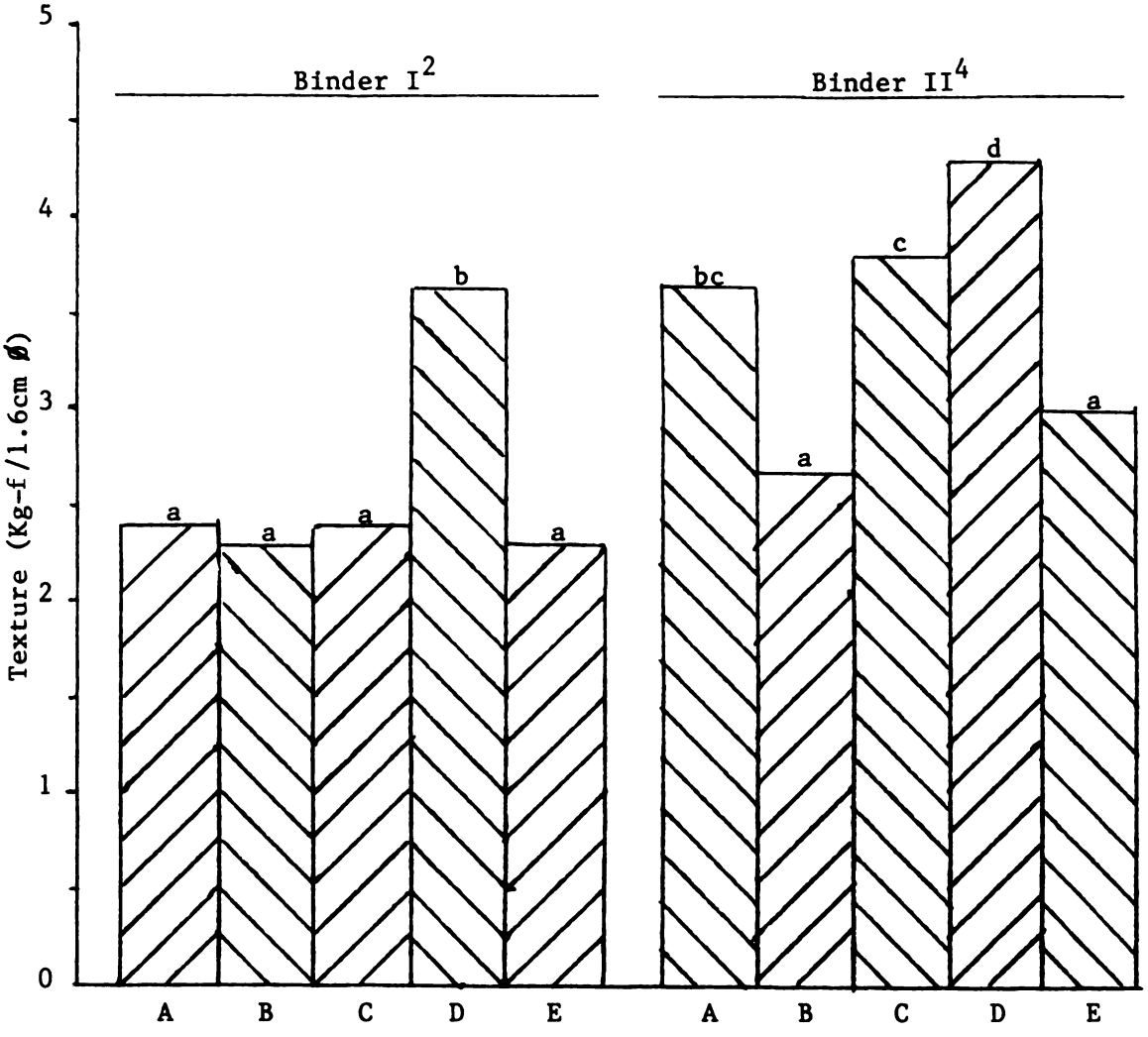

Figure 1 - Results of the interaction between pre-freezing handling[1] and binder effects on the texture of the smokehouse cooked sucker flesh, expressed as Kg-f/1.8cm ø [1,2]

[1]Pre-freezing handling conditions A to E as described on Table 12.

[2]Columns (N=12) under each binder treatment topped by the same letter are not statistically different ($p<0.01$).

[3]Regular binder and 2 minutes cutting.

[4]Regular binder plus 2% salt and 15 minutes revolving mixing.

round fish frozen slowly.

These results tend to indicate, one more time, the drastic effect of freezer storage on the minced sucker flesh. They also suggest that fish frozen under proper freezing conditions give flesh with better textural properties than fish under slow freezing conditions. The washing procedure for dressed fish before freezing seemed to improve the texture of the sucker flesh when compared to the unwashed treatment group.

Sucker fish intended for mechanical deboning and further processing into fabricated fish products might be stored under proper freezing conditions, preferably in the dressed form with an appropriate washing procedure before freezing. Freezer storage of mechanically deboned sucker flesh, even under proper freezing conditions, seemed not to be a desirable treatment for sucker flesh in terms of functional properties.

SUMMARY

Some characteristics of the sucker flesh obtained by mechanical deboning were examined from the chemical, physical and microbiological standpoints.

The sucker flesh was modified by different binder systems and cooking methods and its functional properties then evaluated in terms of water-holding capacity and texture. Four water-holding capacity techniques and three texture methods were examined to decide which one was most appropriate.

The influence of freezing conditions on properties of the sucker flesh was recorded after a 13 month storage period. The effect of handling the fish before freezing was also evaluated.

The following observations were obtained:

1. Yield, moisture, protein, fat, TBA value, and microbiological load of the mechanically deboned sucker flesh were not affected by passing the mince a second time through the meat and bone separator. An approximate 50% reduction in scale content could be the only important modification introduced by this operation.
2. Bacterial growth seemed not to be a critical

factor affecting the sucker flesh during processing operations. The slight reduction in bacterial count on the fish surface due to the washing method used in this study suggests that a more drastic washing procedure should be carried out where a considerable bacterial reduction is desired. Adequate low temperature in the freezer are required to prevent bacterial growth.

3. Cooked sucker flesh showed poor water-holding capacity and texture characteristics with low binding, low gelation strength and high losses during cooking. Although 2% salt or 2% soy protein isolate in combination with regular binder seemed to be the best binder systems used in this study, they improve only in a slight way the functional properties of the sucker flesh.
4. The centrifuge technique for water-holding capacity and the Instron universal testing instrument for texture proved to be the most reliable methods used in this study to assess the functional properties of the cooked sucker flesh.
5. When stored under proper freezing conditions (-29° C, blast freezer) for 13 months, suckers intended for further processing into fabricated fish products are best stored dressed and washed rather than in the round or as mechanically deboned flesh.

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