Utilization of Lizardfish, *Saurida tumbil*, for Surimi Production

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Abstract

Lizardfish, Saurida tumbil, is an abundant resource that is relatively underutilized. It is a potential raw material for surimi processing. Characterized by its ability to produce formaldehyde endogenously after catch, the lizardfish tends to have comparatively higher levels of formaldehyde, which is known to accelerate protein denaturation. As such minced meat from lizardfish has to be treated to enhance its gel-forming ability.

The objective of this project is to improve the gel-forming ability of surimi made from fresh and frozen lizardfish by sodium pyrophosphate leaching (PL), and the use of egg white and beef-plasma protein concentrate. This was compared against the usual leaching (UL) method.

Pyrophosphate leaching (PL) resulted in better gel-forming ability. Two-times of leaching using 0.2% sodium pyrophosphate resulted in the production of reasonably good quality fish jelly products from fresh and frozen lizardfish. Both egg white and beef-plasma protein concentrate improved the gel-forming ability of surimi from lizardfish. However, if the frozen raw material is of poor quality, neither pyrophosphate leaching nor the addition of egg-white or beef-plasma could improve the gel-forming ability of the surimi. The critical control point for raw material quality is its formaldehyde level. The best quality surimi is obtained when the formaldehyde level is below 15 ppm.

Introduction

The surimi production of Thailand is primarily based on threadfin bream (*Nemipterus* spp) and bigeye snapper (*Priacanthus* spp). There are 15 surimi processing plants in Thailand which operate intermittently throughout the year. From January to August 1993, the amount of Thai surimi exported to Japan, especially those made from threadfin bream, was 16,126 tonnes (*Minato Shinbun*, 21 Oct 1993). However, threadfin bream and bigeye snapper resources are expected to decrease in the future. On the other hand, the demand for surimi-based products has been increasing, not only in Japan, but also in western countries, particulary the United States of America (Wu, 1992).

Lizardfish is considered a low market value fish in this region. It has long been considered a good raw material for the manufacture of fish jelly products in Japan, particularly for *kamaboko*. The annual catch of lizardfish from the South China Sea area ranged from 45,000 and 65,000 tonnes for the period between 1985 and 1991, reaching 74,355 tonnes in 1992. In Thailand, the amount of lizardfish landed in 1991 was 23,677 tonnes and valued at US$7.127 million (Fishery Statistical Bulletin for the South China Sea Area, 1991). In 1992, it was 38,312 tonnes valued at US$10.588 million *(ibid*, 1992). The wholesale prices of the lizard fish at landing ports in Thailand varied from US$ 0.29-0.48 per kg for the period between 1985 to 1990 (*ibid*, 1990), and is about half to one third the value of threadfin bream.

In view of the relatively large landing and low price of lizardfish, and the decline in the supply of other fish species, lizardfish should be considered as a potential source of raw material for the surimi industry. The advantages of using very fresh lizard fish are that the surimi produced is very white with good flavour and has very high gel-forming ability. However the gel-forming ability decreases drastically even with ice storage of the raw material, although the freshness did not change much. Hence, utilization of this fish in this region is presently limited to dried products or used as a filler with other good gel quality fish to reduce costs of production.

Generally, frozen lizardfish cannot be used for frozen surimi (Holmes *et al.*,1992) because it does not produce surimi with good gel-forming ability. Nozaki and co-workers (1978) reported the formation of dimethylamine and formaldehyde by trimethylamine oxide (TMAO) decomposition during low temperature storage of the fish. Formaldehyde is known to denature muscle protein, and subsequently reduce its gel-forming ability.

Theoretically, if TMAO and its breakdown components can be removed from the flesh, for example through leaching of minced meat, gel-forming ability should be improved. The improvement of gel-forming ability of lizardfish by washing minced meat with sodium pyrophosphate

solution have been reported by many researchers (Oka *et al.*, 1985; Oka *et al.*, 1988 and Oka and Ono, 1987).

The textural quality is an important functional property of surimi-based products. The use of ingredients such as egg white, beef-plasma protein, and other additives to increase the gel strength of the products are now widely practiced. The purposes of using these additives in the preparation of surimi-based products is to improve both the water-binding capacity and the textural properties. Egg white and beef-plasma protein serve as protease inhibitors and thereby prevent gel softening. Moreover, egg white also imparts a whiter and glossier appearance to the gel (Lee *et al.*, 1992). Several studies on the use of ingredients to inhibit the lowering of gel strength in surimi at various cooking temperatures were reported (Burgarella *et al.*, 1985; Chung and Lee, 1990; Hamann *et al.*, 1990). They all concluded that when these ingredients are added into surimi-based products, they improved the gel strength of the products.

The objectives of this study are to improve the gel forming ability of surimi made from iced and frozen lizardfish by pyrophosphate leaching, and the use of additives such as egg-white powder and beef-plasma protein concentrate to improve the textural properties of surimi-based products.

Materials and Methods

1. Experiment 1 : Effects of sodium pyrophosphate leaching on gel-forming ability of surimi from iced lizard fish.

Fresh lizardfish (*Saurida tumbil*), 27.6 ± 0.9 cm length and 220 ± 90 g by weight were purchased from Punggol Fish Market and transported in ice in an insulated box to MFRD. The fish were labelled as Day-0 fish. However, the fish had been kept in ice on-board for 3 days before landing at Punggol Fish Port. The fish were repacked in ice *viz* fish layer alternating with ice layer and stored in an insulated box. The fish were removed for processing and chemical analysis on Day-0, Day-2, Day-4 and Day-6. Six whole round fish were sampled on the same days as the processing trials, packed in plastic bags and kept at -80°C for further chemical analysis for formaldehyde (FA) and K-value.

The processing procedures for obtaining fish jelly products from three treatments are shown in Fig. 1.

Treatment 1.1 : Unwashed minced meat (MM)

Treatment 1.2 : Minced meat which were washed 2 times in iced water and the 3rd time in iced water with 0.3% salt; called Usual Leaching (UL)

Treatment 1.3 : Minced meat which were washed 3 times leaching in iced water, with 0.2% sodium pyrophosphate during 1st leaching and with 0.3% salt in the 3rd leaching; called pyro-phosphate leaching (PL)

The percentage of sodium pyrophosphate (tetra-sodium diphosphate decahydrate, $Na_4P_2O_7.10H_2O$) used was calculated based on the weight of leaching water used. The moisture content of MM, UL and PL was measured immediately after the samples were dehydrated by hydraulic press.

The fish paste samples were prepared from the leached meat by mixing with 2% salt and the necessary amount of iced water, to adjust the moisture to 82% for MM and 85% for UL and PL. The mixing process was done in a vacuum bowl cutter for 1 min 20 sec in order to maintain the temperature of the meat at below 10°C during mixing.

The fish paste was then filled into sausage casings and set at 40°C for 20 min and boiled at 90°C for 20 min. It was then immediately cooled in iced water, then placed under running water for 20 min (Fig. 1). The cooked gel samples from the three treatments were then cut into cylinders of 1 inch height for the determination of gel strength, whiteness, folding ability and teeth cutting score.

2. Experiment 2 : Effects of frequency of leaching on gel-forming ability of surimi from iced lizardfish.

Two batches of lizardfish were bought from Punggol Fish Market on different days. Six whole fish were collected for K-value and formaldehyde determination. Minced meat were prepared from the fish and treated as follows :

Treatment 2.1 : Minced meat washed twice by usual leaching (UL-2)

Treatment 2.2 : Minced meat washed twice by pyrophosphate leaching (PL-2)

Treatment 2.3 : Minced meat washed three times by usual leaching (UL-3)

Treatment 2.4 : Minced meat washed three times by pyrophosphate leaching (PL-3)

For UL-2 and PL-2, 0.3 % of salt was added to the leaching water at second washing. The concentration of sodium pyrophosphate used for PL-2 and PL-3 was 0.2%. Preparation of samples and determination of chemical and physical properties were as described in Experiment 1.

3. Experiment 3 : Effects of various sodium pyrophosphate concentration on gel-forming ability of surimi from iced lizardfish.

Two batches of iced lizardfish were purchased from Punggol Fish Market on different days. Six whole fish were collected for K-value

analysis. The minced meat prepared from the meat-bone separator was collected for formaldehyde analysis and measurement of moisture and pH. Leaching water with three different concentrations of sodium pyrophosphate were used for the first leaching process, as follows :

Treatment 3.1 : 1st leaching water with 0.1 % sodium pyrophosphate
Treatment 3.2 : 1st leaching water with 0.2 % sodium pyrophosphate
Treatment 3.3 : 1st leaching water with 0.3 % sodium pyrophosphate

Preparation of samples and determination of chemical and physical properties were as described in Experiment 1.

4. Experiment 4 : Effects of sodium pyrophosphate leaching on gel-forming ability of surimi from frozen lizardfish.

Frozen headed and gutted lizardfish were purchased from a Thai fishing boat equipped with freezing facilities. Two batches from the same lot of fish were processed on different days. Frozen fish were left to thaw overnight at 10°C (approximately 16-17 hours) before further processing. Preparation of samples, determination of chemical and physical properties were as described in Experiment 1.

Treatment 4.1 : Unwashed minced meat from frozen lizardfish (MMF)
Treatment 4.2 : Minced meat from frozen lizardfish washed twice by usual leaching (ULF)
Treatment 4.3 : Minced meat from frozen lizardfish washed twice by pyrophosphate leaching (0.2% sodium pyrophosphate) during 1st leaching

5. Experiment 5 : Effects of various sodium pyrophosphate concentration on the gel-forming ability of surimi from frozen lizardfish.

Two batches of frozen lizardfish, from the same lot as in Experiment 4, were washed twice in iced water with three different concentrations of sodium pyrophosphate. Preparation of samples and the determination of chemical and physical properties were as described in Experiment 1.

Treatment 5.1 : Minced meat washed twice in iced water with 0.1% sodium pyrophosphate (0.1PL)
Treatment 5.2 : Minced meat washed twice in iced water with 0.2% sodium pyrophosphate (0.2PL)
Treatment 5.3 : Minced meat washed twice in iced water with 0.3% sodium pyrophosphate (0.3PL)

6. Experiment 6 : Effect of egg-white powder and beef-plasma protein concentrate on the gel-forming ability of frozen stored surimi made from iced lizardfish.

Commercial egg-white powder and AMP 600N beef-plasma protein concentrate (Wee Hoe Cheng Chemicals Pte Ltd., Singapore) were used.

Six to ten fish were sampled for chemical analysis for formaldehyde, K-value, moisture content and pH. 100 kg of lizardfish was used for making surimi. The surimi were prepared as shown in Fig. 2. The treatments were as follows :

Treatment 6.1 : Minced meat washed twice by usual leaching (UL)
Treatment 6.2 : Minced meat washed twice in iced water with 0.2% sodium pyrophosphate during first leaching (PL)

The surimi (UL and PL) were prepared from iced lizardfish. After the preparation of surimi, one lot was analysed for its gel-forming ability (Day-0 sample). The other lots of surimi were frozen and kept at -20°C and sampled for gel-strength testing after 4, 11, 18 and 32 days at -20°C storage.

7. Experiment 7 : Effects of egg white and beef - plasma protein concentrate (AMP600N) on the gel-forming ability of surimi made from frozen lizardfish.

Lizardfish which were kept in frozen storage for two months were used in this experiment. They were headed, gutted and frozen on board. The frozen fish were delivered to MFRD and kept in cold storage at -20°C. Prior to the making of surimi, they were thawed overnight in a chiller room (15°C). The surimi was prepared according to Fig. 2. After the preparation of the surimi, the moisture content of the surimi was measured.

For preparing the fish jelly product samples (Fig. 3), the frozen surimi was thawed at ambient temperature (25-28°C) and cut into smaller pieces. The surimi pieces were chopped in a Stephan (UM 5 Universal) vertical cutter/mixer with 3% NaCl, 0.5% of egg-white powder or 1.0% of beef-plasma protein concentrate (AMP600N) and water to adjust to a moisture of 85%. The mixing time was about 1 min 20 sec with a maximun temperature of 10°C. The resulting paste was stuffed into 25 mm diameter sausage casing of approximately 150 mm length and heated at 40°C for 20 min followed by 90°C for 20 min. The samples were then cooled immediately under running water. The samples of cooked gel were kept overnight at 5°C in the refrigerator (5°C).

Before measuring the gel strength, whiteness, folding test and teeth cutting test as

previously mentioned, samples were put under running water for about 20 min until their temperature was stabilized.

8. Determination of chemical and physical properties.

The pH, K-value, formaldehyde, gel strength, whiteness, folding test and teeth cutting test was conducted according to the procedures listed in the Laboratory Manual on Analytical Methods and Procedures for Fish and Fish Products (Miwa and Low, 1992).

For moisture determination, 5g of minced meat was spread evenly on an aluminium-foil dish. The dish was placed in an infra-red moisture meter (Mettler LP 16) for about 30-35 min and the moisture content was determined.

The grading for the folding test as in Miwa and Low (1992) are as follows :

M : No breakage when folded in quarter
A : Slight tear when folded in quarter
B : Slight tear when folded in half
C : Breakage (but 2 pieces still connected) when folded in half
D : Break completely into 2 pieces when folded in half

The grading for the teeth cutting test as in Miwa and Low (1992) is as follows :

10 Extremely strong springiness
9 Very strong springiness
8 Strong springiness
7 Quite strong springiness
6 Acceptable springiness
5 Acceptable, slight springiness
4 Weak springiness
3 Quite weak springiness
2 Very weak springiness
1 Mushy texture, no springiness

Results and Discussion

1. Experiment 1 : Effects of sodium pyrophosphate leaching on gel-forming ability of surimi from iced lizardfish.

As the raw material was 3 days after catch on arrival at the laboratory, it was fairly fresh with a K-value of 12.81% (Fig. 4). As it was stored in ice, the K-value increased significantly ($P<0.05$) to 23.52% after 6 days in ice at the laboratory (or 9 days after catch). The pH remained relatively unchanged for the minced meat sample. However, the leaching process led to an increase in the pH for both UL and PL samples (Fig.5). As expected PL samples had the highest pH ranging from 6.84 - 6.98. The leaching process also increased the moisture of the leached meat for both UL and PL. Usual leaching resulted in a lesser increase in moisture than pyrophosphate leaching.

Fresh lizardfish, upon arrival at MFRD, had formaldehyde levels of 7.12 ppm and increased significantly ($P<0.05$) to 44.97 ppm at Day-2 (Fig. 6). It continued to increase to 81.29 ppm on Day-6. In this experiment, the white meat fillets of the fish was used for formaldehyde determination instead of the minced meat. Minced meat produced after the fish has passed through the meat bone separator is expected to have a higher level of formaldehyde. This is because the mincing process probably results in increased enzymatic activity, converting trimethylamine oxide (TMAO) in the fish meat to dimethylamine and formaldehyde. This is shown in the higher formaldehyde levels found in the leached meat samples at Day-0. However, as the quality of the fish deteriorated during iced storage, the leaching process would then be more effective in removing the TMAO as well as some of the formaldehyde formed from the minced meat. This is shown in the significantly ($P<0.05$) lower formaldehyde values of UL and PL samples compared with the fillet samples (Fig. 6). Lim and Yasui (1987) studied the effects of usual leaching and alkaline leaching in lizardfish and concluded that leaching was effective in washing out most of trimethylamine oxide (TMAO) in the minced meat, resulting in an increase of meat sol and salt soluble protein extraction. However, leaching not only remove formaldehyde and enzymes responsible for gel degradation (Suwansakornkul *et al.*, 1993), but the process also weakens the firm bond between myosin and actin in fish muscle resulting in improved gel forming ability (Nishioka and Tokunaga, 1990).

The leaching process significantly ($P<0.05$) increased the whiteness (Fig. 7) of the leached meat (both UL and PL) as blood and other water soluble pigments were washed away by leaching. However, sodium pyrophosphate does not result in any improvement in the whiteness of the leached meat as compared with UL.

Although the gel strength continued to drop with the decrease in the quality of the raw material during ice storage, the leaching process significantly ($P<0.05$) enhanced the gel-forming ability (Fig. 8). The effect of pyrophosphate leaching in significantly ($P<0.05$) enhancing the gel-forming ability of the surimi (PL) as compared with surimi from usual leaching (UL) was only observed in surimi made from raw material that were stored in the ice for 4 days. However, when the raw material has been stored in ice for 6 days (or 9 days after catch), the leaching process (both UL and PL) did not enhance the gel-forming ability. Oka and Ono (1987) concluded from their study that lizardfish stored at 5°C for 4 days could be used to make good quality *kamaboko* by leaching in pyrophosphate solution. However, if the

lizardfish was stored for 8 days at 5°C, it could not be used to make surimi with good gel.

Folding and cutting scores rated by experienced panelists showed that leaching in pyrophosphate solution gave higher scores due to better springiness (Fig. 8). However, on the sixth day of storage, no difference between UL and PL was observed. Oka *et al.* (1985) stated that the elasticity of *kamaboko* made by leaching lizardfish meat in fresh water was weak, but strong elasticity was formed by leaching in 0.2 % pyrophosphate solution. The results (Fig. 8) showed that throughout the ice storage, except on Day-6, the panelists agreed that PL gave better springiness to the products in terms of teeth-cutting scores. This is especially so for surimi made from Day-4 fish, where folding ability of UL was rated A and B whilst PL's was rated AA. There is a trend that PL always gave higher gel strength and springiness compared to UL even though they were not statistically different .

Therefore, the use of lizardfish for surimi processing is highly dependant on the freshness of the raw material, which in turn depends very much on handling on-board. Our results showed that even though the fish was fairly fresh upon arrival and well iced throughout its post-harvest storage, the lizardfish which are 9 days after harvesting could not produce surimi with good gel-forming ability. From this study, pyrophosphate leaching was effective to a limited extent, when the freshness of the fish has only deteriorated somewhat. However, once the lizardfish has reached its threshold value, when the formaldehyde formed was above about 50ppm, leaching is not able to enhance the gel-forming ability of its surimi.

2. Experiment 2 : Effects of frequency of leaching on gel-forming ability of surimi from iced lizardfish.

The K-value and formaldehyde levels of the 2 batches of raw material (Table 1) used were different. The first batch was of better quality with a K-value of 15.3% and formaldehyde level of 10.45 ppm. The second batch had a K-value of 22.51% and a formaldehyde level of 20.61 ppm upon arrival at the laboratory. This resulted in Batch 1 producing surimi with better gel forming ability than Batch 2. The results showed that once the raw material quality has dropped below a certain level, e.g., when formaldehyde level was above 20 ppm, the leaching process could not produce surimi with good gel-forming ability (Fig. 9).

The gel strength (Fig. 9) of Batch 1 with two times leaching increased significantly ($P<0.05$) from 730 (UL-2) to 1,102 g.cm (PL-2). This is in agreement with the findings of Oka *et al.* (1985) regarding the gel-strength enhancing effect of leaching with a 0.2% sodium pyrophosphate solution. However, in Batch 2 there was no difference in gel strength amongst the various treatments; this could be attributed to the lower freshness of the raw material. In never-frozen raw material, pyrophosphate leaching may not be as effective if the raw material quality is low. More experiments should, however, be conducted to confirm the effects of pyrophosphate leaching made from lizardfish of different freshness.

In both batches, there was no significant difference in the number of leaching times on the gel strength of the jelly product. Folding-test and teeth-cutting scores correlated well with the gel strength in both batches. Pyrophosphate seemed to give slightly higher scores in folding test,and springiness in both batches. In Batch 1, the number of times of leaching did not affect the gel-forming ability of the surimi, whilst in Batch 2, made from poorer quality lizardfish, three-times leaching in pyrophosphate solution resulted in surimi with a slightly better gel-forming ability, although the difference was not significant (Fig. 9).

Whiteness of the products depended on initial quality of raw material. Slightly lower whiteness was found in Batch 2 due to inferior freshness, however the various treatments did not result in a significant difference in the whiteness.

When the minced meat was washed twice, the recovery of the minced meat based on the original weight used ranged from 71.67 - 72.99% for UL-2 and 73.66 - 75.99% for PL-2. However, when a third wash was introduced, the recovery dropped by 9-13% for usual leaching and 12-16% for pyrophosphate leaching (Fig. 10).

3. Experiment 3 : Effects of various sodium pyrophosphate concentration on gel-forming ability of surimi from iced lizardfish.

The raw material for both batches were similar in freshness with K-values of 13.54% for Batch 1 and 14.54% for Batch 2. The formaldehyde levels were 23.34 ppm for Batch 1 and 30.62 ppm for Batch 2. The moisture content (Fig. 11) and pH (Fig. 12) increased as the amount of pyrophosphate used was increased. Thus, it can be concluded that pyrophosphate enhanced water absorbing and holding capacity of fish meat; and resulted in higher pH because of its natural alkali property.

In this experiment, minced meat after passing through the meat bone separator was used for formaldehyde analysis. A significant decrease ($P<0.05$) in formaldehyde content from 10.45 ppm in MM to 16.22 ppm in UL-2 and 14.43 ppm in PL-2 for Batch 1, and from 20.61 ppm in MM to 14.90 ppm in PL-2 for Batch 2. It can be concluded that formaldehyde in the fish meat was removed by the leaching process. However, the results showed that different concentrations of pyrophosphate used had

no significant effect on the amount of formaldehyde removed.

Fig. 13 shows the effects of pyrophosphate concentration on gel strength. In Batch 1, leaching solutions containing various concentrations of pyrophosphate showed no significant difference in its effect on whiteness, gel strength, folding ability and teeth cutting scores of the products. In Batch 2, however, higher gel strength and whiteness was obtained when the minced meat was leached in 0.2% and 0.3% sodium pyrophosphate solutions. The panelists however, could not differentiate springiness among the samples. Nishioka and Tokunaga (1990) concluded from their findings that gel strength of kamaboko depended on concentration of sodium pyrophosphate and optimum concentration for sardine meat was 0.15-0.2%. The results of this study also showed that the highest gel strength was obtained in surimi made from 0.2% sodium pyrophosphate leached meat. Thus 0.2% sodium pyrophosphate solution is suitable for use as a leaching solution for the preparation of surimi from lizardfish.

4. Experiment 4 : Effects of sodium pyrophosphate leaching on gel-forming ability of surimi from frozen lizard fish.

For this experiment, the minced meat was washed twice and 0.2% sodium pyrophosphate was used as one of the treatment (PLF), comparing with usual leaching (ULF) and non-leached minced meat (MMF). The fish from Batch 1 and Batch 2 were of similar quality. They were quite fresh and the K-values were 13.73% for Batch 1 and 12.11% for Batch 2. However the initial formaldehyde content in the unwashed minced meat was very high, 52.90 ppm for Batch 1 and 60.57 ppm for Batch 2. It has been reported that during frozen storage, the TMAO in gadoid fishes break down into dimethylaine (DMA) and formaldehyde (Regenstein *et al.*, 1982). There apparently is an enzyme present in some species of fish (Watson, 1939; Amano and Yamada, 1964; Yamada and Amano, 1965). Lizardfish may also have such an enzyme system.

The gel strength of the surimi made from these two batches was very poor as shown in Fig. 14 and the fish jelly product prepared from the unwashed minced meat (MMF) was even lower. This is due to the freezing denaturation of protein in the fish meat caused by the presence of formaldehyde. From this trial, it can be concluded that though the samples were fresh, the poor gel strength was due to the high level of formaldehyde present. Therefore, the gel-forming ability of surimi from lizardfish is highly dependent on the level of formaldehyde present, especially if the lizardfish was frozen.

Fig.14 shows the effect of pyrophosphate leaching on the gel strength of surimi made from frozen lizardfish, resulting in a surimi with comparable gel-forming ability as those prepared from iced fish. These results compared well with those from folding test and teeth cutting scores rated by the panelists. Folding ability was improved from D to AA by leaching in both batches. It can be concluded that pyrophosphate leaching (PLF) was effective in improving the gel-forming ability of surimi from frozen lizardfish compared to usual leaching (ULF) and unwashed minced meat (MMF). The same observation was reported by Oka and Ono (1987) who concluded that lizardfish stored at -35°C for 3 months could still be used to produce good quality kamaboko by leaching in pyrophosphate solution.

The physical appearance of the raw material (headed and gutted block frozen fish) in both batches were not good with the presence of a yellowish taint and rancidity. Whiteness of the products is highly dependent on initial fish quality. The poor quality of the frozen lizardfish gave a darker coloured final fish jelly product compared to those produced from iced fish. Leaching significantly improved the whiteness (Fig. 15).

5. Experiment 5 : Effects of various sodium pyrophosphate concentration on the gel-forming ability of surimi from frozen lizardfish.

The results (Fig. 16) showed that a 0.2% sodium pyrophosphate solution was significantly effective in improving the gel-forming ability of surimi made from frozen lizardfish as compared to a concentration of 0.1%. However, further increases in the strength of the sodium pyrophosphate solution to 0.3% did not significantly increase the gel strength as compared with the effect of 0.2% sodium pyrophosphate. Therefore 0.2% sodium pyrophosphate was suitable for use in leaching solution. Folding and cutting scores showed the same trend in Batch 1, whereas for Batch 2, the panelists could not diflerentiate springiness amongst three samples (0.1%, 0.2% and 0.3% sodium pyrophosphate).

The use of 0.2% and 0.3 % sodium pyrophosphate in Batch 2 resulted in significantly whiter fish jelly products than 0.1%. It can be concluded that 0.2 and 0.3 % pyrophosphate are the optimum concentrations for improving gel-forming ability of frozen lizardfish. Therefore, 0.2 % should be the reasonable concentration for industry point of view.

6. Experiment 6 : Effect of egg-white powder and beef-plasma protein concentrate on the gel-forming ability of frozen stored surimi made from iced lizardfish.

The iced lizardfish (3 days after catch) had K-value of 18.62 ± 4.30%, formaldehyde levels of 11.15 ± 3.05 ppm, pH 6.34 and moisture of 78.68%. These lizardfish were rather fresh. Suwansakornkul *et al.*, (1993) also found that moisture content and pH of iced lizard fish *(S. undosouamis, S. wanieso* and *S. elonnata)* ranged from 77.03 - 81.72% and pH 6.53 - 6.71 respectively.

At the beginning of the storage period for frozen surimi, a significantly higher ($P<0.05$) gel-forming ability was found in UL than PL of frozen surimi made from the iced lizardfish (Fig. 17). The gel strength of UL and PL surimi decreased with the length of frozen storage. However the decrease was not significant. Pyrophosphate leaching did not result in a significant increase in the gel-forming ability of the surimi as compared with UL surimi. However, the quality of both the UL and PL surimi was still acceptable as shown by the folding and teeth cutting scores of AA 5-6. A slightly rough texture, springy-firm gel and dull appearance were observed in samples made from UL surimi, but a smooth texture, springy-soft gel and glossy appearance were observed in PL surimi samples (Table 2).

Theoretically, actomyosin is the main component contributing to kamaboko gel. During the leaching process, actomyosin was probably broken down into myosin and actin as a result of homogenization. In addition, pyrophosphate can dissociate actomyosin into myosin and actin besides enhancing the water holding capacity, protein solubility and improving textural properties. The texture of final product made from myosin was slightly softer than that of actomyosin (Thammarutwasik, 1988). It could be concluded that lower gel strength of PL surimi as compared with UL surimi can be attributed to the formation of myosin gel. In addition, pyrophosphate plays an important role as a cryoprotectant (Suzuki, 1981). Therefore the gel strength of PL surimi during storage at -20°C decreased slower than that of UL surimi (Fig. 17). Thammarutwasik (1988) also concluded that alkaline pyrophosphate leaching of minced sardine meat produced surimi with gel-forming ability that was not significantly different from surimi made by usual leaching.

After the surimi, which were made from iced fish, were frozen stored for 11 days, egg white and beef-plasma protein concentrate were added into both the UL and PL lizardfish surimi in the proportion of 0.5% egg-white and 1.0% beef-plasma protein concentrate (based on weight of surimi used) during the process of gel preparation. Both additives resulted in a slight improvement in the gel forming ability of the surimi as compared with the control (Fig. 17). Beef-plasma protein concentrate showed a higher effectiveness than egg white in the gel strength but the differences between them were not significant, as in folding test, teeth cutting test and sensory evaluation (Table 2).

Both egg-white and beef-plasma protein concentrate are known to inhibit the activity of protease which causes textural degradation of surimi gels (Lee *et al.*, 1992). Moreover, the effects of egg-white and beef-plasma protein concentrate on the setting ability of surimi seemed to be dependent upon the species of fish as well as the temperature and length of cooking (Hamaan *et al.*, 1990, Chung and Lee, 1990 and Shimizu *et al.*, 1981). Hamaan and co-workers (1990) reported that addition of egg-white solid and beef-plasma hydrolysate in low grade Alaska pollack and menhaden surimi increased torsional shear stress and strain for all gels precooked at 60 °C and with a final cook at 90°C, and decreased the density of the myosin heavy chain as observed by electrophoresis. Chung and Lee (1990) reporting on the thermal effects of the gel-forming additives, concluded that the compressive force of surimi gels containing lactalbumin, egg white and wheat gluten increased markedly when the fish paste was initially cooked at 40°C and subsequently at 85°C.

7. Experiment 7 : Effects of egg-white and beef-plasma protein concentrate (AMP600N) on the gel-forming ability of surimi made from frozen lizardfish.

The 2-month old frozen lizardfish used in this experiment had a K-value of 20.29% and a rather high formaldehyde level of 66.90 ppm. In addition, after thawing, the fish meat was fibrous and dehydration was also observed. These physical characteristics observed in the raw material indicated that the fish protein of this batch of 2-month frozen lizardfish had already undegone denaturation during the course of freezing and frozen storage on board. Therefore, the quality of surimi made from this frozen fish was very poor regardless of the various additives used.

At Day-0, or the day the frozen lizardfish arrived at MFRD, the gel strength of UL and PL frozen lizardfish surimi were less than 100 g.cm. Sensory scores were also very low, at a score of D2. Even though egg-white and beef-plasma protein concentrate were added into these surimi (UL and PL) after 4 days storage (-20°C), there was no improvement in the gel forming ability of the surimi (Fig. 18). Therefore, the experiment was terminated. These results showed that if the initial quality of the raw material was too low, additives cannot enhance the gel-forming ability of the surimi. Therefore, it is very important to use good quality raw materials and to ensure that the formaldehyde level is preferably below 25 ppm. From Experiment 6, it was clearly demonstrated that frozen surimi made from good quality iced lizardfish (K-value 18.62% and

formaldehyde level 11.15 ppm) had reasonably good gel-forming ability even after about 1 month in frozen storage (-20°C); and that egg-white and beef-plasma protein concentrate were able to increase the gel strength of the 1-month stored surimi.

Conclusion

The results showed that a two-time leaching in 0.2% sodium pyrophosphate solution was effective in enhancing the gel-forming ability of lizardfish surimi under certain conditions. When the iced lizardfish raw material was of good quality (K-value < 20.0%; formaldehyde < 25 ppm) pyrophosphate leaching did not result in a significant increase in the gel-forming ability of the surimi. However, when the raw material quality has dropped (K-value ranged from 21-23%; formaldehyde 30-50 ppm), pyrophosphate leaching was effective in enhancing the gel-forming ability of surimi from lizardfish. But, when the fish was of very poor quality (K-value > 23%; formaldehyde > 50 ppm), pyrophosphate leaching was ineffective.

When using frozen lizardfish as raw material, two times leaching using 0.2% sodium pyrophosphate solution, and the use of additives such as egg-white or beef-plasma concentrate were effective in enhancing the gel forming ability only when the frozen fish was of good quality (K-value < 20%; formaldehyde < 50 ppm). However, once the raw material was not of good quality, pyrophosphate leaching and addition of egg-white or beef-plasma protein concentrate were not effective in enhancing gel forming ability.

The critical point in management of raw material quality for production of surimi from lizardfish is the control of the formaldehyde level. The formaldehyde level must not exceed 50 ppm. Moreover, the best quality surimi from lizardfish is obtained when the formaldehyde level was less than 15 ppm.

Recommendations

The following is a list of recommendations for future research into the use of lizardfish for surimi production :

1. The effect of formaldehyde on the degradation of lizardfish protein should be further studied.
2. The development of formaldehyde in lizardfish during frozen storage should be studied to find the maximum period of frozen storage for the lizardfish raw material, so that surimi with good gel forming ability can be produced.
3. The effect of storage period on the gel forming ability of frozen stored lizardfish surimi should be studied.

Acknowledgement

The authors would like to express our gratitude to Mr. Hooi Kok Kuang, Dr. Katsutoshi Miwa, Mr. Tan Sen Min, Dr. Shiro Konagaya and Mr. Tadahiko Kiya, for their guidance and advice. Special thanks are also due to the staff of MFRD for their help and support in this project.

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Discussion

Ms Ng added that the critical point in the management of raw material quality for production of surimi from lizard fish is the control of the formaldehyde levels which should not exceed 50 ppm. She emphasized that the best quality surimi from lizard fish was obtained when the formaldehyde level was less than 15 ppm.

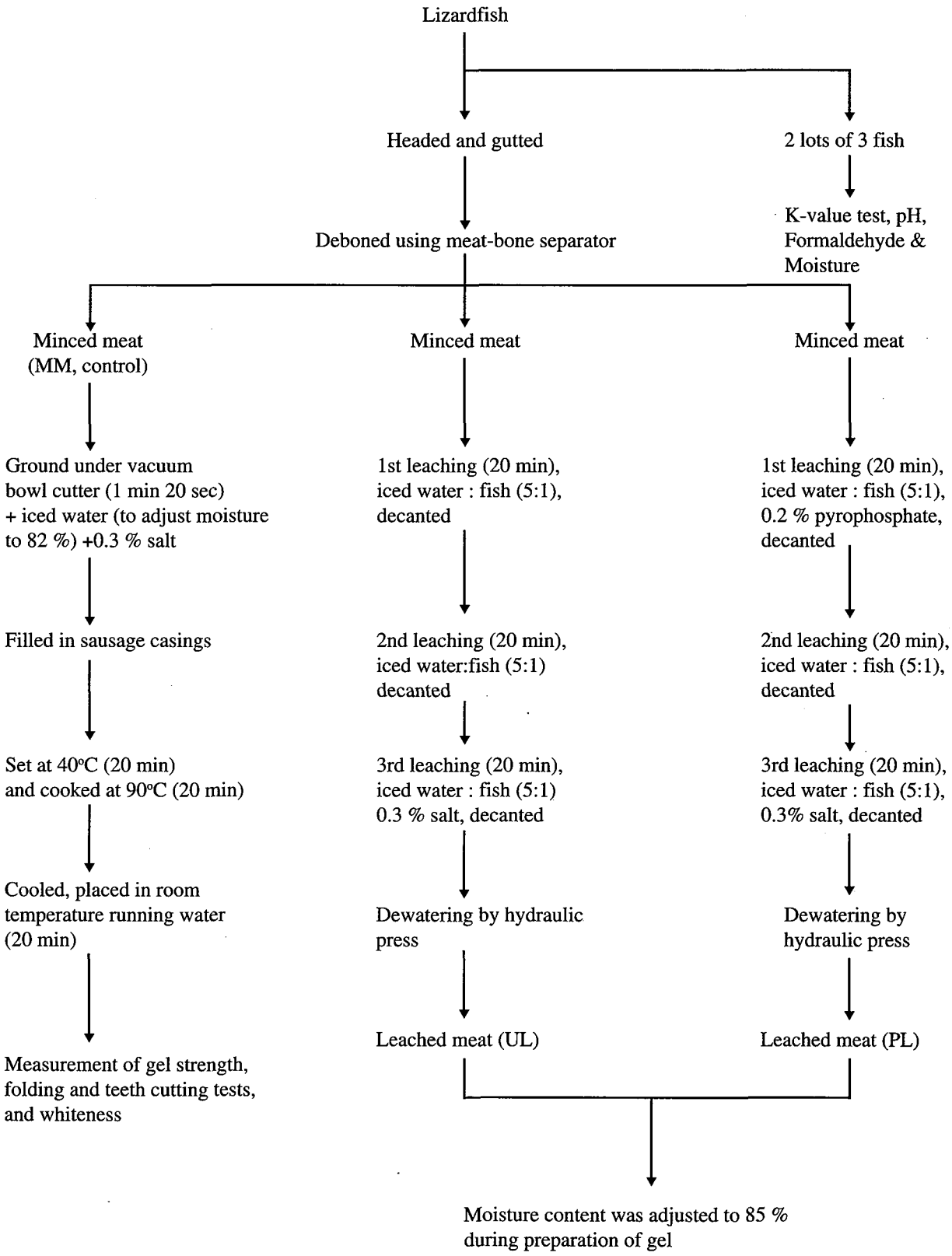

Fig. 1. Preparation of samples for Experiment 1.

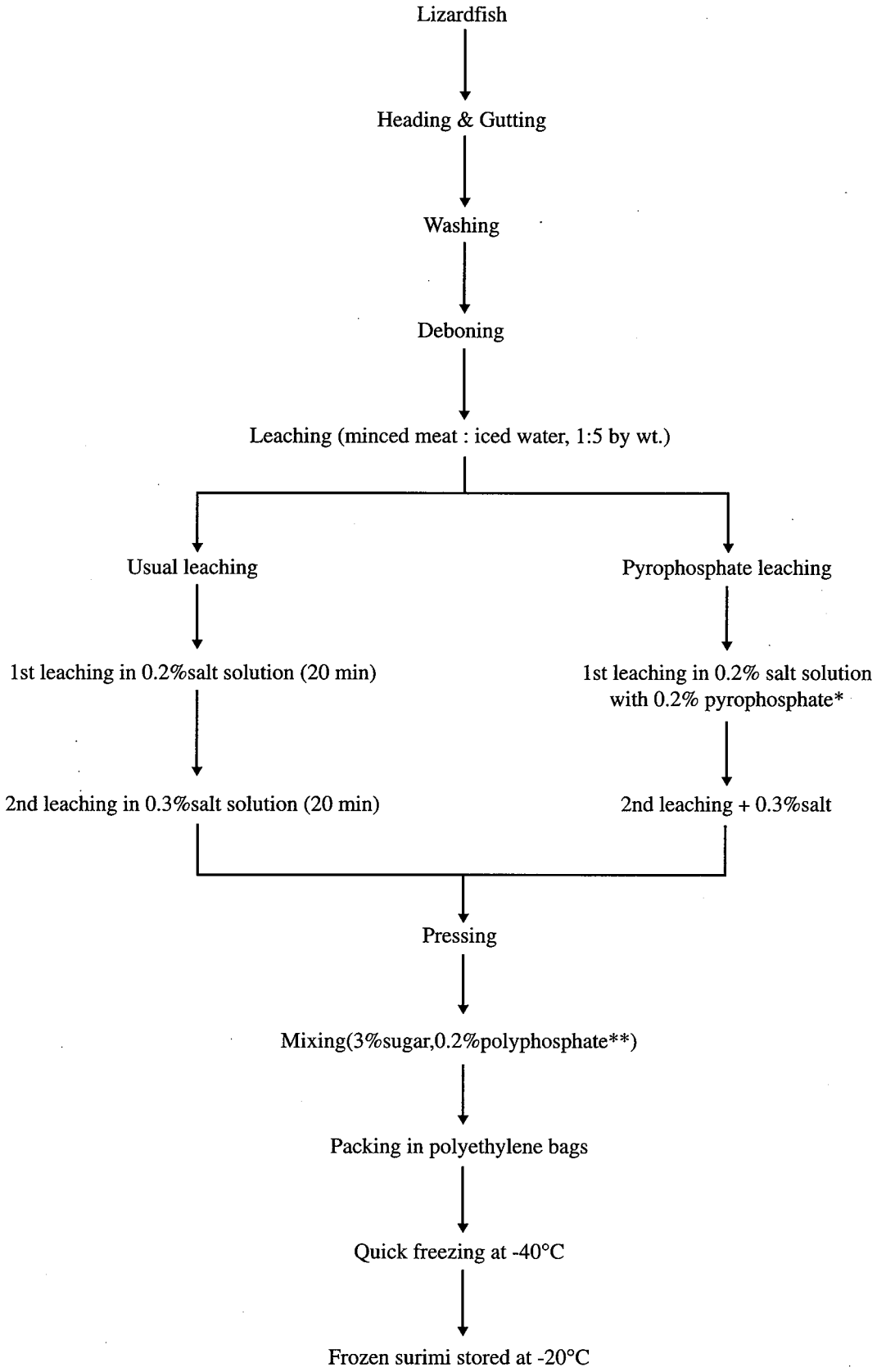

Fig. 2. Diagram showing the production of frozen surimi.

* tetra-Sodium-diphosphate decahydrate ($Na_4P_2O_7$. $10H_2O$)
** 50% pyrophosphate and 50% tripolyphosphate

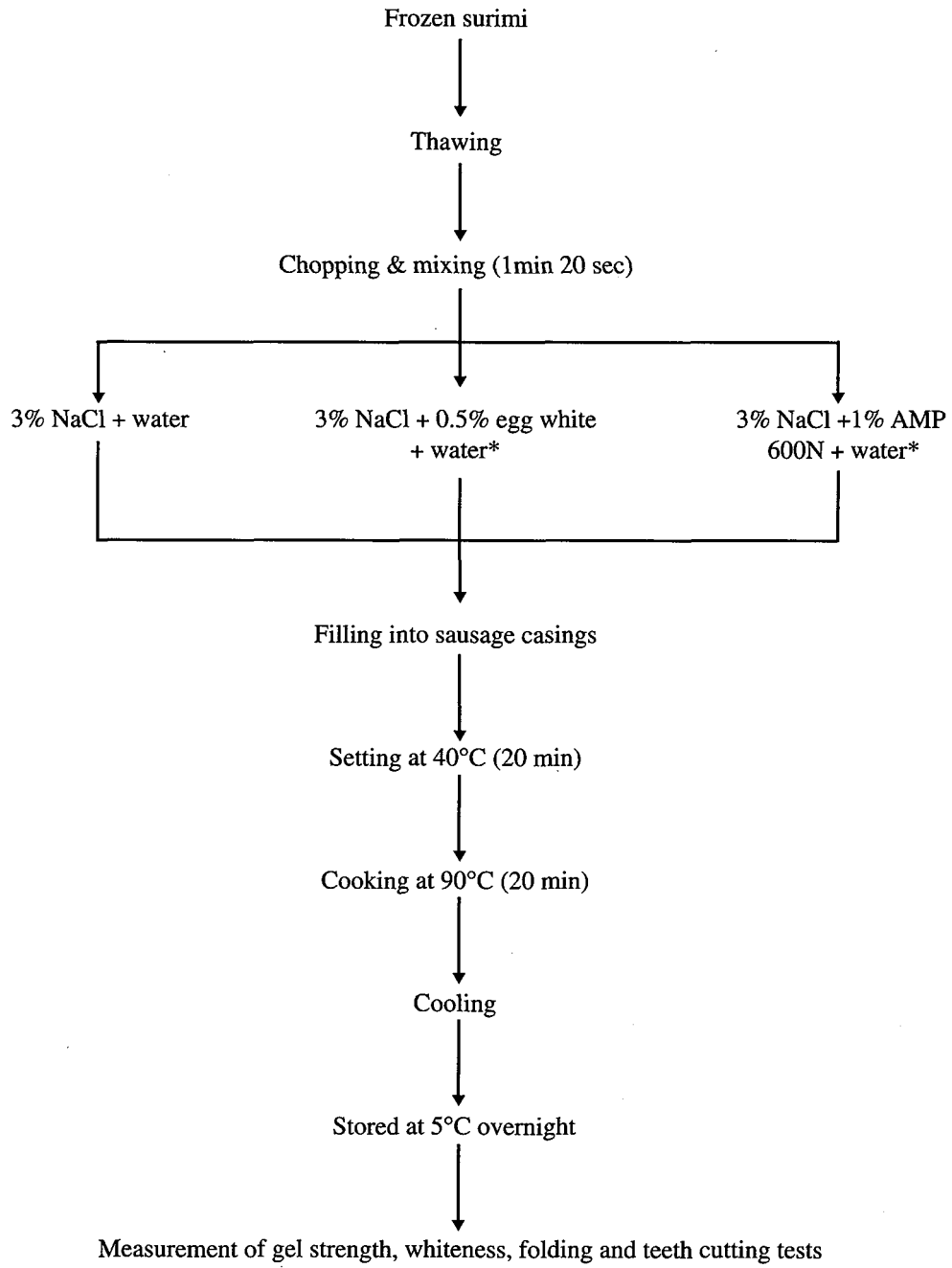

Fig. 3. Diagram showing preparation of samples for testing gel strength.

* Moisture content adjusted to 85%.

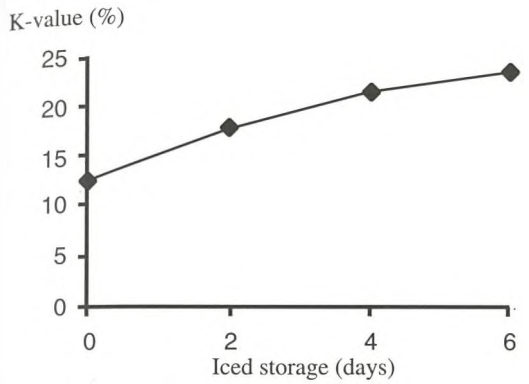

Fig. 4. K-value (%) of lizardfish used for preparing surimi during iced storage. (Day-0 is 3 days after catch.)

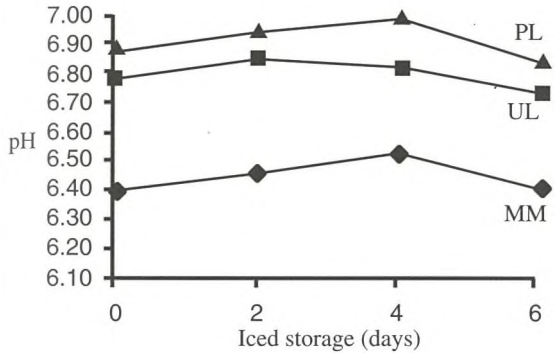

Fig. 5. Changes in pH of minced meat (MM), usual leached meat (UL) and pyrophosphate leached meat (PL) made from iced lizardfish.

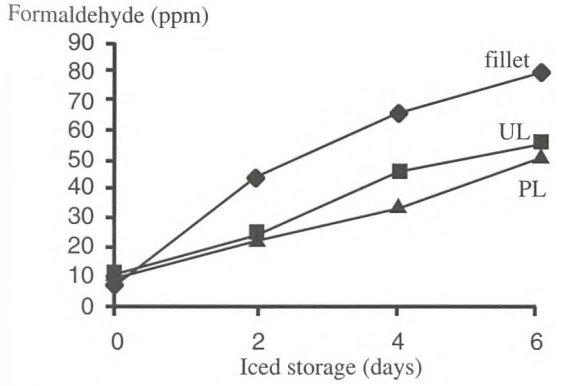

Fig. 6. Changes in formaldehyde levels (ppm) of lizardfish fillet, usual leached meat (UL) and pyrophosphate leached meat (PL) made from iced lizardfish.

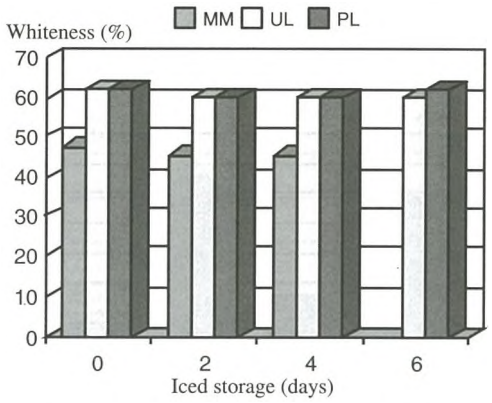

Fig. 7. Changes in whiteness (%) of minced meat (MM), usual leached meat (UL) and pyrophosphate leached meat (PL) made from iced lizardfish.

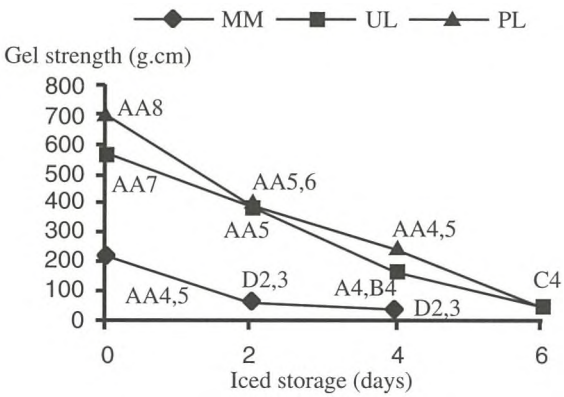

Fig. 8. Changes in gel strength, teeth cutting and folding tests scores of minced meat (MM), usual leached meat (UL) and pyrophosphate leached meat (PL) made from iced lizardfish.
(e.g. AA=Folding test score; 8=teeth cutting test score)

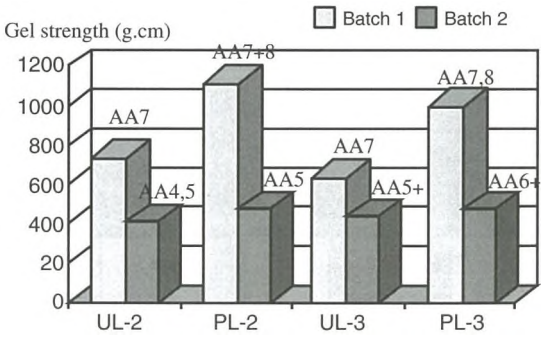

Fig. 9. Changes in the gel strength of surimi made from iced lizardfish which were subjected to different types and times of leaching.UL-2 = Two leaching times by usual leaching without sodium pyrophosphate; UL-3 = Three leaching times by usual leaching without sodium pyrophosphate; PL-2 = Two leaching times by 0.2% sodium pyrophosphate leaching; L-3 = Three leaching times by 0.2% sodium pyrophosphate leaching. (e.g. AA=Folding test score; 8=teeth cutting test score)

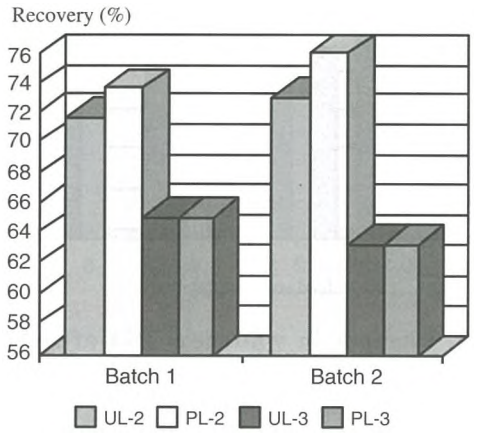

Fig. 10. Percentage recovery of leached minced meat after washing by usual leaching (UL) and pyrophosphate leaching (PL).
UL-2 = Two leaching times by usual leaching without sodium pyrophosphate
UL-3 = Three leaching times by usual leaching without sodium pyrophosphate
PL-2 = Two leaching times by 0.2% sodium pyrophosphate leaching
PL-3 = Three leaching times by 0.2% sodium pyrophosphate leaching

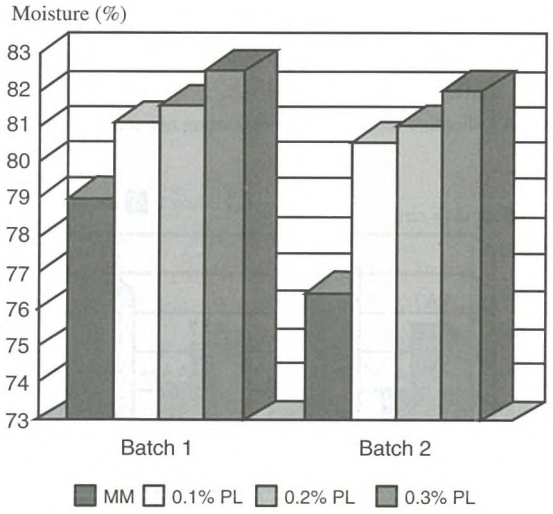

Fig. 11. Effect of different concentration of pyrophosphate leaching on the moisture content (%) of leached meat from iced lizardfish as compared to the minced meat control (MM).

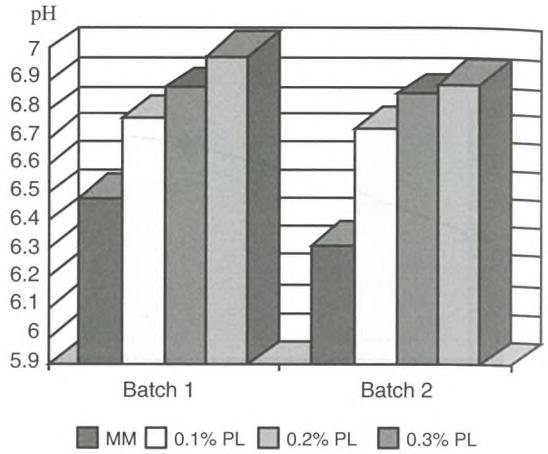

Fig. 12. Effect of different concentration of pyrophosphate leaching on the pH of leached meat from iced lizardfish as compared to the minced meat control (MM).

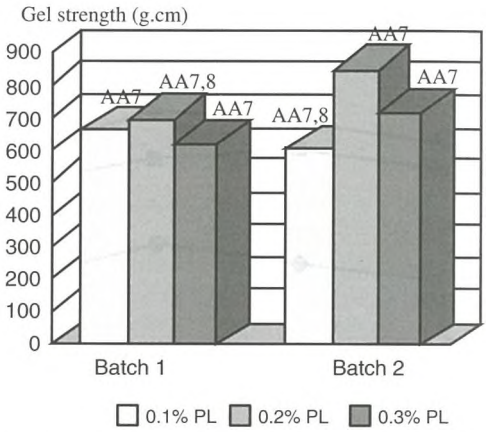

Fig. 13. Gel strength, folding test and teeth cutting test characteristics of lizardfish meat leached in different concentrations of pyrophosphate solution.
(e.g. AA=Folding test score; 8=teeth cutting test score)

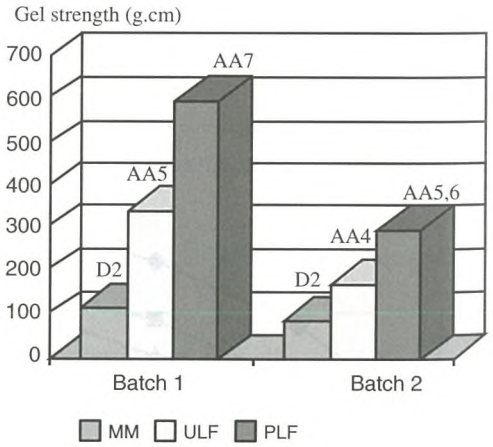

Fig. 14. Gel strength, folding test and teeth cutting test characteristics of surimi from frozen lizard fish after usual leaching (ULF) and pyrophosphate leaching (PLF) as compared with unwashed minced meat (MMF). Pyrophosphate leaching was done using 0.2% sodium pyrophosphate and two leaching times. (e.g. AA=Folding test score; 8=teeth cutting test score)

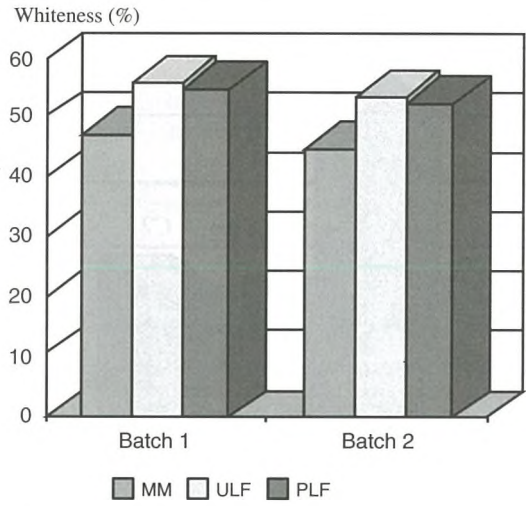

Fig. 15. Whiteness reading of jelly product made from frozen lizardfish after usual leaching (ULF) and pyrophosphate leaching (PLF) compared with unwashed minced meat (MMF).
Pyrophosphate leaching was done using 0.2% sodium pyrophosphate and two leaching times.

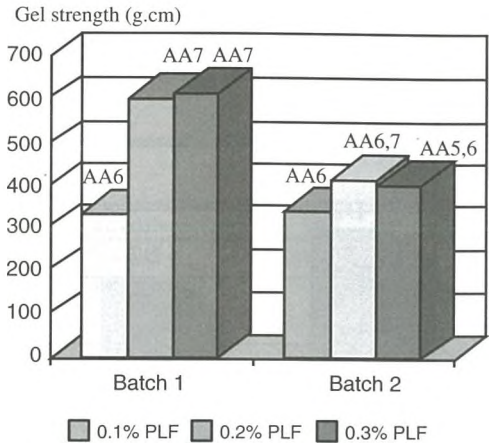

Fig. 16. Gel strength, folding test and teeth cutting test characteristics of surimi made from frozen fish leached with different concentrations of sodium pyrophosphate solution.
0.1% PLF = leaching using 0.1% sodium pyrophosphate solution
0.2% PLF = leaching using 0.2% sodium pyrophosphate solution
0.3% PLF = leaching using 0.3% sodium pyrophosphate solution
(e.g. AA=Folding test score; 8=teeth cutting test score)

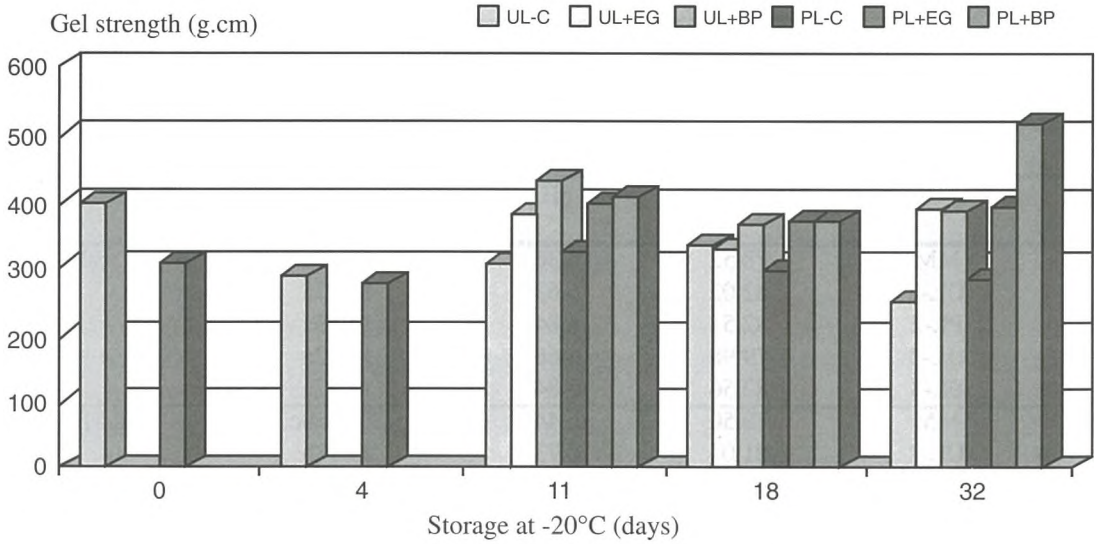

Fig. 17.The effect of leaching and additives on changes in gel strength of surimi made from iced lizardfish and kept under frozen (-20°C) storage.
UL-C = Usual leaching control
UL-EG = Usual leaching and 0.5% egg white used in gel preparation
UL-BP = Usual leaching and 1.0% beef-plasma protein concentrate used in gel preparation
PL-C = Pyrophosphate leaching control
PL-EG = Pyrophosphate leaching and 0.5% egg white used in gel preparation
PL-BP = Pyrophosphate leaching and 1.0% beef-plasma protein concentrate used in gel preparation

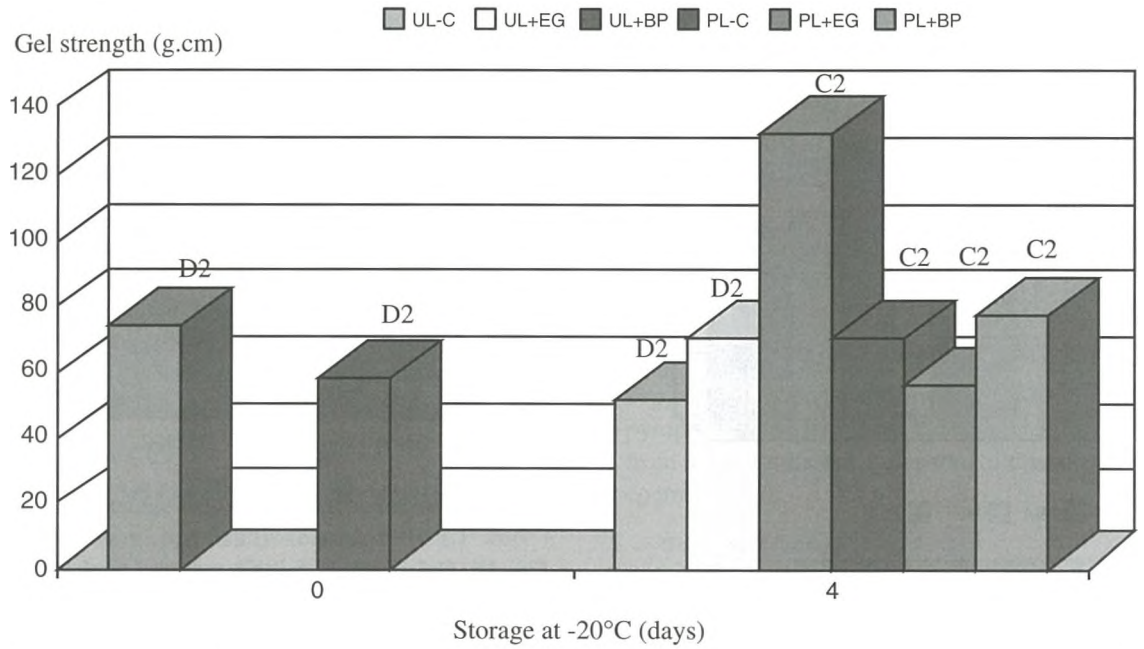

Fig. 18. Effect of leaching and additves on the gel forming ability, folding test and teeth cutting test results of surimi made from 2-month old frozen stored lizardfish.
UL-C = Usual leaching control
UL-EG = Usual leaching and 0.5% egg white used in gel preparation
UL-BP = Usual leaching and 1.0% beef-plasma protein concentrate used in gel preparation
PL-C = Pyrophosphate leaching control
PL-EG = Pyrophosphate leaching and 0.5% egg white used in gel preparation
PL-BP = Pyrophosphate leaching and 1.0% beef-plasma protein concentrate used in gel preparation

Table 1. Chemical properties of minced meat (MM), usual leached meat (UL) and pyrophosphate leached (PL) meat made from iced lizardfish.

Batch	Treatment	Moisture (%)	pH	Formaldehyde (ppm)	K-value (%)
1	MM	78.52	6.36	10.45a	15.30
	UL-2	82.02	6.63	16.22a	-
	PL-2	82.51	6.84	14.43a	-
	UL-3	79.98	6.66	15.52a	-
	PL-3	82.56	6.84	12.27a	-
2	MM	78.50	6.44	20.61abc	22.51
	UL-2	81.04	6.73	23.18b	-
	PL-2	83.00	6.94	14.90c	-
	UL-3	80.50	6.79	17.41c	-
	PL-3	82.99	6.90	16.80c	-

MM = Minced meat
UL-2 = Two leaching times by usual leaching without sodium pyrophosphate
UL-3 = Three leaching times by usual leaching without sodium pyrophosphate
PL-2 = Two leaching times by 0.2% sodium pyrophosphate leaching
PL-3 = Three leaching times by 0.2% sodium pyrophosphate leaching
a,b,c Means of the same trial followed by identical letters are not significantly different ($P<0.05$)

Table 2. Effect of leaching and additives on folding test, teeth cutting test and sensory evaluation results of surimi made from iced lizardfish and kept under frozen storage (-20°C).

Treatments	Storage days	Folding & teeth cutting tests	Sensory evaluation		
			Texture	Gel	Appearance
UL-control	0	AA 6	Slightly	Springy & firm	Dull
	4	AA 5-6	rough		
	11	AA 5-6			
	18	AA 6			
	32	AA 5			
UL + 0.5%	11	AA 6	Slightly	Springy & firm	Dull, white
egg white	18	AA 6	rough		
	32	AA 5-6			
UL + 1.0%	11	AA 6	Slightly	Hard	Dull, dark
beef plasma	18	AA 6	rough		
	32	AA 5-6			
PL-control	0	AA 6	Smooth	Springy & soft	Glossy, white
	4	AA 5-6			
	11	AA 5-6			
	18	AA 5-6			
	32	AA 5-6			
PL + 0.5%	11	AA 6	Smooth	Springy & soft	Glossy, white
egg white	18	AA 6			
	32	AA 6			
PL + 1.0%	11	AA 6	Smooth	Hard	Dark
beef plasma	18	AA 6			
	32	AA 6			

UL = Usual leaching
PL = Pyrophosphate leaching (0.2% sodium pyrophosphate, leached twice)