MICROBIOLOGICAL PROFILING OF SURIMI PRODUCTION: PHASES I & II

Final Reports Completed:
October 6 &25, 1989

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This information was produced with funds provided through the Saltonstall-Kennedy program administered by the National Marine Fisheries Service under Cooperative Agreements #NA85-ABH-00044 and #NA-88-ABH-00007.

MICROBIOLOGICAL PROFILING OF SURIMI PRODUCTION: PHASE I

FINAL REPORT

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Final Report on

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Summary

The aerobic plate count (APC), total coliforms (TC), and Escherichia coli Most Probable Number (MPN) were determined from pollock flesh that was minced, washed and screened, refined, dehydrated, and formed into surimi blocks which also contained cryoprotectants. The median APC of the mince was 2.0×10^3. It increased to 2.3×10^3 after washing and screening, and further increased to 4.2×10^4 after refining and to 1.6×10^4 after dehydration. The second refining and dehydration employed for non-analog grade surimi yielded APC of 1.2×10^5 and 3.0×10^5 respectively. The APC of analog grade surimi was 5.5×10^4 and that of the non-analog grade surimi was 2.0×10^6. The highest TC count of >2,400 was recorded from a non-analog grade surimi and a mince that was refined for the second time. The highest E. coli MPN of 460 was recorded from a mince.

Microorganisms associated with surimi were predominantly Flavobacterium spp. and Arthrobacter/Corynebacterium spp., which may have originated either from the raw fish during surimi production or from other fish being processed within the plant.

Once the fish were minced, the microorganisms contained in the mince were resistant to being washed or pressed out of the fish flesh. Higher microbial counts in the raw fish resulted in higher microbial levels in the surimi.

The processing plant environment could have been the source of the coliform bacteria. E. coli might have been introduced either prior to or during the mincing step. The highest E. coli count recorded from the surimi was 9 from one sample.

This study did not reveal any potential public health hazard associated with surimi. If further improvement in microbiological quality is desired, better handling of raw fish on board the vessel as well as after unloading, prompt processing of the fish without undue delay, and thorough washing of the fish fillets before the mince step, would most appropriately accomplish that aim.

Introduction

Surimi manufacturing in Alaska is increasing, with 8000 metric tons being processed in Kodiak alone between September 1987 and April 1988 (Anon., 1988). Yet, few studies have been undertaken to determine the microbiological quality of Alaska produced surimi. A variety of psychrotrophic bacteria that are associated with cold water fish can contaminate the surimi during processing. In addition, the sanitary quality of the surimi will be affected by contamination from coliform bacteria and Escherichia coli.

The purpose of this investigation was to microbiologically assess each surimi processing step and to assist in the development of a rational hazard analysis and critical control point (HACCP) system.

Materials and Methods

Sampling. Alaskan pollock (Theragra chalcogramma) were harvested from Shelikof Strait by three refrigerated sea water (RSW) system equipped draggers and were delivered to the Kodiak plant at regular intervals (Appendix I). The fish were iced and kept in totes in the plant until processed. The plant apparently operated the surimi line around the clock until either the fish supply was exhausted or some mechanical problem arose (Appendix II).

The surimi manufacturing steps and sampling sites are presented as a flow diagram (Figure 1). The sampling sites were: the minced pollock flesh as it exited the mincer, the minced flesh after the last wash, the washed mince that had passed through the refiner, the refined mince that had been dewatered by the screw press, and the finished surimi prior to freezing. The reject mince at the refiner was collected, re-washed, refined again, and dehydrated again to produce the non-analog grade surimi.

Samples were obtained from each step of the commercial surimi manufacturing process during a period of six weeks. A total of ten samples from two shifts per day were examined with a weekly maximum of 40 samples. A total of 531 data points were thus collected from 36 samples and 133 sub-samples for aerobic heterotrophic microorganisms, coliform bacteria, and E. coli.

Since the purpose of this study was to obtain background information, no attempt was made to influence any of the plant operations. Thus, all samples were collected, according to our

instruction, by the plant personnel and were delivered to the laboratory. Interpretation of the results were performed at the conclusion of the laboratory analyses.

The first set of samples was collected at 7:00 a.m. or when the night shift was about to finish and the second set of samples was collected at noon when the day shift was about to take a lunch break. The analog grade and non-analog grade surimi were tested alternately, with a few exceptions.

Microbial Enumeration. Twenty-five gram samples were stomached (Stomacher 400, Tekmar) in whirl pack bags (Nasco) containing 225 ml of sterile Butterfield's phosphate buffer (0.0043% KH_2PO_4 in H_2O). Aerobic plate counts (APC) were done by spread-plating, in triplicate, 0.1 ml from serial dilutions onto Plate Count Agar (PCA, Difco) that was supplemented with 0.5% (w/v) NaCl. The plates were incubated at 25°C for 48 to 72 hours or until no additional colonies had developed.

Lauryl Tryptose (LT) broth (Difco) was supplemented with 100 ug of MUG (4-methylumbelliferyl-B-D-glucuronide, Hach Co., Loveland, CO) per ml of broth (Feng and Hartman, 1982). One ml from each of the 1:10, 1:100, and 1:1000 dilutions was inoculated into triplicate LT-MUG tubes, containing inverted Durham tubes, and were incubated in a 35°C water bath for 24 h. Turbidity due to growth and no gas production was considered coliform-negative, growth with gas was considered coliform-positive, and growth with gas and fluorescence under ultraviolet (UV) light (366 nm) was considered E. coli-positive. A

MUG-positive and a MUG-negative control, E. coli K_{12} and Enterobacter aerogenes, respectively, were included in the LT-MUG test.

Microbial Identification. Colonies isolated on PCA plates, for the APC enumeration of analog grade surimi, non-analog grade surimi, and minced fish, were picked and their taxonomic identities established by the following procedure.

All colonies from two countable plates (between 30 and 300 colonies) were streaked for purification onto PCA. The isolated microorganisms were subjected to the following taxonomic tests (Smibert and Krieg, 1981): colony pigmentation, colony shape, gram stain or KOH reaction (Buck, 1982), cell shape, catalase and oxidase activities, and reactions on triple sugar iron agar (Difco). Motility was determined from motility test medium (Difco) or by microscopic observations of wet mounts. A 21-point replica plating device (Corlett Jr., et al., 1965) was used to test the microorganisms on the following differential or selective agar plates: Hugh-Leifson O-F, Simmons citrate (Difco), arginine, peptone iron (Difco), King's B, gelatin, casein, tween 80, starch (Difco), urea, penicillin G, and vibriostatic agent O/129.

Hugh-Leifson O-F agar was produced by increasing the agar concentration to 15 grams per liter (w/v) of Hugh-Leifson O-F medium (Smibert and Krieg, 1981). Hugh-Leifson fermentation plates were placed in GasPak jars (BBL) prior to incubation. Oxidation or fermentation of glucose was determined as a yellow color surrounding the colonies. Arginine agar was produced by increasing the agar concentration to 14 grams per liter (w/v) of Thornley's semi-solid arginine medium (Smibert

and Krieg, 1981). Arginine hydrolysis was determined as a pink color surrounding the colonies. King's B agar (King et al., 1954) was modified to contain, in grams per liter of distilled H_2O: proteose peptone #3 (Difco), 20; glycerol, 15; K_2HPO_4, 1.5; $MgCl_2 \cdot H_2O$, 1.5; agar, 14. Ultraviolet (UV) fluorescent colonies were detected by a black light (longwave UV of 366 nm). Gelatin agar contained, in grams per liter of distilled H_2O: gelatin, 4; NaCl, 5; yeast extract, 1; agar, 12. Gelatinase activity was detected as a clear, hydrolytic zone surrounding the colonies. Caseinate agar, a modification of the method of Martley et al. (1970), contained, in grams per liter of distilled H_2O: sodium caseinate, 5; casamino acids, 5; yeast extract, 5; NaCl, 5; N-2-hydroxyethylpiperazine-N'-2-ethanesulfonic acid (HEPES), 11.92; $CaCl_2 \cdot H_2O$, 0.74; agar, 15. Caseinase activity was determined as a clear, hydrolytic zone surrounding the colonies. Tween 80 agar, used in detecting lipase activity, was prepared by including 1% (w/v) Tween 80 (polyoxyethylenesorbitan monooleate) in PCA. Lipase activity was determined as an opaque zone surrounding the colonies. Christensen's urea agar (Smibert and Krieg, 1981) was modified in which glucose was omitted, the agar concentration was reduced to 15 grams per liter (w/v), and yeast extract (0.1 gram per liter of medium) included in the original formula. Urease activity was determined as a pink color surrounding the colonies. Penicillin G and vibriostatic agent O/129 (2,4-diamino-6,7- diisopropylpteridine phosphate) agars were produced by including penicillin G (3 units per liter) and vibriostatic agent O/129 (10 mg per liter), respectively, in PCA. Microbial sensitivity was determined as the absence of microbial growth on PCA containing either

inhibitor. Bergey's Manual of Systematic Bacteriology (Holt, 1986) was used in confirming the identity, based on the results of the above taxonomic tests. All chemicals, except where noted, were of highest reagent grade and were purchased from either Sigma, Fisher, EM Science, or Baker.

Results and Discussion

Aerobic Plate Count (APC). The APC data for analog grade and non-analog grade surimi manufacturing processes were tabulated (Tables 1A and 1B). Both processes share the same mincing steps and washing and screening steps, therefore, these data were later combined (Table 4).

In the surimi manufacturing steps, washing and screening seemed to reduce the microbial load of the mince slightly. However, these samples contained a high percentage of water, therefore, the microbial count on a dry weight basis is expected to be higher for the washed mince than for the raw mince.

As the mince was refined and dehydrated, the microbial count tended to increase. This increase resulted from water being expelled out of the mince, which concentrated the solids and the microorganisms. Furthermore, an increased microbial count indicated that either the microorganisms were not being pressed out of the mince or bacterial growth was occurring.

When the microbial count of the mince was high, the counts from further processed samples tended to be higher. Similar results were previously reported in an earlier study of surimi production (Elliott, 1987), in which the average APC's (colony-forming units/gram or CFU/g) were: mince, 2.6×10^3; washed mince, 2.8×10^4; refined mince, 8.5×10^4; dehydrated mince, 6.6×10^5; and surimi, 7.2×10^5.

The non-analog grade surimi was processed similarly to analog grade surimi but a second refining and a second dehydration step were added. When we tested samples from both of the refiners and from both of the

dehydraters, the average APC had increased from 1.1×10^4 to 1.2×10^5 CFU/g for the first and second refiners. Similarly, the average APC increased from 1.1×10^4 to 2.4×10^5 CFU/g for the first and second dehydraters. The higher APC of non-analog grade surimi, as compared to analog grade surimi, must have been due to these additional processing steps.

Samples were obtained during the end of the season when fish were nearing spawn and were soft-fleshed. The surimi yield from spawning fish is poor and signifies the season closure. Roe were recovered by hand from such fish which introduced an additional point for microbial contamination. The APC of the mince fluctuated from a low of 2.3×10^2 CFU/g to a high of 1.7×10^4 CFU/g. If the seasonal processing was responsible for the microbial count fluctuation, the count should have increased toward the end of the season. This did not appear to have been the case.

The pollock delivery log had an entry for the percentage of fish smaller than 13 inches (Appendix I). These undersized fish could not be processed by the Baader 182 and were not utilized. Since similar sized fish school together, a lot that contained a higher proportion of undersized fish would have more smaller sized fish. The fish delivered between March 24 and 29, 1988, therfore, would have been smaller. Since smaller fish are filleted by the Baader 182 with minimum human handling, surimi made from these fish should have had lower microbial counts. This, however, was not the case.

The surimi line operated around the clock except when the fish supply had been exhausted or some mechanical breakdown had occurred

(Appendix II). A shutdown period exceeding eight hours was due to a lack of fish. Eight sets of samples had coincided with the long work stoppages. The samples obtained prior to a work stoppage were considered from "aged" fish, while the samples obtained immediately after the stoppage were considered from "fresh" fish. The APC data (Tables 1A and 1B) were rearranged (Tables 5A and 5B) to isolate the work stoppage information. The APC of surimi that was processed from "aged" fish contained five out of the nine highest counts. If the samples obtained immediately prior to the "aged" fish samples were included, then seven out of the nine highest APC's were included. In contrast, the APC of surimi that was processed from "fresh" fish contained four of the lowest counts. If the surimi samples from "fresh" fish processed during the subsequent shift on the same day were included, then all eight of the lowest APC's were included.

Microbial Identification. Microorganisms were isolated from analog grade and non-analog grade surimi and were identified to the genus level (Table 6). Both high count samples contained a high proportion of pigmented Flavobacterium. Adams et.al. (1964) reported that fresh fish contain a high proportion of pigmented bacteria. The high Flavobacterium count for surimi, therefore, would indicate two possibilities: (a) the microorganisms found in surimi were due to contamination from the raw fish and (b) the surimi manufacturing process did not effectively remove the bacteria. The second most predominant group of bacteria found was the Arthrobacter/Corynebacterium spp. These gram-positive bacteria are not generally associated with raw fish but

the bacteria do persist in RSW fishholds (Lee and Kolbe, 1982). Due to their resistance to environmental stresses, the Arthrobacter/Corynebacterium spp. would be found in larger proportions in an environment that had not been frequently cleaned. In addition, these results contrast with data from a previous microbial taxonomy study of surimi. Elliott (1987) reported the predominant microorganisms in surimi were Pseudomonas, Acinetobacter, Moraxella, and Vibrio/Aeromonas, while the Flavobacterium spp. and Arthrobacter/Corynebacterium spp. accounted for only 17% of the microflora.

The microbial flora of minced fish, in the present study, was similar to the microbial flora of surimi. This suggested that the raw fish was the origin of the Flavobacterium spp. and Arthrobacter/Corynebacterium spp. that were found in surimi. Although these three bacterial genera were predominant in surimi and minced fish, Flavobacterium spp. and Arthrobacter/Corynebacterium spp. are not considered as fish spoilage bacteria (Lerke et.al., 1965).

Three major enzymatic activities - proteolytic, lipolytic, and saccharolytic - of the surimi isolates were determined (Table 7). The majority of the isolates were gelatinase-positive and a high proportion were also lipase- and amylase-positive. The analog grade surimi had more caseinase-, lipase-, and amylase-positive microorganisms than the non-analog grade surimi which may relate to the specific microfloral differences of the two surimi grades (Table 6). The enzymatic activity patterns of microorganisms isolated from minced fish and those isolated from the surimi were similar.

Total coliforms (TC). The total coliform MPN's for surimi production were calculated (Tables 2A and 2B). Similar to the APC, the TC level decreased after the washing and screening step, then increased with each subsequent processing step. Elliott (1987) also observed the average TC count (MPN/g) increase during surimi production: mince, 0.6; washed mince, 10; refined mince, 54; dehydrated mince, 250; and surimi, 610. In the present study, the TC count for non-analog grade surimi appeared to be higher than the TC count for analog grade surimi. Many of the minced fish samples and most of the washed and screened minced fish samples had a TC count below detectable levels (MPN <3/g). The TC found in the surimi were either due to the TC present in the raw fish that was processed into surimi or due to other fish being processed within the plant.

E. coli. Despite the high TC count the E. coli counts of surimi were low (Tables 3A and 3B). The E. coli MPN of the non-analog grade surimi was similar to the E. coli MPN for analog grade surimi. A low E. coli count, MPN <15/g, for surimi was also previously reported (Elliott, 1987).

Indications of potential public health risks were revealed by TC and E. coli. Historically TC has been the most widely used test for the presence of fecal contamination in water. The presence of large proportions of non-fecal microorganisms in the TC group, however, has prompted microbiologists to include an E. coli test as a more reliable indication of fecal contamination. (Mack, W.N., 1977)

The contrast between TC and E. coli could not have been more dramatic than the data presented here. The TC levels tended to increase as the fish was minced, washed, refined or dehydrated. In other words, the increase in the TC count tended to reflect the degree of exposure to the plant environment and to human and mechanical handling. E. coli on the other hand, was the highest in the mince but decreased steadily as the mince was washed, refined and dehydrated.

The data thus indicated that E. coli could perhaps have originated from the raw fish and in the immediate environment the fish was subjected to, while contamination by non-fecal TC had occurred in the processing plant.

In any event, the E. coli level in the surimi was too low to cause any public health concern.

Conclusions. An increase in the total number of microorganisms (APC) correlated with the amount of processing in surimi manufacturing. Raw minced fish and washed mince contained the lowest APC's while the additional processing steps of refining, dehydrating, and forming resulted in higher APC's. Fresh fish that were immediately processed into surimi resulted in a lower APC than for aged fish that were used as the surimi starting material. The TC usually increased after the mincing and washing steps and during the concentrating steps (refining and dehydrating). E. coli remained low throughout surimi processing except for sporadic high counts that were associated with the minced fish and prior to the washing step. Additional processing, used in the

production of non-analog grade surimi, resulted in a ten-fold increase in the APC and a two- to four-fold increase in TC over analog grade surimi. The predominant microorganisms in either the analog grade surimi, non-analog grade surimi, or minced fish were Flavobacterium spp. and Arthrobacter/Corynebacterium spp. Gelatinase activity was the predominant enzymatic activity among the surimi or minced fish isolates.

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Table 1A.

Aerobic Plate Count (APC/g)
of Analog Grade Surimi Production

Date*	Mince	Wash/ Screen	Refine	Dehydrate	Surimi I
2/25 A	---[a]	---	---	2.2×10^3	1.1×10^4
2/25 P	4.5×10^2	8.7×10^2	4.2×10^4	4.1×10^3	1.5×10^4
2/26 A	1.4×10^3	9.7×10^2	4.4×10^4	1.1×10^4	4.1×10^5
2/26 P	3.9×10^2	6.9×10^2	6.9×10^4	1.1×10^4	3.1×10^4
3/03 A	1.7×10^4	7.1×10^3	8.7×10^4	7.0×10^4	1.8×10^5
3/03 P	5.0×10^3	2.6×10^3	4.3×10^4	1.4×10^5	1.5×10^5
3/04 A	6.5×10^2	5.2×10^1	5.6×10^3	1.1×10^4	2.2×10^4
3/04 P	5.0×10^2	9.3×10^2	9.6×10^3	1.3×10^4	1.8×10^4
3/10 A	2.3×10^2	1.2×10^3	9.3×10^3	1.6×10^3	1.5×10^4
3/10 P	2.9×10^2	2.1×10^3	3.4×10^3	1.9×10^3	9.8×10^3
3/11 A	5.9×10^3	2.2×10^3	1.8×10^4	2.9×10^4	3.0×10^4
3/17 A	5.2×10^3	6.3×10^3	2.0×10^5	4.8×10^4	2.7×10^5
3/17 P	1.7×10^4	3.6×10^3	4.2×10^4	3.3×10^4	2.9×10^5
3/24 P	2.5×10^3	1.0×10^3	9.9×10^3	1.2×10^4	3.7×10^4
3/25 A	2.7×10^3	4.9×10^3	2.0×10^4	4.7×10^4	2.0×10^5
3/25 P	1.8×10^3	1.5×10^3	7.3×10^4	1.9×10^4	7.2×10^4
3/31 P	2.4×10^3	2.0×10^4	2.0×10^5	5.1×10^5	8.1×10^5
4/01 P	4.4×10^3	9.4×10^3	3.7×10^5	2.3×10^5	8.2×10^5

* Date of sampling: 2/25 A represents February 25, 1988 a.m. and 3/03 P represents March 3, 1988 p.m., etc.

[a] No sample

Table 1B.

Aerobic Plate Count (APC/g)
of Non-Analog Grade Surimi Production

Date*	Mince	Wash/ Screen	Refine (twice)	Dehydrate (twice)	Surimi II
3/01 A	2.0×10^3	1.3×10^3	1.2×10^5	---[a]	2.9×10^6
3/01 P	5.5×10^2	4.4×10^2	1.1×10^5	---	2.4×10^6
3/07 A	2.5×10^3	6.7×10^3	4.4×10^5	1.4×10^5	---
3/07 P	4.3×10^3	6.8×10^3	1.1×10^5	3.8×10^5	1.6×10^6
3/08 A	3.1×10^3	7.7×10^3	8.9×10^5	4.3×10^5	4.7×10^6
3/08 P	2.4×10^3	2.6×10^4	2.0×10^5	6.5×10^5	5.2×10^6
3/14 A	1.2×10^3	1.2×10^3	5.8×10^4	2.8×10^4	6.8×10^5
3/14 P	3.4×10^2	5.0×10^2	8.6×10^4	1.0×10^5	9.4×10^5
3/15 A	1.1×10^3	8.6×10^3	1.3×10^5	3.7×10^5	1.1×10^6
3/15 P	1.1×10^3	1.1×10^3	---	1.9×10^5	7.5×10^5
3/21 A	4.7×10^3	2.3×10^3	2.0×10^4	6.8×10^4	2.0×10^6
3/21 P	4.0×10^3	8.0×10^2	---	2.6×10^4	1.5×10^5
3/22 A	9.2×10^2	1.1×10^3	6.1×10^4	6.6×10^4	5.5×10^5
3/22 P	1.9×10^3	2.1×10^3	7.3×10^4	3.0×10^4	4.0×10^5
3/28 A	2.4×10^3	1.6×10^4	2.0×10^5	1.8×10^6	2.9×10^6
3/28 P	1.3×10^4	4.4×10^3	5.6×10^5	3.0×10^5	1.9×10^6
3/29 A	1.6×10^3	5.1×10^3	3.4×10^5	1.3×10^6	5.7×10^6
3/29 P	1.9×10^3	6.5×10^3	1.0×10^5	6.8×10^5	2.3×10^6
4/05 P	4.7×10^3	1.9×10^4	4.3×10^5	9.9×10^5	5.0×10^6

* Date of sampling: 3/01 A represents March 1, 1988 a.m. and 4/05 P represents April 5, 1988 p.m., etc.

[a] No sample

Table 2A.

Total Coliform (MPN/g)
of Analog Grade Surimi Production

Date*	Mince	Wash/ Screen	Refine	Dehydrate	Surimi I
2/25 A	---[a]	---	---	<3	23
2/25 P	<3	<3	<3	9	<3
2/26 A	<3	<3	9	4	23
2/26 P	<3	<3	23	23	23
3/03 A	150	<3	43	93	460
3/03 P	460	<3	43	75	43
3/04 A	4	<3	4	<3	7
3/04 P	<3	<3	4	<3	4
3/10 A	4	<3	<3	<3	4
3/10 P	5	<3	3	23	93
3/11 A	93	<3	39	<3	43
3/17 A	460	15	240	240	1,100
3/17 P	23	4	460	1,100	240
3/24 P	<3	<3	9	9	23
3/25 A	<3	<3	43	93	240
3/25 P	<3	<3	1,100	240	43
3/31 P	<3	9	240	460	1,100
4/01 P	9	9	120	460	1,100

* Date of sampling: 2/25 A represents February 25, 1988 a.m. and 3/03 P represents March 3, 1988 p.m., etc.

[a] No sample

Table 2B.

Total Coliform (MPN/g)
of Non-Analog Grade Surimi Production

Date*	Mince	Wash/ Screen	Refine (twice)	Dehydrate (twice)	Surimi II
3/01 A	<3	<3	11	---[a]	23
3/01 P	<3	<3	9	---	43
3/07 A	23	<3	23	43	---
3/07 P	43	4	93	<3	1,100
3/08 A	23	4	43	93	1,100
3/08 P	23	<3	23	23	43
3/14 A	43	<3	75	23	460
3/14 P	23	23	93	240	1,100
3/15 A	<3	<3	1,100	93	>2,400
3/15 P	150	9	---	460	>2,400
3/21 A	4	<3	15	43	1,100
3/21 P	<3	<3	---	93	150
3/22 A	<3	<3	23	23	75
3/22 P	<3	<3	43	23	93
3/28 A	23	<3	75	1,100	1,100
3/28 P	4	<3	240	93	240
3/29 A	23	9	>2,400	460	>2,400
3/29 P	43	<3	240	240	150
4/05 P	9	<3	21	93	240

* Date of sampling: 3/01 A represents March 1,1988 a.m. and 4/05 P represents April 5, 1988 p.m., etc.

[a] No sample

Table 3A.

E. coli (MPN/g)** of
Analog Grade Surimi Production

Date*	Mince	Wash/ Screen	Refine	Dehydrate	Surimi I
2/25 A	---[a]	---	---	<3	<3
2/25 P	<3	<3	<3	<3	<3
2/26 A	<3	<3	<3	<3	<3
2/26 P	<3	<3	<3	<3	<3
3/03 A	150	<3	4	<3	<3
3/03 P	460	<3	4	<3	<3
3/04 A	<3	<3	<3	<3	<3
3/04 P	<3	<3	4	<3	<3
3/10 A	4	<3	<3	<3	4
3/10 P	5	<3	<3	<3	<3
3/11 A	21	<3	23	<3	<3
3/17 A	460	15	15	<3	4
3/17 P	23	4	3	4	9
3/24 P	<3	<3	<3	<3	<3
3/25 A	<3	<3	<3	<3	<3
3/25 P	<3	<3	<3	<3	<3
3/31 P	<3	<3	<3	<3	<3
4/01P	<3	<3	<3	<3	<3

* Date of sampling: 2/25 A represents February 25, 1988 a.m. and 3/03 P represents March 3, 1988 p.m., etc.

** Glucuronidase positive on 4-methylumbelliferyl-B-D-glucuronide (MUG).

[a] No sample

Table 3B.

E. coli (MPN/g)** of
Non-Analog Grade Surimi Production

Date*	Mince	Wash/ Screen	Refine (twice)	Dehydrate (twice)	Surimi II
3/01 A	<3	<3	<3	---[a]	<3
3/01 P	<3	<3	<3	---	<3
3/07 A	9	<3	4	<3	---
3/07 P	43	<3	4	<3	<3
3/08 A	23	4	9	<3	4
3/08 P	23	<3	4	23	<3
3/14 A	43	<3	<3	<3	<3
3/14 P	23	4	23	<3	3
3/15 A	<3	<3	9	4	3
3/15 P	150	9	---	9	<3
3/21 A	<3	<3	<3	<3	<3
3/21 P	<3	<3	---	<3	<3
3/22 A	<3	<3	<3	<3	<3
3/22 P	<3	<3	<3	<3	<3
3/28 A	4	<3	4	4	4
3/28 P	4	<3	<3	<3	<3
3/29 A	23	<3	9	<3	<3
3/29 P	4	<3	<3	<3	3
4/05 P	9	<3	<3	<3	4

* Date of sampling: 3/01 A represents March 1, 1988 a.m. and 4/05 P represents April 4, 1988 p.m., etc.

** Glucuronidase positive on 4-methylumbelliferyl-B-D-glucuronide (MUG).

[a] No sample

Table 4.

Summary Data on the
Microbiological Profile of Surimi Production

Sample (No.)*		APC/g	TC/g	FC/g
Mince (36)	{Low	2.3×10^2	<3**	<3
	{Median	2.0×10^3	4.5	4
	{High	1.7×10^4	460	460
Wash/ Screen (36)	{Low	5.2×10^1	<3	<3
	{Median	2.3×10^3	<3	<3
	{High	2.6×10^4	23	15
Refine (22)	{Low	3.4×10^3	<3	<3
	{Median	4.2×10^4	31	<3
	{High	3.7×10^5	1,100	23
Dehydrate (18)	{Low	1.6×10^3	<3	<3
	{Median	1.6×10^4	23	<3
	{High	5.1×10^5	1,100	4
Second Refine (17)	{Low	2.0×10^4	9	<3
	{Median	1.2×10^5	43	<3
	{High	8.9×10^5	>2,400	23
Second Dehydrate (19)	{Low	2.6×10^4	<3	<3
	{Median	3.0×10^5	93	<3
	{High	1.8×10^6	1,100	23
No. 1 Surimi (18)	{Low	9.8×10^3	<3	<3
	{Median	5.5×10^4	43	<3
	{High	8.2×10^5	1,100	9
No. 2 Surimi (18)	{Low	1.5×10^5	23	<3
	{Median	2.0×10^6	350	<3
	{High	5.7×10^6	>2,400	4

* No. of samples analyzed.
** Below detection limit of the test procedure.

Table 5A.

APC of Surimi Processing
Samples from "Aged" Fish

Sample	Aerobic plate count/g *			
	3/03 A	3/08 P	3/17 P	4/01 P
Mince	$\underline{1.7 \times 10^4}$	2.4×10^3	$\underline{1.7 \times 10^4}$	4.4×10^3
Wash/screen	7.1×10^3	$\underline{2.6 \times 10^4}$	3.6×10^3	9.4×10^3
Refine	8.7×10^4		4.2×10^4	$\underline{3.7 \times 10^5}$
Dehydrate	7.0×10^4		3.3×10^4	2.3×10^5
Second refine		2.0×10^5		
Second dehydrate		6.5×10^5		
Analog grade surimi	1.8×10^5		2.9×10^5	$\underline{8.2 \times 10^5}$
Non-analog grade surimi		5.2×10^6		

* Underlined are the highest counts encountered.

Table 5B.

APC of Surimi Processing
Samples from "Fresh" Fish

Sample	Aerobic plate count/g*			
	2/26 A	3/10 A	3/21 A	4/05 A
Mince	1.4×10^3	$\underline{2.3 \times 10^2}$	4.7×10^3	4.7×10^3
Wash/screen	9.7×10^2	1.2×10^3	2.3×10^3	1.9×10^4
Refine	4.4×10^4	9.3×10^3		
Dehydrate	1.1×10^4	$\underline{1.6 \times 10^3}$		
Second refine			$\underline{2.0 \times 10^4}$	4.3×10^5
Second dehydrate	1.6×10^5		6.8×10^4	9.9×10^5
Analog grade surimi	4.1×10^5	1.5×10^4		
Non-analog grade surimi			2.0×10^6	5.0×10^6

* Underlined are the lowest counts encountered.

Table 6.

Microbial Flora
of Surimi*

Genus	Percent of total isolates	
	Analog grade surimi	Non-analog grade surimi
Flavobacterium	44	59
Arthrobacter/ Corynebacterium	33	26
Pseudomonas	13	6
Acinetobacter	2	3
Cytophaga	1	0
Citrobacter	0	1
Enterobacter	1	1
Alcaligenes	1	0
Serratia	1	0
Streptococcus	2	0
Lactobacillus	1	2
Bacillus	0	1
Micrococcus	0	1
Yeast	1	0
Total isolates identified	147	130

* From high microbial count samples of 8.2×10^5 and 5.0×10^6, respectively.

Table 7.

Enzymatic Activities
of Surimi Isolates

Enzymatic Activity	Percent positive	
	Analog grade surimi	Non-analog grade surimi
Gelatinase	63	75
Caseinase	45	22
Lipase	44	16
Amylase	35	30

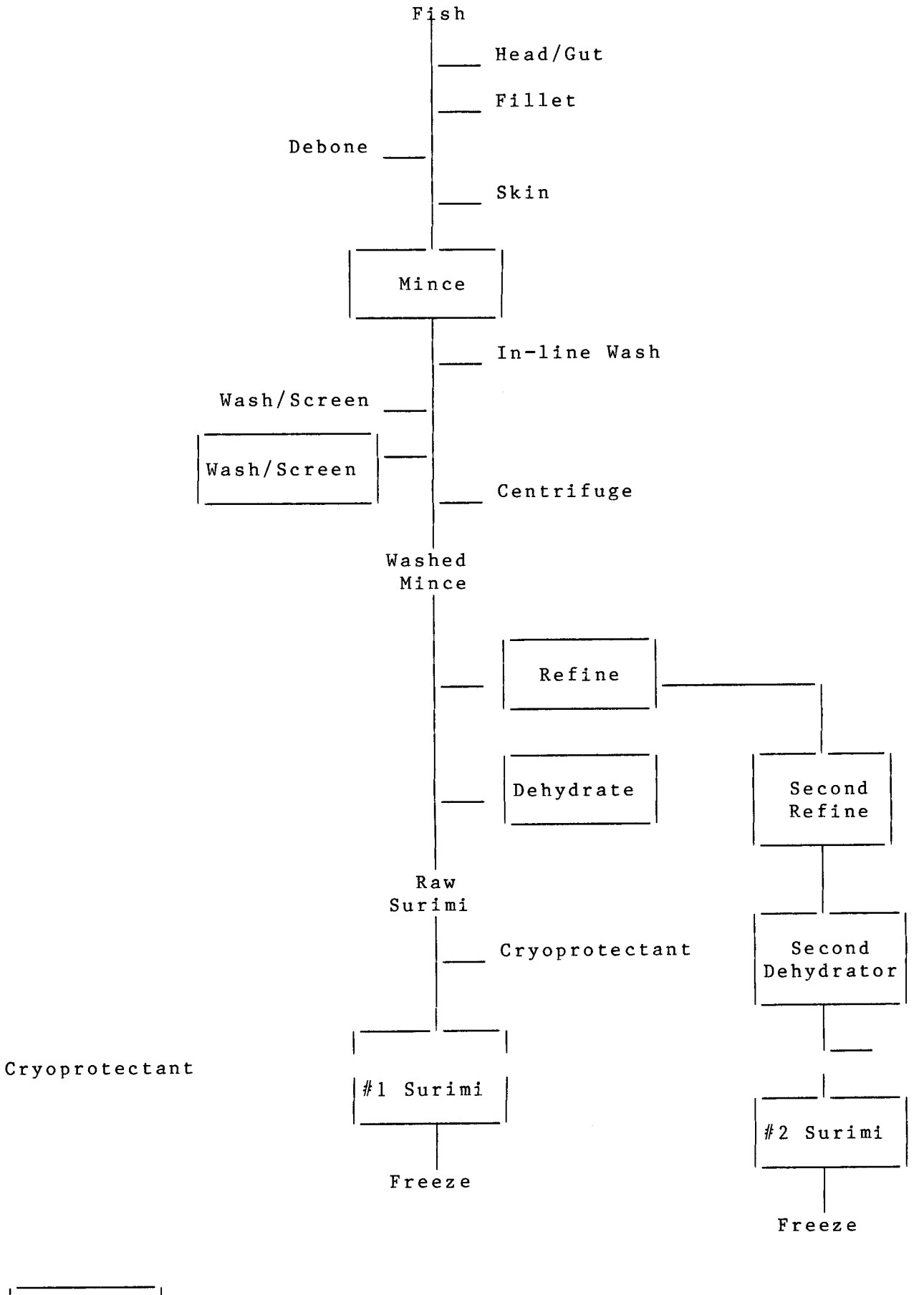

Figure 1. Surimi Manufacturing Steps

Appendix I

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ALASKA PACIFIC SEAFOODS
BOAT DATA SHEET
HACCP SAMPLING

	DATE	AREA	POUNDS	BOAT	ARRIVAL DATE	BOAT #	LOT # AM	LOT # PM	FISH SIZE % < 13"
F	3/11/88	535-802	339445	Alyeska	3/10	(094)	070-3	071-1	3.65
M	3/14/88	535-731	555959	Aldeberan	3/13	(097)	073-3	074-1	3.90
Tu	3/15/88	535-731	548747	Alyeska	3/14	(098)	074-3	075-1	2.19
TH	3/17/88	535-731	350660	Alyeska	3/16	(100)	076-3	077-1	5.94
M	3/21/88	525-801	294581	Aldeberan	3/21	(103)	079-3	081-1	6.41
Tu	3/22/88	535-802	251703	Arcturus	3/21	(104)	081-3	082-1	5.85
TH	3/24/88	545-732	453549	Arcturus	3/24	(107)		084-1	12.01
F	3/25/88	545-732	453549	Arcturus	3/24	(107)	084-3	085-1	12.01
M	3/28/88	545-732	499265	Arcturus	3/27	(110)	087-3	088-1	7.82
Tu	3/29/88	535-731	452039	Alyeska	3/28	(111)	088-3	089-1	9.91
TH	3/31/88	545-804	581844	Arcturus	3/31	(113)		091-1	1.70
F	4/01/88	545-804	581844	Arcturus	3/31	(113)		092-1	1.70
Tu	4/05/88	545-804	490626	Aldeberan	4/04	(115)		096-1	1.97

Barbara

All these stat numbers refer to Shelikof Strait on the N.W. side of Kodiak Island.

Appendix II

Q.C. NOTES

SURIMI

SHUT DOWNS 3/25 - 4/5

3/25 5P — 3/26 7A

3/3 1P - 7P.

3/8 11P - 9P 3/9

3/11 2P - 9P.

3/17 11P - 3/18 12P

3/20 9A - 7P.

3/20 10P - 7A 3/21

3/24 4P - 7P 3/21

3/23 4A - 7P

3/30 11P - 7A 3/31

3/31 9P 9A 4/1

4/1 11P 1pt/2.

4/2 9P - 7P

4/2 11P - 11A 4/3

4/3 10P - 9A 4/4

4/4 8P - 8A 4/5