SUMMARY REPORT

on

ASSESSMENT OF INDUSTRIAL MARKETS FOR POLLOCK SURIMI PHASE I: FUNCTIONAL PROPERTIES

to

ALASKA FISHERIES DEVELOPMENT FOUNDATION

AUGUST 5, 1985

by

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EXECUTIVE SUMMARY

The purpose of this brief study was to measure the functional properties of dried surimi in model systems and to interpret, preliminarily, the results of the functional property measurements in terms of potential application opportunities based on past experiences.

Initially, AFDF provided four samples of dried surimi which were evaluated on a preliminary basis. AFDF and Battelle mutually agreed that further evaluation would focus upon the higher quality domestic surimi sample. The tests conducted were composition analysis, protein solubility, water binding, oil binding, foam formation and stabilization, emulsion capacity, emulsifying activity and stability, and rheological properties.

The results of the tests demonstrated that surimi has limited solubility in aqueous systems and would not function as a thickener in diluent systems. Dried surimi does have excellent water binding properties and can be used to form thick pulpy or mealy suspensions or soft elastic gels.

Potential application opportunities for dried surimi as a food ingredient might include bread doughs, spaghetti sauce, processed meats, pasta, and extruded or formed pet food products. Dried surimi's functional properties suggest that it might provide desirable attributes in these applications. In some cases, flavor might be a limiting factor; however, based on the initial screening provided by this program, the previous mentioned applications merit additional investigations.

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INTRODUCTION

The Alaska Fisheries Development Foundation (AFDF) is interested in expanding the use of surimi as a food ingredient. Frozen surimi gel is currently being used in the manufacture of seafood analogs such as crab legs and shrimp. This is a limited market. AFDF would like to identify a number of formulated food categories where surimi could be marketed competitively as a functional ingredient.

Two basic questions needed to be addressed in order to focus the marketing of surimi as a food ingredient. First, what functional properties does surimi have, at significant levels, that are of interest to users of proteins or other functional food ingredients? Secondly, in food systems that represent applications of these functional properties, how does the performance of surimi compare with that of alternative ingredients? Since surimi is manufactured both as a frozen gel and in dehydrated form, the questions needed to be answered for each form of surimi. AFDF requested Battelle's assistance in addressing these questions for dehydrated surimi.

In response to AFDF's request, Battelle proposed a research program having the following specific objectives:

(1) To determine the functional properties of dried surimi in model systems.

(2) To relate the functional characteristics of dried surimi to the functional attributes desired in specific food products.

(3) To compare the properties of the dried surimi with those of alternative protein materials which are currently used in these applications.

(4) To identify candidate food product applications that merit further investigation.

In order to achieve these objectives, Battelle proposed a research program consisting of the following five tasks:

Task I. Measure Functional Properties of Dried Surimi in Model Systems

Task II. Relate Functional Properties to Specific Food Applications

Task III. Identify Key Alternative Protein Ingredients Used in These Food Applications

Task IV. Compare Relevant Functional Properties of Surimi with Those of Specific Alternative Protein Ingredients

Task V. Identify Candidate Food Products and Market Potential for Dried Surimi.

Due to budget limitations, AFDF elected to fund Task I with the understanding that Battelle would make a preliminary attempt to interpret the results of Task I in terms of potential application opportunities based on past experience.

This report summarizes the results of this Phase I study on measuring the functional properties of dried surimi. It also includes a discussion of the significance of these results in terms of potential food application opportunities for dried surimi.

METHODS AND MATERIALS

Surimi Samples

Initially, four samples of dried surimi were provided by AFDF; two of Japanese origin and two forms of experimental material produced in the United States. One of the Japanese materials was freeze-dried (J-FD) and the other was spray-dried (J-SD). Both domestic samples were freeze-dried, with one being of higher quality (U.S.-C1) than the other (U.S.-C2). All samples were stored in sealed jars at 40°F (4.4°C) during the study.

After a few preliminary measurements on all four samples were run, it was mutually agreed between AFDF and Battelle that the higher quality domestic material (U.S.-C1) would be selected as the sample to be used for more extensive evaluation.

Analysis of Composition

Initially, all four sample materials were analyzed for moisture, protein, and fat content. Subsequently, the U.S.-C1 sample was subjected to a complete proximate analysis (moisture, fat, protein, ash, and total carbohydrate), as well as analyses for fiber, nonprotein nitrogen, and salt content. These analyses were run by Midwest Laboratories (Columbus, Ohio) using standard A.O.A.C. procedures.

Protein Solubility

The percent of total sample protein which was soluble in either water or salt solution as a function of pH was determined using the following procedure:

1. Suspend 300 mg of sample in 10 ml of cold distilled water (or salt solution) by vortexing for 5 minutes.
2. Adjust to the desired pH using 2N NaOH or 2N HCl.
3. Hold for 30 minutes and readjust pH if necessary.

4. Centrifuge at 1600 x G for 25 minutes.
5. Analyze supernatant for protein.

The percent soluble protein is equal to the protein content of the supernatant divided by the protein content of the sample multiplied by 100.

The protein content of the supernatant was determined using a Bio Rad Assay test kit with the standard curve developed using a bovine gamma globulin standard. A correction factor was applied based on the ratio of total protein as determined by the Bio Rad method to total protein as determined by the Kjeldahl technique. To determine the total proteins using the Bio Rad method, 10 ml of 1N NaOH was used in place of the distilled water. Using this procedure, the Kjeldahl protein = 0.844 x Bio Rad protein.

Water Binding

The water binding capacity of the samples expressed as the weight of water retained per unit weight of sample were determined by the method described by Gierhart and Potter[1]. This procedure is as follows:

1. Add 1 g of sample to test tube and weigh the tube.
2. Add 10 ml of distilled water and vortex.
3. Hold for 1 hour at 25°C.
4. Centrifuge at 1600 x G for 25 minutes.
5. Pour off free water, invert tube to 45° angle, and drain for 30 minutes.
6. Reweigh tube.

Drained weight-Dry weight = g H_2O retained/g sample.

Oil Binding Capacity

The oil binding capacity of the surimi was measured using the method described by Gierhart and Potter[1]. This procedure is as follows:

1. Add 0.5 g of sample to test tube and weigh the tube.
2. Add 3 ml of vegetable oil and vortex.
3. Hold for 1 hour at 25°C.
4. Centrifuge at 1600 x G for 25 minutes.
5. Pour off free oil, invert tube to 45° angle, and drain for 30 minutes.
6. Reweigh tube.

Drained weight-Dry weight = g oil retained/500 mg sample.

Foam Formation and Stabilization

The ability of the surimi to form and stabilize aqueous foams was determined using the following procedure:

1. Slurry 2 g of sample in 75 ml of distilled water (4°C).
2. Adjust pH to desired value with 2N NaOH or 2N HCl.
3. Blend for 2 minutes at high speed in a water cooled semi-micro Waring Blender jar.
4. Pour into a graduated cylinder and hold 2 minutes.
5. Determine volume of the foam.
6. Hold for 1 hour and remeasure foam volume to determine stability.

Emulsifying Capacity

To determine the emulsion forming capacity of the surimi, the following procedure, modified slightly from that of Gierhart and Potter[1], was used.

1. Prepare 50 ml of sample slurry containing 0.5 percent sample in 4°C distilled water.

2. Adjust pH to desired value with 2N NaOH or 2N HCl.

3. Place slurry in pint blender jar and blend for 10 seconds on a Waring Blender at high speed.

4. Add peanut oil (no additives) colored with Oil-Red O at a constant rate of 1 ml/sec. with continuous blending until emulsion inverts.

ml oil ÷ total ml x 100 = Oil Phase Volume.

Emulsifying Activity and Stability

The ability of the sample to form emulsions in the presence of excess oil and the stability of these emulsions was determined following the procedure of Gierhart and Potter[1] as described below.

1. Slurry 1.75 g of sample in 50 ml distilled water (4°C).

2. Adjust the pH to desired level with 2N NaOH or 2N HCl.

3. Place in precooled Waring Blender semi-micro jar with 50 ml of colored peanut oil and blend at high speed for 2 minutes.

4. Divide sample into two halves.

5. Centrifuge one-half at 1600 x G for 10 minutes.

6. Heat second half for 30 minutes in 80°C water bath, cool quickly, and centrifuge at 1600 x G for 10 minutes.

The emulsifying activity is calculated as the volume of emulsified layer as a percent of the total volume on the unheated sample. The same value for the heated sample is used as a stability measure.

Rheological Properties

The rheological properties of surimi slurries were determined using a Model RVT Brookfield visiometer with size F crossbar spindle at a rotational speed of 2.5 revolutions per minute. The unit was mounted on a Brookfield

Helipath stand which lowers the spindle into the sample as it turns so that it constantly cuts through fresh sample. Measurements were made on samples which were held under the following conditions after preparation.

(a) Room temperature for 15 minutes to 2 hours

(b) 40°C for 15 minutes

(c) 40°C for 15 minutes followed by 15 minutes at 90°C.

EXPERIMENTAL RESULTS

Sample Composition

Table 1 presents the results of analysis for moisture, protein, and fat for all four surimi samples, as well as the more extensive analysis of sample U.S.-C1. These results show that while the dried surimi contains little moisture or fat, it does contain ~30 percent total carbohydrate. Since the original surimi gel contains about 4 percent sugar and 4 percent sorbitol, and has a moisture content of about 75 percent, it also contains about 30 percent carbohydrate on a dry weight basis. Since the raw fish would contain virtually no carbohydrate, the carbohydrate content of the dried surimi is obviously due entirely to the sucrose and sorbitol which are added as cryoprotectants during the manufacture of the surimi gel.

This lowers the total protein content of the material to approximately 65 percent. A typical soy protein isolate by comparison contains approximately 90 percent protein and a soy protein concentrate about 70 percent protein on a dry weight basis. Whey protein concentrates are available in a range of protein contents from 50 to 75 percent. Typically, dried egg white contains approximately 80 percent protein.

Sensory Properties

All four surimi samples had a distinctly fishy aroma and flavor both in the dry form and when slurried in water. This aroma was quite evident even in dilute solutions. While the aroma was fresh and pleasant, it was definitely fish-like or seaweedy.

TABLE 1. COMPOSITION OF SURIMI SAMPLES

Constituent	Percent			
	U.S.-C1	U.S.-C2	J-FD	J-SD
non protein nitrogen	29.58)	64.15	68.20	56.20
H_2O	1.50	1.07	1.66	1.20
Protein	65.10	64.15	68.20	56.2
Fat	1.17	0.78	0.58	0.45
Ash	2.65	--	--	--
Carbohydrate	29.58	--	--	--
Fiber	(1.80)	--	--	--
Non Protein Nitrogen	(0.97)	--	--	--
Salt	(0.26)	--	--	--

Protein Solubility

The percent of the total protein which is soluble in water at various pH levels is presented in Table 2 for the four surimi samples, as well as Supro 620 (Ralston Purina) a soy protein isolate. All of the samples have an isoelectric point in the region of pH 4.5 to 5.0 having greater solubility at higher and lower pH values. The solubility of the surimi tends to increase more below the isoelectric point than above it, while the opposite is true for the soy isolate.

TABLE 2. PERCENT SOLUBLE PROTEIN IN WATER AS A FUNCTION OF pH

pH	Percent of Total Protein Soluble				
	U.S.-C1	U.S.-C2	J-FD	J-SD	Supro 620
4.0	10.50	14.32	15.14	3.59	4.79
4.5	1.81	3.09	1.64	1.39	3.21
5.0	1.60	2.02	1.08	3.80	6.41
6.0	8.40	10.19	6.89	7.30	20.73
6.5	10.99	14.08	10.48	8.86	31.05
7.0	14.81	17.32	15.28	9.70	30.71
8.0	23.82	25.64	24.27	12.62	34.61

Since water-soluble proteins are removed during the manufacturing of surimi, it is not surprising that the water soluble fraction of the remaining protein is low. At pH 7.0, for example, for sample U.S.-C1, the percent of total protein which is soluble is 14.81 percent. Since the sample contains 65.1 percent total protein, this means that it contains a total of 9.64 percent soluble protein. In an aqueous solution containing 5 percent surimi, the concentration of soluble protein would be 0.48 percent. Under identical conditions, the soy protein isolate would contribute 1.38 percent soluble protein (90x0.3071x0.05=1.38).

Table 3 contains data for the soluble protein in various salt solutions for sample U.S.-C1. These data show a definite increase in protein solubility with an increasing salt concentration at pH 7.0 at salt concentrations greater than 1 percent. For the 2 percent salt concentration, the solubility as a function of pH seems to indicate a shift in the isoelectric point to a lower value with greater increases in solubility between pH 5 and 7. However, since these data are limited to one series of duplicate measurements, the exact figures would need to be confirmed with additional measurements. The significant point is that the solubility is not increased in salt solutions to the extent that it would be a deciding factor in determining areas of potential application. Basically, the material is one which can be suspended and hydrated in aqueous solvents, but has relatively low solubility.

Water Binding

The water binding properties of the four surimi samples and the soy protein isolate are presented in Table 4. The surimi samples, except for J-FD, surpass the soy isolate in this functional property. Because of the nature of this measurement, proteins with low water solubilities but good hydration characteristics will score higher than highly soluble materials having equivalent hydration properties. This is obvious since the soluble protein is lost in part with the drain water. This simple point is often overlooked in the literature.

The combination of low water solubility and high water binding properties determine to a large extent the rheological properties discussed later in this report.

TABLE 3. PERCENT SOLUBLE PROTEIN AS A FUNCTION OF NaCl CONCENTRATION FOR U.S.-C1 FREEZE DRIED SURIMI

NaCl (%)	pH	Percent of Total Protein Soluble
1.0	7.0	8.34
2.0	3.5	3.85
	4.0	2.24
	5.0	7.22
	6.0	14.43
	7.0	16.17
	8.0	18.60
3.0	7.0	22.44

TABLE 4. WATER BINDING PROPERTIES OF SURIMI AND SOY PROTEIN ISOLATE - pH 7.0

Sample	g. H_2O/g. Sample
U.S.-C1	4.05
U.S.-C2	3.88
J-FD	3.07
J-SD	4.09
Supro 620	3.32

Oil Binding Properties

The attempt to characterize the oil binding properties of surimi following the procedure described earlier was unsuccessful. The surimi did not form a pellet when centrifuged and suspended particles were lost with the oil. After several unsuccessful attempts, this measurement was dropped from the study. Time and funding did not allow for the development of a more

suitable procedure. It was our judgment that this effort could be spent more profitably on other aspects of the study.

Foaming Properties

The ability of surimi sample U.S.-C1 to form and stabilize foams in 2 percent salt solution is compared with similar properties for soy protein isolate in water in Table 5. As illustrated by the effect of pH, the ability to foam is directly related to the soluble protein content of the sample. While the surimi has some foam forming ability, it is less functional in this respect than the soy isolate, which in itself is not used for this functional property. Compared with a protein like egg albumin, neither of these materials have exceptional foaming ability. The surimi foams did tend to be more stable with time than the soy isolate foams.

TABLE 5. FOAMING PROPERTIES OF U.S.-C1 FREEZE DRIED SURIMI AND SOY PROTEIN ISOLATE

	Percent Foam			
	U.S.-C1[a]		Supro 620[b]	
pH	2 min.	1 hr.	2 min.	1 hr.
3.0	85.9	35.9	--	--
3.5	83.0	33.5	100.0	27.6
4.0	67.1	18.2	--	--
5.0	71.6	34.6	100.0	31.9
6.0	93.3	56.3	--	--
6.5	88.5	55.3	--	--
7.0	81.8	54.7	--	--
8.0	94.2	56.9	100.0	42.5

(a) 2% in 2% NaCl solution.

(b) 2% in H_2O.

Emulsion Capacity

Table 6 shows that when oil is added at a fixed rate to a 1 percent suspension of U.S.-C1 surimi in 2 percent salt under continuous blending, the amount of oil which can be emulsified is less than the volume of the aqueous solution. The soy protein isolate at the same concentration will emulsify more than an equivalent volume of oil at pH values below 4.0 or greater than 6.0

TABLE 6. EMULSION CAPACITY OF U.S.-C1 FREEZE DRIED SURIMI AND SOY PROTEIN ISOLATE

pH	Percent Oil Phase Volume	
	U.S.-C1[a]	Supro 620[b]
3.0	41.9	68.8
3.5	37.5	53.5
4.0	28.6	37.1
5.0	44.4	35.5
6.0	44.4	45.1
6.5	40.5	59.8
7.0	45.1	68.3
8.0	48.7	70.6

(a) 1% in 2% NaCl solution.

(b) 1% in H_2O.

Emulsifying Activity and Stability

The data in Table 7 show that in the presence of excess oil and with a fixed input of energy, the surimi sample is a more effective emulsifier than the soy protein. It is also less susceptible to pH variations. When compared with the emulsion capacity data discussed above, these results are inconclusive as to whether the surimi is more or less effective as an emulsifying agent than soy protein isolate. However, the surimi stabilized emulsions are definitely more heat stable and less pH sensitive.

TABLE 7. EMULSIFYING ACTIVITY AND STABILITY OF U.S-C1 FREEZE DRIED SURIMI AND SOY PROTEIN ISOLATE

	Emulsified Volume, percent			
	U.S.-C1[a]		Supro 620[b]	
pH	Initial	Heated	Initial	Heated
3.0	54.4	61.9	57.5	50.0
3.5	62.5	56.9	54.1	55.3
4.0	60.0	52.5	12.5	15.0
5.0	57.9	60.0	5.0	20.0
6.0	63.8	61.3	48.6	55.0
6.5	60.0	65.0	48.6	47.4
7.0	66.5	65.5	60.0	50.0
8.0	65.0	58.3	60.3	56.8

(a) 3.5% in 2% NaCl solution.

(b) 3.5% in H_2O.

Rheological Properties

The evaluation of rheological properties was limited to the U.S.-C1 surimi sample. The initial intent was to begin with dilute solutions of the surimi and then work up to more concentrated systems. It was anticipated that 0-5% solutions would form uniform dispersions which could be characterized for their shear stress/shear rate characteristics using a cone and plate viscometer. At higher surimi levels where gelling would be important, the viscometry of the gels would be characterized using cross-bar spindles with the Brookfield viscometer.

In working with the surimi both in water and 2% NaCl systems, we found that the material does not form homogeneous solutions or stable dispersions at low concentrations. Rather, the material tends to flocculate and settle out of solution rather rapidly. Therefore, shear stress/shear rate measurements are not practical or meaningful.

When the concentration of surimi is raised to about 10 percent, the system has the consistency of thin mashed potatoes. From this point on it becomes progressively thicker, and above about 15 percent it becomes difficult to prepare uniform mixtures because of the rapid uptake of water to form elastic clumps.

Table 8 presents the results of viscosity measurements on 10 and 15 percent surimi systems in water and 2 percent NaCl. The results of holding at 40°C, as well as combined holding at 40°C and 90°C as is done in forming firm gels from frozen surimi, are also presented. It is clear that higher viscosities are obtained in salt solutions and that heating causes further firming of the gel structure. Holding for up to two hours at room temperature had no effect on the gel strength.

When surimi is mixed with water or salt solutions, even at 4°C, it binds the water very rapidly, and forms granular dispersions. At high concentrations of surimi, therefore, the thick, gelled structure also has a mealy or grainy characteristic. It resembles an instant starch gel which has been stirred after gelling.

TABLE 8. VISCOSITY OF U.S.-C1 FREEZE DRIED SURIMI IN WATER AND SALT SOLUTION AS A FUNCTION OF HEATING

	Viscosity (1000 cps)			
Concentration	In H_2O 15 min. @ 25°C	In 2% NaCl 15 min. @ 25°C	In 2% NaCl 15 min. @ 40°C	In 2% NaCl 15 min. @ 40°C/ 15 min. @ 90°C
10%	80	220	320	800
15%	1080	1600	1600	2000

Thick pastes or gels of surimi appear to be less adhesive than starch pastes or other proteins such as egg white. On the other hand, they are quite cohesive although less so than wheat gluten.

DISCUSSION AND CONCLUSIONS

Key Findings

On the basis of these studies of the functional properties of dried surimi, three properties appear to be most important in determining how surimi might be used as a food ingredient. These properties are:

1. Water binding
2. Gel formation
3. Odor.

Surimi has excellent water binding properties. While there are other hydrocolloids such as gums and modified starches which are more effective water binders, surimi is more effective than many proteins.

Dried surimi has interesting rheological properties when rehydrated. Its ability to form short elastic gels is the most unique feature. In this respect, it resembles some instant starch products. The rapid hydration and cohesive nature of surimi causes some problems in achieving uniform dispersions. Dilute suspensions of surimi are relatively unstable and settle out rapidly.

The distinctive odor of surimi even in very dilute solutions will be a significant factor in its use as a food ingredient.

While surimi does exhibit foam- and emulsion-stabilizing properties, these properties are not exceptional and it is doubtful if surimi would be selected for use based solely on these functionalities.

Potential Application Areas

Based on the key properties of dried surimi, each of the major categories where proteins and other hydrocolloid ingredients are commonly used was reviewed for potential application opportunities. Each of these categories is discussed below.

Bakery Products

Within the general category of bakery products, hydrocolloid materials such as natural and synthetic gums, starches, and proteins are used in items such as bread doughs and mixes, doughnuts, cake batters and mixes, icings and glazes, and pie fillings. They perform functions such as foam and emulsion stabilization, moisture retention, and syneresis control including freeze-thaw stabilization.

The water binding properties of surimi suggest that it could be used in icings and fillings to control syneresis or in frozen pie fillings to provide freeze-thaw stabilization. However, the availability of a wide variety of bland, inexpensive and effective modified starches make it extremely unlikely that surimi would be competitive in these applications.

The water binding and elastic gel properties of surimi also suggest that it might have some use as an ingredient in bread doughs although it does not have the elastic film forming properties of wheat gluten. Flavor could be a limiting factor in such a bland product. Product application studies would be needed to determine its usefulness in such products.

Beverages

Hydrocolloid materials are used to improve pulp suspension in fruit drinks, to stabilize beer foam, and to provide body to artificially sweetened beverages. The low solubility and poor suspension properties of surimi, in addition to its flavor, make it a poor candidate for these applications.

Dairy Products

Dairy products provide a significant market for many hydrocolloid ingredients. A variety of materials are used to control overrun and ice crystal growth in ice cream. Ease of dispersion, smoothness, and bland flavor are important properties in this application, as well as functionality at very low levels. Surimi would not be competitive with the natural and synthetic gums for this application.

Hydrocolloids are used in milk shakes, chocolate milk, and other flavored milk products for building body and stabilizing colloidal suspensions. Surimi could not compete with carrageenan and alginates in these applications.

Similarly, surimi would not be competitive in cottage cheese creaming mixtures, cheese spreads, yogurt, or whipped toppings where colloid stabilization and clean, bland flavor are important considerations.

Dressings and Sauces

Almost all pourable salad dressings contain hydrocolloids to control viscosity and stabilize suspended particles or emulsions. Normally, materials such as propylene glycol alginate or xanthan gum are used for this purpose since they provide the desired pseudoplasticity and emulsion stabilizing properties at concentrations below 0.5 percent without affecting color or flavor. Surimi would not be useful in such products.

Natural gums and starches are also used to modify viscosity and control syneresis in a variety of gravy and sauce products. Surimi does not have the necessary solubility and viscosity building properties required for most of these applications. However, it might be useful in providing a pulpy texture to a product such as spaghetti sauce. Specialty starches are used for this purpose currently. Surimi might work as well or better in this application, assuming that flavor is not a limiting factor.

Confectionary

Materials such as gum arabic, pectin starch, and gelatin are widely used in the confectionary industry in the manufacture of products such as gum drops, jujubees, cough drops, nougats, and marshmallows. In addition to providing the desired gelling properties, these materials control sugar crystallization and fat migration in such products. In most of these confectionary applications, it is important for the material to dissolve smoothly in the mouth. Surimi would not meet this requirement.

Meat Products

A number of materials, such as milk powder, dried whey, and various soy proteins, have been used as extenders and binders in processed meat products. Because of its excellent water binding and gelling properties, this is an attractive potential application for surimi. AFDF is currently funding research in this field of application. Legal problems and labeling considerations need to be considered in this application, as well as functionality, as AFDF is aware. However, from a technical point of view, meat products may be the most attractive potential application for surimi other than seafood analogs.

Pasta

Surimi's water binding and elastic gelling properties suggest that it might be useful as a protein supplement in pasta. It could have beneficial effects in maintaining the texture of pasta products which are thermally processed, such as canned products, or in dishes which are held under steam table conditions. Use application studies would be required to determine how surimi would function in pasta. Since these are basically bland products, flavor could be a problem. Nevertheless, this application area would represent a significant market and it merits further investigation.

Pet Foods

Surimi's functionality might be useful in formed or extruded products, such as intermediate moisture pet food products. Its use in these products would depend on how it might alter the processing properties of the dough and the textural properties of the final product. It would probably not be competitive just as another source of nutritional protein.

The original data for this program are recorded in Battelle Laboratory Record Book No. 40881.

REFERENCE

1. Gierhart, D. L., and N. N. Potter. 1978. Effects of ribonucleic acid removal methods on composition and functional properties of Candida utilis. J. Fd. Sci., 43: 1705.