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Production and Quality Assessment of Surimi from Selected Atlantic Groundfish and Male Capelin

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PRODUCTION AND QUALITY ASSESSMENT OF SURIMI FROM SELECTED ATLANTIC GROUNDFISH AND MALE CAPELIN

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ABSTRACT

Chandra, C.V., 1988. Production and Quality Assessment of Surimi from Selected Atlantic Groundfish and Male Capelin. Can. Ind. Rep. Fish. Aquat. Sci. :vii+59p.

This was the second phase of a three phase surimi project on the suitability of surimi produced from trawler cod, trap cod, capelin, redfish and flounder. Laboratory and pilot scale surimi were produced from fillets, split fish, frames and collar-bone napes. The quality of surimi produced was assessed using standardized methods and the surimi yield obtained was also ascertained.

Findings indicated that good quality surimi can be produced from cod (both trawler and trap). Surimi produced from male capelin was encouraging. It was found that surimi can be produced from previously frozen trawler cod and male capelin. Capelin surimi blended well with cod surimi to produce a final product, the quality of which was between the two. Investigations revealed that pH of the leach water during the pilot runs appeared to have a direct influence on the quality of the surimi produced. Cool setting of surimi in a refrigerator at temperatures 2°C-3°C from one to nine days greatly improved the stress and strain values of the test samples.

Collar-bone napes from trawler cod can be used to produce surimi with high gel strength. Trawler cod and flounder frames were used to produce an acceptable quality surimi.

PREFACE

A contract was awarded to a research team from The Marine Institute to assess the potential of selected fish species to produce surimi. This is a continuation of research to identify the surimi producing potential of certain Canadian Atlantic fish species (Chandra 1986), (Haard 1986), (Voigt 1986). Surimi was produced from redfish, capelin, flounder and cod (trawler and trap) and information was generated on yields and acceptability for processing into final products.

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

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INTRODUCTION

Surimi is a Japanese word which literally means minced meat. It is mechanically deboned fish flesh that has been washed in water, dehydrated and mixed with cryoprotectants. It is nutritious, high in protein, low in fat, cholesterol and calories. It has long term frozen storability without major protein degradation and it is malleable. The range of surimi-based products is almost limitless, (eg. seafood analogues, sausages, chips, pasta and bread). For its versatility and nutritional value it has become very popular with consumers. The sales of surimi-based products, especially crab-flavoured surimi analogues, have doubled each year in the U.S.A. since 1980 until 1985 when it reached $300 million retail value (76,000,000 lbs. of product), (Spaulding, 1986). Sales are expected to reach three billion dollars in the early 1990's (Anon, 1985).

About 90% of the world production of surimi is derived from Alaskan pollock. Most of what is known about surimi has been based on work done on Alaskan pollock, with very little research having been carried out on surimi produced from the Canadian Atlantic fish species. Some early work has been done by Dr. Cosmos Ho (pers. comm.) with the opening in 1984 of Terra Nova Fisheries Ltd. of Clarenville, Newfoundland. He has shown that trap cod is a good raw material for the manufacture of surimi and surimi-based products.

During 1986-87, the Marine Institute's Food Technology Department carried out the second phase of a three phase surimi project. Studies on the suitability of surimi produced from trawler cod and redfish, and yields from these species, which were initiated during phase one were continued. New laboratory and pilot scale studies on the production of surimi from male capelin and trap cod and suitability of fish plant by-products (frames and napes) for surimi production on a pilot scale were included in this phase of the project.

Since October, 1986, CanPolar Consultants Ltd. has been involved, together with the Marine Institute, in the study of process in a technology of surimi production (Canpolar Consultants Ltd. 1988). Probes were installed at various points in the Bibun pilot line at the Marine Institute to monitor such factors as temperatures, pH and dewatering pressure during surimi production.

The main objective of this project was to expand our limited knowledge and gain expertise on the production of surimi from selected Atlantic Canadian fish species. The work commenced in June, 1986, and ended in March, 1987.

MATERIALS AND METHODS

The cod (Gadus morhua) used in this project were market-sized trawler cod, 50cm to 64cm (20" to 25") crux length, and mostly undersized trap cod ranging from 36cm to 46cm (14" to 18") crux length. Both laboratory and pilot scale tests were carried out on the cod in various forms; ie. skinless, full nape fillets, skin-on full nape fillets, regular split, split one side, split with the backbone completely removed, napes/collar bones, trimmed cod frames, frozen skinless fillets and frozen regular split. Other species investigated for their suitability in surimi production included capelin (*Mallotus villosus*), redfish (*Sebastes marinus*) and flounder (*Hippoglossoides platessoides*). Fish used in storage studies were kept in ice in a chill room temperature of 2°C to 4°C. In this report, when a fish is termed as "split", it refers to headless, gutted fish that has been cut ventrally to the dorsal edge, leaving the whole backbone intact, unlike the "regular split" where the soundbone has been removed together with the anterior part of the backbone.

LABORATORY SCALE SURIMI

Laboratory scale surimi was produced by deboning fillets in a deboner (Baader 694, drum size 3mm or 5mm bore) and washing the meat in cool tap water (2°C-7°C). The amount of water used for the washing was twice the weight of the minced flesh. After 10 minutes washing, the mixture was decanted through a stainless steel China cap strainer (1mm bore). A total of three washings was carried out, each for a duration of 10 minutes. The third and final washing was carried out in 0.3 NaCl. The washed minced fish flesh was then put in a heavy grade, closely woven muslin bag and dewatered with a Carver press at 5,000 p.s.i. for five minutes. Cryoprotectants (4% sorbitol, 4% sucrose and 0.3% sodium polyphosphate) were mixed with the dewatered flesh in a Hobart mixer for about three minutes to produce surimi.

PILOT SCALE SURIMI

The surimi pilot line was shipped and installed by the Bibun Company of Japan in February, 1986, at the Marine Institute, St. John's, Newfoundland (Figs. 1 and 2).
Essentially, the pilot scale surimi production on the Bibun surimi line followed steps similar to that described for the laboratory scale surimi production, except the whole process was automatic and had only two washings (each of 10 minutes duration). Also, the ratio of water to meat, by weight, was 3:1. The second washing was carried out in 0.3% saline. Another difference was that the pilot line had a refiner which separated the impurities (bones, scales, dark meat, etc.) from the washed fish flesh. The resulting refined fish flesh was dewatered through a screw press. The dewatered fish flesh was then mixed with cryoprotectants (4% sucrose, 4% sorbitol, and 0.3% sodium polyphosphate) in a silent cutter for about three minutes to produce surimi.

The surimi produced in both the laboratory and the pilot scale production were frozen in plate freezers prior to testing their quality. These production methods were departed from, and the variation is described in the report.

SURIMI QUALITY TESTING (SURIMI ANALYSES)

The following tests were conducted on the surimi produced: (All tests, unless otherwise stated, were carried out in triplicate and the results averaged).

1) Moisture content was determined by measuring the weight loss of 10g of surimi after drying in an oven at 105°C for about six hours (until there was no further reduction of weight). A numerical value for the moisture content was obtained by dividing the loss in weight by the original weight and multiplying it by 100.

2) Lightness (whiteness) was measured by identifying the "L" value using the Hunter-Gardner tristimulus colorimeter, in which the standard white tile gives an "L" value of 93.7 while the standard black tile gives an "L" value reading of 0).

3) pH was measured by adding 10g of surimi to 90ml of distilled water, blending it in a food processor and measuring the slurry with a pH meter.

4) The foreign element test (Suzuki, 1981) was carried out by noting the number of foreign elements (such as scales, black or white membranes etc.) in 10g of surimi that had been spread out to 1mm thickness. Only elements at or above 1mm long were considered; results were scored on a 10-point scale:

TEST SCORE	NO. OF FOREIGN ELEMENTS
10	0
9	1 - 2
8	3 - 4
7	5 - 7
6	8 - 11
5	12 - 15
4	16 - 19
3	20 - 25
2	26 - 30
1	Over 31

Surimi test specimens were prepared by mixing, under vacuum, 2 per cent salt to about 3kg of sliced, tempered (-2°C) surimi in a Stephan cutter until the temperature rose to 5°C. The resulting paste was stuffed into two types of stainless steel tubes (i.d. 1.25cm x 17.5cm and i.d. 1.9cm x 17.5cm) and sausage casings (i.d. 3.0cm x 30cm). They were cooked at three different temperatures (40°C, 60°C and 90°C). The 40°C specimens were heated a second time at 90°C for 10 minutes (small tubes), 15 minutes (medium tubes) and 20 minutes (sausage casings). The resulting cooked surimi specimens were cooled and their heat-induced gel properties analysed within 24 hours of preparation.

Torsion failure tests were carried out as described by Montejano et al., (1983). Cylindrical surimi specimens were ground to a dumbbell shape with a length of 2.87cm, end diameter of 1.9cm and middle diameter of 1cm. Using a modified Brookfield viscometer, the true stress and strain at failure of the surimi specimens were calculated using appropriate equations (Hamann 1983). Shear stress (gel strength) is the maximum force required to bring the dumbbell shaped cooked surimi to breaking point (ie. failure). This is expressed in kilopascals. Shear strain (ductility or pliability) is the degree of deformation that occurs in bringing the dumbbell shaped specimen to the failure point. This is a ratio and is dimensionless. Rigidity or modules of elasticity is the ratio of shear stress over shear strain and is expressed in kilopascals.

The fold tests were conducted to make elasticity using cooked surimi (kamaboko) slices 3mm thick and 30mm in diameter, after it had been cooled to room temperature. The slices were first folded in halves, then quarters. The cracks or breaks that occurred as a result of the folding were recorded and scored as follows:

SCORE	RESULT OF FOLDING
5	Does not crack after folding in quarters.
4	Does not crack after folding in halves.
3	Cracks gradually when folding in half.
2	Cracks immediately when folding in half.
1	Breaks or crumbles by finger pressure.

Five fold tests were carried out for each sample and the average score noted.

RESULTS AND DISCUSSION

TRAWLER COD

Properties of Surimi from Trawler Cod

Some properties of surimi prepared from 32 lots of trawler cod are summarized in Tables 1, 2 and 11, according to the process used. It is indicated in the tables whether the surimi was prepared by laboratory or pilot operation.

The type of raw material being used for the surimi production appeared to have a direct effect on the colour of the product. The whitest surimi was produced from skinless full nape fillets, followed in descending levels of whiteness by skin-on full nape fillets, regular split, split-one-side, trimmed frames, napes and lastly whole frames (untrimmed). The "L" values for each are shown in Tables 1 and 2. The trawler cod full nape skinless fillets had a higher "L" value than that of surimi made from both trap cod at Terra Nova Fisheries and the shore based pollock sample tested. (Table 3).

Foreign element tests in general on surimi, using the above as raw material, followed the same order in the degree of impurities found (skin, blood, black belly lining, etc.); the surimi produced from the skinless fillet appeared to have the least number of impurities or foreign elements while the whole frames had the highest number of foreign elements. This would be expected as the cleaner the raw material used, the cleaner the surimi products. Compared to the pilot scale, there were many foreign elements found in the surimi produced in the laboratory scale. This probably was due to the presence of a refiner in the pilot line. As was shown in a previous study (Chandra, 1986) surimi prepared from frames and split cod contained more foreign elements than surimi prepared from fillets.

Pilot scale trawler cod surimi produced from fillets, regular split cod and split cod with the back bone completely removed gave a maximum fold test score of five. However, trawler surimi made from split-one-side and whole frames obtained lower fold test scores. Compared to whole frame, the surimi produced from trimmed trawler cod frames (where the kidney region and the back bone had been removed) had higher fold test scores denoting better elasticity. Further details of exact fold tests obtained for each samples have been tabulated. (Table 1)

Trawler cod skinless full nape fillet, compared to split trawler cod and cod frames, produced the best quality surimi. It produced the highest "L" value scores, scored well in the fold test, and contained the least number of foreign elements. The stress and strain values were also high, indicating good gel strength and elasticity (ductility).

In comparing stress values against moisture content of surimi produced from trawler fish and other species of fish investigated, it was noticed that there was a general inverse correlation between these two characteristics; there was a tendency to obtain higher stress values with lower moisture content of the surimi. This was also noted in the previous study (Chandra 1986).

Surimi Production from Frozen Cod

In December, 1986, surimi was produced successfully from frozen trawler cod on the pilot line. The product was white and gave the maximum score of five (5) for the fold test. The stress (gel strength) and especially the strain (ductility) values were remarkably good (Table 1 - process date December 16, 1986). Another batch was produced from frozen trawler cod (process date February 13, 1987). Although the stress and strain values were lower, it confirmed that surimi can be produced from previously frozen cod.

This was the first time surimi had been produced successfully from frozen cod.

TRAP COD SURIMI

In 1986, the Newfoundland trap cod season was short and catches were poor. Both laboratory and pilot scale production of surimi were carried out using trap cod when it was available (Table 3).

Generally, the trap cod surimi was less white than that produced from trawler cod. This may be attributed partly to the fact that trap cod was processed round and unbled while trawler cod was gutted and bled. The mean (90°C) "L" values from the trap cod fillet surimi was 72.2 while the corresponding value for trawler cod surimi was 77.0 in the pilot scale studies. Some of the values for moisture content of trap cod surimi produced were quite low compared to figures obtained from trawler cod tested in the pilot scale studies. Better dehydration in the screw press may help explain this difference. Good quality surimi with good gel strength (stress) and pliability, can be produced from trap cod.

From the limited pilot scale studies conducted, the stress and strain values obtained from the trap cod surimi were generally slightly higher than those obtained from the trawler cod surimi. However, the post-mortem age of the trap cod used was mostly one day while that of the trawler cod used ranged from four to 10 days. On the other hand, much better stress and strain values were obtained from surimi produced from trawler skinless fillets (pilot scale) with a post-mortem age of five days than from the surimi made from a day old trap cod.

CAPELIN

One of the main limitations of capelin studies is the brief period of availability of fresh capelin. The gutting and skinning of the male capelin is also difficult because of its small size. After carrying out numerous trials, a nobbing machine (Baader 561) was used to gut and a squid skinning machine was adapted to help in the washing of the capelin after it had been gutted and sectioned.

Capelin Skinning

Various experiments were carried out with previously frozen capelin in an attempt to achieve the best skinning process. The Norwegian process, as described by Eide et al. (1982), was carried out where sections of capelin in low pH were agitated rapidly in water between 40°C and 50°C. There were some skinning effects but the results were not as positive as indicated in the research paper. Very few black membranes were removed.

More effective skinning results were obtained by immersing the gutted, sectioned capelin in hot water (90°C - 95°C) for four to five seconds and then washing it in chilled 0.05% NaCl. Fairly good results were also obtained by immersing the gutted capelin in warm water (45°C) for about three minutes and subsequently running the capelin through a scaler. (There is a fine balance involved in providing just enough heat to skin the capelin easily, while not overheating and thus affecting the underlying flesh).

Both laboratory and pilot scale surimi were produced from male capelin. The results, which are summarized in Tables 5 and 6, were encouraging. Surimi produced from capelin differed from that of cod in that it was less white, having a grey to beige colour. This was expected, as capelin flesh is not as white as that of cod. The average "L" value of raw capelin surimi (pilot scale) was 39.6 while the corresponding value for trap cod surimi was 53. Capelin surimi had lower fold test values than trap or trawler cod surimi, and there was also more foreign matter found in the surimi produced from the imperfectly skinned capelin than in the boneless fillet cod surimi.

The average stress values of capelin surimi were generally lower than those of cod surimi. The strain values, which indicate pliability, were comparable to those of cod surimi. There was a faint odour of capelin detected on the capelin surimi produced.

Capelin Surimi Bleaching

Capelin surimi is usually grey in colour. Of the various experiments conducted to produce a whiter colour, the most successful involved the use of hydrogen peroxide. Various concentrations of hydrogen perioxide (for 5% to 30%) were used and all proved successful. The greyish product turned extremely white even in the weakest concentration. After about 24 hours of reaction time the "L" values were as follows:

H_2O_2 Concentration		"L" Values
Control	0%	37.9
	5%	54.2
	10%	55.7
	15%	57.4
	20%	56.8
	25%	55.9
	30%	56.3

This experiment opens up bright prospects for whitening the product.

Frozen Capelin Surimi

For the first time, surimi from previously frozen capelin was successfully produced during this project (Table 6). The gel strength (shear stress) values were comparable to that produced from fresh capelin. This fact makes it possible for the much greater exploitation of the underutilized male capelin which is now mainly treated as fish meal or waste. During the short, extremely busy capelin season, the male capelin could be frozen for surimi production during the slower, less busy months of the year. This has great possibilities in Newfoundland's fishing industry in creating much needed employment during the idle winter months, especially for the smaller fish plants dependent on the inshore fisheries.

Blending of Capelin and Cod Surimi

As shown in Table 7, when inshore trawl (hook and line) cod surimi and capelin surimi were blended together on a 50 - 50 basis and the quality assessed, it was found that the blended surimi had properties intermediate to the 'higher quality' cod surimi and the 'lower quality' capelin surimi; the colour, stress (gel strength), strain and fold test values were in between the two.

The ease in blending the surimi produced from two completely different fish species is encouraging and should enhance the usefulness of capelin surimi.

What is normally considered 'high quality' surimi is 'rubbery' consistency. Although this is desirable to Japanese consumers, it has been found to be undesirable to Western tastes. Such surimi could be blended with 'low quality' capelin surimi or surimi produced from frozen cod, cod frames or frozen capelin, to develop a less rubbery product more acceptable to North American consumers. Depending on consumer tastes, surimi produced from different species and of varying qualities could be blended to produce the desired qualities.

More detailed studies on capelin surimi production must be conducted to produce more acceptable surimi products. The colour and odour of capelin surimi could be further improved to produce a more refined product. This study has clearly indicated that capelin surimi possessed fairly reasonable gel strength and pliability. The use of male capelin (fresh and frozen) as a raw material in producing surimi opens up a new avenue for the use of this underutilized species. Capelin surimi blended with surimi produced from cod also appears to have potential.

PROPERTIES OF SURIMI FROM OTHER SPECIES

The properties of surimi prepared from redfish skin-on-fillet and flounder frame fillet are summarized in Tables 8 and 9. Redfish surimi has good gel strength (stress) and excellent ductility (strain) and elasticity (fold test). The preliminary results from flounder frame meat, like that for cod frame meat (Tables 1 and 9), indicate a product having lower stress and strain values than that produced from cod fillets. The higher content of proteolytic enzymes, from viscera, blood and bacteria in frame meat may account for this difference.

SURIMI YIELD STUDIES

All yields in this study have been expressed as a percentage of eviscerated cod weight unless otherwise stated; they have all been corrected to 80% moisture content.

The surimi yield from trawler cod (skinless fillet) ranged from 37 per cent to 40 per cent of head-on-gutted weight in the laboratory scale production (Table 2). The yield obtained in laboratory scale was much higher than that obtained from a corresponding sample produced from the pilot line. For instance, the yield obtained from the trawler full nape fillet in the laboratory scale study was around 40 per cent compared to 20 per cent in the pilot study. This would be expected because of the finer pore size of the muslin bag used in the laboratory scale dewatering process compared to the screw press screen. As can be seen from Table 1, in the pilot runs the highest surimi yield (up to 35%) was obtained when head-on gutted, split-one - side trawler cod was used as raw material, while the lowest yield (about 20%) was derived from fillets of eviscerated cod. Regular split gave a surimi yield of about 26 to 29 per cent. Split cod, when the backbone had been completely removed, produced a surimi yield of 21.3 per cent. The higher yields obtained from trawler cod compared to the corresponding figures from trap cod is consistent with the higher myofibrillar protein content in winter trawler fish (Haard and Warren, 1986).

The surimi yield from trap cod skinless fillet on the pilot line ranged from 14 per cent to 22 per cent of head-on-gutted weight, (Table 3) equal to that achieved commercially by Terra Nova Fisheries (David Ho - personal communication). A much higher surimi yield (about 29%) was obtained from trap cod split-one-side.

Two series of pilot scale runs were carried out with trawler cod and inshore trawl cod to ascertain the surimi yields and the extent of loss at various points in the production process. The summary of the results are tabulated in Table 10. About 20 per cent of the cod's head-on-gutted weight was in the head in both trawler and inshore trawl fish.

The soundbone with the anterior part of the backbone accounted for 7% - 8% of head-on-gutted cod weight when it was "regular split". The mincer waste accounted for 9% - 12%, the pilot line refiner waste 8% and the screw press waste 4% - 7%, the surimi stuck to the screw dehydrator accounted for 1% - 2% and the unaccounted loss (soluble proteins, fat, flesh stuck to pilot line) accounted for 21% - 28%. From the inshore trawl cod, the best yield was obtained in the split-one-side (33.7%) followed by regular split (31.4%), and the worst yield (29.6%) was obtained from the split trawl cod where the backbone was completely removed.

In the trawler cod, the regular split cod had the best surimi yield (28.8%), followed by split-one-side cod (26.5%), while split cod with the backbone completely removed accounted for 21.3% of head-on-gutted weight (Table 10).

The surimi yield produced on the pilot line from headed gutted capelin ranged from 18% to 34% of round weight Table 5, compared with the much higher range of 37% to 50% of round weight (Table 6) in the laboratory scale study. In the pilot scale capelin surimi production, the average yield was 23.3 per cent of round weight compared to 42 per cent of round weight in the laboratory scale production.

The pilot run for skin-on redfish fillet surimi ranged from 12% to 14% of round fish weight (Table 8). There was a general decrease in surimi yield with increased post-mortem age of redfish, except for one reading (age 7 days) which indicated that yield dropped lower than was expected (Table 8).

OBSERVATIONS

ACTION OF COOL SETTING

It was determined that by holding the prepared surimi filled stainless steel tubing samples in the refrigerator (2°C - 3°C) for 1, 2, 3 or 9 days, the stress and strain values of the samples greatly improved over the ones that were tested immediately with no refrigeration (Table 12). Improvement in stress value ranged from 26% to 84% for samples kept in the refrigerator for 24 hours. One sample which was left for 9 days in the refrigerator produced a tremendous increase of 641 per cent in the stress (or gel strength) value.

The strain value, (with one exception where there was a decrease of 3.6%), generally increased by 2.5% to 114.3% (Table 12). This limited study indicates that great improvements in the stress and strain value occurin surimi produced from fresh trawler cod, (skinless fillets, split-one-side and frames), frozen trawler cod and frozen capelin when the surimi is refrigerated. Although more work is warranted in this direction, it seems fair to say that this phenomenon of improvement of the gel strength of the surimi by holding it at 2°C - 3°C could be exploited to derive fuller potential of the raw material in the commercial production of surimi-based products like artificial crab legs and other seafood analogues where good gel strength and elasticity are important.

INFLUENCE OF pH

Where the effects of pH were being studied, 0.5N HCl or 0.5N NaOH was used to adjust the pH to the desired level in the leaching or washing tanks.

Two three-run series of production were carried out on the pilot line where the pH of the first and second washing tanks were controlled at 6.1 for the first run, 7 for the second, and 6.8 for the third, in each of the two series of runs. It was noted that the acidification of the wash to pH of 6.1 gave the best results (Table 11). In the first series, (February 19 and 20, 1987), the rigidity value at pH 6.1 was about twice that at pH 6.8 and three times the value achieved at pH 7. Lowering pH also gave improved dehydration of the surimi (Table 11). For pH 6.1 it was 73.9% moisture content compared with 79.3% pH 6.8 and 81.5% pH 7. Similar trends were noted in the second series of runs where the post-mortem age of the cod used was lower.

This experiment indicates that manipulation of the wash water seems to be one way of improving surimi quality. Improvement in dehydration of the surimi is achieved by acidification, and this seems to confirm the results obtained by Bligh et al. (1986).

As pH of leach tank increased the moisture content of the surimi also increased. (Table 11). Usually the older raw material, the higher was the pH of the minced flesh. (They were general observations but no tables constructed).

If sufficient dehydration is obtained by pH manipulation, the addition of .3% NaCl put in the final second wash, to aid the dehydration processin the screw press, may not be necessary. Further experimentation in this direction may be necessary to obtain a clearer picture.

TEMPERATURE

During processing of some of the surimi on the pilot lines, Canpolar Consultants monitored and recorded the temperature of the minced fish flesh during its progress through the line. They also recorded the pressures achieved during the dehydration of the minced fish flesh. In a few runs, the pH was monitored and the anions concentrations (like K^+, Na^+, and Ca^{++}) during the leaching process were recorded. The above information was tabulated, together with the summary of the surimi quality results carried out by the Marine Institute. The combined results are shown from Figs. 3 to 16 (Canpolar Consultants Ltd., 1988).

Generally the temperature of the first leaching tank was maintained below 7°C, and as the fish flesh progressed down the pilot line, the temperature climbed slowly until it reached its peak during the dehydration stage at the screw press or dehydrator. The frictional and shearing forces of the screw press probably created the additional heat. Usually, the temperature was maintained below 10°C but occasionally during the dehydration stage, it climbed above the 10°C mark; this may have had an adverse effect on the gelling properties of the surimi produced. From current literature available, it has been recommended that the temperature of the minced flesh be maintained below 10°C during surimi production as the gel strength is affected above that temperature (Sonu 1986). Although this is mainly based on work done on Alaskan pollock, this may also be true for North Atlantic fish species like cod or capelin. Further work is needed to confirm this.

FRAMES

Because of the present high price of groundfish in general and cod in particular, the once undersized cod (under 18") that a couple of years ago were either dumped or discarded as offal are now in heavy demand. As a result, frames from groundfish have rapidly become very attractive as a cheap, alternate source of almost untapped raw material available to be exploited for surimi production. In 1985, about 250,000 metric tonnes of groundfish frames in Atlantic Canada were a potential source of raw material for surimi production (Grandy 1987). In the present project, the surimi yield from whole headless cod frames was six per cent of head-on-gutted weight (Table 1). From trimmed cod frames, where the central backbone region was removed together with the kidney region, a surimi yield of 21% to 26% of trimmed frame weight was obtained. The trimmed frames produced better quality surimi (Table 1). It had higher stress (gel strength) and strain (ductility and elasticity) values. The high content of enzymes from viscera, blood and bacteria from whole frames may have accounted for this difference. Nevertheless, this project and the work carried out the previous year (Chandra 1986) have demonstrated that it is possible to produce fair to good quality surimi from frames (cod and flounder) and cod napes. It is also felt that further work on frames, especially on other common groundfish like redfish, sole, turbot, etc., would be a worthwhile exercise.

PREWASHING COLLAR-BONE NAPES

A very encouraging result was obtained when skin-on collar-bone napes from trawler cod were used for surimi production in the pilot line. The difference from the usual production procedure was that a 10 minute prewashing of the raw material was carried out in a modified squid washer with vigourous agitation in chilled water. After the collar-bone napes were minced they were directly washed for five minutes in 0.3% saline solution. There was only one washing of the minced flesh carried out instead of the usual two of 10 minutes duration each. The surimi produced from this batch had remarkably good stress (54 kpa for 90°C sample) and strain (3.14 for 90°C sample) values (Table 1). It had a maximum score of five for fold test. This prewashing may be an important step in producing good quality surimi from cod collarbone napes which are waste products for most fish plants.

It is also felt that a similar prewash cycle would help produce better quality surimi, from other raw materials especially from lower quality materials such as frames and second grade fish.

RIGIDITY VS. STRAIN

Lanier (1986) suggested that in plotting a graph of rigidity versus strain values the samples that were brittle, tough, rubbery or mushy tended to favour the four corners of the graph. A graph (Figure 17) was drawn using some of the data obtained during this project. It was found that only two samples produced from capelin on the laboratory scale were found in the brittle corner of the graph. The average moisture content was 75.2%. In the tough sector of the graph were found two samples of pilot scale trawler cod surimi obtained from full nape fillets and collarbone napes and one sample of pilot scale surimi from skin-on redfish fillet. The average surimi moisture content of the trawler cod sample was 75.9% while the moisture content of the redfish sample was 76.9%. In the mushy corner of the graph was found one sample of surimi produced in a laboratory scale from headless gutted capelin. The moisture content was 80%. On the rubbery sector of the graph were found four samples of trawler cod surimi produced from split cod and skinless fillets. The average moisture content of these samples was 80.7%. In the centre of the graph were six samples of trawler cod surimi made from trimmed frames and fillets (pilot scale) and four trap cod samples produced from fillets. The average moisture content was 78.4%.

Analysis of the graph indicated that the moisture content had some correlation with the type of surimi produced. When the moisture was about 75%, the samples were found around the brittle end of the scale and when about 76 per cent, they were found in the tough sector. The mushy sector surimi indicated the moisture content to be around 80 per cent while the rubbery sector of the surimi had an average moisture content of 80.7%. However, many more sets of values are needed to further verify this hypothesis.

Figure 18 shows the position each of the pilot scale pH runs occupies in the graph of rigidity plotted against strain values. Figure 19 shows the position that each run occupies in the graph of rigidity versus strain values for the different species of fish investigated (cod, capelin, redfish and flounder). The latter graph differentiates neither between laboratory and pilot scale runs nor the processed forms of raw material used (ie. whether it was a fillet, split or frame form).

STRESS AND STRAIN RELATIONSHIPS

Analysis of data obtained for the 90°C cooked sample from trawler cod, (pilot and laboratory scale production) and redfish (pilot) indicate that variation of stress values was influenced by moisture content of the surimi, while strain values appeared to be more influenced by the post-mortem age of the raw material (Tables 13 and 14). Similar relationships were reported in a previous study (Chandra 1986).

CONCLUSIONS

The present study did show further support to work carried out the previous year (Chandra, 1986) that moisture content does have a direct relationship with the stress values and that good quality surimi can be produced from trawler cod.

The pH of the wash (leach) water appeared to have an effect on the moisture content, indicating that the pH adjustment of the wash tanks could possibly be used to control the moisture content of the final surimi product.

The study indicated there is a potential for production of good quality surimi from trap cod. It is also anticipated that fair quality surimi could be produced from male capelin. The strain values, which indicate pliability, were comparable to that of cod surimi.

Frames (trawler cod and flounder) have been found to be suitable for surimi production.

This study has also shown that cool setting in the refrigerator at 2°C - 3°C for 1 to 9 days improved signficantly the gel strength and the strain value of surimi produced from trawler cod and capelin.

The best overall quality of surimi was produced from skinless fillet, while the best surimi yield was obtained generally when the fish was split-one-side.

Prewashing of raw material like collar-bone napes appeared to be beneficial to the quality of surimi produced. It may probably be particularly useful in improving the quality of surimi produced from lower grade raw materials like frames, napes and the like.

Odourless surimi was produced from trawler frames having an odour that would have meant rejection for whole fish. Surimi production could be a good means of salvaging raw materials of second or third grade quality.

This study has also established that surimi can be produced from both previously frozen trawler cod and capelin.

Very encouraging results were obtained by blending capelin and cod surimi, indicating that because of its versatility, surimi produced from different species of varying properties could be blended to produce the desired qualities to meet varying market needs.

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BIBLIOGRAPHY

Anon, 1985. As Surimi bandwagon rolls, big food firms seem ready to hop along. Frozen Food Age, 33(c):33-57.

Bligh, E.G., R.F. Ablett, C. Hotton and K. Spencer. 1986. Surimi potential of selected Atlantic fish. Fisheries Development Branch - Scotia-Fundy Region, Halifax, N.S. Project Report 111:29p.

Canpolar Consulting Ltd., 1988. Development of Process Controls for Surimi Production.

Chandra, C.V., 1986. A Study of the Use of Cod, Cod By-Products and Crustacean By-Products: Part I - Raw Material Assessment. Can. Ind. Rep. Fish. Aquat. Sci. 177:46p.

Eide, O., T. Borresen and T. Strom. 1982. Minced fish production from capelin (Mallotus villosus). A new method for gutting, skinning and removing fat from sall fatty fish species. J. Food Sci. 47:347-350.

Grandy, M. 1987. The availability of raw material for surimi processing in Atlantic Canada. [In: Atlantic Canada Surimi Workshop. Clarenville, Nfld.] General Education Series 4:34-58.

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 Can. Ind. Rep. Fish. Aquat. Sci. 177.

Haard, N.F., and J.E. Warren, 1986. Influence of Holding Fillets from Undersize Atlantic Cod (Gadus morhua) at 0°C or -3°C on the Yield and Quality of Surimi. In: International Symposium on Engineered Seafoods (R.E. Martin, ed.). National Fisheries Institute. Washington, D.C.

Hamann, D.D. 1983. Failure Characteristics of Solid Foods. In "Physical Properties of Food," (Ed.) Bagley, E.G. and Peleg, M. Avi Publishing Co., Westport, CT.

Lanier, T.C., D.D. Hamann and M.C. Wu. 1984. Development of Methods for Quality and Functionality Assessment of Surimi Minced Fish. Report. Prepared for the Alaska Fisheries Development Foundation, Inc. 103 p.

Lanier, T.C. 1986. Functional properties of surimi. Food Technology. 40:107-114, 124.

Montejano, J.G., D.d. Hamann and T.C. Lanier. 1983. Final strengths and rheological changes during processing of thermally induced fish muscle gels. J. Rheol 27: 557.

Sonu, J.C. 1986. Surimi NOAA Technical Memorandum NMFS. NOAA-TM-NMFS-SWR-013). U.S. Dept. of Commerce. 99p.

BIBLIOGRAPHY

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Spaulding, M. 1986. Crabmeat-type products have a "fishy" tale to tell. Prepared Foods 155 (1):137, 139.

Suzuki, T. 1981. Fish and Krill Protein: Processing Technology Applied Science Publishers Ltd., Longon. 260 p.

Canpolar Consulting Ltd., 1988. Development of Process Controls for Surimi Production (In Press) 1988.

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. Can. Ind. Rep. Fish. Aquat. Sci. 177 viii + 46 p.

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. Can. Ind. Rep. Fish. Aquat. Sci. 177 viii + 34 p.

Voigt, Michael N., Memorial University of Newfoundland, 1987. Research on the Use of Low Cost Fish, Fish and Crustacean Processing By-Products for Surimi and Surimi-Based Products - Objective 2: Shellfish Flavourant Extraction and Processing Studies In Press).

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. Can. Ind. Rep. Fish. Aquat. Sci. 177 vii+ 42p.

TABLE 1

SUMMARY OF SURIMI RESULTS (Trawler Cod - Pilot Scale)

Sample	Age (Days)	Process Date	Moisture Content	pH	Colour ("L" Value)				Fold Test			Foreign Elements	Surimi Yield 80% Moisture Content	Stress (KPA)			Shear Strain			Rigidity (KPA)90°
					Raw	40°C	60°C	90°C	40°C	60°C	90°C			40°C	60°C	90°C	40°C	60°C	90°C	
Full Nape Fillet Skinless	5	10-29-86	75.2	6.89	58.1	76.4	73.6	77.0	5	5	5	8	20.2	71.5	61.5	61.3	3.50	3.47	3.44	17.82
Skin-on, Full Nape Fillet	6	11-13-86	78.0	7.15	53.4	75.8	76.0	75.7	5	5	5	9	19.5	36.5	30.7	34.6	3.51	3.69	3.59	9.64
Regular Split	5	11-18-86	78.7	7.01	49.6	75.2	75.2	75.4	5	5	5	8	28.8	45.7	29.4	20.1	4.10	3.96	3.44	5.84
" "	-	06-04-86	81.2	6.74	48.2	73.6	72.0	74.2	-	-	-	5	25.7	6.5	-	5.0	1.40	-	1.47	3.40
Split One Side	3	04-09-86	78.7	N/A	51.9	74.4	73.5	73.6	2	2	2	-	20.6	8.5	8.8	8.5	1.53	1.05	1.37	6.20
" " "	4	04-10-86	79.1	6.89	47.7	75.4	75.3	75.0	2	2	2	-	34.4	8.6	8.8	8.4	1.94	1.64	1.78	4.72
" " "	5	11-19-86	80.3	7.25	49.0	71.2	72.6	72.6	5	3	5	6	26.5	31.3	11.2	24.0	3.89	1.92	3.71	6.5
" " "	5	09-30-86	75.8	6.97	45.2	70.1	70.7	71.0	3	2	3	8	29.2	30.3	12.9	28.1	1.50	0.79	1.56	18.01
Split, Backbone Completely Removed	5	11-21-86	80.3	7.41	52.9	75.6	74.7	73.5	5	5	5	6	21.3	16.0	18.3	17.7	3.31	2.73	3.06	5.8
#Collar Bone/Napes	5	12-10-86	74.8	6.97	48.7	70.2	69.0	69.6	5	5	5	8	--	66.0	56.9	54.3	3.07	3.14	3.14	17.29
Whole Cod Frames	5	10-29-86	76.9	7.02	40.5	66.0	64.6	63.1	1	1	2	2	5.8	9.5	--	15.6	1.04	--	1.34	11.64
Trimmed Cod Frames	6	10-30-86	77.3	7.10	48.2	72.1	72.0	72.2	5	2	4	3	--	27.4	10.0	22.4	2.37	1.36	1.77	12.7
*Trimmed Cod Frames	7	03-12-87	79.9	7.44	51.4	72.0	70.9	71.8	5	5	5	6	*25.7	10.4	13.0	15.6	3.63	3.32	2.74	5.69
*Trimmed Cod Frames	7	03-12-87	79.6	7.17	53.7	71.7	71.3	70.8	5	5	5	6	*21.4	17.4	12.0	14.4	2.46	2.52	2.69	5.35
+Skinless Fillet (frozen)	4	12-16-86	79.8	6.91	52.8	76.1	77.3	77.6	5	5	5	9	28.9	22.9	10.8	14.3	3.26	2.77	2.55	5.6
+Skinless Fillet (frozen)	4	02-13-87	80.5	7.07	52.3	77.6	76.9	77.6	3	2	4	9	18.8	9.6	6.3	5.4	1.51	1.83	1.59	3.4
+ Regular Split (frozen)	4	12-23-86	84.0	7.28	56.1	77.3	77.7	76.7	2	2	2	9	--	-	-	-	-	-	-	-

+ Surimi produced from previously frozen trawler cod.
* Surimi yield based on trimmed cod frame.
# Collar bone napes were prewashed for 10 minutes and their minced flesh was only washed once for 5 minutes.

TABLE 2

SUMMARY OF SURIMI TEST RESULTS (Trawler Cod - Lab Scale)

Sample	Age (Days)	Process Date	Moisture Content	pH	Colour ("L" Value)				Fold Test			Foreign Elements	Surimi Yield 80% Moisture Content	Stress (KPA)			Shear Strain			Ridigity(KPA)
					Raw	40°C	60°C	90°C	40°C	60°C	90°C			40°C	60°C	90°C	40°C	60°C	90°C	90°C
Straight Cut Fillet	5	08-19-86	77.7	6.84	61.6	74.8	75.9	74.7	5	5	1	9	--	19.8	13.8	13.5	1.28	1.20	1.19	11.34
" "	6	08-20-86	78.7	8.09	54.7	75.2	75. 2	74.9	2	2	2	8	--	14.9	13.1	14.5	1.22	1.16	1.21	11.98
" "	7	08-21-86	78.6	6.94	57.7	76.5	75.9	76.0	5	2	2	9	36.7	19.7	13.5	16.2	1.89	1.31	1.28	12.66
" "	8	08-22-86	78.6	6.97	57.1	76.0	73.3	74.3	5	2	5	8	37.7	17.4	13.4	12.1	1.47	1.50	1.53	7.91
Full Nape Fillet	6	09-10-86	78.8	6.88	60.3	74.3	75.8	76.5	5	5	5	7	40.4	19.1	8.7	14.4	1.70	1.16	1.51	9.54
" "	7	08-26-86	77.5	6.97	58.4	76.0	75.0	74.3	-	-	-	7	--	--	--	--	--	--	--	N/A
" "	8	09-04-86	78.1	7.27	57.4	76.4	75.1	76.7	5	5	5	7	40.1	20.3	17.3	16.4	2.13	1.88	2.09	7.85
" "	10	09-05-86	76.1	6.98	57.7	77.6	75.5	--	5	5	5	7	38.7	31.9	26.5	28.8	2.41	2.24	2.35	12.26

TABLE 3

SUMMARY OF SURIMI TEST RESULTS (Trap Cod)

Sample	Age (Days)	Process Date	Moisture Content	pH	Colour ("L" Value)				Fold Test			Foreign Elements	Surimi Yield 80% Moisture Content	Stress (KPA)			Shear Strain			Ridigity(KPA)
					Raw	40°C	60°C	90°C	40°C	60°C	90°C			40°C	60°C	90°C	40°C	60°C	90°C	90°C
Full Nape Skinless Fillet (Pilot)	< 1	07-23-86	78.4	6.86	54.0	80.1	79.3	79.8	5	5	5	6	13.8	30.7	19.5	24.2	2.50	2.00	2.30	10.52
	1	07-22-86	77.1	6.87	52.3	79.1	75.2	75.7	5	1	5	7	15.9	37.5	15.4	23.3	2.40	1.50	1.90	12.26
	2	07-29-86	75.2	6.99	51.9	74.9	73.2	73.6	5	5	5	7	21.7	41.0	23.2	27.4	2.40	1.70	1.40	19.57
	3	07-30-86	74.4	6.92	53.8	76.7	72.7	74.5	5	3	5	6	18.9	47.7	43.8	50.4	3.10	2.40	2.30	21.91
Straight Cut Skinless Fillet (Pilot)	1	07-16-86	79.7	7.56	51.9	65.1	65.5	63.4	5	1	5	7	19.7	36.7	14.3	16.6	3.20	2.10	2.36	7.03
	1	07-17-86	81.9	7.04	55.0	66.2	65.6	66.3	5	2	5	6	--	9.4	3.6	4.8	3.00	1.80	2.20	2.18
Split One Side (Pilot)	1	07-24-86	74.5	6.85	42.7	68.3	68.1	--	1	1	1	4	28.5	55.9	16.3	41.7	2.60	1.00	2.20	18.95
Skinless Fillet Trap Cod (Lab)	< 1	07-21-86	75.6	6.97	50.4	61.0	62.1	61.6	5	5	5	7	--	49.1	29.3	35.7	2.97	2.50	2.29	
*Skinless Fillet Trap Cod (Terra Nova Fisheries)	1	08- -85	76.1	6.3	58.6	76.0	74.6	74.8	4	1	1	7	--	22.8	9.2	18.9	1.89	1.38	1.72	
Alaska, Pollock Shore Grade Surimi (Alaska)	6	--	77.6	6.95	53.3	65.9	68.9	66.0	5	2	5	6	--	31.6	18.3	36.8	2.08	1.51	2.44	

TABLE 4

SUMMARY OF SURIMI TEST RESULTS (Inshore Trawl Cod-Pilot Scale)

Sample	Age (Days)	Process Date	Moisture Content	pH	Colour ("L" Value)				Fold Test			Foreign Elements	Surimi Yield 80% Moisture Content	Stress (KPA)			Shear Strain			Ridigity(KPA)
					Raw	40°C	60°C	90°C	40°C	60°C	90°C			40°C	60°C	90°C	40°C	60°C	90°C	90°C
Regular Split	1	10-15-86	78.8	7.26	48.8	72.0	72.4	72.3	5	5	5	3	31.4	22.5	18.6	13.8	3.10	2.84	2.72	5.07
Split One Side	2	10-16-86	77.2	7.11	44.3	69.2	69.4	69.6	5	2	5	4	33.7	33.4	11.2	26.2	2.39	1.13	1.92	18.45
Split, Backbone Completely Removed	3	10-17-86	77.8	7.05	47.4	71.8	70.1	70.6	5	5	5	3	29.6	38.1	16.6	25.7	3.17	2.17	2.64	9.72

TABLE 5

SUMMARY OF SURIMI TEST RESULTS (Capelin - Pilot Scale)

Sample	Age (Days)	Process Date	Moisture Content	pH	Colour ("L" Value)				Fold Test			Foreign Elements	Surimi Yield 80% Moisture Content	Stress (KPA)			Shear Strain			Ridigity(KPA)
					Raw	40°C	60°C	90°C	40°C	60°C	90°C			40°C	60°C	90°C	40°C	60°C	90°C	90°C
Round	2	06-12-86	82.3	6.96	43.3	49.0	--	49.0	2	-	2	5	21.2	4.4	--	3.6	1.7	--	1.90	1.89
Headless Gutted	1	07-10-86	79.7	7.22	28.4	40.1	40.0	40.4	5	5	5	1	18.9	24.5	19.5	26.5	2.80	2.50	2.70	9.81
"	1	06-18-86	88.0	6.68	46.0	--	--	--	-	-	-	5	26.5	--	--	--	--	--	--	N/A
"	1	06-24-86	81.7	7.18	37.4	46.7	45.5	46.0	5	2	5	6	17.8	11.3	3.8	11.0	3.2	1.8	2.4	4.58
"	2	06-19-86	85.9	7.46	45.0	52.4	52.8	53.8	-	-	-	6	25.2	--	--	--	--	--	--	N/A
"	2	06-25-86	81.5	7.36	38.5	46.8	43.9	46.6	2	2	2	5	33.5	12.5	3.8	11.2	1.1	1.0	1.1	10.18
"	2	07-04-86	83.2	7.12	38.4	45.3	45.0	45.4	1	1	1	2	17.6	4.3	2.4	4.7	1.5	1.1	1.5	3.13
Headed, Gutted, & Skinned	Frozen July 2	01-21-87	81.5	7.28	N/A	41.6	42.0	40.9	1	1	1	N/A	N/A	--	--	No	Gel	Strength	--	--

TABLE 6

SUMMARY OF SURIMI TEST RESULTS (Capelin - Lab Scale)

Sample	Age (Days)	Process Date	Moisture Content	pH	Colour ("L" Value)				Fold Test			Foreign Elements	Surimi Yield 80% Moisture Content	Stress (KPA)			Shear Strain			Ridigity(KPA) 90°C
					Raw	40°C	60°C	90°C	40°C	60°C	90°C			40°C	60°C	90°C	40°C	60°C	90°C	
*Round	--	10-07-86	75.2	7.17	26.5	39.4	38.9	39.3	1	1	1	1	57.8	16.4	6.3	13.3	0.93	0.63	0.85	15.65
Skinless Fillet (Fresh)	1	07-01-86	81.0	7.17	34.6	48.7	45.7	47.9	5	4	5	1	15.4	7.4	6.4	5.8	1.85	1.88	1.88	3.09
Headless Gutted (Fresh)	2	07-03-86	81.4	7.31	33.9	44.9	42.7	45.6	1	1	1	1	--	--	2.8	--	--	0.79	--	N/A
*Headless Gutted	--	07-08-86	76.4	7.08	26.1	34.8	46.1	44.8	1	1	1	1	36.8	11.3	12.0	9.2	1.01	1.07	1.03	8.93
" "		10-06-86	75.6	7.07	30.2	40.4	43.2	41.5	1	1	1	1	46.3	12.5	--	14.6	0.49	--	0.74	19.73
" "		10-08-86	74.7	7.06	29.6	41.8	42.4	42.1	1	1	1	1	49.6	12.6	7.4	--	0.81	0.44	--	N/A
" "		10-09-86	80.0	7.23	30.2	43.9	44.7	42.7	1	1	1	1	37.9	6.0	4.0	5.5	0.44	0.50	1.03	5.34
*Headed, Gutted and Skinned	--	01-21-87	81.5	7.28	N/A	41.6	42.0	40.9	1	1	1	N/A	--	No	Gel	Strength				
		12-02-86	83.6	7.17	35.6	41.8	41.1	40.3	1	1	1	1	--	No	Gel	Strength				

*Capelin was plate frozen within 24 hrs. of catch on July 2, 1986

TABLE 7

SUMMARY OF SURIMI TEST RESULTS (Blended Capelin and Cod Surimi)

Sample	Process Date	Moisture Content	pH	Colour ("L" Value)				Fold Test			Foreign Elements	Surimi Yield 80% Moisture Content	Stress (KPA)			Shear Strain			Rigidity(KPA 90°C
				Raw	40°C	60°C	90°C	40°C	60°C	90°C			40°C	60°C	90°C	40°C	60°C	90°C	
1. Regular Split (Inshore Trawl Cod)	10-15-86	78.8	7.26	48.8	72.0	72.4	72.3	5	5	5	3	31.4	22.5	18.6	13.8	3.10	2.34	2.7	--
2. Capelin (Headless Gutted)	07-10-86	79.7	7.22	28.4	40.1	40.0	40.4	2	-	2	5	21.2	4.4	--	3.6	1.7	--	1.9	--
3. Blended Cod(50%) & Capelin(50%) (i.e. 1 + 2)	02-11-87 (tested)	--	--	39.1	53.7	53.8	54.0	4	3	4	-	--	16.4	10.3	16.0	1.97	1.79	2.0	--

TABLE 8

SUMMARY OF SURIMI TEST RESULTS (Redfish - Pilot Scale)

Sample	Age (Days)	Process Date	Moisture Content	pH	Colour ("L" Value)				Fold Test			Foreign Elements	Surimi Yield 80% Moisture Content	Stress (KPA)			Shear Strain			Ridigity(KPA)
					Raw	40°C	60°C	90°C	40°C	60°C	90°C			40°C	60°C	90°C	40°C	60°C	90°C	90°C
Skin On Fillet	4	09-18-86	77.5	7.07	56.2	72.5	70.6	70.8	5	5	5	7	14.2	39.9	55.1	48.6	2.15	3.15	2.61	18.6
" " "	5	09-19-86	77.4	7.10	55.5	74.1	71.0	73.3	5	5	5	8	14.0	38.8	30.7	42.1	3.00	2.19	2.73	15.4
" " "	6	09-23-86	77.5	7.22	55.4	71.6	69.9	70.7	5	5	5	9	13.9	41.4	47.1	45.7	2.84	3.59	3.23	14.15
" " "	7	09-24-86	76.6	7.16	51.7	67.2	65.4	--	5	5	5	9	11.7	42.0	49.3	51.4	2.12	2.47	2.46	20.89
" " "	8	09-25-86	75.7	7.23	49.4	64.8	68.8	68.6	5	5	5	7	13.7	41.5	42.3	46.4	1.96	2.40	2.11	21.99
" " "	9	09-26-86	77.3	7.21	50.7	70.7	68.6	67.5	5	5	5	7	13.4	34.0	33.1	45.1	2.47	2.68	2.36	19.11

TABLE 9

SUMMARY OF SURIMI TEST RESULTS (Flounder)

Sample	Age (Days)	Process Date	Moisture Content	pH	Colour ("L" Value)				Fold Test			Foreign Elements	Surimi Yield 80% Moisture Content	Stress (KPA)			Shear Strain			Ridigity(KPA)
					Raw	40°C	60°C	90°C	40°C	60°C	90°C			40°C	60°C	90°C	40°C	60°C	90°C	90°C
Whole Frame (Pilot)	5	10-30-86	75.9	7.02	64.6	75.1	75.5	75.0	3	2	2	6	--	19.5	13.3	22.3	1.26	1.14	1.24	17.98
Trimmed Frames (Pilot)	10	11-04-86	82.4	7.49	66.0	77.9	76.9	76.6	1	1	1	5	--	--	--	--	--	--	--	N/A
*Fillet (Lab)	1	08-13-86	78.0	6.87	61.7	74.0	75.8	75.6	2	2	2	6	16.2	10.7	8.8	8.6	2.4	2.4	2.5	3.44

* Surimi yield based on round weight.

TABLE 10 Breakdown of Yield Losses in a Pilot Scale Surimi Production

Point of Loss	Percent Loss of Dressed Weight (80% Moisture)					
	Trawler Cod Regular Split 5D.	Trawler Cod Split One Side 5D.	Trawler Cod Split, Back-Bone Removed 5D	Inshore Trawl Cod Regular Split 1D	Inshore Trawl Cod Split One-Side 2D	Inshore Trawl Cod Split, Backbone Removed 3D
Fish Head	20.2	19.5	18.9	18.1	19.9	19.1
Sound Bone	7.4	--	--	8.2	--	--
Complete Backbone	--	-	8.7	--	--	10.3
Mincer Waste (Skin & Bones)	10.4	12.0	9.0	9.6	11.5	9.5
Refiner Waste	5.4	5.8	6.1	3.4	7.5	5.9
Screw Press Waste	4.4	6.5	N/A	N/A	N/A	N/A
Surimi Stuck to Screw Press	2.0	1.8	1.2	0.9	0.9	1.0
Surimi Yield	28.8	26.5	21.3	31.4	33.7	29.6
Unaccounted Loss (Soluble Proteins, Fats, and Flesh Stuck to Pilot Line)	21.4	27.9	--	--	--	--

TABLE 11

SUMMARY OF SURIMI TEST RESULTS (Trawler Cod (Pilot Scale))= pH Series

Sample	Age-Days	Process Date	Moisture Content	pH-leach tank	Colour ("L" Value)				Fold Test			Foreign Elements	**Surimi Yield 80% Moisture Content	Stress (KPA)			Shear Strain			Rigidity(KPA 90°C
					Raw	40°C	60°C	90°C	40°C	60°C	90°C			40°C	60°C	90°C	40°C	60°C	90°C	
Skinless Fillet	8	02-19-87	79.3	6.80	54.2	77.1	76.3	75.2	5	5	5	10	23.2	25.4	18.8	22.5	2.99	2.72	2.94	7.7
" "	9	02-20-87	73.9	6.1	51.5	71.7	72.8	72.7	5	5	5	10	22.3	29.3	33.0	30.0	2.36	2.80	2.41	12.45
" "	9	02-20-87	81.5	7.0	57.5	77.3	76.8	77.2	5	5	5	9	20.1	11.3	14.2	12.7	2.89	3.05	3.19	4.0
Skinless Fillet	5	03-04-87	81.5	6.8	53.9	78.7	77.0	79.1	5	5	5	9	19.4	17.3	11.1	11.3	3.42	3.23	3.42	3.30
" "	6	03-05-87	78.5	6.1	54.0	76.5	76.8	78.1	5	5	5	9	19.4	17.1	22.3	16.8	2.95	3.05	2.52	6.67
" "	6	03-05-87	83.3	7.0	59.2	78.5	78.0	78.3	5	5	5	9	16.7	4.4	4.3	4.0	2.82	2.08	2.13	1.88
Trimmed Frame	8	03-13-87	80.2	6.1	51.2	70.1	69.0	70.3	5	3	4	4	19.2	8.2	8.3	8.5	1.63	1.63	1.57	5.41

** Surimi yield based on trimmed cod frames.

Meat ratio to water during leaching time was 1:5

TABLE 12 Action of Cool Setting in Refrigerator (2°C - 3°C) on Stress and Strain Values

Samples	Days Held @ 2°-3°C	Process Date	STRESS						STRAIN					
			Regular Samples		Samples Held @ 2°-3°C				Regular Samples		Samples Held @ 2°-3°C			
			40° C	90°C	40°C	% change	90°C	% change	40°C	90°C	40°C	% change	90°C	% change
Trawler Cod (split 1 side)	1	11-19-86	31.3	24.0	39.8	27.2	35.0	45.8	3.89	3.71	3.75	-3.6	4.17	12.4
Skinless Fillet(fresh)	1	03-04-87	17.3	11.3	23.9	38.2	17.1	51.3	3.42	3.42	3.96	15.8	4.49	31.3
Skinless Fillet	3	03-05-87	17.1	16.8	56.6	231.0	37.2	121.4	2.95	2.52	3.85	30.5	3.42	35.7
Skinless Fillet	9	03-05-87	4.4	3.9	30.4	590.1	28.9	641	2.8	2.1	4.3	53.6	4.5	114.3
Cod Frames	1	03-12-87	17.4	14.4	27.8	59.8	22.2	54.2	2.46	2.69	3.48	41.5	3.13	14.1
Cod Frames	2	03-13-87	8.2	8.5	12.5	52.4	10.5	23.5	1.63	1.57	1.91	14.7	1.96	24.8
Trawler Cod (frozen) Skinless Fillets	1	12-16-86	22.9	14.3	28.9	26.2	26.3	83.9	3.26	2.55	3.34	2.5	2.98	16.9
*Capelin(frozen) (Headless Gutted)	1	12-02-86	--	--	--		18.4		--	--	--		--	1.35

* Cooked capelin samples were too brittle to form the dumbbell shaped test samples. However, on cool setting overnight in refrigerator (2°C - 3°C) the gel strength improved and the 90°C sample could be tested.

TABLE 13 Relation Between Moisture Content of Surimi and Stress

	$(R^2)^1$	N
Stress (Trawler Cod Pilot Scale - 90°C sample)	0.72	17
Stress (Trawler Cod, Lab Scale - 90°C sample)	0.88	7
Stress (Redfish Pilot Scale - 90°C sample)	0.29	6

$(R^2)^1$ is coefficient of determination for linear regression analysis for N lots of surimi samples.

TABLE 14 Relation Between Post-Harvest Age and Strain

	$(R^2)^1$	N
Strain (Trawler Cod Pilot Scale - 90°C sample)	0.43	17
Strain (Trawler Cod Lab Scale - 90°C sample)	0.87	7
Strain (Redfish Pilot Scale - 90°C sample)	0.54	6

$(R^2)^1$ is coefficient of determination for linear regression analysis for N lots of surimi samples.

Figure 1 - A Flow Chart of the Surimi Production Process Using the Bibun Pilot Line

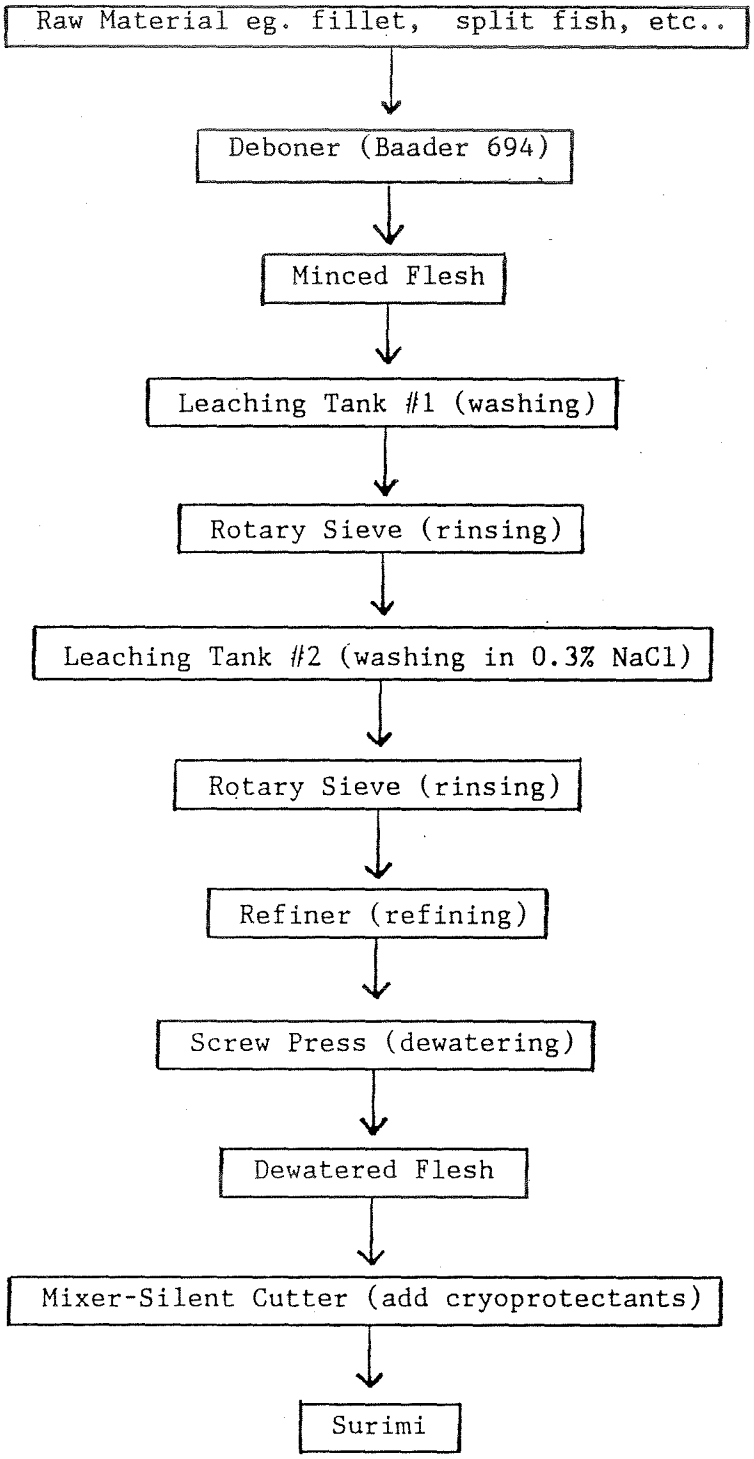


Figure 2 SURIMI PILOT LINE DRAWING

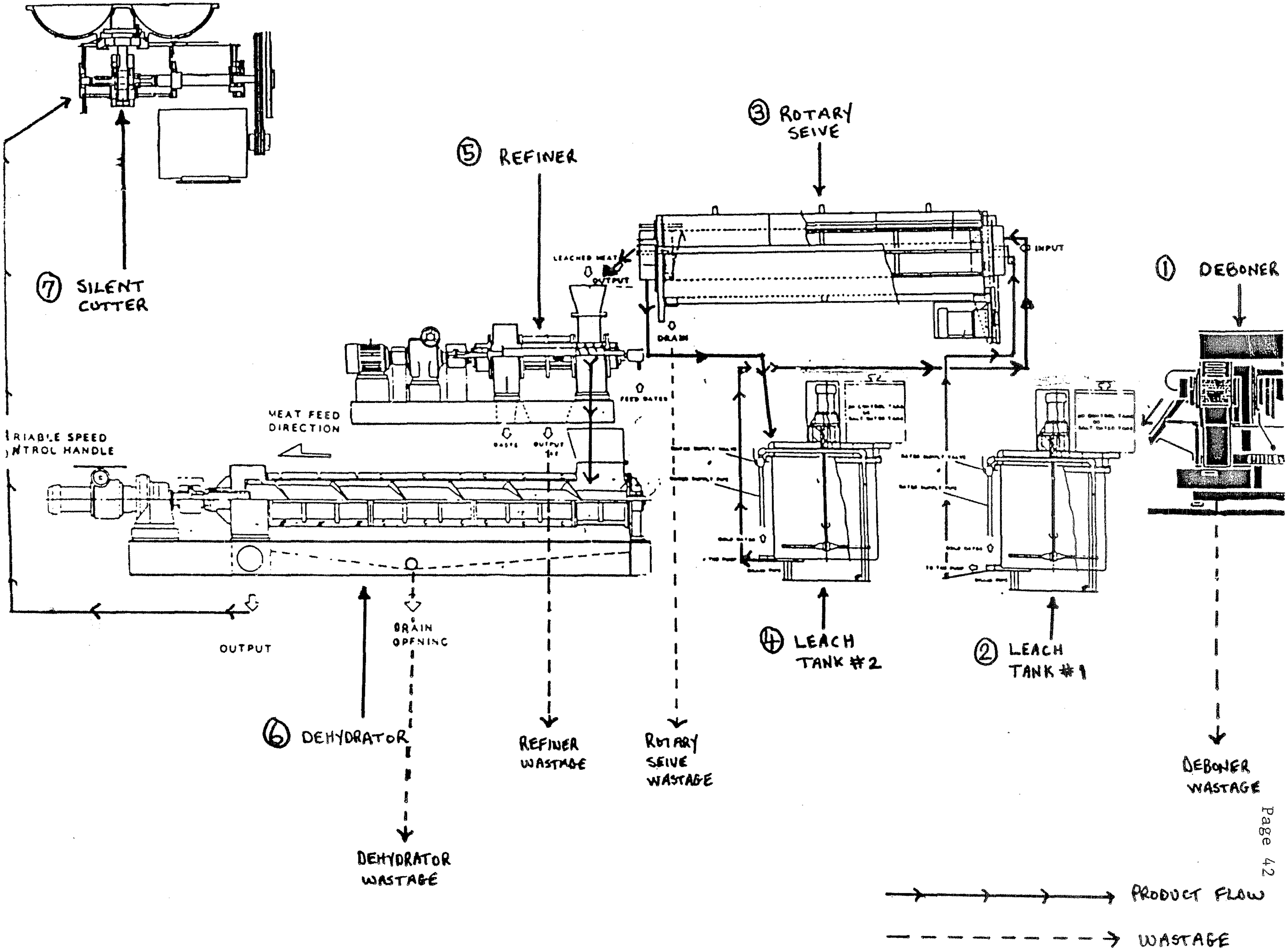
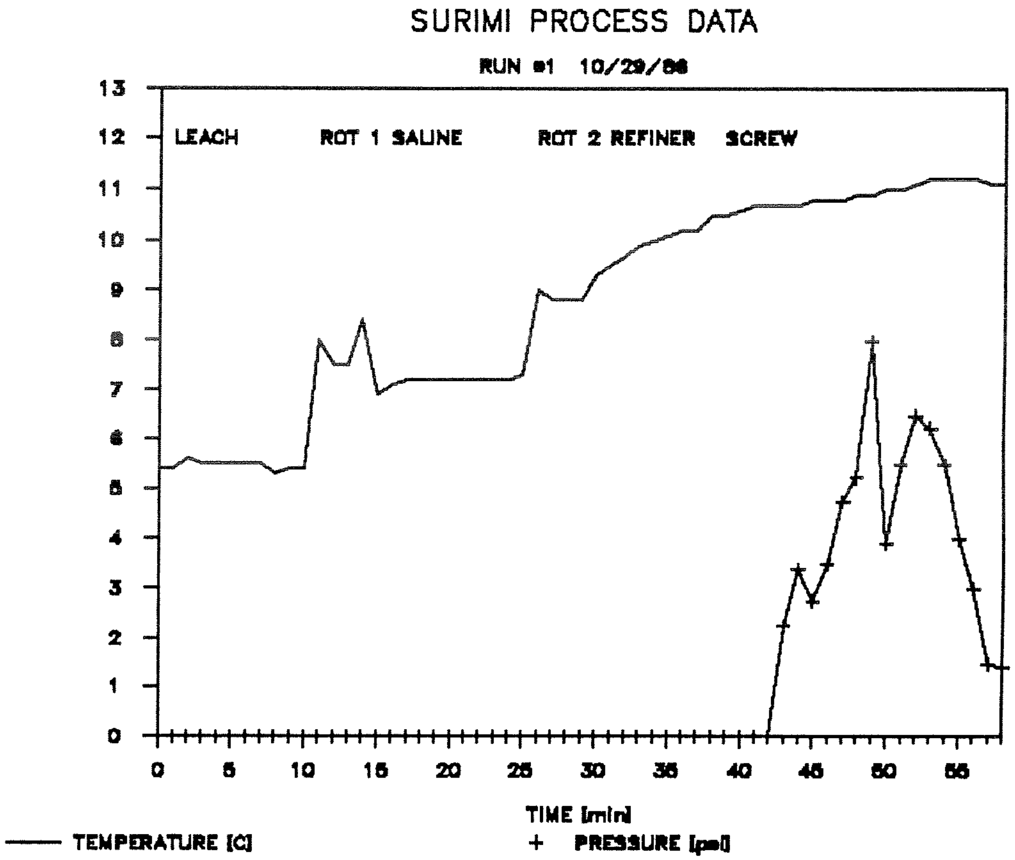


Figure 3



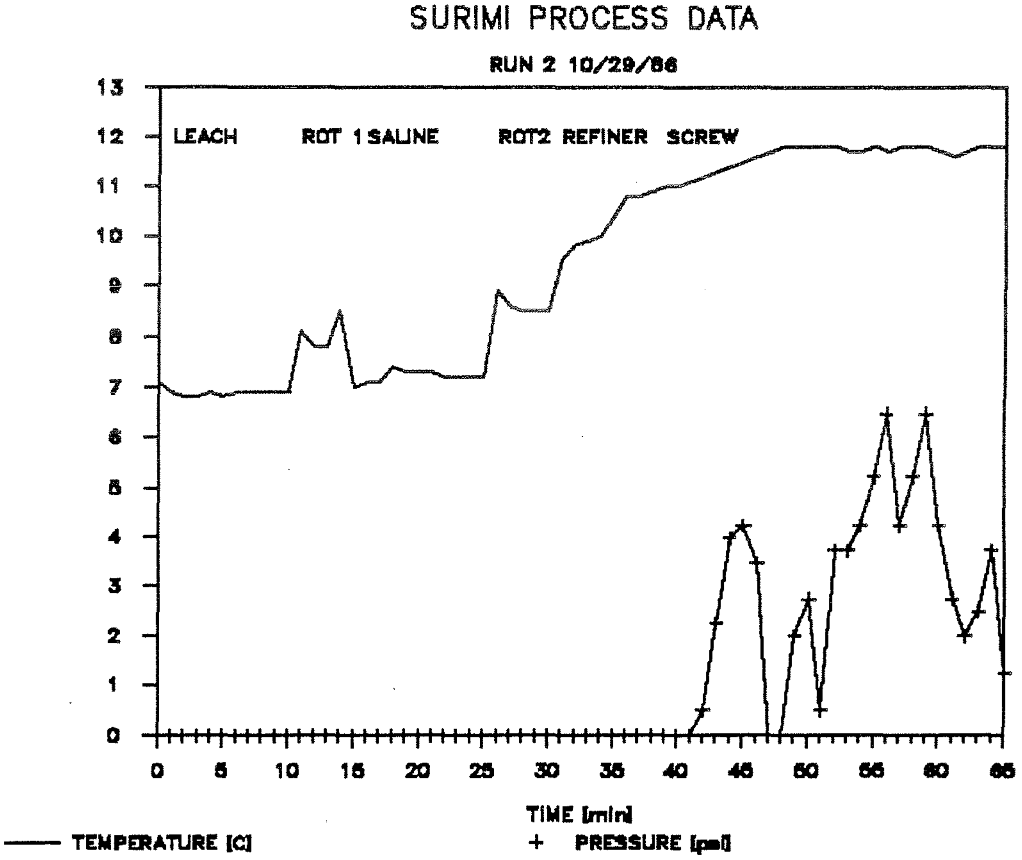
SURIMI PRODUCT DATA

RUN NO. 1	TEMPERATURE DEGREES CELCIUS			
10/29/86	RAW	40 C	60 C	90 C
5 DAY OLD				
COD FILLET				
STRESS (kPa)		71.5	61.5	61.3
STRAIN		3.50	3.47	3.44
MODULUS of ELASTICITY(kPa)		20.43	17.72	17.82
COLOR	58.1	76.4	73.6	77.0
FOLD		5.0	5.0	5.0

MOISTURE %	YIELD @ 80% MOISTURE	FOREIGN ELEMENTS	pH = 6.89
75.2	43.0	8	

NOTE: MODULUS of ELASTICITY = STRESS/STRAIN

Figure 4



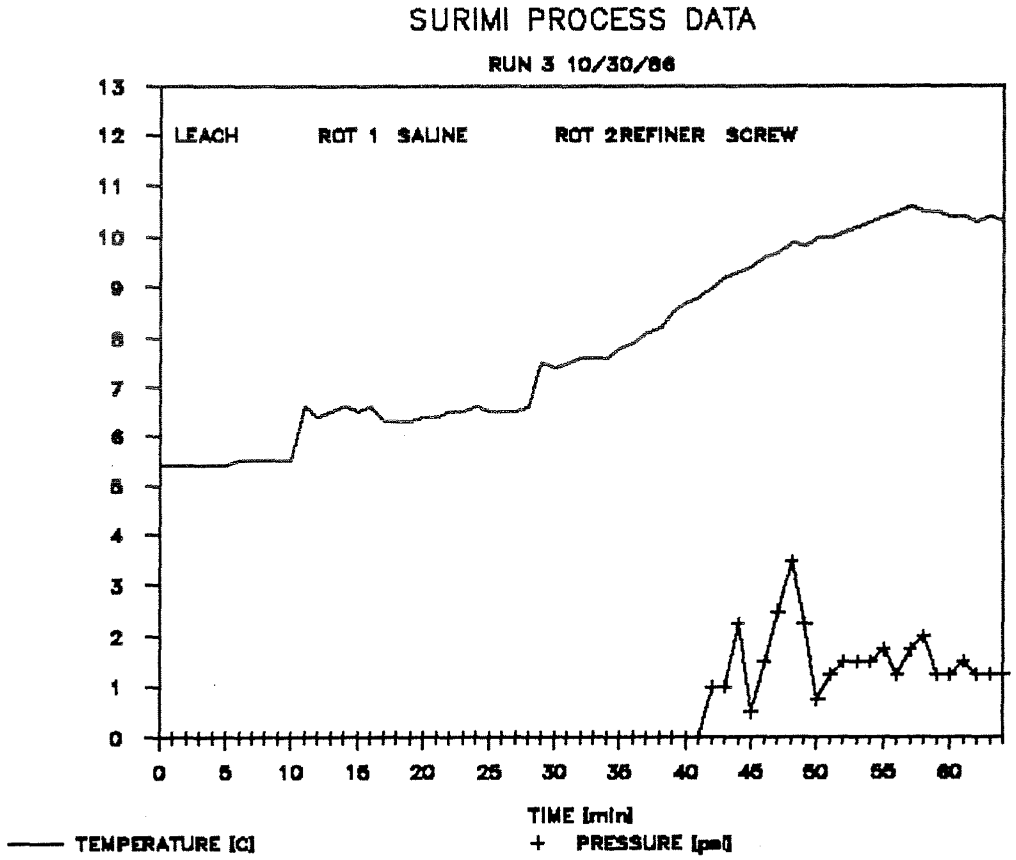
SURIMI PRODUCT DATA

RUN NO. 2 10/29/86 **5 DAY OLD** **COD FRAMES**	RAW	40 C	60 C	90 C
		TEMPERATURE DEGREES CELCIUS		
STRESS (kPa)		9.50	n/a	15.6
STRAIN		1.04	n/a	1.34
MODULUS of ELASTICITY(kPa)		9.13	n/a	11.6
COLOR	40.5	66.0	64.6	63.1
FOLD		1.0	1.0	2.0

MOISTURE %	YIELD @ 80% MOISTURE	FOREIGN ELEMENTS	pH = 7.02
76.9	42.3	3	

NOTE: MODULUS of ELASTICITY = STRESS/STRAIN

Figure 5



SURIMI PROCESS DATA

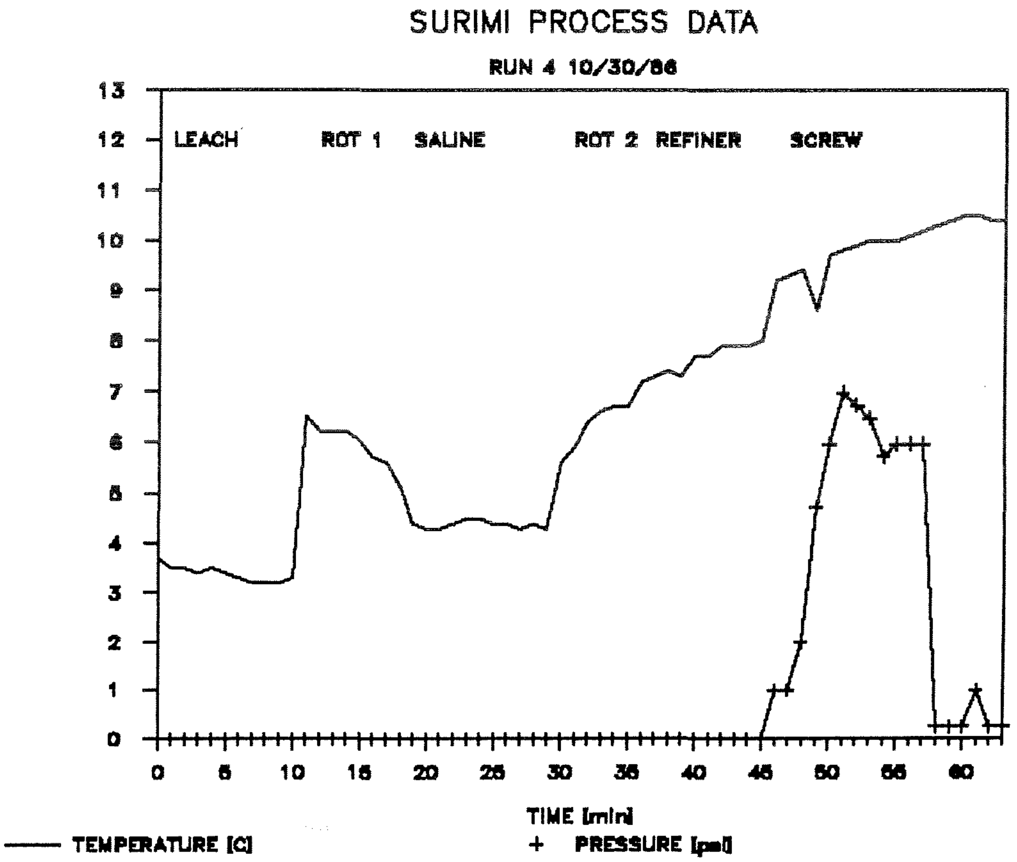
RUN 3 10/30/86

SURIMI PRODUCT DATA

RUN NO. 3 10/30/86 6 DAY OLD COD FRAMES	TEMPERATURE DEGREES CELCIUS			
	RAW	40 C	60 C	90 C
STRESS (kPa)		27.4	10.0	22.4
STRAIN		2.37	1.36	1.77
MODULUS of ELASTICITY(kPa)		11.6	7.4	12.7
COLOR	48.2	72.1	72.0	72.2
FOLD		5.0	2.0	4.0
MOISTURE %	YIELD @ 80% MOISTURE	FOREIGN ELEMENTS	pH = 6.73	
77.3	25.6	4		

NOTE: MODULUS of ELASTICITY = STRESS/STRAIN

Figure 6



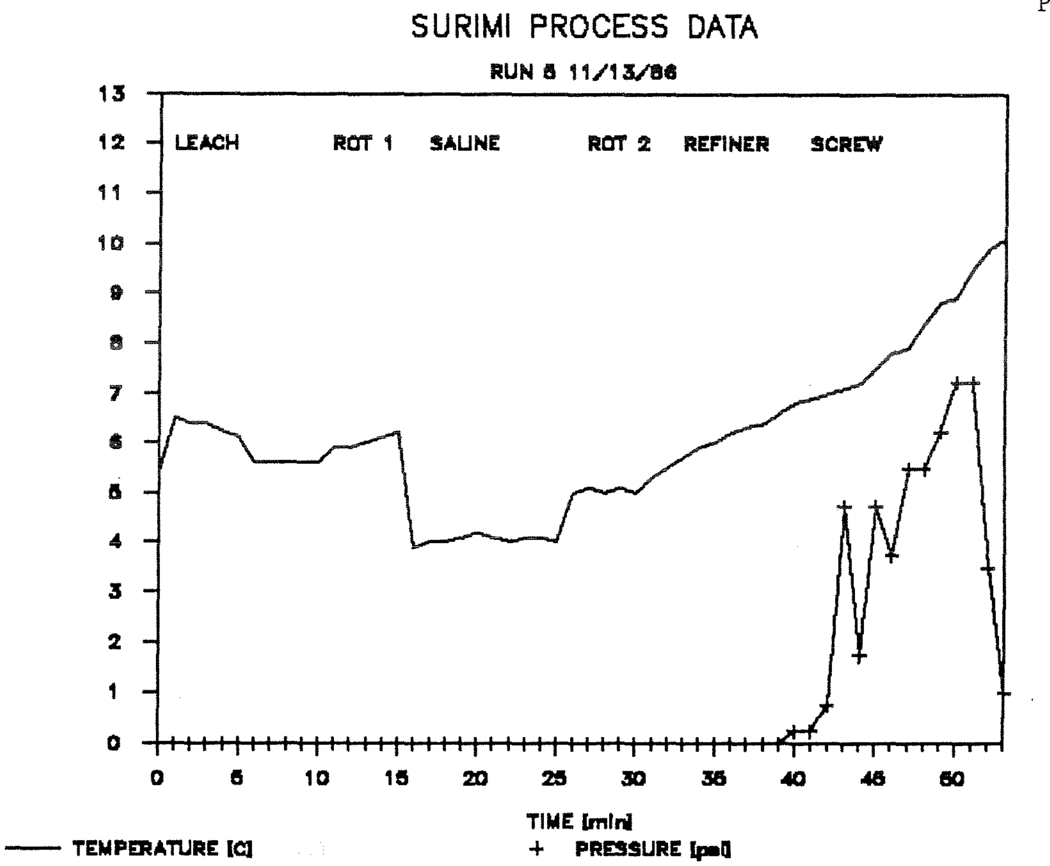
SURIMI PRODUCT DATA

RUN NO. 4 10/30/86 5 DAY OLD FLOUNDER FR.	TEMPERATURE DEGREES CELCIUS			
	RAW	40 C	60 C	90 C
STRESS (kPa)		19.5	13.3	22.3
STRAIN		1.26	1.14	1.24
MODULUS of ELASTICITY(kPa)		15.5	11.7	18.0
COLOR	64.6	75.1	75.5	75.0
FOLD		3.0	2.0	2.0

MOISTURE %	YIELD @ 80% MOISTURE	FOREIGN ELEMENTS	pH = 6.89
75.9	N/A	6	

NOTE: MODULUS of ELASTICITY = STRESS/STRAIN

Figure 7



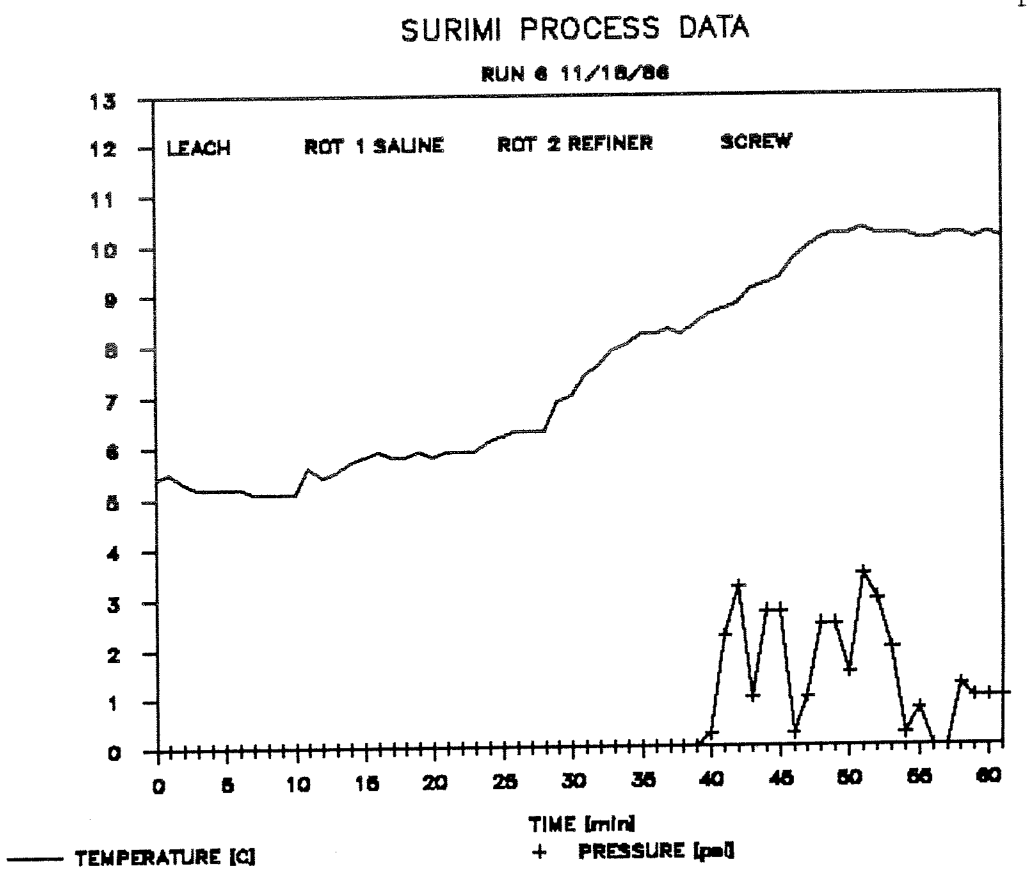
SURIMI PRODUCT DATA

RUN NO. 5	TEMPERATURE DEGREES CELCIUS			
11/13/86 6 DAY OLD TRAWLER COD	RAW	40 C	60 C	90 C
STRESS (kPa)		36.5	30.7	34.6
STRAIN		3.51	3.69	3.59
MODULUS of ELASTICITY(kPa)		10.4	8.3	9.6
COLOR	53.4	75.8	76.0	75.7
FOLD		5.0	5.0	5.0

MOISTURE %	YIELD @ 80% MOISTURE	FOREIGN ELEMENTS	pH = 6.74
78.0	19.5	9	

NOTE: MODULUS of ELASTICITY = STRESS/STRAIN

Figure 8



SURIMI PRODUCT DATA

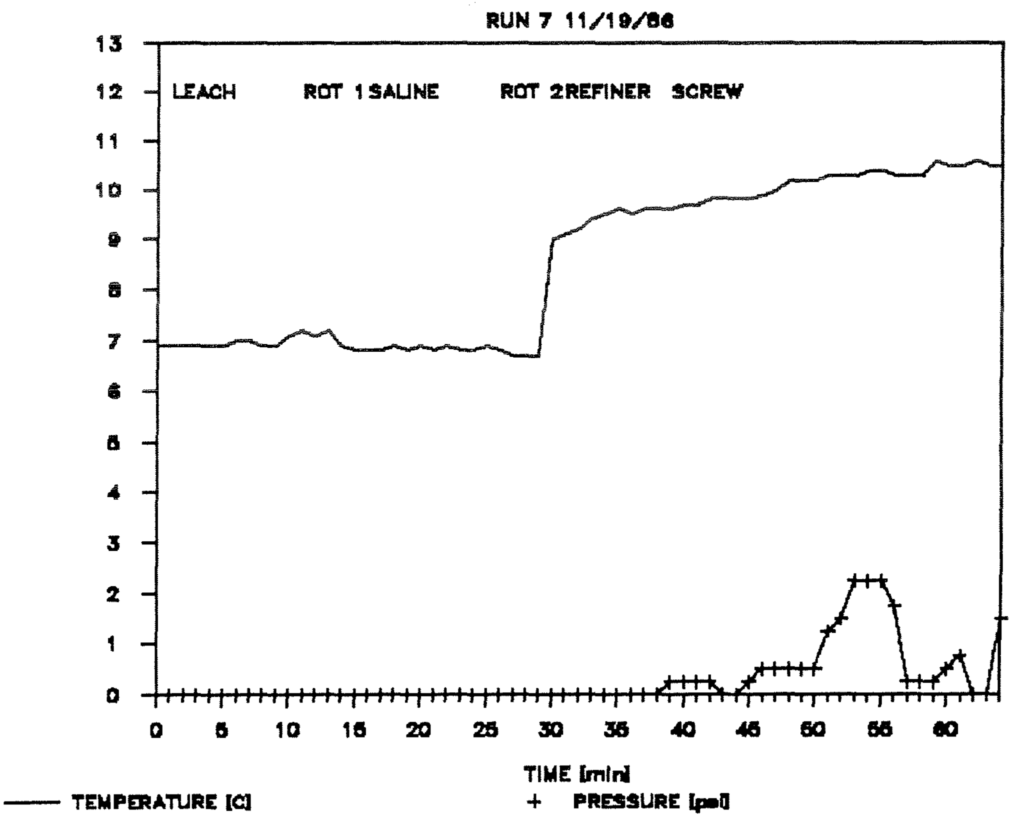
RUN NO. 6	TEMPERATURE DEGREES CELCIUS			
11/18/86	RAW	40 C	60 C	90 C
5 DAY OLD				
TRAWLER COD				
STRESS (kPa)		45.7	29.4	20.1
STRAIN		4.12	3.96	3.44
MODULUS of ELASTICITY(kPa)		11.1	7.4	5.8
COLOR	49.6	75.2	75.2	75.4
FOLD		5.0	5.0	5.0

MOISTURE %	YIELD @ 80% MOISTURE	FOREIGN ELEMENTS	pH = 6.70
78.7	N/A	8	

NOTE: MODULUS of ELASTICITY = STRESS/STRAIN

Figure 9

SURIMI PROCESS DATA



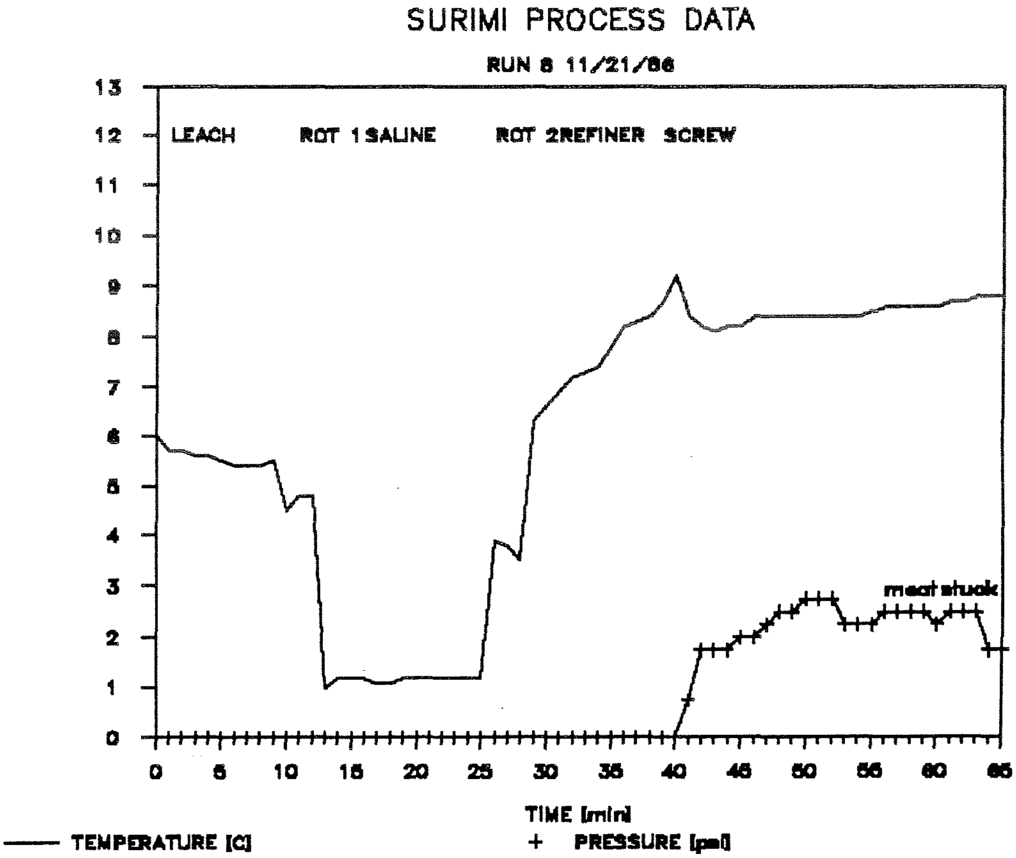
SURIMI PRODUCT DATA

RUN NO. 7 11/19/86 5 DAY OLD TRAWLER COD	TEMPERATURE DEGREES CELCIUS			
	RAW	40 C	60 C	90 C
STRESS (kPa)		31.3	11.2	24.0
STRAIN		3.89	1.92	3.71
MODULUS of ELASTICITY(kPa)		8.0	5.8	6.5
COLOR	49.0	71.2	72.6	72.6
FOLD		5.0	3.0	5.0

MOISTURE %	YIELD @ 80% MOISTURE	FOREIGN ELEMENTS	pH = 6.80
80.3	26.5	7	

NOTE: MODULUS of ELASTICITY = STRESS/STRAIN

Figure 10



SURIMI PRODUCT DATA

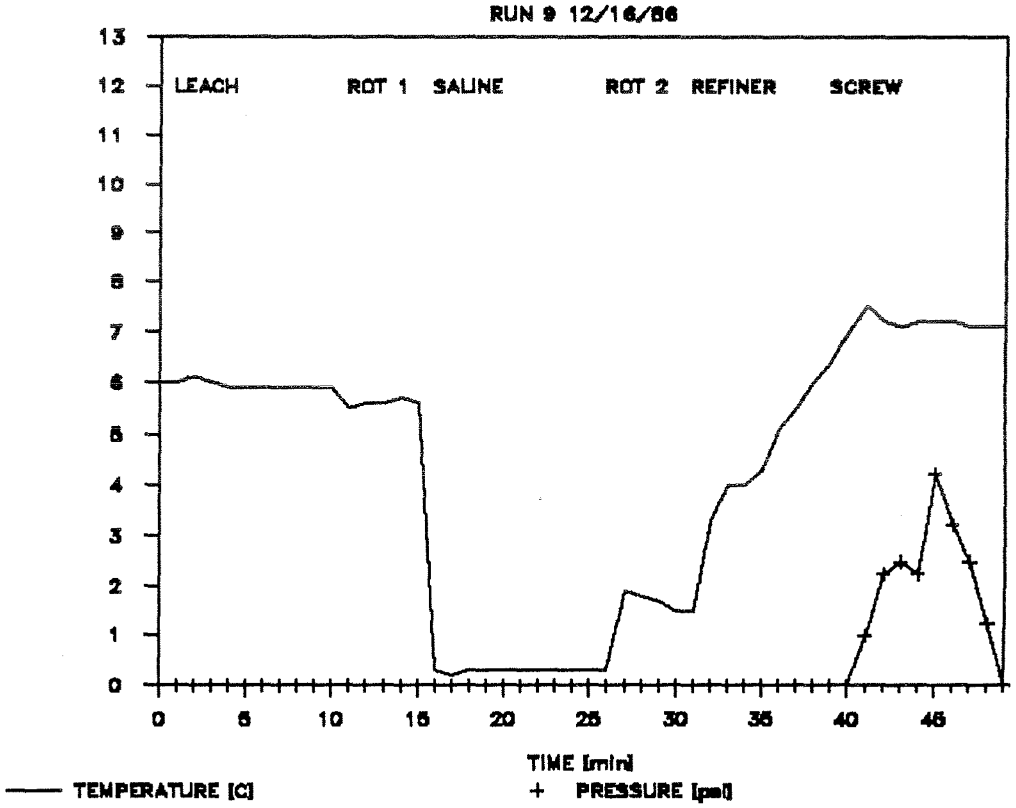
RUN NO. 8 11/21/86 **5 DAY OLD** **TRAWLER COD**	RAW	40 C	60 C	90 C
		TEMPERATURE DEGREES CELCIUS		
STRESS (kPa)		16.0	18.3	17.7
STRAIN		3.31	2.73	3.06
MODULUS of ELASTICITY(kPa)		4.8	6.7	5.8
COLOR	52.9	75.6	74.7	73.5
FOLD		5.0	5.0	5.0

MOISTURE %	YIELD @ 80% MOISTURE	FOREIGN ELEMENTS	pH = 6.73
80.3	21.3	7	

NOTE: MODULUS of ELASTICITY = STRESS/STRAIN

Figure 11

SURIMI PROCESS DATA



SURIMI PRODUCT DATA

RUN NO.9 12/16/86 4 DAY OLD FROZEN COD	TEMPERATURE DEGREES CELCIUS			
	RAW	40 C	60 C	90 C
STRESS (kPa)		22.9	10.8	14.3
STRAIN kPa		3.26	2.77	2.55
MODULUS of ELASTICITY(kPa)		7.0	3.9	5.6
COLOR	52.8	76.1	77.3	77.6
FOLD		5.0	5.0	5.0

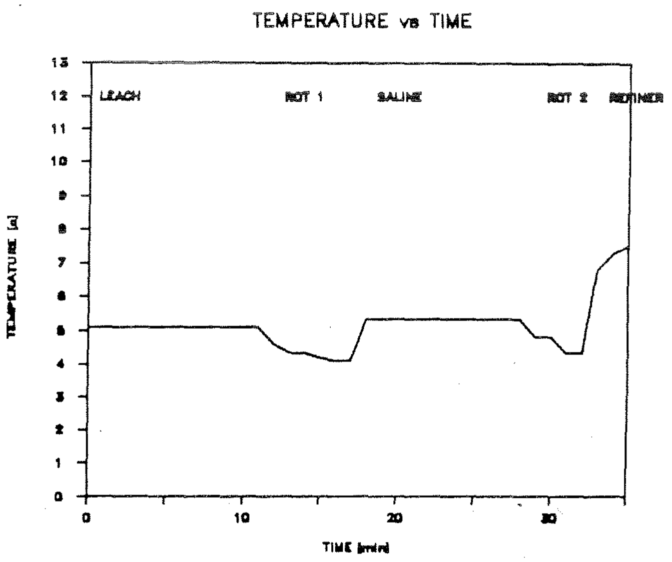
MOISTURE %	YIELD @ 80% MOISTURE	FOREIGN ELEMENTS	pH = N/A
79.8	28.9	9	

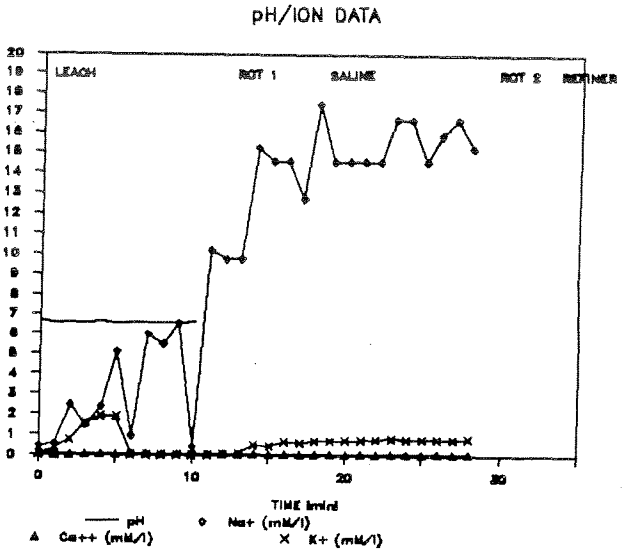
NOTE: MODULUS of ELASTICITY = STRESS/STRAIN

Figure 12

SURIMI PROCESS DATA

RUN 11 01/21/87





NOTE:DATA LOST AT 35 MIN. DUE TO TECNICAL MALFUNCTION

SURIMI PRODUCT DATA

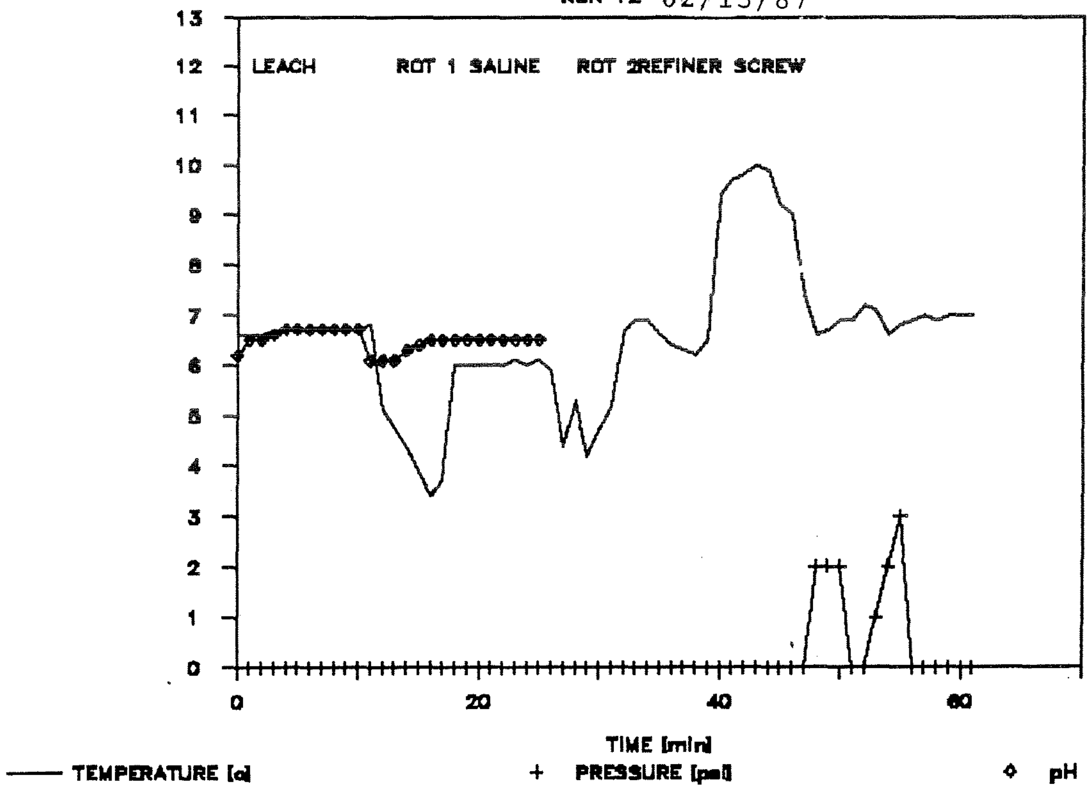
RUN NO.11	TEMPERATURE DEGREES CELCIUS				
01/21/87	RAW	40 C	60 C	90 C	
FROZEN CAPLIN					
STRESS (kPa)		N/A	N/A	N/A	
STRAIN (kPa)		N/A	N/A	N/A	
MODULUS of ELASTICITY(kPa)		N/A	N/A	N/A	
COLOR	N/A	41.6	42.0	40.9	
FOLD		1.0	1.0	1.0	
MOISTURE %	YIELD @ 80% MOISTURE		FOREIGN ELEMENTS		pH = 6.8*
81.5	N/A		N/A		*see graph

NOTE: MODULUS of ELASTICITY = STRESS/STRAIN

Figure 13

SURIMI PROCESS DATA

RUN 12 02/13/87



SURIMI PRODUCT DATA

RUN NO. 12 02/13/87 4 DAY OLD FROZEN COD	RAW	40 C	60 C	90 C
		TEMPERATURE DEGREES CELCIUS		
STRESS (kPa)		9.6	6.3	5.4
STRAIN		1.51	1.83	1.59
MODULUS of ELASTICITY(kPa)		6.4	3.4	3.4
COLOR	52.3	77.6	76.9	77.6
FOLD		3.0	2.0	4.0

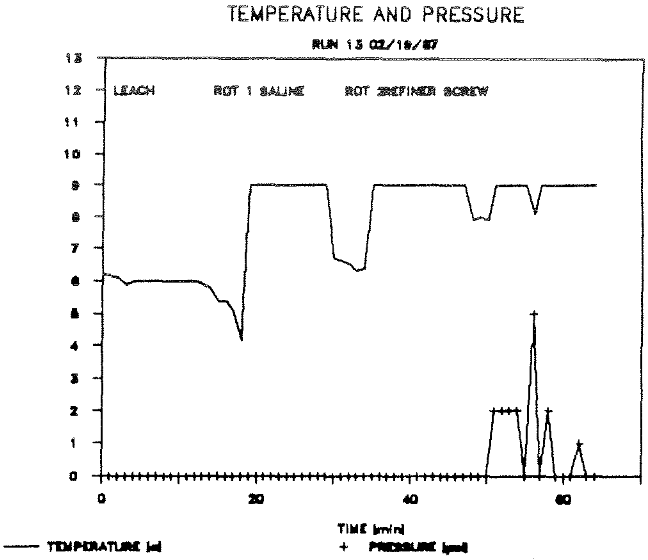
MOISTURE %	YIELD @ 80% MOISTURE	FOREIGN ELEMENTS	pH = 6.7*
80.5	18.8	9	*see graph

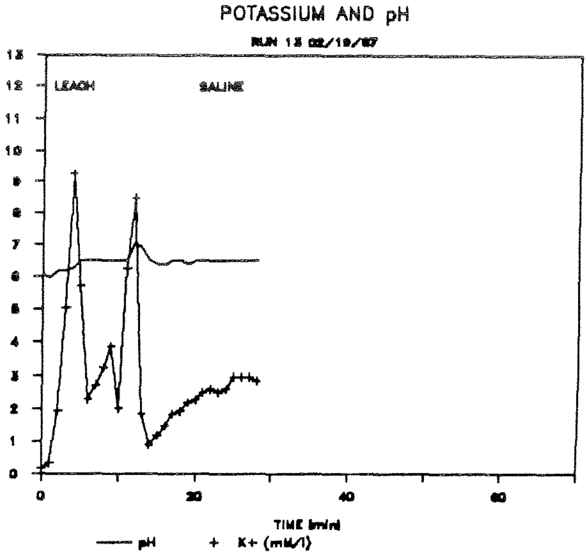
NOTE: MODULUS of ELASTICITY = STRESS/STRAIN

Figure 14

SURIMI PROCESS DATA

RUN 13 02/19/87





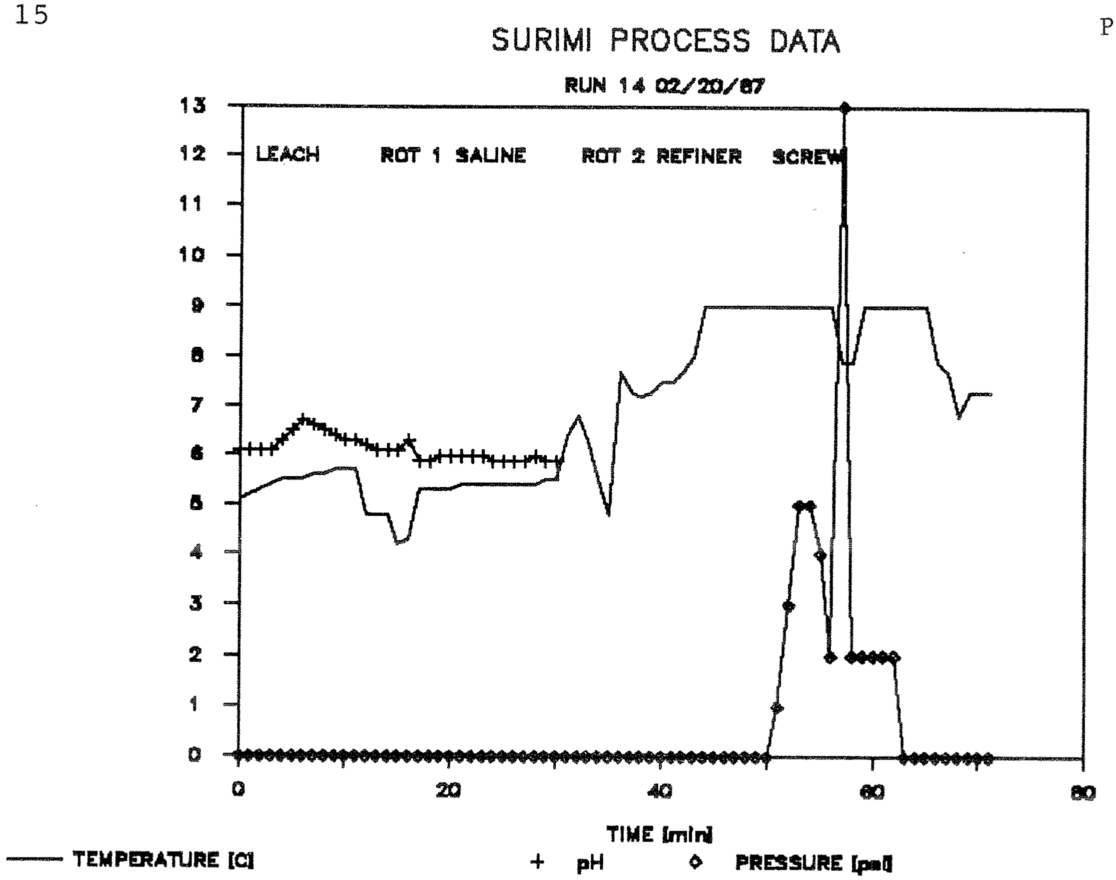
SURIMI PRODUCT DATA

RUN NO.13	TEMPERATURE DEGREES CELCIUS			
02/19/87	RAW	40 C	60 C	90 C
8 DAY OLD				
FROZEN COD				
STRESS (kPa)		25.4	18.8	22.5
STRAIN (kPa)		2.99	2.72	2.94
MODULUS of ELASTICITY(kPa)		8.5	6.9	7.7
COLOR	54.2	77.1	76.3	75.2
FOLD		5.0	5.0	5.0

MOISTURE %	YIELD @ 80% MOISTURE	FOREIGN ELEMENTS	pH = 6.8*
79.3	23.2	10	*controlled

NOTE: MODULUS of ELASTICITY = STRESS/STRAIN

Figure 15



SURIMI PRODUCT DATA

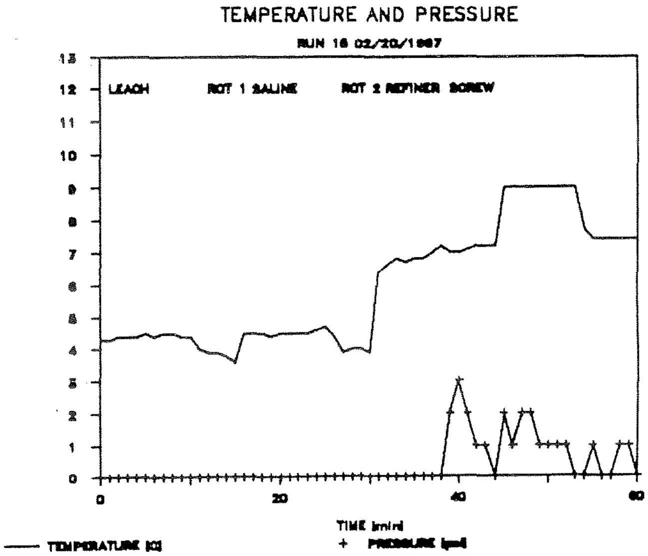
RUN NO.14 02/20/87 9 DAY OLD FROZEN COD	RAW	TEMPERATURE DEGREES CELCIUS 40 C	60 C	90 C
STRESS (kPa)		29.3	33.0	30.0
STRAIN		2.36	2.80	2.41
MODULUS of ELASTICITY(kPa)		12.4	11.8	3.9
COLOR	51.5	71.7	72.8	72.7
FOLD		5.0	5.0	5.0
MOISTURE % 73.9	YIELD @ 80% MOISTURE 22.3		FOREIGN ELEMENTS 10	pH = 6.1* *controlled

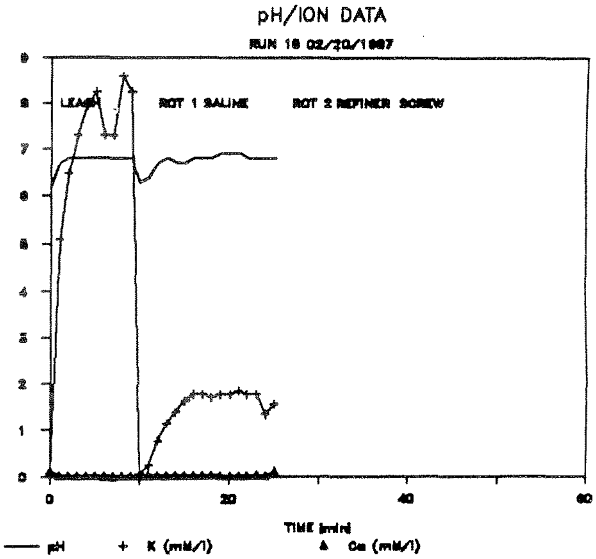
NOTE: MODULUS of ELASTICITY = STRESS/STRAIN

Figure 16

SURIMI PROCESS DATA

RUN 15 02/20/1987





SURIMI PRODUCT DATA

RUN NO.15	TEMPERATURE DEGREES CELCIUS			
02/20/87 **9 DAY OLD** **FROZEN COD**	RAW	40 C	60 C	90 C
STRESS (kPa)		11.3	14.2	12.7
STRAIN		2.89	3.05	3.19
MODULUS of ELASTICITY(kPa)		3.9	4.7	4.0
COLOR	57.5	77.3	76.8	77.2
FOLD		5.0	5.0	5.0

MOISTURE %	YIELD @ 80% MOISTURE	FOREIGN ELEMENTS	pH = 7.0*
81.5	20.1	9	*controlled

NOTE: MODULUS of ELASTICITY = STRESS/STRAIN

Figure 17

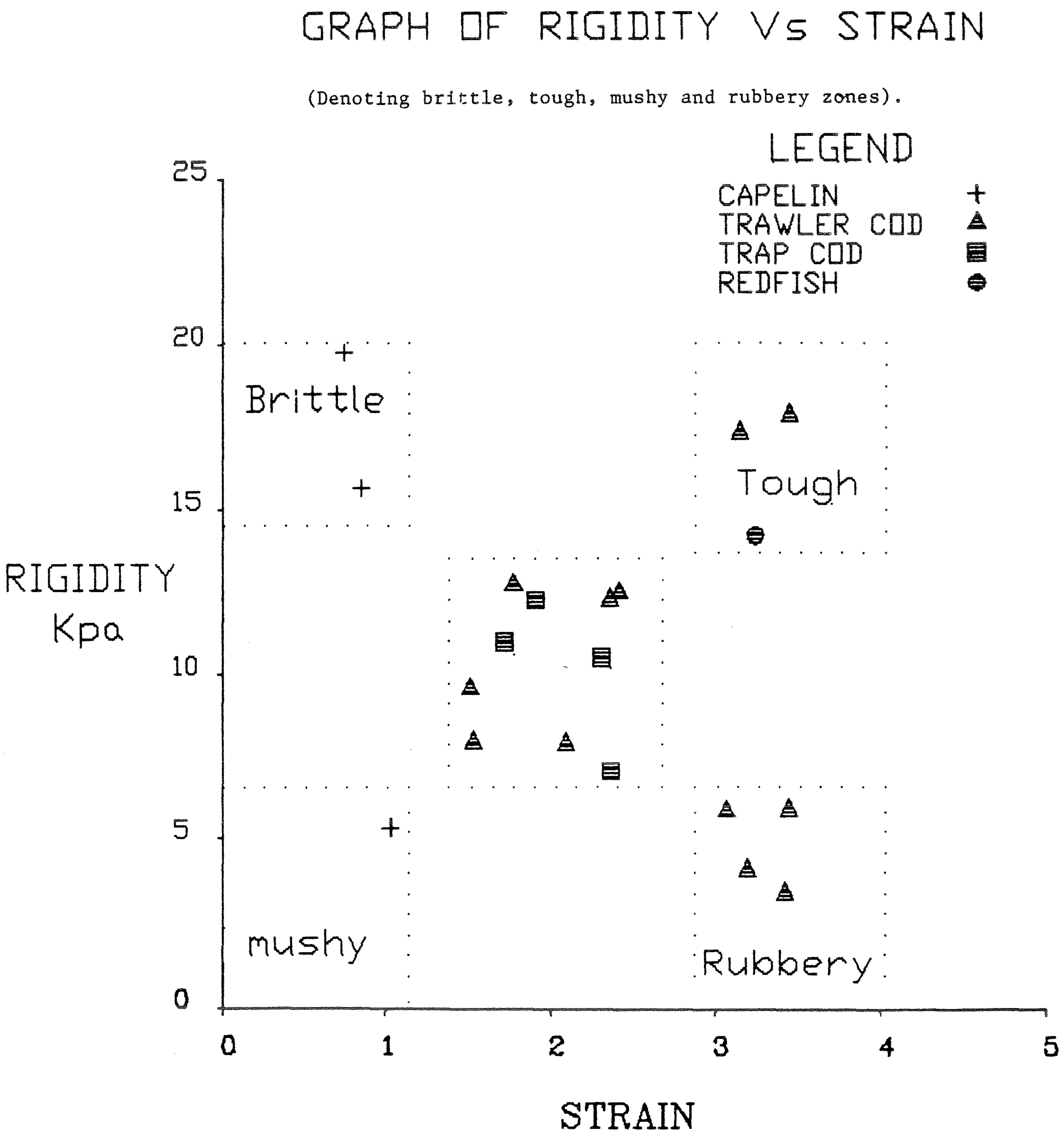

GRAPH OF RIGIDITY Vs STRAIN
(Denoting brittle, tough, mushy and rubbery zones).
LEGEND
CAPELIN +
TRAWLER COD ▲
TRAP COD ▤
REDFISH ●
Brittle
Tough
mushy
Rubbery
RIGIDITY
Kpa
STRAIN
0
5
10
15
20
25
0
1
2
3
4
5

Figure 18

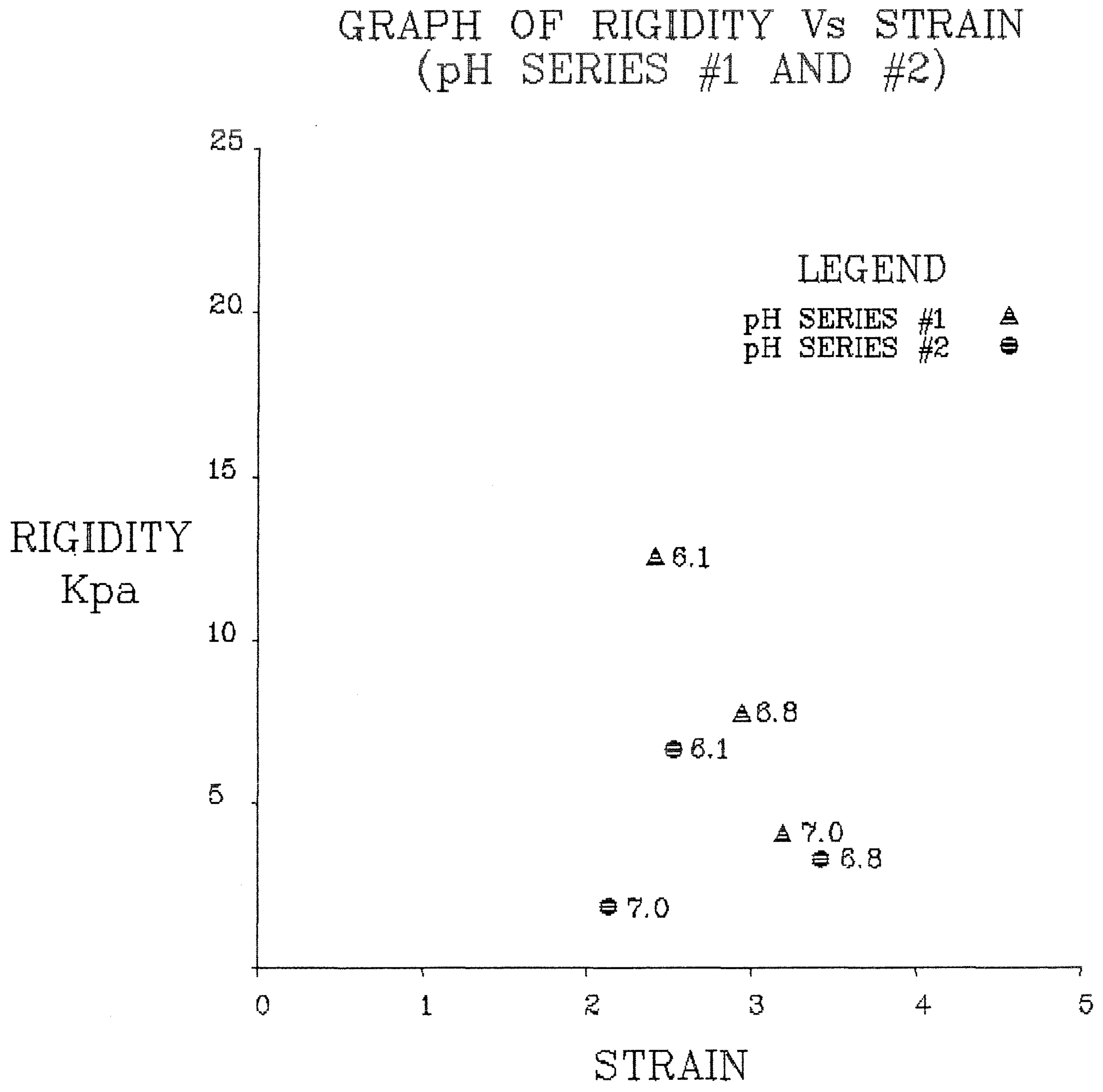

GRAPH OF RIGIDITY Vs STRAIN
(pH SERIES #1 AND #2)
LEGEND
pH SERIES #1 ▲
pH SERIES #2 ●
RIGIDITY
Kpa
25
20
15
10
5
0
1
2
3
4
5
STRAIN
6.1
6.8
6.1
7.0
6.8
7.0

FIGURE 19

GRAPH OF RIGIDITY Vs STRAIN