Some Factors Influencing The Gel Strength Of Tropical Sardine (*Sardinella gibbosa*)

NG CHER SIANG, LEE HOW KWANG and NG MUI CHNG

Marine Fisheries Research Department
Southeast Asian Fisheries Development Center
Singapore

Abstract

Initial investigations into the use of *Sardinella gibbosa* for making surimi showed that gel strength (G.S.) of around 400 g cm was achievable under normal surimi processing conditions. Adjusting the pH during the leaching process, by means of $NaHCO_3$ and by means of $Na_4O_7P_2$ with vacuum, did not improve the G.S. The fat content of local sardine was low and did not interfere with the surimi processing. The optimum conditions for setting the gel of paste were subjected to between 40 to 50°C for 20 min, followed by 20 min at 90°C. The surimi underwent *modori** when subjected to 60°C for 20 min. Sugar was necessary as a cryoprotective agent for frozen surimi.

It was found that crude aqueous extract of unfrozen *S. gibbosa* kidney tissues had G.S. enhancing effect. Kidney extract made from frozen sardine which were then frozen again, lost this G.S. enhancing effect.

Kidney extract made from unfrozen *Caesio erythrogaster* also had this G.S. enhancing effect. The kidney extract was heat stable, and retained the G.S. enhancing effect after exposure to 80°C for 10 min. However, the kidney extract did not prevent *modori* when the gel was exposed to 60°C for 20 min.

Introduction

In Southeast Asia, sardine is an abundant resource. However, sardines and other pelagic fish species are reputed to be difficult to use for surimi processing on account of their high oil content, rapidly deteriorating meat, and dark colour. Many researchers in Europe and in Japan have studied the temperate sardine species, and have proposed numerous ways to utilise the sardines.

Sardine as a raw material for the production of surimi have been investigated by Japanese researchers for many years. The main difficulties encountered in utilising sardine appear to be its low meat pH, high fat content , strong fish odour, dark meat colour, and its rapid spoiling characteristics. All these factors may contribute to the generally lower G.S. of the resulting surimi. Efforts to improve the G.S. were centered on the effects of meat pH, and consequently different alkaline leaching conditions were investigated. Some recent developments by Nishioka *et al* (1990) provided a different perspective on sardine surimi, and proposed a promising solution to some of the problems associated with sardine surimi production.

Note: This paper was presented at the Seminar by Ms Ng Mui Chng.

* the breakdown and loss of elasticity in the surimi gel attributed to unsuitable temperature and/or proteolytic enzyme activity.

Review And Re-Interpretation Of Some Past Results

The Marine Fisheries Research Department (MFRD) conducted a short study on the use of *Sardinella gibbosa* for making surimi (MFRD, 1984). It was found that chilled sardine of average freshness (K value = 50%) could be made into surimi with G. S. of around 400 g.cm. It was found that setting the paste at 40°C for 20 min, followed by 20 min at 90°C gave good gel strength. The meat pH of *S. gibbosa* was found to be from 6.7 to 7.0. The total lipid of *S. gibbosa* did not exceed 2.5%, and fat was therefore not a problem in the processing of surimi.

In an experiment, alkaline leaching was achieved by first dispersing the mince meat in four times its volume of water containing 0.2% NaCl (c.a.5°C). After stirring, the pH was adjusted by using $NaHCO_3$, to 6.5, 7.0 and 7.5 respectively for the three treatments. After standing for 15 min, the supernatant was decanted, and the meat slurry was washed three times with cold water. The meat was leached a second time with 0.3% NaCl. The control sample was leached in succession with 0.2% and 0.3% NaCl respectively without adjusting the pH. The results showed that alkaline leaching did not produce any improvement in the G.S., compared with normal leaching (Fig. 1).

The effects of freezing on the differently treated surimi were examined. The experiment was set up as shown in Fig. 2, and the results are presented in Table 1. Treatments 1, 3 and 5 were samples without sugar and polyphosphates. Treatments 2, 4 and 6 each contained 3% sugar and 0.2% polyphosphate. The samples were then contact frozen and stored at -20°C, monitoring intervals were 0, 2, 4 and 8 weeks. In all cases, after freezing, surimi with sugar and polyphosphate showed better G.S. than those without.

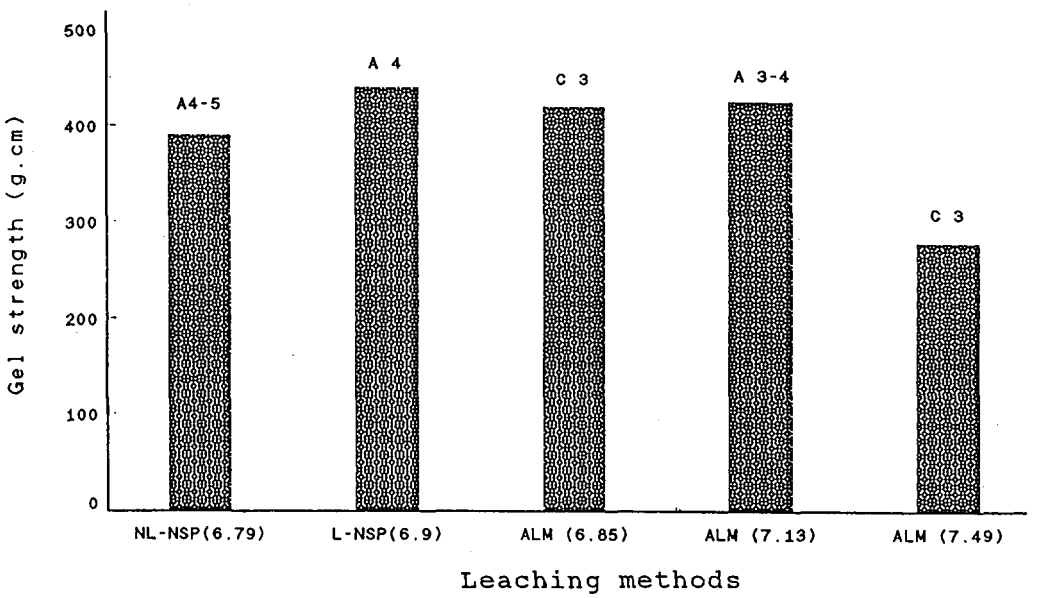


Fig. 1. Comparison of different leaching methods on gel strength.

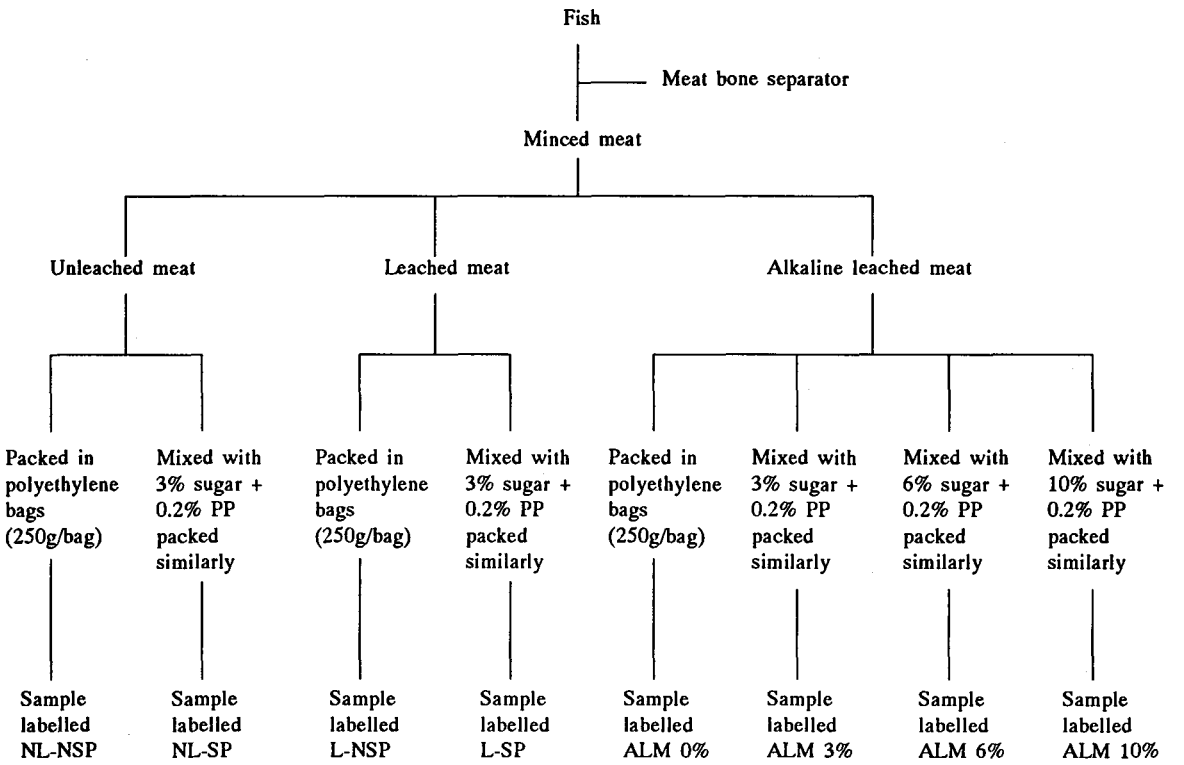


Fig. 2. Diagram of the experimental set-up for studying the effects of freezing and storage on the gel strength of surimi.

The optimum sugar concentration for cryoprotection of the surimi during frozen storage was investigated (Treatments 5, 6, 7 and 8). The G.S. of unfrozen surimi of Treatment 5 was much higher than those of Treatments 6, 7 and 8. This could be due to the higher percentage of protein in Treatment 5 compared with the other treatments, which had, respectively 3%, 6% and 10% less fish meat. However, after freezing, the G.S. of Treatment 5 was the lowest, showing the cryoprotective effects of sugar on freezing of surimi.

During frozen storage of the surimi, the G.S. dropped from about 400 to 300 g.cm. The G.S. was maintained at around 300 g.cm during the 8 weeks of frozen storage. The effect of freezing caused a decrease in G.S.

From Table 1 it was observed that the normal leached surimi (Treatments 3 and 4) had the highest G.S. It appears that alkaline leaching as defined here was not effective in increasing the G.S. of sardine surimi.

Report On Our Recent Findings

At a recent scientific meeting (IIR, 1990), Hamann provided a summary of the round table discussion on surimi/*kamaboko*. On the topic of *modori*, the latest postulate is that it is due to a group of serum proteinases called *modori*-inducing proteinases (MIPs). It was also mentioned that proteolytic activities were involved in *modori*, and that inhibition of proteolytic activity was commonly practiced in the USA, by mixing wide-spectrum inhibitors such as α-macroglobulin from bovine plasma. For example, it was essential to use α-macroglobulin when processing Pacific whiting (hake) and menhaden or when kidney tissue was present.

Table 1. The effect of freezing on the gel strength (G.S.) of different sardine surimi. (n = 5).

Treatment	Before freezing	After freezing	% drop G. S.
1 (NL - NSP)	306	114	62.7
2 (NL - SP)	268	224	16.4
3 (L - NSP)	631	142	77.5
4 (L - SP)	645	279	56.7
5 (ALM-0% S)	570	134	76.5
6 (ALM-3% S)	340	302	11.2
7 (ALM-6% S)	246	280	(13.8)
8 (ALM-10% S)	292	237	20.2

L = Leached
NL = Non leached
ALM = Alkaline leached meat
SP = Sugar + Polyphosphate
NSP = No sugar and no polyphosphate
S = Sugar

The action mechanism of α-macroglobulin however is still not clear.

In the local context, sardines that are landed are often inadequately iced, and autolytic degradation is assumed to be significant. The following studies were designed to understand the local sardine surimi better.

Experiment 1

Aim : (i) To determine the influence of different temperatures on the gel strength of the sardine surimi.
(ii) To determine the influence of kidney tissue extract on the G.S.

Procedure:

Surimi preparation: A batch of *S. gibbosa* (K value = 20%; meat pH 6.5) was used. The fish were beheaded and degutted, and made into surimi. A batch of unfrozen surimi, and a batch of surimi that was blast frozen to -30°C and stored at -20°C for a week were used for the experiment.

Kidney tissue extract: The fish frames were trimmed to remove all other tissues except the kidney tissues which were encased by the backbone. These materials were kept cold and were pounded with a mortar. A ratio of 1:2 fish material to water (w/w) was prepared, centrifuged and the supernatant used as the crude kidney tissue extract.

Experimental samples: The unfrozen and frozen surimi for Treatments A, B and C, were individually ground with salt. The paste were filled into sausage casing using a manual sausage filler. Fifteen sausages (25mm D; 140mm L) were prepared from each of the batches of surimi. In the case of Treatment D, the unfrozen surimi was ground with the kidney extract instead of water. The paste was filled into three sausage tubes. For all the paste, the final moisture was adjusted to 85%. The samples made from unfrozen and frozen surimi were subjected to the following conditions:

Treatment A:
Setting at 50°C x 20 min.

Treatment B:
Setting at 50°C x 20 min, then at 90°C x 20 min.

Treatment C:
Setting at 90°C x 20 min.

Treatment D:
Setting at 50°C x 20 min, then 90°C x 20 min.

After setting, the sample temperature was equilibrated in running tap water before the G.S. was measured. Four cylindical samples, each measuring 25 mm in height, were prepared from each sausage, and the G.S. readings were taken with a rheometer (Fudoh Model NRM 2002J).

Result:

The data (Tables 2a & 2b) were subjected to Analysis of Variance (ANOVA) test. It was found that in the unfrozen surimi, the G.S. of the 3 treatments were not significantly different whereas the results were significantly different for the frozen surimi. The G.S. of Treatment D was found to be significantly higher than that of Treatment B (Student's t-test, $p \leq 0.01$).

Discussion:

The result for the unfrozen surimi showed that the samples were not subjected to setting temperature conditions where *modori* was significant. The differences found in the frozen surimi were attributed to the effects of freezing rather than to the setting temperature.

Table 2a. The gel strength (G.S.) obtained from unfrozen surimi paste incubated at different temperatures.

Treatment A		Treatment B		Treatment C		Treatment D	
190	260	357	359	220	216	374	248
371	366	390	174	280	227	290	409
304	304	228	334	223	279	334	
317	262	327	358	271	183	417	
161	158	245	185	189	196	437	
240	191	271	243	221	274	307	
274	301	189	231	143	320	310	
272	214	142	280	198	248	464	
233	322	175	250	236	298	321	
173	316	238	290	300	288	273	
$n = 20$		$n = 20$		$n = 20$		$n = 12$	
$\bar{x} = 262$		$\bar{x} = 263$		$\bar{x} = 241$		$\bar{x} = 349$	
$s_{n-1} = 65.0$		$s_{n-1} = 72.2$		$s_{n-1} = 46.9$		$s_{n-1} = 69.8$	
TC = 5		TC = 5 to 6		TC = 5		TC = 6 to 7	
FT = AA		FT = AA		FT = AA		FT = AA	

Treatment A: Setting at 50°C x 20 min.
Treatment B: Setting at 50°C x 20 min, then at 90°C x 20 min.
Treatment C: Setting at 90°C x 20 min.
Treatment D: Setting at 50°C x 20 min, then 90°C x 20 min.
TC = Teeth cutting test
FT = Folding test

Table 2b. The gel strength (G.S.) obtained from frozen surimi paste incubated at different temperatures.

Treatment A		Treatment B		Treatment C	
189	202	263	318	163	164
311	262	197	327	124	144
231	232	335	175	191	182
201	205	272	394	198	162
193	122	406	257	223	210
157	180	222	268	172	150
238	267	303	356	198	207
205	243	221	237	144	138
208	283	303	238	102	254
307	----	290	179	195	141
$n = 20$		$n = 20$		$n = 20$	
$\bar{x} = 223$		$\bar{x} = 278$		$\bar{x} = 173$	
$s_{n-1} = 48.8$		$s_{n-1} = 65.7$		$s_{n-1} = 36.9$	
TC = 5		TC = 6		TC = 5	
FT = AA		FT = AA		FT = AA	

Treatment A: Setting at 50°C x 20 min.
Treatment B: Setting at 50°C x 20 min, then at 90°C x 20 min.
Treatment C: Setting at 90°C x 20 min.
TC = Teeth cutting test
FT = Folding test

The result from Treatment D was unexpected, and it appears that something in the kidney extract had G.S.-enhancing effect. The mode of action needs to be investigated further.

Experiment 2

Aim: To determine the influence of the kidney tissue extract on the G.S. of sardine surimi.

Procedure:

S. gibbosa (K value = 17%; meat pH 6.2) was purchased from Punggol Fishing Port. A batch of surimi was made from the usual beheaded and degutted fish, which had kidney tissues embedded

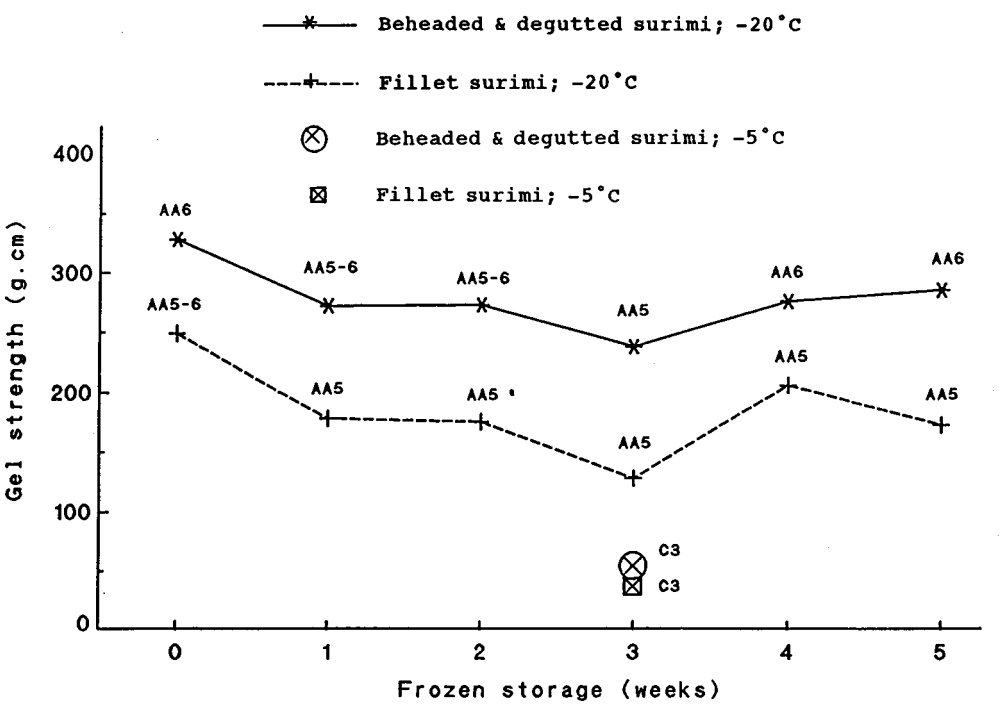
in the backbone (Treatment A). A second batch of surimi was made from fillets, excluding any kidney tissues (Treatment B). The G.S. from these 2 types of surimi were compared before freezing, and after frozen storage at -20°C for up to 6 weeks. A single batch of surimi from each of the treatments was kept at -5°C for 3 weeks , and the G.S. was compared with similar surimi kept at -20°C for the corresponding period. In the weekly monitoring, surimi from each treatment was ground separately. The paste was made into a single long sausage. Ten to 12 sample pieces were prepared from each sausage for G.S. measurement.

Result :

The data is presented in Fig. 3. The average G.S. (n=10) from each weekly monitoring for the treatments were subjected to the Student's t-test (paired comparison). The G.S. of Treatment A was significantly higher than that of Treatment B ($P \leq 0.01$). In the single sample comparison of both treatments at -5°C, both exhibited very low G.S., with Treatment A having a higher G.S.

Discussion:

The presence of some factors in the kidney tissue in Treatment A enhanced the G.S. significantly. Based on the single sample comparison, this active fraction was not stable and was lost during storage at -5°C.



AA5-6 and C3 = AA : Folding test, 3,5 and 6 : Teeth-cutting test

Fig. 3. Changes in gel strength of frozen surimi made from beheaded and degutted sardine and sardine fillets.

Experiment 3

Aim: To study the effects of kidney extract made from frozen sardine on the G.S. of frozen sardine surimi.

Procedure:

Kidney tissue was obtained from frozen sardines (5 weeks storage at -20°C) and the extract made as described previously. The kidney extract was frozen and stored for 2 weeks at -20°C. Frozen sardine surimi prepared from beheaded and degutted fish, and stored for 5 weeks at -20°C was used for the experiment. The following treatments were made:

Treatment A:
Frozen surimi ground with water.
Set at 50°C x 20 min, then at 90°C x 20 min.

Treatment B:
Frozen surimi ground with water.
Set at 60°C x 30 min, then at 90°C x 20 min.

Treatment C:
Frozen surimi ground with kidney extract.
Set at 50°C x 20 min, then at 90°C x 20 min.

Treatment D:
Frozen surimi ground with kidney extract.
Set at 60°C x 30 min, then at 90°C x 20 min.

Data were collected by measuring the G.S. of 5 sample pieces per sausage, and for each treatment, six sausages were sampled. Within each treatment, the mean G.S. values of the individual sausage were grouped (Table 3). These means were subjected to the Student's t-test.

Table 3. The effect of setting temperature and kidney extract on the gel strength (G.S.) of frozen sardine surimi.

Mean G.S. from individual sausage (n = 6)			
Treatment A	Treatment B	Treatment C	Treatment D
246	100	202	61
241	90	226	124
192	93	235	61
194	84	226	95
240	76	226	41
214	156	248	47
$\bar{X}_x$ = 221	$\bar{X}_x$ = 99.8	$\bar{X}_x$ = 227.2	$\bar{X}_x$ = 71.5
S.E. = 24.5	S.E. = 28.6	S.E. = 15.1	S.E. = 31.8

Treatment A: Frozen surimi ground with water. Set at 50°C x 20 min, then at 90°C x 20 min.
Treatment B: Frozen surimi ground with water. Set at 60°C x 30 min, then at 90°C x 20 min.
Treatment C: Frozen surimi ground with kidney extract. Set at 50°C x 20 min, then at 90°C x 20 min.
Treatment D: Frozen surimi ground with kidney extract. Set at 60°C x 30 min, then at 90°C x 20 min.

Result:

Comparisons of Treatment A and Treatment C showed no significant difference between the two treatments. This meant that the frozen kidney extract made from frozen sardine had lost its G.S.-enhancing effect.

In comparing Treatment A and B, and Treatment C and D respectively, significant differences were found between the two temperature-treatment pairs. The paste made from frozen sardine surimi underwent *modori* at 60°C irrespective of whether the kidney extract was present or not.

Discussion:

In this experiment, since the G.S.-enhancing effect was lost due to freezing, it was not possible to conclude the influence of the kidney tissue extract on the *modori* phenomenon.

Experiment 4

Aim: To determine if kidney extract from *Caesio erythrogaster* exhibits gel-enhancing properties.

Procedure:

Chilled fish frames of *C. erythrogaster* (body length about 12 cm) were obtained from a factory and the kidney extract (c.a. 7.5 mg protein per ml) was made as before. A portion of the kidney tissue extract was heated to 80°C for 10 min in a water bath. The extract was centrifuged to remove the preciptated proteins, and the clear supernatant was cooled before use. Commercial surimi was used in this experiment. The following conditions were investigated:

Treatment A:
Surimi ground with kidney extract.
Set at 40°C x 20 min, then at 90°C x 20 min.

Treatment B:
Surimi ground with heat treated kidney extract.
Set at 40°C x 20 min, then at 90°C x 20 min.

Treatment C:
Surimi ground with water (Control sample).
Set at 40°C x 20 min then at 90°C x 20 min.

Ten sausages were sampled per treatment. Five sample pieces per sausage were used for measuring the G.S. Within each treatment, the mean G.S. value of all the samples from each individual sausage were grouped. These mean values were subjected to the Student's t-test (Table 4).

Result:

The G.S. from Treatment A was significantly higher than that from Treatment C (Student's t-test $P \leq 0.01$). The kidney tissue extract from *C. erythrogaster* had a G.S.-enhancing effect.

The G.S. from Treatment B was signficantly higher than that of Treatment C (Student's t-test $P \leq 0.01$). The heating process up to 80°C for 10 min did not destroy the G.S.-enhancing effect.

The G.S. of Treatment B was significantly higher than that of Treatment A (Student's t-test $P \leq 0.01$). This implied that the kidney extract may have more than one factor influencing the G.S. Heating the kidney extract to 80°C may have destroyed some of the proteolytic enzymes reportedly present in kidney tissues which had negative effects on the G.S.

Experiment 5

Aim: To determine whether kidney extract from *C. erythrogaster* can prevent *modori*.

Procedure:

Kidney extract from *C. erythrogaster* was prepared as described before. Commercial surimi was used in this experiment. The following treatments were prepared:

Treatment A:
Surimi paste with kidney extract.
Setting at 60°C x 20 min, then 90°C x 20 min.

Table 4. The effect of kidney extract from *C. erythrogaster* on the gel strength (G.S.) of commercial surimi.

Mean G.S. from individual sausage (n = 10)		
Treatment A	Treatment B	Treatment C
73	69	52
62	58	45
53	87	48
57	74	41
62	68	66
54	75	54
52	65	47
56	68	44
47	70	50
62	78	51
$\overline{X}_x$ = 57.8	$\overline{X}_x$ = 71.2	$\overline{X}_x$ = 49.8
S.E. = 7.3	S.E. = 7.9	S.E. = 6.9

Treatment A: Surimi ground with kidney extract. Set at 50°C x 20 min, then at 90°C x 20 min.
Treatment B: Surimi ground with heat treated kidney extract. Set at 60°C x 30 min, then at 90°C x 20 min.
Treatment C: Surimi ground with water. Set at 50°C x 20 min, then at 90°C x 20 min.

Treatment B:
Surimi paste with kidney extract.
Setting at 40°C x 20 min, then 90°C x 20 min.

Treatment C:
Surimi paste with water.
Setting at 40°C x 20 min, then 90°C x 20 min.

Ten sausages were prepared for each treatment, and five sample pieces per sausage were used to measure the G.S. The mean G.S. from sausages within each treatment was used in analysis.

Result:

The data is shown in Table 5. There were significant differences between Treatments A and B (Student's-test $p \leq 0.01$). The kidney extract did not prevent *modori*. There were significant differences between Treatments B and C, confirming that the kidney tissue extract had a G.S.-enhancing effect.

Discussion:

Paiboon *et al* (1988) repeated the earlier work done by MFRD (1984, unpublished) on alkaline

Table 5. The effect of kidney extract of *C. erythrogaster* on the *modori* phenomenon.

Mean G.S. from individual sausage (n = 10)		
Treatment A	Treatment B	Treatment C
62	211	206
72	232	224
65	235	228
62	214	185
71	208	228
73	225	175
71	224	156
70	217	191
85	220	186
71	185	204
$\overline{X}_x$ = 70	$\overline{X}_x$ = 217	$\overline{X}_x$ = 198
S.E. = 6.6	S.E. = 14.2	S.E. = 24.1

Treatment A: Surimi ground with kidney extract. Set at 60°C x 20 min, then at 90°C x 20 min.
Treatment B: Surimi ground with kidney extract. Set at 40°C x 20 min, then at 90°C x 20 min.
Treatment C: Surimi ground with water. Set at 40°C x 20 min, then at 90°C x 20 min.

leaching with *S. gibbosa* and *S. fimbriata*. In addition, leaching with sodium pyrophosphate ($Na_4O_7P_2$) under vacuum was also studied. The results showed conclusively that both types of alkaline leaching were not effective in improving the G.S. The raw sardine meat had pH of 6.7 to 7.0, and did not warrant alkaline leaching. It was noted that the final product after pyrophosphate leaching had a smoother and more elastic texture. This was attributed to the homogenisation process where the fish meat was finely minced and the added pyrophosphate. Whereas normal water-leached surimi, actomyosin is recognised as the main component in forming gel. In pyrophosphate leaching, the actomyosin was believed to be broken into actin and myosin. The resulting gel was due to the myosin instead of the actomyosin. This difference in network formation could account for the different gel characteristics observed.

Recently Nishioka *et al* (1990) reported a surimi-processing technique incorporating leaching with $Na_4O_7P_2$ to moderate the meat pH, and vacuum leaching to remove the excessive fat in pelagic fishes. They also postulated a new hypothesis on the mechanism of *kamaboko* formation (gel formation). Briefly, they proposed that (a) myosin plays the most important role in forming gel due to its strong water-holding capacity; (b) the

increase in gel-strength resulting from leaching the meat is brought about by the relaxation of the firm bond between actin and myosin that occurs after death; (c) the weaker the binding between myosin and actin, the stronger the gel- strength.

In reviewing our data, we found that the local sardine species has only about 3% total lipid, and this did not interfere with the surimi production. Vacuum leaching for fat removal as proposed by Nishioka is not required. Moreover, in the case of chilled tropical sardines, leaching with $Na_4O_7P_2$ did not produce any increase in G.S. However, as Nishioka's group have reported the best results so far for making surimi from frozen sardine, more work should be done along similar lines with the local species, especially frozen sardine.

Paiboon, *et al* (1988) also studied the relationship between fish freshness (K value) and gel-forming ability (Fig. 4). The G.S. of *S. fimbriata* was high at zero day, dropped after three days in ice, then showed an increase after five days in ice. The G.S. of *S. gibbosa* showed a decreasing trend during storage. Paiboon concluded that the K value showed no relationship to the G.S. for *S. fimbriata*. However, the present authors feel that the K value at which the dip in G.S. occurred was indicative of the gel forming potential. Based on Fig. 4, the cut-off point for fish freshness suitable for surimi was about K value 50% . This was further substantiated by the earlier work where sardine of 50% K value were successfully made into surimi with good G.S.

The peculiar upturn in the G. S. of *S. fimbriata* meat during ice storage was not explained by Paiboon. Recently, Kinoshita *et al* (1990) studied the *modori* phenomenon in relation to the meat pH of freshly killed *Tilapia* (Fig. 5). They observed a similar decrease in G.S. from the time of death till about nine hours. At about 12 hrs after death, the G.S. increased and peaked at about 24 hours before decreasing again after 48 hours of storage. During the first 12 hours, the meat pH decreased from about 6.8 to 6.3, and thereafter remained stable despite the increase and sub-

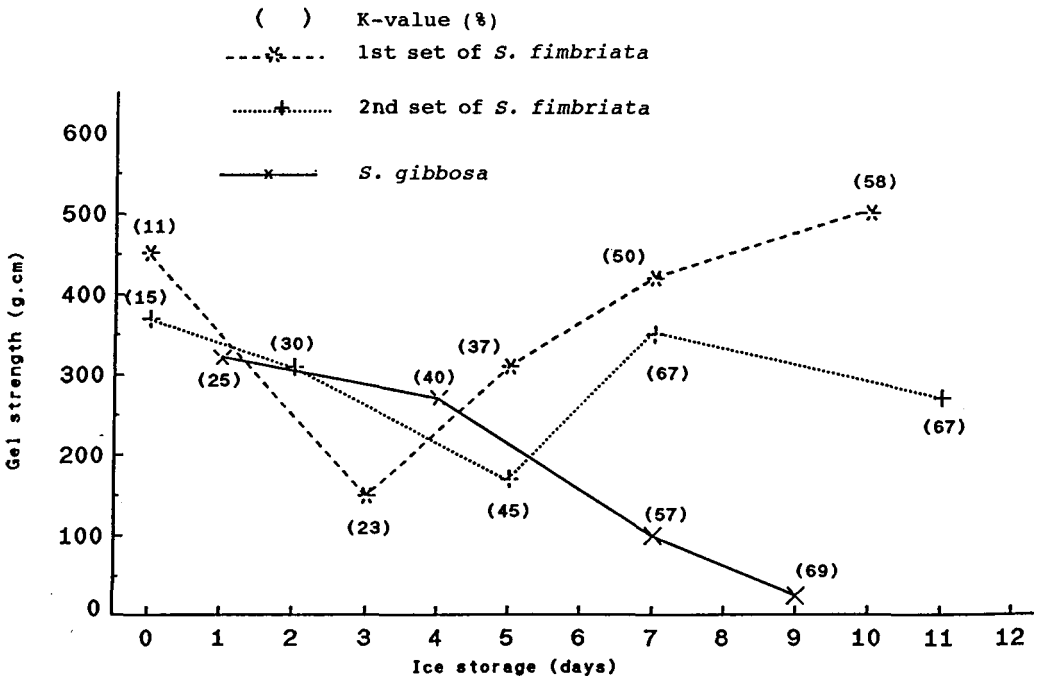


Fig. 4. Relationship between fish freshness K value (%) and gel strength in Sardinella fimbriata *and* S. gibbosa.

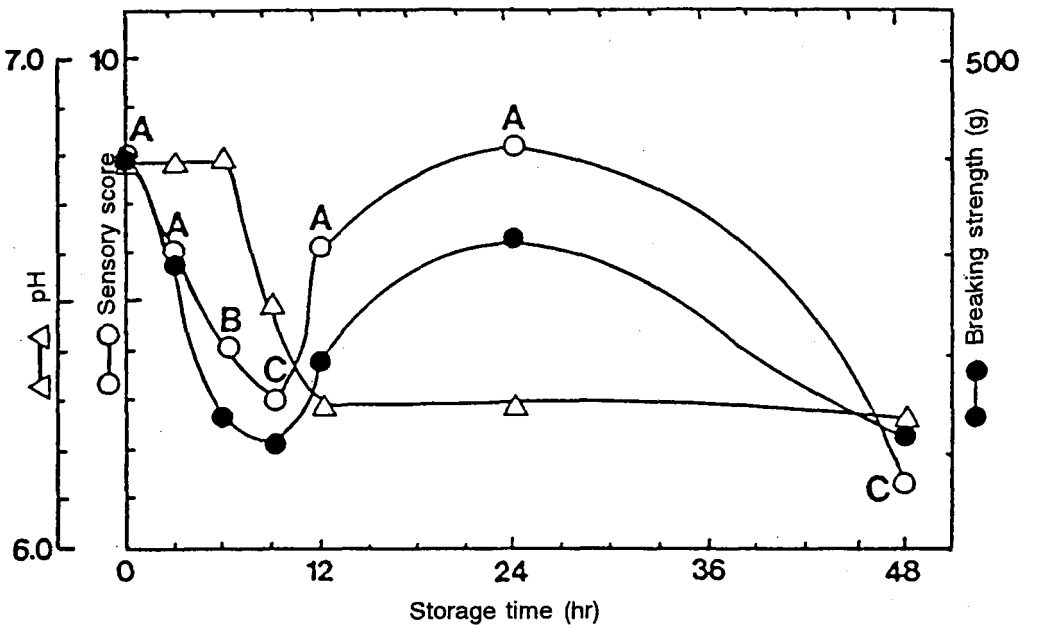


Fig. 5. Change of degree of modori *during storage period. Letters in the figure denote the score values in the folding test. (Figure from a paper presented at IIR Commission Meeting on 'Chilling and Freezing of New Fish Products', Aberdeen, 1990, p.65. Series-Refrigeration Science and Technology).*

sequent decrease in the G.S. Kinoshita did not relate the changes in G.S. to fish freshness. Instead, he postulated that the newly described *modori* inducing proteinases (MIPs) may play a role in this observed phenomenon.

In the recent study, it was found that adding kidney tissue extract during the grinding of the surimi paste gave an enhanced G.S. This was contrary to the popular belief that enzymes in the kidney contributed to the decrease in G.S. through proteolytic activities. The exact nature of the fraction in the kidney tissue extract that was responsible for this observation is not known.

Kimura (1989) reported that, during setting, the myosin heavy chain decreased and cross-linked myosin with large molecular sizes (dimers, trimers etc) was formed in the *suwari* gel. He also reported that a protein factor in the water-soluble fraction of surimi catalysed this cross-linking reaction. This protein factor was identified as a transglutaminase. In our experiments, the factor responsible for enhanced G.S. effect was fairly heat stable, and is not likely to be similar to what Kimura reported.

Autio and Mietsch (1990) reported that addition of blood globins and plasma changed the thermal gelation of myofibrils. Both these were present in the kidney tissue extract. However, the amount of kidney extract used in the study was small in comparison with the amount of surimi, and so the contribution of the blood globins and plasma to G.S. was unlikely to be significant.

Conclusion

Tropical sardine species are generally low in fat content, and the meat pH is fairly neutral. It was possible to produce surimi with good gel strength from chilled tropical sardines of average freshness.

Alkaline leaching and vacuum alkaline leaching did not improve the G.S. There were no additional steps required for processing the surimi. Frozen tropical sardine could not give good G.S. under the present processing method.

There was a fraction in the kidney extracts from *S. gibbosa* and *C. erythrogaster*, which, when added to the surimi during grinding, enhanced the G.S. The extract did not prevent the *modori* phenomenon . This crude fraction, with about 7.5 mg protein per ml, was fairly heat stable. It retained the G.S.-enhancing effect even after exposure to 80°C for 10 min. However, freezing seemed to destroy this characteristic. Further work to concentrate and purify the kidney extract is in progress.

Autio, K. and Mietsch, F. 1990. Heat induced gelation of myofibrilla proteins and sausages: effect of blood plasma and globin. Journal of Food Science 55 (6): 1494 - 1496.

Hamann, D. D. 1990. Summary report on round-table discussion on "*Surimi-kamaboko*" in International Institute of Refrigeration Conference "Chilling and Freezing of New Fish Products": 131 - 132. Aberdeen, Sep 18 - 20, 1990.

Kimura, I. 1989. Setting phenomenon (*suwari*) of fish meat paste. Paper presented at "The 1989 International Chemical Congress of Pacific Basin Societies" Agrochemistry Paper No. 351, Honolulu, Dec 17 - 22.

Kinoshita, M., H. Toyohara, and Y. Shimizu. 1990. Proteolytic of fish gel (*modori*-phenomenon) during heating process in International Institute of Refrigeration Conference "Chilling and Freezing of New Fish Products": 61 - 67. Aberdeen Sep 18 - 20, 1990.

MFRD, 1984. Preliminary studies of utilization of sardine (*Sardinella gibbosa*) for production of surimi. MFRD Fellowship Report (unpublished).

Nishioka, F., T. Tokunaga, T. Fujiwara and S. Yoshioka. 1990. Development of new leaching technology and a system to manufacture high quality frozen surimi. *In* International Institute of Refrigeration Conference "Chilling and Freezing of New Fish Products": 123 - 130. Aberdeen Sep 18 - 20, 1990.

Paiboon, T., H.K. Lee, S. Loo, M.C. Ng, and N. Tsukuda. 1988. A preliminary study on the gel forming ability of two kinds of sardine meat during ice-storage. Songkanakarin Journal of Science and Technology 3: 339 - 347.

Discussion

A comment was made that in the present study, only the effects of proteinases and gel promoting factors were considered. The sardine is a very special fish species because sardine meat contains enzymes which affect the gelation process, and there is also a non-enzymatic *modori* phenomenon reaction present. Therefore, future studies should take into consideration both the enzymatic and non-enzymatic reactions on the *modori* phenomenon.

Also in the present study, only the gel strength was measured for estimating the occurrence of the *modori* phenomenon. It was suggested that a complementary study on the breakdown of the myosin heavy chain by the SDS-PAGE electrophoresis be conducted to better understand the conditions.