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A Study of the Use of Cod, Cod By-Products and Crustacean By-Products for Surimi and Surimi-Based Products: Part III — Shellfish Flavour Extraction Studies

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A STUDY OF THE USE OF COD, COD BY-PRODUCTS AND CRUSTACEANS BY-PRODUCTS FOR SURIMI AND SURIMI-BASED PRODUCTS: PART III - SHELLFISH FLAVOUR EXTRACTION STUDIES

by

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Eleven of twelve identified taste-active components have been analyzed from crab and scallop wastes and commercially produced flavourants. Crab cooker water and crab leg shells and tip shells have been identified as good potential sources for flavour extracts. The rate of accumulation of flavour components in cooker water decreased after 2 hours of processing. Except for adenosine monophosphate, scallop offal and adductor muscle have equal contents of flavour-active components. Green pigment in scallop wastes constitutes a problem. A scallop-flavoured kamaboko product has been successfully developed. An extruder for texturizing kamaboko has been developed for producing scallop and crab-flavoured analogues on a laboratory scale.

RÉSUMÉ

Voigt, M.N. August 1986. A Study of the Use of Cod, Cod By-Products and Crustacean By-Products for Surimi and Surimi-Based Products: Part III - Shellfish Flavour Extraction Studies. Can. Ind. Rep. Fish. Aquat. Sci. 177 vii + 42 p.

On a analysé onze des douze composantes gustatives identifiées dans les déchets de pétoncle et de crabe et les assaisonnements commerciaux. L'eau de cuisson du crabe ainsi que les coquilles des pattes et l'avant de la carapace ont été reconnues comme de bonnes sources potentielles d'extraits de saveur. Le taux d'accumulation des composantes gustatives dans l'eau de cuisson a diminué après 2 h de traitement. Sauf pour le monophosphate d'adénosine, les issues et le muscle adducteur du pétoncle contiennent la même teneur en composantes gustatives. Le pigment vert retrouvé dans les issues de pétoncle constitue un problème. Du kamaboko à saveur de pétoncle ainsi qu'une boudineuse pour la texturation du kamaboko ont été mis au point. Celle-ci servira à la fabrication expérimentale d'analogues à saveur de pétoncle et de crabe.

PREFACE

A contract was awarded to a research team from the Newfoundland and Labrador Institute of Fisheries and Marine Technology (The Marine Institute) and Memorial University to study the potential of selected Canadian Atlantic fish species and shellfish processing wastes to produce surimi and shellfish flavours. Research to develop methodology for rapidly determining the potential of raw materials to produce surimi was initiated, objective laboratory techniques for evaluating the quality of surimi were established, a pilot line for producing surimi was installed, surimi was produced from cod and other groundfish. Some biochemical indices of cod were analyzed under various conditions of storage and methods were established which may assist as predictors of surimi potential from cod and possibly other species. Crab process wastes and scallop process wastes were analyzed for their contents of flavour-active components. Methods of concentrating flavours were identified.

Three separate publications from this contract were issued. Correct citation for these are:

Chandra, C.V. 1986. A Study of the Use of Cod, Cod By-Products and Crustacean By-Products for Surimi and Surimi-Based Products: Part I - Raw Material Assessment.

Haard, N. 1986. A Study of the Use of Cod, Cod By-Products and Crustacean By-Products for Surimi and Surimi-Based Products: Part II - Physiology Studies.

Voigt, M.N. 1986. A Study of the Use of Cod, Cod By-Products and Crustacean By-Products for Surimi and Surimi-Based Products: Part III - Shellfish Flavour Extraction Studies.

The opinions and interpretations expressed in the report are those of the author, and do not necessarily reflect those of the Department of Fisheries and Oceans.

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INTRODUCTION

American sales of surimi, mainly for preparation of shellfish analogues, have risen in five years from about two million to about three hundred million dollars in 1985 (Katayama, Pers. Comm.). The latter figure represents about 34.5 million kgs. (76 million lbs.) of products, with crab-flavoured surimi-based analogues accounting for more than eighty percent of the total (Katayama, Pers. Comm.). It is forecast that North American consumption of surimi-based products will rise to over three billion dollars worth in the early 1990's, and that market will include a variety of shellfish analogues (Anon. 1985); (Harris, 1984).

The North American supply of natural and surimi-based crab combined grew from 22.7 million kgs. (50 million lbs.) (meat weight) in 1974 to 63.5 million kgs. (140 million lbs.) in 1984 (Vondruska, 1985). Thirty million kgs.(66 million lbs.) of the increase was due to the introduction of the crab analogue. The yield of meat from the shellfish is relatively low, ie. about 30 percent from snow crab, 12 percent from the Giant scallop and 36 percent from the Icelandic scallop. As a result, large quantities of offal are produced. Processing of snow crab and scallop produced more than 24,000 and 70,000 tonnes respectively. In Atlantic Canada, the offal from shellfish processing is not utilized at this time, thus causing environmental and disposal problems. Shellfish wastes contain significant amounts of compounds responsible for flavour.

Recently, a process based on chelation and specific enzymic catalysis has been developed in Newfoundland for extraction of carotenoprotein and flavour components from shrimp offal (Simpson and Haard, 1985). Additional study is needed to determine the suitability of this process for recovering crab essence. A Canadian patent (No. 210795) has been filed by United Maritime Fisherman (Moncton, N.B.) for an enzymic process to extract flavourant from lobster shells with spray drying being used to produce a powder. It is recognized that the taste of protein hydrolyzates is influenced by the type and degree of protein hydrolysis (Godfrey and Reichelt, 1983), and this factor will be an important consideration in developing a method for recovering flavour essence from crustacean process offal. In this regard, it is known that a proteolytic enzymic preparation from the hepatopancreas of Atlantic short finned squid has been shown to promote the formation of a brothy, meaty flavour when used as a supplement to fermentation of squid (Lee et al., 1982) and to fish sauce prepared from capelin (Raksakulthai et al., 1986). The active enzyme appears to be cathepsin C (Hameed and Haard, 1985).

Flavourants for the processing of shellfish analogues in North America are currently imported from Japan. Costs for the flavourants in 1986 are 40 percent higher than in 1985 (personal communication with Dr. C. Ho, Terra Nova Fisheries, March 26, 1986). The primary objective of the shellfish flavourant research during the first contract period was to determine the suitability of crab offal as a raw material for production of a natural crab flavourant. Preliminary work was initiated on texturizing surimi/kamaboko analogues, and also on flavouring the texturized kamaboko with crab and scallop.

MATERIALS AND METHODS

COLLECTION OF SAMPLES

Samples from the processing line for male snow crab, **Chionoecetes opilio** were collected four times during the processing season with at least one week intervals between samplings. The following types of samples were collected: waste fluids (butchering, cooking, cooling, shoulder shell washer, leg roller exudate, tip roller exudate), shells (tips and legs, shoulders) and meat (tip, leg, shoulder). Live Icelandic scallops, **Chlamys islandicus,** were collected on the St. Pierre Bank in October, 1985. After shucking, the adductor muscle was packaged separately from the viscera and mantle in heat sealed 4.5 mm polyester film pouches (Kopak Corp., St. Louis, Minn.). All samples were stored at -20°C. Extractions were normally completed on the samples within one week of collection.

PREPARATION OF TEST MATERIALS

The taste-active components present in the samples of crab and scallop were prepared using a modified version of a method described by Konosu et al., 1978). The modifications were as follows:

a) Liquids: Strained through 1 mm^2 stainless steel wire mesh; 150 ml of sample placed in one litre Erlenmeyer flask; heated in a boiling water bath for 15 minutes; cooled in an ice bath; 600 ml absolute ethanol added; stirred; let stand for 15 minutes; filtered through Whatman No. 1 filter paper with suction; filtrate washed twice with 25 ml aliquots of 80 percent ethanol; filter residues discarded; filtrates

combined and evaporated to 150 ml under vacuum at 40°C. For sensory evaluation, the filtrates were brought to dryness under vacuum at 60°C and then reconstituted with water.

b) Shells: 100 g of shells combined with 100 ml of water and mascerated for 2 minutes in a Waring Blender; cooled in an ice bath; centrifuged at 15,000 rpm for 15 minutes; supernatant decanted into a 250 ml graduated cylinder; precipitate washed twice with 20 ml of water, all of the supernatants combined; volume brought to 150 ml with water; and then proceeded using the procedure described for broths.

c) Meats: 30 g of meat combined with 50 ml of water; mascerated for two minutes in a Waring Blender; heated in a boiling water bath for 15 minutes; supernatant decanted into a 100 ml graduate cylinder; precipitate washed twice with 20 ml water; all of the supernatants combined; the volume brought to 100 ml with water and transferred to a one litre Erlenmeyer flask; added 400 ml absolute ethanol with stirring let stand for 15 minutes, filtered through Whatman No. 1 filter paper with suction and washed twice with 25 ml aliquots of 80% ethanol; the filtrates combined and evaporated to 100 ml under vacuum at 40°C.

All extracts were stored frozen at -20°C.

CONTENTS OF SHELL

Ten millilitre aliquots of liquid samples were filtered through Whatman No. 1 filter paper. The filter paper that contained the insoluble residue, as well as the filtrate that contained the soluble solids were dried under vacuum at 40°C for 16 to 24 hours.

FREE-AMINO ACIDS

One ml of the extracts from the liquids, shells and meats were diluted with 9 ml of 0.1 M hydrochloric acid. Twenty mg of commercial crab flavourants were diluted to 10 ml with lithium citrate buffer (pH 2.2, 0.2N, containing 1% thiodiglycol and 1% phenol; Pierce Chemical Co., Rockford, Ill).). Samples were deproteinized with 10% sulfosalicylic acid (SSA; four parts of sample to one part SSA) and diluted 1:2 with lithium citrate buffer. Deproteinized samples were analyzed on a Beckman 121 MB Amino Acid Analyzer using Benson D-X8.25 resin (Benson Co., Reno, Nevada) in a single column and using the three buffer lithium method for physiological fluid analysis as per Beckman 121 MB-TB-017 application notes (1979, Beckman Instruments Inc., Palo Alto, CA).

INORGANIC IONS

The contents of sodium, potassium, chloride and phosphate (PO_4^{3-}) in the extracts were determined by using ion specific electrodes (Beckman Astra-8 for sodium, potassium and chloride but the Hitachi-705 Boehringer Mannheim Canada Ltd., Dorval, PQ for phospate). The results were confirmed using the Technicon Autoanalyzer II (Technical Canada Inc., Montreal, P.Q.) for chloride (ferricyanide/thiocyanate, Naquadat No. 17206) and phosphate (ammonium molybdate, Naquadat No. 15406). However, atomic absorption spectrometry (AA; Varian Canada Inc., Georgetown, Ont.) was used for sodium (Naquadat No. 11105) and potassium. For the Technicon and AA analyses, ca 0.2 g of samples were placed in 10 ml of 50% ultrapure nitric acid (Seastar Chemicals, Sydney, B.C.) and left for one hour. The samples were heated

gently without being allowed to dry for two hours, the volumes were adjusted to 100 ml with Type One water (Barnstead Nanopure Ion Exchange System, Barnstead Company, Pickering, Ont.), and then the samples were analyzed using the application notes cited above.

NUCLEOTIDES

A reverse phase High Pressure Liquid Chromotography (HPLC) procedure was used for the analyses of nucleotides. The chromotograph was a Waters (Water Associates, Inc., Milford, MA) equipped with two solvent delivery pumps (Model 6000A), solvent programmer (Model 660) and a universal injector (Model U6K). A fixed wavelength detector (Model 440) monitored the effluent at 254 nanometer. A HP 3390 integrator (Hewlett Packard Ltd., Mississauga, Ont.) was used for the calculation of peak areas and retention times. A micro Bondapak TM C18 stainless steel column (3.9 mm I.D. x 30 cm. Waters No. 27324) was employed for the separations. The buffer (0.05M sodium dihydrogen orthophosphate, Analar grade, BDH Chemicals, Toronto, Ont.) was prepared fresh every second day in double distilled water, adjusted to pH 4.70 with 1.0 M phosphoric acid (Reagent grade, Caledon Laboratories, Georgetown, Ont.) or 1.0 M sodium hydroxide and filtered through a 0.45 micrometer Millipore filter disc (Millipore Ltd., Mississauga, Ont.). The standards were dissolved in double distilled water and diluted to desired concentrations (ca 25ug/ml). Adenosine, cytidine, guanosine, uridine and their mono, di and triphosphates were purchased from Sigma Chemical Co. (Kit No. K100-25A; St. Louis, Mo.). Other standards were inosine monophosphate (Boehringer Mannheim Ltd., Dorval, P.Q.)

inosine, hypoxanthine and uric acid. All samples were homogenized before analysis. A 1 g sample was weighed into a 10 ml volumetric flask, 5 to 7 ml of 0.05 M pH 4.70 buffer was added, dissolation was assisted by ultrasonication for 10 minutes, and finally the solutions were diluted to volume. Extracts of the samples were then filtered through a 0.45 micrometer Millipore filter disc and injected into the HPLC system (5 to 40uL). The eluting program was isocratic with a flow rate of 1 ml/minute. The eluted peaks were identified by their retention times and peak areas were used for quantification.

BETAINE

Glycine betaine was determined using the sample preparation procedure by Hayashi et al. 1978 and the method of Konoso and Hayashi (1975) for separation and quantification. Five ml of the extracts prepared as described above were used for the analyses.

BREADING AND BATTER SYSTEMS

Scallop flavoured and texturized kamaboko was coated with six breading and tempura battering systems at Griffith Laboratories (Scarborough, Ont.). "Consumer" (prefried) rather than "institutional" type (un-fried) products were prepared. For the breading systems, the kamaboko was predusted with Predust 1559, battered with Kristobatter 4543 (07.2520) and then breaded with the following:

1. Kristobreading 7697 (a blend of tender homestyle and crisp Japanese style crumbs).

2. Kristobreading 8025 (low density Japanese style crumbs).
3. Kristobreading 8035 (toasted Japanese style crumbs), or
4. Kristobreading 8048 (crispy Japanese style crumbs that maintain good texture over prolonged freezer storage).

The coated kamaboko products were blanch fried for 30 sec at 199°C and stored frozen at -20°C. To reconstitute in an oven, the oven was set at 204°C and the products were baked 12 to 17 min. with turning of the products halfway through the cooking time. For the tempura battering systems, the kamaboko was predusted as previously and then battered with the following:

1. Kristobatter 4582 (a tender crisp leavened batter), or
2. Kristobatter 4584 (a crisp leavened batter).

The coated kamaboko products were blanch fried for 40 seconds at 199°C and then stored frozen at -20°C. The tempura products were reheated by baking for 10 to 15 minutes at 204°C with turning of the product halfway through the cooking time. The Kamaboko was tempered at 5°C before pre-dusting.

TEXTURIZATION

Uncooked crab-flavoured kamaboko was obtained from Terra Nova Fisheries and was blended with 10% homogenized scallop adductor muscle plus 2% Instant clear gel (pregelatinized corn starch, Griffith Laboratories, Scarborough, Ont.). The kamaboko was texturized by extrusion through a die system that produced a product that had a uniform skin on the surface and a

fibrous texture on the interior. After extrusion, the texture of the kamaboko was set by passing the product through a steam tunnel for 20 minutes and cooking in a humidified oven at 90°C for 20 minutes.

TASTE

Vocabulary for describing the taste characteristics of natural and synthetic extracts of snow crab has been developed by Hayashi et al., (1981a). Nine taste sensations were shown to be of primary importance, ie. umami (monosodium glutamate-like taste or mouth satisfying meaty taste), sweetness, saltiness, complexity, fullness, naturalness, continuance, viscosity and extension. Omission tests with synthetic crab extracts that examined the effect of omitting each of the twelve taste-active components of the synthetic extract resulted in the following findings by Hayashi et al., 1981b:

1. Omission of amino acids resulted in a decrease in sweetness, saltiness, aftertaste, body and crab-taste.
2. Omission of nucleotides weakened the characteristic crab-taste, sweetness and umami.
3. Omission of betaine resulted in declines in marine umami, sweetness and aftertaste.
4. Omission of inorganic ions markedly decreased crab-likeness, sweetness and umami, while bitterness increased slightly.

The twelve taste-active compounds that were identified by Hayashi et al. 1981b to be important for the taste of snow crab were also analyzed for in the research reported here.

An untrained panel of six experienced panelists, four females and two males ranging in age from 20 to 44, was used to evaluate the scallop-flavoured kamaboko. Panel judges were staff members, faculty and students in the Food Science Group at Memorial University of Newfoundland. Samples of the reconstituted products were assessed by preference testing using a nine point hedonic scale to evaluate colour, flavour, texture and overall acceptability as described by Larmond (1977). Statistical analyses for differences were performed by using analysis of variance with statistical significant set at $P \leq 0.05$. Least significant differences (LSD) were calculated by employing the multiple comparison method outlined by the American Society for Testing Materials (ASTM..., 1968). Only one session was conducted for the four sensory characteristics examined (colour, flavour, etc.).

For the evaluation of the extracts obtained from the processing line for crab and also for the commercial crab flavourants, the samples were presented to panelists in 250 ml beakers for the evaluation of characteristic odour. About 100 ml of the extracts obtained from the processing line for crab were brought to dryness *in vacuo* at 60°C in the beakers prior to evaluation. The commercial crab flavourants were evaluated as obtained. The panelists were only informed that the samples were crab extracts or flavourants and were asked to provide terminology to describe the odours of each sample. Only one session was conducted with the six panelists.

EQUIPMENT

Pilot scale reverse osmosis and swept-surface flash evaporation equipment were identified as being essential for the development of processes for concentrating shellfish flavourants.

A laboratory scale extrusion and thermal processing unit for texturizing kamaboko products was designed and built. A proposal was submitted to the Department of Fisheries and Oceans for the development and construction of an industrial scale extruder. A laboratory scale minced fish washer/de-waterer unit for the processing of surimi was also designed and built. Funding for designing and fabricating the pilot scale extruder and the minced fish washer was not provided by the DFO contract.

RESULTS AND DISCUSSION

COOKER WATER AS A SOURCE OF FLAVOURANT

Cooker water from the crab processing line was identified as being the initial source of raw material for producing a crab flavourant. Therefore, the rate of accumulation of solids (soluble and insoluble) in the cooker water from a continuous crab processor was measured (Fig. 1, App. Table 6). The rate of accumulation of solids decreased markedly after 2 hours. The concentration of solids reached a value of about 1.5% with the soluble fraction representing about half of the total. This indicates that cooker water could be continuously withdrawn after 2 hours and then either cooled and stored or fed directly into a flash evaporator. Feeding directly to a flash evaporator would have the advantage of utilizing the heat carried

with the hot liquor for partially providing the heat of vaporization for the vacuum flash evaporator.

The second option would be to transfer the cooker water from the continuous cooker at greater than 2 hour intervals to a storage tank after filtering and cooling. This approach would permit all of the cooker water to be concentrated after a critical volume has been accumulated. Disadvantages of this batch approach is the greater opportunity for thermal damage, the high energy requirements for cooling and reheating and also the need for substantial cold storage tanks. If the evaporation facility was not located within the crab processing plant, bulk storage of cooker water would be necessary.

The predicted yield of concentrated soluble solids per day (based on the 24 hour processing day at the Bay de Verde, Newfoundland plant, was calculated at 2143 L/batch x 12 batches/day x 0.75% soluble solids = 193 kg (dwb)/day. This was given an estimated value of $10 - $25/kg = $1930 to $4825/day. However, using the 1986 cost paid by a local shellfish analogue processor = 193 kg (dwb)/day x $87/kg (dwb) = $16,891/day. Assuming a 200 day crab processing season, the value of the crab flavourant would be about $386,000 to $965,000. The yields would be dramatically affected by the type of system(s) used to remove insoluble solids or to hydrolyze insoluble solids. Further treatment of shells may also contribute to increased yields.

CONTENTS OF TASTE-ACTIVE COMPONENTS

The contents of selected taste-active components and solids (soluble, insoluble and total) in samples obtained from a commercial line for processing crab are listed in Tables 1 and 2, respectively. Appendix Tables 1 and 2, respectively, provide a comprehensive report of the contents of free-amino acids (and other ninhydrin-positive substances) and of nucleotides and their metabolites in the samples obtained from the line for processing crab. The higher level of sodium in the butchering and shoulder water and also in the shoulder meat reflects the usage of seawater in these steps. In addition, the employment of seawater affected the odour of the vacuum dried residues of extracts obtained from these steps in the process (Table 9). The leg meat contained the highest concentration of the selected taste-active components.

The contents of these selected components decreased by approximately 50 percent decrements in the following order: a) in tip meat, b) in cooker water and in water collected from the tables where the tip meat was expressed from the shell, c) in water collected from the tables where the leg meat was expressed from the shell, in the shoulder meat and in the extracts from the tip/leg shell, d) in the extracts from the shoulder shell, and e) in the water used to wash the shoulder meat from the shoulder shell.

The concentrations of these components were the lowest in butchering and cooling waters. The crab cooker water and the extracts of leg meat showed the highest levels of nucleotides and their degradation products (Table 1 and App. Table 2). The shoulder meat contained markedly lower

amounts of these taste-active substances, compared to leg and tip meats, due to the large volumes of water used to separate this meat from the cavities in the shoulder shell. The same leaching effect resulted in lower contents of these substances in shoulder vs tip/leg shells.

The concentration of soluble solids present in the samples obtained from the crab processing line (Table 2) decreased from 3.3 to 0.45 percent in the following order: leg meat, tip meat, butchering water, cooker water and shoulder water (both 1.50), shoulder shell, tip/leg shell, cooler water, leg water. Thus, after considering the contents of selected taste-active components and soluble solids, the odour of the vacuum-dried residues, and the quantity of by-product raw material produced, cooker water was selected as the initial raw material for producing a natural crab flavourant. The tip/leg shells and the juices collected from the tables where the leg and tip meats were expressed from the shells also showed potential as raw materials; seawater would need to be eliminated from these processing steps, however. Enzymic or other chemical treatments would be needed to increase the yield of soluble solids from the shells.

The analyses of the selected taste-active components in the commercial crab flavourants shows that the product identified by the trade name gulesen is essentially glycine (Table 4). The ingredients entitled 'crab extracts' or 'seasoning base' contained the highest levels of these flavour-active components (Tables 3 and 4). Guanine and inosine monophosphates were the important nucleotide components present in the commercial crab flavourants (Table 3). The relative ratios of the selected flavour-active components in these crab flavourants, as well as in the

natural, will be important markers in targeting the levels of these components to be used in producing crab flavour bases from the flavour concentrates obtained from the cooker water. The author is aware of the compounds comprising the various trade-named ingredients of commercial crab flavourants; these cannot be revealed due to a secrecy agreement. The analyses completed in this research reveals the ratios of some of these compounds.

The contents of selected taste active compounds and solids (soluble, insoluble and total) in adductor muscle and offal (Visera and Mantle) of scallops are listed in Tables 5 and 6, respectively. A comprehensive listing of other ninhydrin-positive substances and nucleotides and their degradation products are listed in App. Tables 4 and 5, respectively. The results show that only adenosine monophosphate occurs at a markedly lower concentration in the offal, and thus may need to be fortified. As yet, commercial scallop flavourants have not been analyzed. A problem that needs to be solved in order to utilize the scallop offal is the presence of a dark green colour due to the ingestion of plankton by the scallops.

The analyses for the content of glycine betaine in the crab and scallop samples are incomplete. The procedure is a tedious protocol that only permits one analysis per day. However, the protocol has yielded good recoveries from spiked samples (about 97%), even though four chromotographic columns are employed.

SENSORY EVALUATION

The results of the sensory evaluation on certain commercially available crab and scallop flavourants are reported in Tables 7 and 8, respectively. The crab flavourants were grouped into those that were considered to be of good vs fair to poor quality. The strength, crab or scallop-likeness and presence of off-notes in the flavourants were reported. The Bibun products were also subjected to compositional analyses. The Bibun products are currently being formulated into the crab analoques being processed at Terra Nova Fisheries.

The odours of extracts dried in vacuo obtained from sampling at the various stages of the processing line for crab are reported in Table 9. A distinctive and unpleasant seawater odour was present in extracts of liquid samples where seawater was employed in the operation (ie. butchering water and in water used for dislodging meat from the shoulder shell cavities). The dried extract from the meat washed from the shoulder shells did not possess a crab-like odour and contained several off-notes. The leaching accentuated undesired attributes. The most desirable odours were present in the dried extracts from the cooker water, tip/leg shells, leg meat and tip meat. A comprehensive listing of the terms suggested by the sensory evaluation panelists for characterizing the odour of the crab is presented in Table 10.

SCALLOP FLAVOURED KAMABOKO

A scallop-flavoured kamaboko product was produced by incorporating 10% homogenized adductor muscles from scallops. The scallop analogue paste was texturized, cooked, chopped and then either breaded or tempura battered. The results of the sensory evaluation on four types of breadings and two types of tempura batters are listed in Table 11. Breading 8035 resulted in a product with a significantly greater overall acceptability compared to the other coatings ($P = \leq .05$). The tempura coated products were the least preferred. The judges praised the taste of the scallop analogues, although the texture of the product is softer than may be desirable.

EQUIPMENT

The pilot scale extrusion system that was developed for texturizing shellfish analogues prepared from kamaboko is shown in Fig. 2. The diameter of the extruder stream can be altered by changing the extruding die. The size of the fibers in the extruded stream can also be selected. Fig. 3 is a photograph of cooked and texturized shellfish kamaboko products. Of particular interest is the smooth surface skin which encloses the fiber core. The texture of the extruded kamaboko is also affected by the thermal processing protocol as well as by the extrusion aids that are blended into the kamaboko. The existing unit produces batches of either a crab or a scallop analogue every 20 minutes. A longer thermal tempering tunnel would permit the unit to operate continuously.

The system developed for washing and dewatering minced fish for producing surimi is shown in Fig. 4. The unit rotates a perforated stainless steel basket containing the minced fish at a low speed for washing, but for dewatering the rate of rotation is increased markedly. Two washing modes are available, ie. either by using the spray nozzles present in the interior of the basket or by filling the tank to immerse the basket. The unit is semiautomatic in that it can be operated by a timed control module.

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Fig. 1. Concentration of solids in cooker water obtained from a continuous crab processing line.

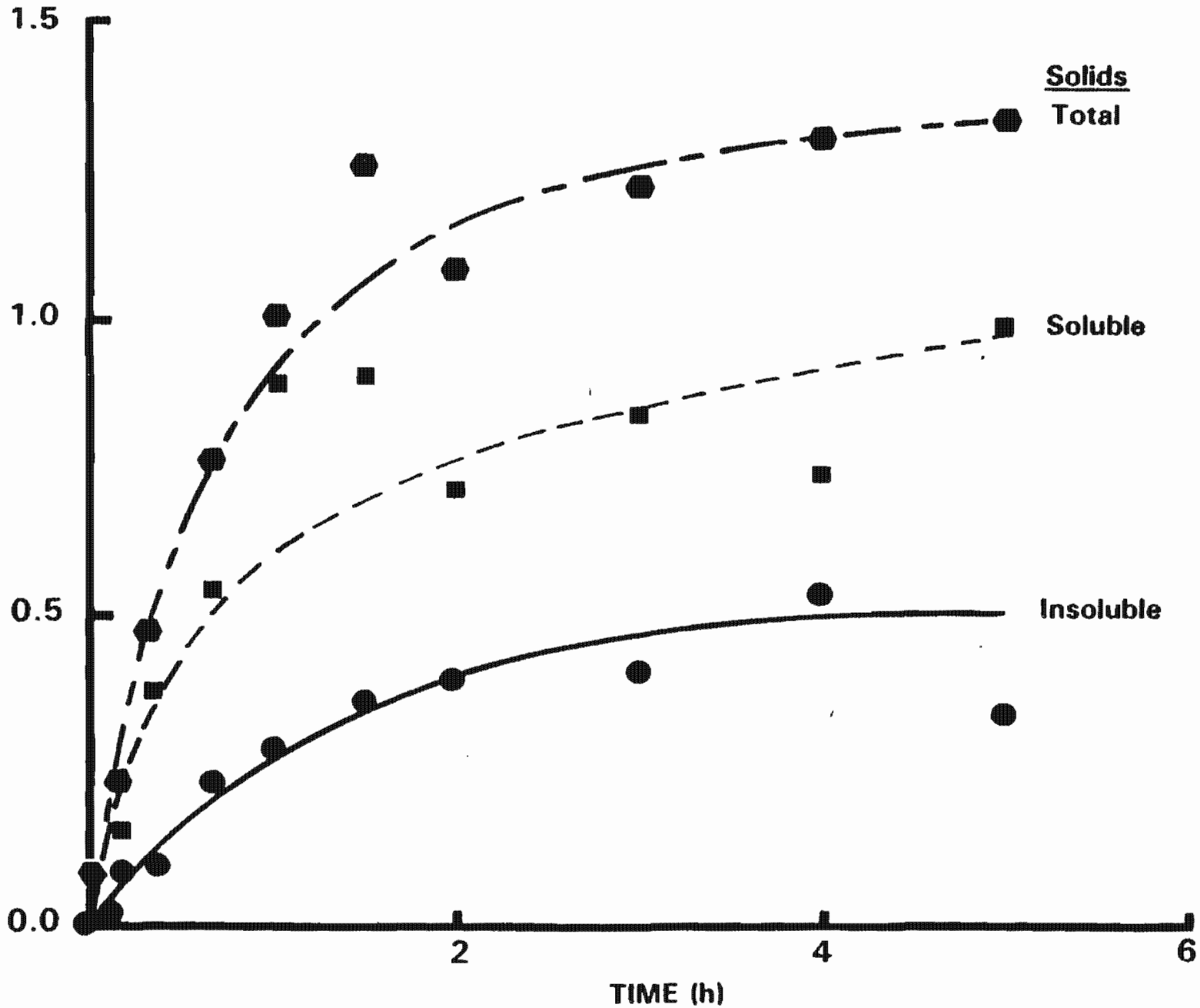


Fig. 2. Pilot scale extrusion system for texturizing surimi/kamabok (left: extrusion unit, right: thermal unit).

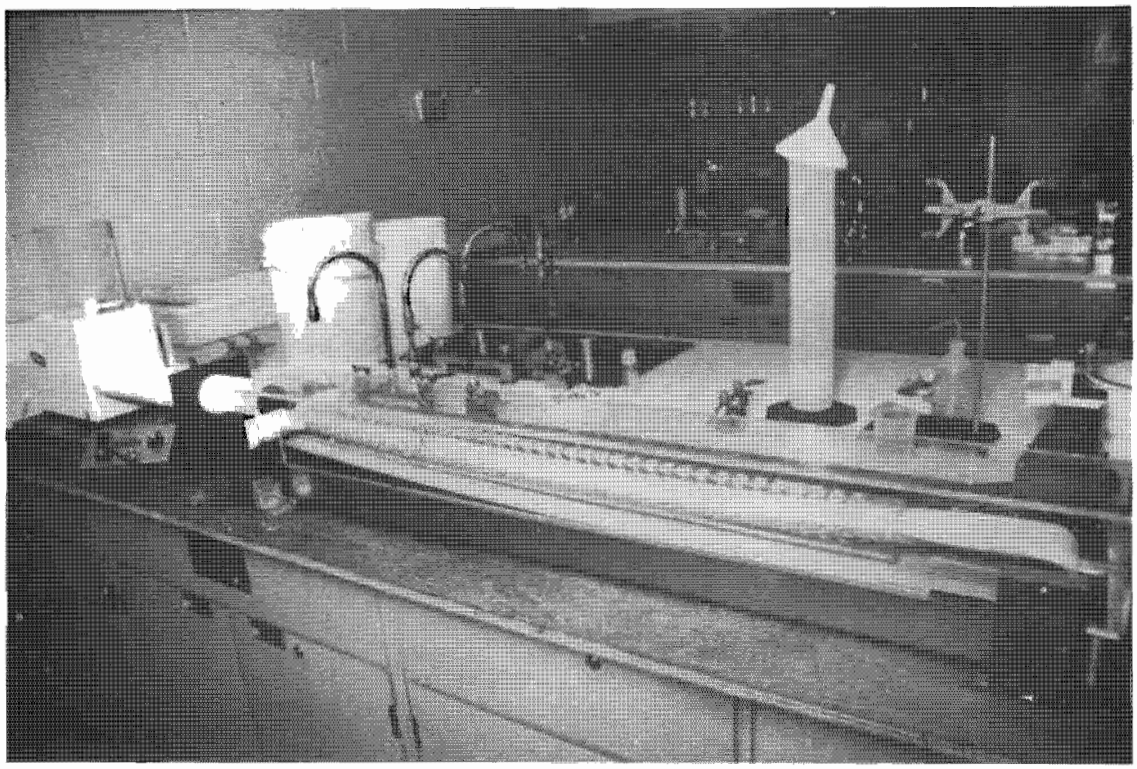


Fig. 3. Texturized surimi/kamaboko products.

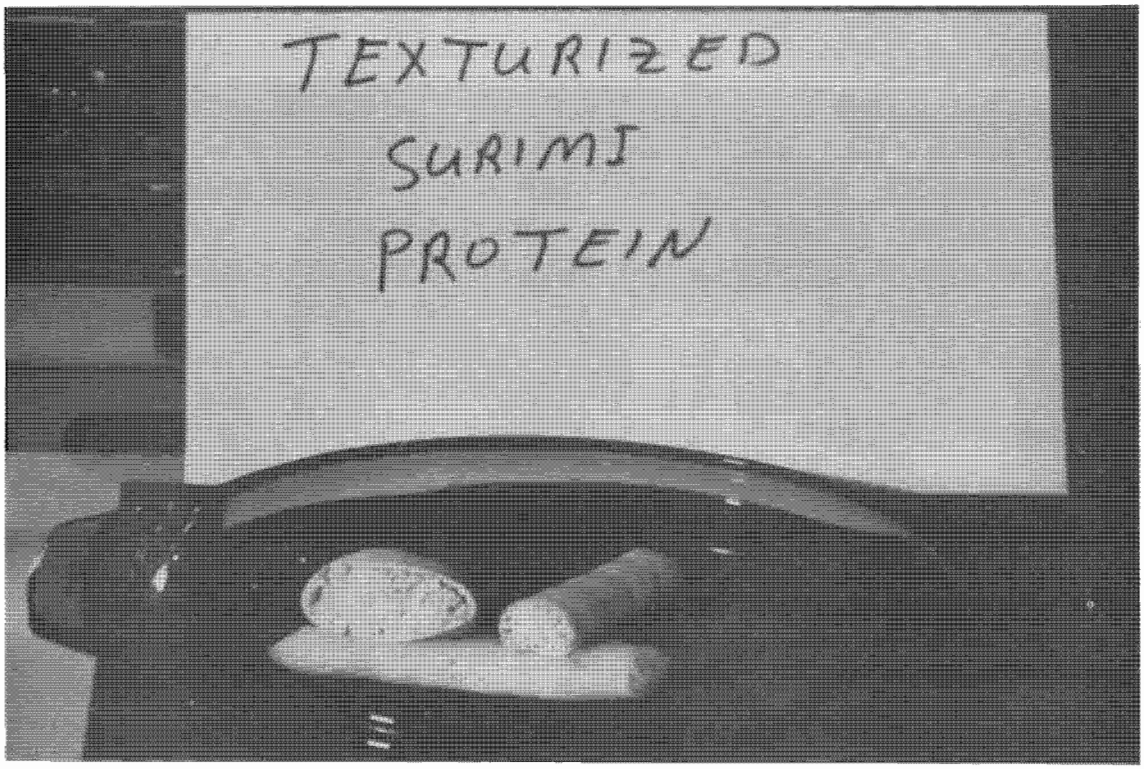
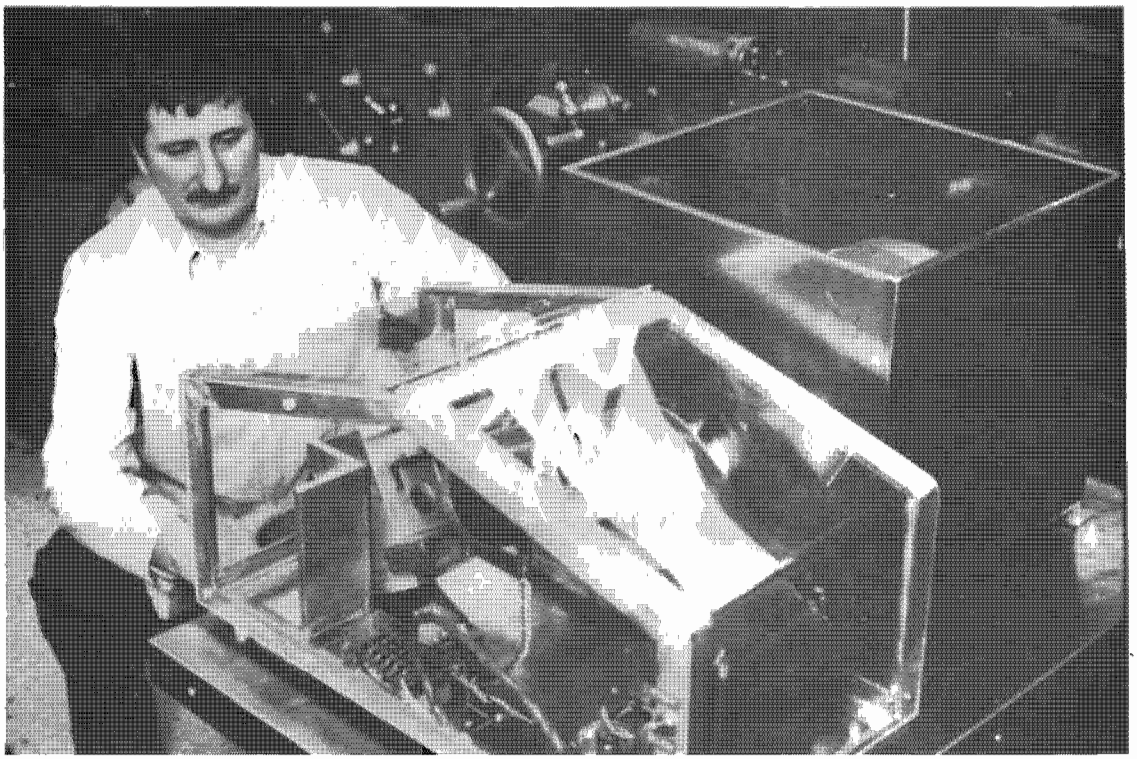


Fig. 4. System for washing and dewatering minced fish for the producing surimi (top: multiple speed drive system, bottom: perforated stainless steel basket that retains the minced fish).



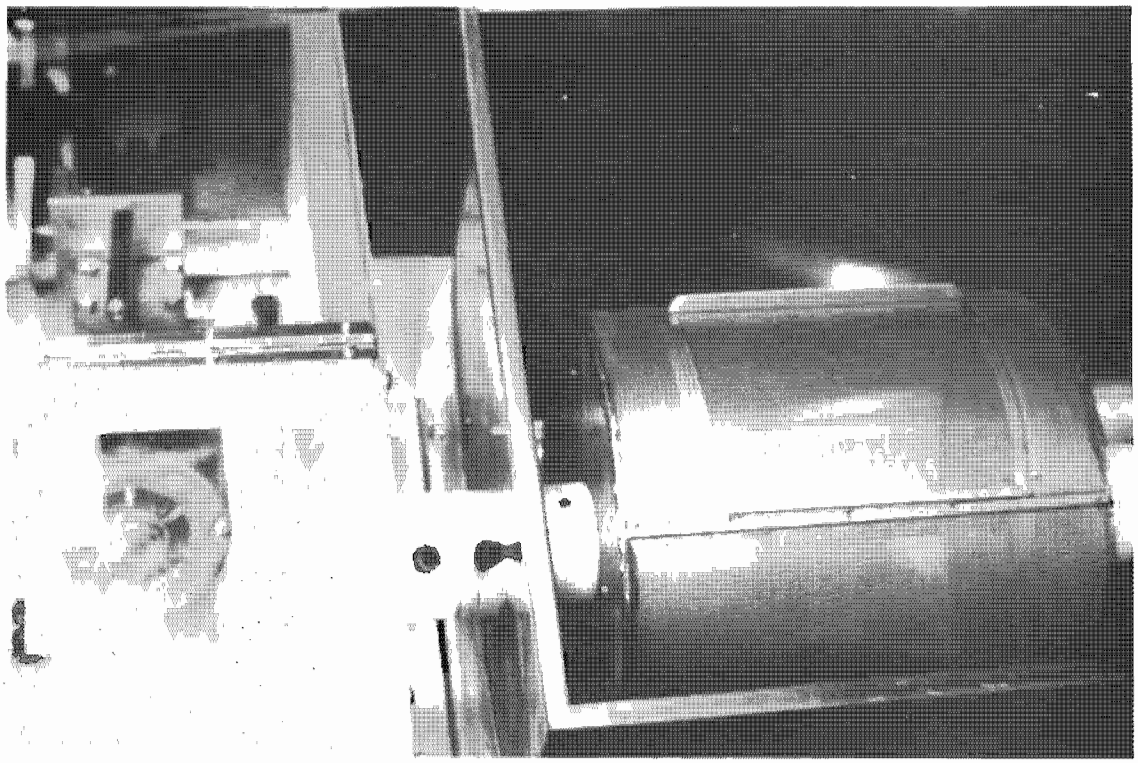


TABLE 1. CONTENTS OF IDENTIFIED TASTE-ACTIVE COMPONENTS IN SAMPLES OBTAINED FROM THE PROCESSING LINE FOR CRAB

Component (Unites/g or mL)	Subsamples from the line for the processing of crab[a]										
	Butchering water[b]	Cooker water	Cooler water	Shoulder water[b]	Leg water	Tip water	Shoulder shell[b]	Tip/leg shell	Leg meat	Tip meat	Shoulder meat[b]
Alanine (nmol)	94.5±140	3270±870	68.4±31	516±480	2130±1510	3910±1400	1370±560	2810±890	15200±4800	6920±4500	2210±930
Arginine (nmol)	93.2±140	3330±770	60.1±39	550±470	2580±1880	4160±1160	2100±550	3550±950	21700±5500	8590±4700	4410±1800
Glycine (nmol)	130±140	10100±2350	243±92	1750±1470	6520±4520	10200±2400	4580±1500	8570±2100	41200±16000	18500±12000	6310±2200
Glutamic acid (nmol)	12.8±24	353±110	3.30±4.7	69.2±76	166±120	377±110	126±40	310±94	926±260	552±350	174±100
Chloride (umol)	420±62	121±31	ND[c]	219±12	16.5±21	36.8±12	15.8±18	36.5±13	58.3±41	28.3±33	139±18
Phosphate (umol)	0.03±0.01	0.06±.03	0.06±0.02	0.05±0.02	0.42±0.14	0.06±0.36	0.15±0.08	0.15±0.03	13.6±4.0	3.43±2.2	0.47±0.07
Potassium (umol)	8.45±2.0	17.3±4.4	ND	4.90±0.42	6.00±5.0	10.2±2.0	4.95±3.6	13.6±2.70	37.6±26	16.7±12	7.33±0.47
Sodium (umol)	328±52	118±36	ND	204±18	16.3±15	28.5±7.4	19.5±15	46.2±7.7	45.0±33	32.5±24	116±28
Adenosine monophosphate (nmol)	<15.2	90.9±28	<15.2	<15.2	72.9	122	41.5	93.0±80	569±280	142	100
Inosine monophosphate (nmol) + Guanine monophosphate (nmol)	<5.77	45.3±8.1	<5.77	8.08	33.5	50.5	22.5	32.2±24	262±100	119	43.2

[a]Mean ± standard deviation of four values obtained from four separate sampling dates. If a standard deviation is not listed the samples were pooled prior to analysis.

[b]Seawater employed for the operation.

[c]Not detected at levels less than ca 0.1 nmol/mL or g.

TABLE 2. CONTENT OF SOLIDS IN SAMPLES OBTAINED FROM THE PROCESSING LINE FOR CRAB

	Subsamples from the line for the processing of crab (% solids)[a]										
Solids	Butchering water[b]	Cooker water	Cooler water	Shoulder water[b]	Leg water	Tip water	Shoulder shell[b]	Tip/leg shell	Leg meat	Tip meat	Shoulder meat[b]
Soluble	2.60±0.21	1.50±0.24	0.47±0.06	1.50±0.27	0.45±0.35	0.90±0.20	0.65±0.11	0.63±0.40	3.30±0.49	2.00±0.77	1.10±0.31
Insoluble	0.80±0.04	0.65±0.24	0.01±0.00	0.04±0.03	0.90±0.10	0.20±0.10	43.7±12.0	43.7±3.40	18.6±0.81	11.5±1.23	12.4±1.59
Total	2.68±0.25	2.15±0.48	0.06±0.06	1.54±0.30	0.54±0.45	0.54±0.45	44.3±3.80	43.3±3.80	19.9±1.30	13.5±2.00	13.5±1.90

[a]Mean ± standard deviation of four values obtained from four separate sampling dates.

[b]Seawater employed for the operation.

TABLE 3. CONTENT OF NUCLEOTIDES AND THEIR METABOLITES IN COMPONENTS OF COMMERCIAL CRAB FLAVOURS

	Nucleotides and metabolites (nmol/g)							
Ingredients	Adenosine diphosphate	Adenosine monophosphate	Adenosine triphosphate	Guanine monophosphate	Hypoxanthine	Inosine	Inosine monophosphate	Uric acid
Crab extract (Bibun)	0.328	1.37	0.276	25.9	0.471	1.23	29.6	< 2.98
Crab extract NH (Bibun)	0.258	1.03	< 0.197	16.4	1.03	1.38	19.3	< 2.98
Crab flavour (Bibun)	0.220	0.820	0.168	ND[a]	0.471	< 0.746	ND	<1.19
AK crab flavour P	0.143	0.851	0.101	7.59	1.84	0.784	10.1	< 2.98
AK crab extract NH	< 0.468	0.577	<0.394	10.6	0.390	1.53	13.1	< 2.98
Seasoning base BT	< 0.468	0.608	0.730	2.93	0.956	1.19	16.3	< 2.98

[a]Not detected at less than 0.1 nmol/g.

TABLE 4. CONTENT OF TASTE-ACTIVE COMPONENTS AND SOLIDS IN COMPONENTS OF COMMERCIAL CRAB FLAVOURS

Ingredients	Amino acids (nmol/g)				Ions (umol/g)				Nucleotides (nmol/g)		Solids (%)[a]
	Alanine	Arginine	Glycine	Glutamate	Chloride	Phosphate	Potassium	Sodium	Adenosine monophosphate	Guanine monophosphate	
Gelmin	ND[b]	ND	ND	ND	ND	ND	2210	1010	NDT[c]	NDT	89.2
Crab gold	ND	ND	ND	ND	ND	5.77	ND	ND	NDT	NDT	89.7
Fresh P	ND	ND	ND	ND	ND	51.9	ND	1180	NDT	NDT	91.5
Crab extract	170000	75200	5750000	1480000	4420	5.77	ND	5190	1.37	25.9	96.6
Wakesee starch	ND	ND	1900	1200	ND	ND	ND	ND	NDT	NDT	88.8
Pulran	ND	ND	3000	ND	ND	ND	260	ND	NDT	NDT	92.8
Guleaen	ND	ND	12200000	700	ND	ND	ND	ND	NDT	NDT	97.1
Aage	7000	ND	6800	12000	ND	ND	ND	ND	NDT	NDT	6.82
Silkpolly	ND	ND	ND	ND	ND	ND	ND	ND	NDT	NTD	63.9
Crab extract NH	6720	4690	124000	246000	3080	5.77	ND	2880	1.03	16.4	51.3
Crab flavour	879	404	1080	30300	ND	ND	ND	ND	0.820	NDT	47.7
Gel-Ace P	ND	ND	ND	ND	ND	0.96	ND	ND	NDT	NDT	98.6
AK crab flavour P	10400	1000	6200	871000	ND	3.85	ND	1250	0.851	7.59	89.5
AK crab extract NH	7000	4700	153000	359000	2400	5.77	ND	2120	0.577	10.6	59.5
Seasoning base BI	195000	48700	588000	3130000	2400	24.0	57.7	4130	$<$ 0.608	2.93	77.9

[a]Total.

[b]Not detected at levels less than ca 0.1 nmol/ml or g.

[c]Not determined.

TABLE 5. CONTENTS OF SELECTED TASTE-ACTIVE COMPOUNDS IN ICELANDIC SCALLOPS

Compound (Units/mL or g)	Subsamples of butchered scallops[a]	
	Adductor muscle	Viscera and mantle
Alanine (nmol	5310±1110	6950±1160
Arginine (nmol)	4980±2570	7710±2230
Glycine (nmol)	78600±24800	79800±22300
Glutamic acid (nmol)	2370±2200	2960±915
Chloride (umol)	33.0±0.0	204±12
Phosphate (umol)	12.9±4.3	5.45±1.7
Potassium (umol)	50.0±0.0	42.0±4.0
Sodium (umol)	37.7±7.7	222±11
Adenosine monophosphate (nmol)	236±290	<50.6±0.0
Inosine monophosphate (nmol) + Guanine monophosphate (nmol)	92.1±61	69.1±5.3

[a]Mean ± standard deviation of three values representing three separate extractions from the same collection lot of scallops.

TABLE 6. CONTENTS OF SOLIDS IN BUTCHERED ICELANDIC SCALLOPS

Solids	Subsamples of butchered scallops (% solids)[a]	
	Adductor muscle	Viscera and mantle
Soluble	1.47±0.12	1.90±0.87
Insoluble	17.4±0.10	12.3±1.14
Total	18.9±0.21	14.2±1.86

[a]Mean ± standard deviation of three values representing three separate extractions from the same collection lot of scallops.

TABLE 7. SENSORY EVALUATION OF COMMERCIALLY AVAILABLE CRAB FLAVOURANTS

Quality/Product	Supplier	Comments
Good quality:		
Crab extract powder (1300)	Nikken Food	Crab-like, needs to be enhanced
Natural and artificial crab flavour powder (EP-14835)	Norda	Crab-like lingering note, artificial note
Natural crab flavour (71-06779)	Naarden	Crab-like
Natural and artificial crabmeat flavour (NAF-2773)	T. Haseqawa	Crab-like aroma and taste
Crab flavour	Bibun	Crab-like, clean
Crab extract	Bibun	Crab-like, medicinal, no ammonia
Ak crab flavour P powder	Bibun	Crab-like, lingering, no ammonia
Fair to poor quality:		
Crab flavour extract powder (3700)	Intek	Brothy, slightly fishy, fair crab flavour
Taste of crab (R6388)	Haarman & Reimer	Mild fishy note, weak crab flavour
Natural and artificial crabmeat flavour (NAF-2774)	T. Hasegawa	Very weak flavour
Crab flavour extract powder (3700)	Intek	Slightly fishy, whole crab flavour, brothy
Ak crab extract	Bibun	Not crab-like, medicinal, brothy no ammonia
Seasoning base BT	Bibun	Bouillon, spicey, sweet, MSG, salty, not crab-like

TABLE 8. SENSORY EVALUATION OF COMMERCIALLY AVAILABLE SCALLOP FLAVOURANTS

Product	Supplier	Comments
Natural and artificial scallop flavour (TH 620)	T. Hasegawa	Scallop-like, slightly acidic, bitter and astringent aftertaste.
Scallop flavour extract powder 3500	Intek	Reacted HVP-like taste, slightly more fishy than Kikkoman product
Scallop extract 5650	Kikkoman	Reacted HVP-like flavour note

TABLE 9. EVALUATION OF ODOUR OF VACUUM DRIED RESIDUES OF EXTRACTS OBTAINED FROM THE PROCESSING LINE FOR CRAB

Sample	Comments[a]
Liquids:	
Butchering[b]	Fishy, seawater, unpleasant, not crab-like
Cooker	Crab-like, ammonia
Cooler	Tobacco, cow-barn-like
Shoulder[b]	Fishy, seawater, sharky, not crab-like
Shells:	
Tip, leg	Crab-like, ammonia
Shoulder[b]	Mild, ammonia, dried fish, not pleasant, crab-like
Meats:	
Leg	Clean, crab-like
Tip	Mild, clean, crab-like
Shoulder[b]	Cod liver oil-like, hay-like, not crab-like

[a]Results from six experienced panelists.
[b]Seawater employed.

TABLE 10. DESCRIPTION TERMS FOR RANKING QUALITY AND STRENGTH OF ODOUR OF CRAB FLAVOURANTS

Flavour note	Flavour note
ammonia	intence (not)
aromatic	lingering
astringent	medicinal
beef extract-like	MSG-like
bitter	minty
boullion-like	musty
briney	oniony
brothy	pleasant (not)
burnt	poor
clean	
cod liver oil-like	putrid
cow barn-like	rancid
crab-like (not)	reacted sugar
dried fish-like	roasted
dried shrimp-like	seawater-like
dried squid-like	seaweedy
fishy	sharky
good	spicy
green vegetable-like	sweet
hay-like	tobacco-like
HVP-like	yeasty

TABLE 11. RESULTS OF ANALYSIS OF VARIANCE ON THE PREFERENCE TESTING BY HEDONIC SCALE EVALUATION OF THE SENSORY CHARACTERISTICS OF BREADED AND TEMPURA BATTERED SCALLOP FLAVOURED AND TEXTURIZED SURIMI

	Hedonic score[a]			
Breading system[b]	Colour	Flavour	Texture[c]	Acceptability
Breading 8035	8.3±0.5a	7.7±0.5a	7	8.2±0.4a
Breading 7697	7.7±1.5ab	6.2±1.5c	5	7.2±1.6
Breading 8048	7.0±1.4c	7.7±0.5a	6	7.2±0.8b
Breading 8025	7.3±0.8bc	7.3±0.8a	7	7.3±0.5b
Tempura 4582	6.2±2.1d	6.7±1.2b	5	5.2±2.1c
Tempura 4584	6.8±2.5cd	5.8±1.6c	5	5.8±2.0c

[a]Samples were rated using a nine-point Hedonic scale in which 9=excellent and 1=extremely poor; means ± standard deviations are the results of 6 replicates; means followed by the same letter are not significantly different at $P \leq 0.05$, n=36, df=5.25 (P=Probability) (dF=Degrees of Freedom).

[b]Breading systems are defined in the materials and methods section.

[c]One panelist.

APPENDIX

APP. TABLE 1. CONTENTS OF FREE-AMINO ACIDS IN SAMPLES OBTAINED FROM THE PROCESSING LINE FOR CRAB

Component (Unites/g or mL)	Subsamples from the line for the processing of crab[a]										
	Butchering water[b]	Cooker water	Cooler water	Shoulder water[b]	Leg water	Tip water	Shoulder shell[b]	Tip/leg shell	Leg meat	Tip meat	Shoulder meat[b]
Alanine	94.5±140	3270±870	68.4±31	516±480	2130±1500	3910±1400	1370±560	2810±890	15200±4800	6920±4500	2210±920
α-Aminoadipic acid	ND[c]	48.8±9.8	ND	ND	17.0±16	19.0±8.4	ND	7.50±15	58.2±61	16.7±19	8.33±17
α-Amino-n-butyric acid	ND	34.7±20	ND	1.00±2.00	12.2±19	22.8±22	ND	5.85±27	32.3±27	3.33±6.7	ND
Arginine	93.2±140	3330±770	60.1±39	550±470	2580±1900	4160±1200	2100±550	3550±950	21700±5500	8590±4700	4410±1800
Asparagine	5.00±10	37.3±8.3	0.525±1.1	5.50±10	13.1±16	11.9±16	24.5±32	23.9±31	461±55	89.7±62	17.7±15
Aspartic acid	8.25±16	240±63	1.25±1.9	52.0±54	89.5±66	193±89	72.4±17	179±58	540±130	339±210	85.1±35
Citruline	ND	16.0±8.1	ND	1.00±2.0	3.98±8.0	15.0±10	ND	5.21±7.1	16.7±19	ND	ND
Cystathione	0.50±1.0	15.2±12	ND	0.275±0.48	6.25±9.5	6.20±3.5	1.20±1.5	5.45±6.2	24.1±16	11.7±11	ND
Cysteic acid	0.625±1.3	37.3±8.3	0.525±1.1	5.00±1.0	13.1±16	11.9±16	50.4±11	11.4±23	13.5±27	9.58±19	6.33±13
Cystine	2.53±4.4	41.7±18	0.200±0.40	3.53±4.0	42.5±30	12.7±4.9	5.25±2.6	3.71±3.8	60.6±51	13.7±23	0.083±0.17
γ-Aminobutyric acid	ND	34.7±20	ND	1.00±2.0	12.2±19	22.8±23	ND	ND	24.2±16	14.4±14	8.33±17
Glutamic acid	12.8±24	353±110	3.30±4.7	69.2±76	166±120	337±110	126±40	310±94	926±260	552±350	174±100
Glutamine	12.5±24	57.4±24	0.450±0.90	19.1±12	93.8±71	197±80	83.1±53	129±66	872±290	332±230	161±86
Glycine	130±140	10100±2400	243±92	1750±1500	6520±4500	10200±2400	4580±1500	8570±2100	41200±16000	18500±12000	6310±2200
Histidine	27.5±50	220±62	5.33±5.4	157±300	106±80	167±63	126±49	201±95	608±240	378±280	176±140
Isoleucine	36.1±57	1770±490	15.0±4.4	192±310	480±44	915±410	337±130	684±370	1410±730	918±500	217±100
Leucine	74.6±120	2010±510	17.4±5.3	209±340	514±410	977±530	390±140	754±420	1620±860	1000±460	264±120
L-methylhistidine	ND	262±460	ND	ND	9.00±11	16.6±13	ND	0.675±1.4	13.6±27	3.00±6.0	6.65±13
Lysine	78.4±120	1110±750	10.6±1.2	174±220	319±250	555±290	324±120	543±250	1060±470	726±340	255±93
Methionine	29.5±45	1180±260	6.10±2.9	124±210	332±280	618±260	274±98	502±240	1010±470	703±380	222±39
3-methylhistidine	ND	7.25±4.9	ND	2.50±5.0	3.90±6.5	28.7±38	15.2±3.9	42.2±24	197±160	153±110	8.33±17
Ornithine	0.500±1.0	44.8±12	0.200±0.40	1.30±2.5	26.7±26	26.3±13	11.5±8.0	46.2±24	89.3±43	27.6±27	36.1±39
Phenylalanine	40.0±70	1290±300	7.63±3.5	139±220	367±350	590±250	294±100	599±290	906±400	716±320	181±77
Proline	20.0±40	1390±350	13.9±19	219±140	1230±360	2080±830	543±240	1230±300	14400±3900	3730±2200	1390±140
Sarcosine	190±360	4800±1000	3.30±6.6	432±830	1390±240	2670±960	1140±630	2830±1300	4760±1100	3420±2400	354±170
Serine	27.0±50	582±200	3.73±6.2	125±120	265±180	459±150	222±52	413±140	1950±590	955±650	293±150
Taurine	104±140	3860±980	21.0±20	265±140	2540±1900	4670±1500	1780±800	3760±1300	15100±2900	8590±4900	2630±1000
Threonine	18.6±34	333±110	3.50±4.4	55.6±60	130±130	231±96	81±20	128±36	830±270	211±210	119±48
Tryptophan	8.50±16	354±79	3.63±4.8	33.0±58	70.8±72	117±63	101±52	159±64	150±93	202±120	51.3±21
Tyrosine	23.6±47	951±220	7.05±2.5	95.0±160	252±220	395±180	219±68	409±160	631±270	494±160	187±89
Valine	39.6±71	1830±430	9.08±6.7	190±310	442±420	896±370	396±140	696±370	1430±740	1010±570	217±140

[a]Mean ± standard deviation of four values obtained from four separate sampling dates.

[b]Seawater employed for the operation.

[c]Not detectable at levels less than ca 0.1 nmol/mL or g.

APP. TABLE 2. CONTENT OF NUCLEOTIDES AND THEIR METABOLITES IN SAMPLES OBTAINED FROM THE PROCESSING LINE FOR CRAB

Nucleotide or metabolite (nmol/mL or g)	Subsamples from the line for the processing of crab[a]										
	Butchering water[b]	Cooker water	Cooler water	Shoulder water[b]	Leg water	Tip water	Shoulder shell[b]	Tip/leg shell	Leg meat	Tip meat	Shoulder meat[b]
Adenosine diphosphate	11.7	70.0±21	0.936	6.32	111	144	70.2	57.9±63	462±500	177	150
Adenosine monophosphate	15.2	90.9±28	<15.2	<15.2	72.9	122	41.5	93.0±80	569±280	142	100
Adenosine triphosphate	19.7	<19.7±0.0	<19.7	<19.7	<19.7	<19.7	<29.6	<29.6±0.0	<115±42	<65.7	<32.8
Hypoxanthine	2.20	61.5±15	5.14	5.88	21.3	9.55	37.5	27.6±5.2	19.0±15	17.1	26.9
Inosine	3.73	41.7±9.9	<7.46	3.36	30.6	22.0	21.3	35.8±26	85.4±63	47.2	55.9
Inosine monophosphate + Guanine monophospate	<5.77	45.3±8.1	<5.77	8.08	33.5	50.5	22.5	32.2±24	262±100	119	43.2
Uric acid	12.5	196±66	<11.9	10.1	27.4	<29.7	79.4	70.4±41	193±71	99.0	79.2

[a]Mean ± standard deviation of four values obtained from four separate sampling dates.

[b]Seawater employed for the operation.

APP. TABLE 3. CONTENT OF FREE-AMINO ACIDS IN COMPONENTS OF COMMERCIAL CRAB FLAVOURS

Amino acids	Components of commercial crab flavours[a]							
	Crab extract	Gulesen	Asge[b] extract NH	Crab[b] flavour	Crab[b] flavour	Ak Crab flavour P	AK Crab extract	Seasoning base BT
Alanine	170000	ND[a]	7000	6720	879	10400	7000	195000
a-Aminodipic acid	ND	ND	ND	ND	ND	ND	ND	ND
a-Aminobutyric acid	ND	ND	ND	64.1	47.7	3550	ND	ND
Arginine	75200	ND	ND	4690	404	1000	4700	48700
Asparagine	ND	ND	ND	ND	ND	ND	ND	ND
Aspartic acid	86600	ND	14500	757	186	3500	1400	92700
Citrulline	ND	ND	ND	ND	38.7	ND	ND	ND
Cystathione	30	ND	ND	5.70	1.0	ND	ND	ND
Cysteic acid	ND	ND	ND	1690	27.7	7100	3800	1700
Cystine	500	ND	ND	89.2	62.0	1000	ND	1000
r-Aminobutyric acid	500	ND	ND	106	21.0	10500	ND	ND
Glutamic acid	1480000	700	12000	246000	30300	871000	359000	3130000
Glutamine	ND	ND	ND	394	5150.0	52100	ND	ND-
Glycine	5750000	12200000	6800	124000	1080	6200	153000	588000
Histidine	9900	ND	Nd	162	8060	1000	ND	13600
Isoleucine	16100	600	2000	1510	201	7100	1350	16800
Leucine	35000	ND	4000	1970	439	7500	1850	38500
L-methylhistidine	ND	ND	ND	ND	ND	ND	ND	ND
Lysine	46000	ND	ND	1570	374	1150	1600	44900
Methionine	9600	300	15800	313	1270	15000	ND	9650
3-Methylhistidine	ND	ND	ND	6.8	ND	ND	ND	ND
Ornithine	800	ND	ND	310	235	100	ND	100
Phenylalanine	11800	ND	ND	1050	183	500	1000	15500
Proline	101000	ND	ND	1060	284	2500	2500	101000
Sarcosine	ND	ND	ND	2560	ND	ND	ND	ND
Serine	66100	200	12000	769	226	5600	1000	51200
Taurine	700	ND	ND	4030	811	1000	4750	3800
Threonine	34100	ND	2000	707	199	1200	2000	35600
Tryptophan	ND	ND	ND	ND	21	500	500	ND
Tyrosine	2100	ND	ND	499	128	2200	500	2000
Valine	32500	ND	ND	1820	326	6500	ND	37500

[a]Not detectable at levels less than ca 0.1 nmol/mL or g. Free-amino acids were not detected in Gelmin, Crab gold, Fresh P, Silkpolly, Wakesee starch, Pulran or Gelace P.

[b]Results are in units of nmol/mL.

APP. TABLE 4. CONTENTS OF FREE-AMINO ACIDS IN BUTCHERED ICELANDIC SCALLOPS

Amino acids[b] (nmol/mL)	Subsamples of butchered scallops[a]	
	Adductor muscle	Viscera and mantle
Alanine	5310±1110	6950±1160
a-Aminoadipic acid	36.6±32.8	17.8±30.8
Arginine	4980±2570	7710±2230
Asparagine	540±418	349±464
Aspartic acid	1160±1100	637±443
Citrulline	228±322	58.8±64.8
Cystathione	11.6±9.25	3.67±6.35
Cysteic acid	188±102	156±105
Cystine	62.8±58.9	51.7±89.5
Glutamic acid	2370±2200	2960±915
Glutamine	399±530	554±736
Glycine	78600±24800	79800±22300
Histidine	501±418	364±375
Isoleucine	1050±784	790±789
Leucine	1620±1320	1230±1450
Lysine	762±769	866±955
Methionine	776±500	485±624
3-methylhistidine	16.7±28.9	52.7±91.2
Ornithine	585±794	59.4±91.4
Phenylalanine	840±662	628±872
Proline	1270±921	394±510
Serine	766±688	1090±1150
Taurine	20000±1470	31200±10500
Threonine	1650±1480	980±991
Tryptophan	129±158	211±310
Tyrosine	465±369	582±698
Valine	1350±988	880±1160

[a]Mean ± standard deviation of three values representing three separate extractions from the same collection lot of scallops.

[b]The following free-amino acids were not detected at levels less than ca 0.1 nmol/g: a - amino-n-butyric acid, L-methylhistidine and sarcosine.

APP. TABLE 5. CONTENTS OF NUCLEOTIDES AND THEIR METABOLITES IN BUTCHERED ICELANDIC SCALLOPS

Nucleotide or metabolite (nmol/mL or g)	Subsamples of butchered scallops[a]	
	Adductor muscle	Viscera and mantle
Adenosine diphosphate	77.3±54	26.8±18
Adenosine monophosphate	236±290	50.6±0.0
Adenosine triphosphate	<54.7±19	<32.8±0.0
Hypoxanthine	2230±1100	1380±520
Inosine	1090±430	656±140
Inosine monophosphate + guanine monophospate	92.1±61	69.1±53
Uric acid	144±160	184±100

[a]Mean ± standard deviation of three values representing three separate extractions from the same collection lot of scallops.

APP. TABLE 6. THE CONTENT OF SOLIDS (%; TOTAL, INSOLUBLE AND SOLUBLE) IN COOKER LIQUOR OBTAINED FROM A CRAB PROCESSING LINE BASED ON COLLECTION MADE OVER TIMED INTERVALS

	Solids (%)[a]		
Time (h)	Total	Insoluble[a]	Soluble
0.00	0.09±0.04	0.01±0.01	0.08±0.04
0.08	0.09±0.06	0.02±0.01	0.08±0.05
0.17	0.23±0.14	0.09±0.07	0.14±0.07
0.33	0.47±0.09	0.10±0.06	0.37±0.06
0.67	0.76±0.02	0.22±0.21	0.54±0.21
1.00	1.17±0.13	0.28±0.12	0.89±0.03
1.50	1.26±0.53	0.36±0.21	0.90±0.34
2.00	1.09±0.51	0.39±0.10	0.70±0.43
3.00	1.23±0.75	0.40±0.32	0.83±0.43
4.00	131±0.43	0.54±0.13	0.73±0.31
5.00	1.34±0.23	0.35±0.05	0.99±0.20

[a]Values are means ± standard deviations of samples taken in triplicate.