Asian Fisheries Science 11(1998):19-29
Asian Fisheries Society, Manila, Philippines
https://doi.org/10.33997/j.afs.1998.11.1.003

Effect of Washing on the Storage Stability of *Selaroides leptolepis* and *Aristichthys nobilis* Surimi

W.M. SIAH, S.Y. YU, A.R. RUSSLY and M.H. DZULKIFLY

Department of Food Technology
Universiti Putra Malaysia
43400 UPM Serdang
Selangor, Malaysia.

Abstract

This study was undertaken to determine the effects of washing and storage on the quality of *Selaroides leptolepis* and *Aristichthys nobilis* surimi kept at -20°C for 24 weeks. Surimi was prepared from unwashed, once-washed and twice-washed minces. Analyses conducted include changes in texture profile, expressible moisture, color, elasticity, moisture content, pH, salt-soluble protein, trimethylamine, total volatile basic nitrogen and thiobarbituric acid. Results showed that twice-washed surimi of both species were generally more stable than once-washed and unwashed surimi. The storage quality in terms of texture, color, elasticity, moisture content, pH and salt soluble protein values for all samples showed significant decreases during storage. There were increases in expressible moisture, trimethylamine, total volatile basic nitrogen and thiobarbituric acid.

Introduction

Surimi is usually made from white-fleshed and low-fat fish species. The versatility of surimi for production of a vast variety of minced fish analogues, coupled with the decline in supplies of Alaskan pollack (*Theragra chalcogramma*), have prompted substantial efforts to study the suitability of other fish species for surimi production. In the United States, menhaden (*Brevoortia*), a small, oily and dark blue to brown herring-like fish showed promising possibilities as a raw material for surimi processing (Bimbo 1988). In the Southern hemisphere, particularly in New Zealand, hoki (*Macruronus novaezelandiae*) and blue whiting (*Micromesistius*) (MacDonald 1990) exhibited the same potential. Similar efforts are being carried out in Europe, United Kingdom, Norway and other countries to explore the possibilities of using locally-available species for surimi processing (Putro 1989). In developing tropical countries, especially in Southeast Asia, species widely used for frozen surimi production include threadfin bream (*Nemipterus* sp.), bigeye snapper (*Priacanthus* sp.), *barracuda* (*Sphypaena* sp.) *and croaker* (*Pennahia* sp.) (Tan *et al.* 1987). Surimi manufacturing will receive greater attention for further development in future in line with the need for product diversification to meet the growing demand for surimi-based analogues.

This study was conducted to assess the suitability of *S. leptolepis* and *A. nobilis* as raw material for surimi production. *S. leptolepis*, a relatively small pelagic fish, accounted for 3% of the total marine fish catch of 1,065,585 mt in Malaysia in 1994 (Anon. 1994a). *A. nobilis*, on the other hand, is a common cultured species. These two species are underutilized due to their small size (*S. leptolepis*) and muddy flavour (*A. nobilis*), respectively. Both species are normally consumed fresh, are easily available in the wet markets and are cheaper than most other species. A small percentage of (*S. leptolepis*) is salted and dried.

Materials and Methods

Materials

Sorbitol was purchased from Cerester Polyols Gmbh, Germany, sucrose was obtained from R&M Marketing, Essex, U.K., sodium tripolyphosphate from Damah Trading (M) Sdn. Bhd and salt from Seng Hin Brothers (M) Sdn. Bhd. Polyethylene bags (0.08 mm thickness) for the packaging of surimi were purchased from Lam Seng Plastics Industries (M) Sdn. Bhd. *S. leptolepis* was purchased fresh from a wet market and *A. nobilis* captured live from a farm. Both market and farm are located nearby the Universiti Putra Malaysia campus and were processed immediately upon arrival at the laboratories.

Sample Preparation

The fishes were deheaded and gutted manually. The dressed fishes were then washed and filleted. The fillets were fed to a deboner (6 inches horizontal type, made in Taiwan). The minced meat was divided into 3 portions. The first portion was blended with 2.5% sucrose, 2.5% sorbitol and 0.2% sodium tripolyphosphate (unwashed). The second portion was washed in 0.2% saline for 15 minutes. The ratio of minced meat to iced saline (10-15°C) was 1:4. The minced meat was washed by stirring for 5 minutes. After settling, the water was decanted and drained through a nylon mesh. Excess water was spun off until a final moisture content of 80-82%, using a locally-fabricated centrifuge at 200 x g centrifuge (Syarikat Perniagaan Timbang dan Sukat Ban Hing, Malaysia). The washed mince was then mixed with sucrose (2.5%), sorbitol (2.5%) and sodium tripolyphosphate (0.2%). The resulting sample was labeled as once-washed sample. The last portion was prepared following the method above except for two washing cycles. This sample was labeled as twice-washed. All the samples were vacuum sealed in 1 kg blocks in polyethylene bags, blast frozen in 30 mins to -25°C (measured at centre of block) and stored at -20°C (±2°C).

Physical Analyses

The physical tests used to measure changes in surimi quality during storage include texture profile analyses, expressible moisture, color and elasticity.

The surimi gels were prepared as decribed in Ng (1987). For the texture profile, cylindrical gels with uniform geometry (25 mm height x 25 mm diameter) were subjected to compression testing at room temperature (25°C) using an Instron Universal Testing machine (Model 1140, West Germany). The test subjected a specimen to 90% deformation. The speed of the crosshead and recording chart was set at 50 mm per min. A full-scale load range of 50 kg was used and two consecutive bites were measured. Four parameters, namely, hardness, springiness, cohesiveness, gumminess and chewiness, were obtained from the resulting curve. Expressible moisture was determined by measuring the amount of moisture on the two layers of filter paper (No. 1) upon compression and expressed in percentage of sample weight (Lee and Chung 1989). Whiteness of gel was determined using a Hunter Lab Colorimeter (Model D25-2, USA) and the folding test for elasticity of Ng (1987b) was used. Moisture content was determined using the AOAC method (1984).

Chemical Analyses

pH and salt soluble proteins were determined according to Lim (1987). Trimethylamine and total volatile basic nitrogen were determined using Conway's method (Ng 1987a). Thiobarbituric acid number was determined according to the method of Tarladgis *et al.* (1964).

Statistical Analysis

The data was analyzed statistically using theAnalysis of Variance Method (ANOVA) at 5% level. The Duncan's Multiple Range Test (DMRT) was used to determine significant differences between treatments. The statistical program used was the Statistical Analysis System of Bar *et al.* (1976).

Results and Discussion

Physical Analyses

The texture profiles for the cooked gels of unwashed, once- and twice-washed surimi are shown in Tables 1 and 2. Hardness, springiness, gumminess and chewiness of gels made from twice-washed minces were generally greater than those made from unwashed minces. Springiness, gumminess and chewiness of *S. leptolepis* gels made from twice-washed and once-washed minces did not show any significant differences ($P<0.05$). For cohesiveness, gels made from *S. leptolepis* and *A. nobilis* were significantly different for all the treatments. Unwashed mince had the highest values followed by the once- and twice-washed minces.

Differences in elasticity were reflected in the folding test, where minces washed for 1 or 2 times resulted in better elasticity compared to unwashed samples. The elasticity for both species showed significant differences during storage, with unwashed samples showing the fastest decrease. At week 0, both types of surimi were graded as AA quality (score of 5.0). However, quality decreased significantly throughout storage.

Table 1. Changes in hardness and springiness of surimi stored at -20°C.

Species	Treatment	Hardness (kg)	Springiness (mm)
S. leptolepis	Number of washing		
	Unwashed	19.94±3.12^{c}	8.12±0.02^{b}
	Once-washed	22.74±2.12^{b}	8.14±0.04^{a}
	Twice-washed	23.46±1.41^{a}	8.14±0.03^{a}
	Time of storage (week)		
	0	24.75±0.04^{a}	8.12±0.03^{c}
	3	24.16±0.77^{ab}	8.15±0.04^{ab}
	6	23.85±0.91^{bc}	8.12±0.03^{c}
	9	23.06±1.43^{dc}	8.13±0.03^{bc}
	12	22.70±1.99^{de}	8.15±0.04^{ab}
	15	21.89±2.35^{e}	8.17±0.03^{a}
	18	20.34±2.57^{f}	8.12±0.03^{c}
	21	19.47±2.14^{g}	8.13±0.03^{bc}
	24	18.19±2.43^{h}	8.13±0.03^{bc}
A. nobilis	Number of washing		
	Unwashed	18.90±3.83^{c}	7.98±0.03^{c}
	Once-washed	20.31±3.47^{b}	7.98±0.03^{b}
	Twice-washed	22.94±2.64^{a}	8.04±0.03^{a}
	Time of storage (week)		
	0	26.70±0.02^{a}	8.02±0.03^{ab}
	3	24.17±0.94^{b}	8.03±0.07^{a}
	6	22.80±1.63^{c}	8.00±0.04^{bc}
	9	21.34±2.20^{d}	8.02±0.03^{ab}
	12	20.22±2.81^{e}	7.98±0.05^{c}
	15	19.13±2.76^{f}	7.98±0.03^{c}
	18	18.22±2.21^{g}	8.00±0.04^{bc}
	21	17.30±1.95^{h}	8.00±0.04^{bc}
	24	16.36±1.52^{i}	7.98±0.05^{c}

$^{a-i}$means within a column with different letters are significantly different (P<0.05).
Mean of triplicates

From Table 3, changes in moisture contents can be observed. There were significant differences in moisture changes among surimi from unwashed, once- and twice-washed treatments. Results show that moisture content for surimi after two washing cycles was higher than for once-washed and unwashed surimi. The moisture content of unwashed *S. leptolepis* surimi was 76.42%. This increased significantly to 79.42% after one washing and slightly increased to 79.50% after the second washing. For *A.nobilis*, the moisture contents of unwashed surimi was 76.09%, 79.32% for once-washed and 79.49% for the twice-washed surimi. Suzuki (1981) reported that washing generally increases hydrophilic properties of the mince. This causes the muscle to swell and makes the removal of water difficult. In the first 6 weeks, the moisture contents were not significantly different. At week 9, there was a significant decrease and therafter leveled off throughout storage. A slight decrease in moisture content can be explained by the fact that fish proteins lose their

Table 2. Changes in gumminess, chewiness and elasticity of surimi during storage at -20°C.

Species	Treatment	Gumminess	Chewiness	Elasticity
S. leptolepis	Number of washing			
	Unwashed	10.07±1.26[b]	81.17±0.20[b]	2.22±1.22[c]
	Once-washed	10.80±0.76[a]	87.97±6.23[a]	4.07±0.86[b]
	Twice-washed	10.84±0.36[a]	88.28±3.03[a]	4.67±0.48[a]
	Time of storage week			
	0	11.05±0.04[ab]	89.72±0.34[bc]	5.00±0.00[a]
	3	11.46±0.31[a]	93.36±2.05[a]	4.40±0.91[b]
	6	11.43±0.11[a]	92.74±0.63[ab]	4.07±1.28[bc]
	9	11.05±0.23[ab]	89.87±1.95[bc]	3.87±1.41[cd]
	12	10.83±0.56[bc]	88.28±4.98[cd]	3.60±1.24[d]
	15	10.53±0.67[c]	6.00±5.58[d]	3.47±1.19[d]
	18	9.93±0.82[d]	80.63±6.70[e]	3.07±1.44[e]
	21	9.67±0.68[d]	78.62±5.52[e]	2.73±1.39[e]
	24	9.18±0.91[e]	74.66±7.63[e]	2.67±1.29[e]
A. nobilis	Number of washing			
	Unwashed	9.22±1.74[c]	73.54±13.98[c]	2.27±1.39[c]
	Once-washed	9.84±1.51[b]	78.55±12.26[b]	3.44±1.22[b]
	Twice-washed	11.04±1.12[a]	88.82±9.03[a]	4.40±0.58[a]
	Time of storage week			
	0	12.64±0.13[a]	101.33±0.92[a]	5.00±0.00[a]
	3	11.52±0.35[b]	92.54±3.60[b]	4.53±0.64[b]
	6	10.95±0.78[c]	87.59±6.59[c]	4.00±0.85[c]
	9	10.31±0.98[d]	82.63±7.63[d]	3.67±1.18[cd]
	12	9.83±1.27[e]	78.53±10.57[e]	3.40±0.99[d]
	15	9.46±1.36[e]	75.57±11.00[e]	2.73±1.22[e]
	18	8.92±1.08[f]	71.41±8.94[f]	2.67±1.29[e]
	21	8.53±0.90[fg]	68.25±7.54[f]	2.47±1.30[e]
	24	8.12±0.67[g]	64.88±5.73[g]	1.87±1.30[f]

[a-g]Means within a column with different letters are signficicantly different ($P<0.05$).
Mean of triplicates

water-holding ability during storage (Table 3). Another factor may be the transmission of moisture vapor through the packaging material (Anon. 1994b).

Expressible moisture for all samples were significantly different (Table 3). The twice-washed surimi had the lowest amount of moisture expressed. The amount of moisture expressed from twice-washed *S. leptolepis* surimi was 7.46%, compared to 9.04% for the once-washed surimi gel and 15.10% for the unwashed sample. For *A. nobilis* surimi gels, expressible moisture for the unwashed sample was 15.20%, 8.84% for the once-washed, and 7.31% for the twice-washed sample. The amount of expressible moisture in both *S. leptolepis* and *A. nobilis* surimi gels increased from 4.22% to 17.02% during storage. All the samples lost their ability to hold water in the gel, with the rate almost linear throughout storage. At week 0, the percentage of water expressed was 4.97% compared to 16.68% at week 24 for *S. leptolepis*. For *A. nobilis*, the percentage increased from 4.22% at week 0 to 17.02% at the the 24th week.

Table 3. Changes in moisture content, expressible moisture and whiteness of surimi during storage at -20°C.

Species	Treatment	Moisture (%)	Expressible moisture (%)	Whiteness(%)
S. leptolepis	Number of washing			
	Unwashed	76.42±0.06^{c}	15.10±6.03^{a}	61.59±7.69^{c}
	Once-washed	79.42±0.02^{b}	9.04±3.20^{b}	67.37±3.36^{b}
	Twice-washed	79.50±0.01^{a}	7.46±2.02^{c}	70.37±2.53^{a}
	Time of storage (week/s)			
	0	78.49±1.49^{a}	4.97±0.02^{h}	71.17±2.03^{a}
	3	78.47±1.49^{a}	6.45±1.30^{gh}	71.00±1.97^{a}
	6	78.47±1.48^{a}	8.01±2.47^{fg}	69.77±2.12^{ab}
	9	78.44±1.53^{b}	9.04±3.50^{ef}	69.12±2.22^{ab}
	12	78.43±1.54^{b}	10.08±3.94^{de}	68.11±2.61^{bc}
	15	78.44±1.55^{b}	11.80±4.48^{cd}	66.22±3.60^{c}
	18	78.43±1.54^{b}	13.05±4.83^{bc}	63.77±5.15^{d}
	21	78.42±1.55^{b}	14.73±5.07^{b}	61.05±6.50^{e}
	24	78.41±1.54^{b}	16.68±5.92^{a}	57.78±8.98^{f}
A. nobilis	Number of washing			
	Unwashed	76.09±0.02^{c}	15.20±6.25^{a}	68.30±1.65^{c}
	Once-washed	79.32±0.02^{b}	8.84±3.55^{b}	74.91±1.87^{b}
	Twice-washed	79.49±0.03^{a}	7.31±2.41^{c}	76.95±1.91^{a}
	Time of storage (week/s)			
	0	78.34±1.67^{a}	4.22±0.05^{h}	76.11±3.39^{a}
	3	78.32±1.66^{b}	5.80±1.49^{g}	75.30±3.96^{b}
	6	78.3±11.66^{c}	7.40±2.75^{fg}	74.56±4.09^{c}
	9	78.30±1.65^{d}	8.86±3.34^{ef}	74.28±4.08^{d}
	12	78.30±1.66^{de}	10.24±3.89^{de}	73.66±4.41^{e}
	15	78.29±1.65^{e}	11.96±4.58^{cd}	72.68±3.95^{f}
	18	78.29±1.66^{e}	13.41±5.11^{bc}	72.02±3.75^{g}
	21	78.28±1.66^{f}	15.15±5.45^{b}	71.12±3.64^{h}
	24	78.28±1.66^{f}	17.02±6.03^{a}	70.72±3.61^{i}

$^{a\text{-}i}$Means within a column with different letters are signficicantly different ($P<0.05$).

Mean of triplicates

Table 3 gives a comparison of the changes in whiteness of the surimi gels. Results show that there were significant differences among all treatments for both species. Generally, *A. nobilis* surimi gels have inherently whiter color compared to *S. leptolepis*. Before washing, *A. nobilis* mince had a score of 68.30 and *S. leptolepis* 61.59. After one washing, the surimi became whiter with a score of 74.91 for *A. nobilis* and 67.37 for *S. leptolepis*. After two washings, *A. nobilis* surimi had a score of 76.95 and *A. nobilis* 70.37. Washing improves the color of surimi due to removal of blood pigments, fats; and water-soluble proteins (Lee 1984). However, in consideration of the cost of production, it is recommended that two washing cycles are sufficient (Lee 1986). There were significant decreases in whiteness throughout storage. At week 0, the surimi gels had a score of 71.17 for *S. leptolepis* and 76.11 for *A.nobilis*, but at week 24, values decreased to 57.78 for *S. leptolepis* and 70.72 for *A.nobilis*. It is widely accepted that carbonyl compounds from oxidized lipids are involved in color changes (Matsuto *et al.* 1967).

Chemical Analyses

From the results in Table 4, pH values of unwashed, once-washed and twice-washed surimi of *S. leptolepis* and *A. nobilis* were significantly different at 5% level of probability. The pH for unwashed surimi of *S. leptolepis* was 6.79, after one washing cycle, pH increased to 6.83, and further increased to 6.91 after two washing cycles. For *A. nobilis* surimi, pH values increased from 6.87 to 6.88, and the final pH for twice-washed mince was 6.92. pH values for mechanically deboned by-catch surimi as studied by Jantawat and Yamprayoon (1990) was 6.69 before washing and 6.73 after one washing.

Generally, the decreases in pH values of *S. leptolepis* and *A. nobilis* were fairly gradual throughout storage. Both types of surimi had pH ranges of 6.80 to 6.93 where the highest pH reading was at week 0. A similar trend was observed by MacDonald *et al.* (1992) in headed and eviscerated hoki upon storage at -29 C. The decrease in pH is most likely to be due to formation of free fatty acids resulting from enzymic hydrolysis of neutral fats and phospholipids (Olley *et al.* 1962).

Lipid oxidation during storage is shown in Table 4. There were significant differences among all the samples. Unwashed samples had the highest TBA values, followed by the once-washed sample, and the twice-washed sample. TBA values for *S. leptolepis* surimi were 6.80, 3.68 and 2.41 mg malonaldehyde/kg sample for unwashed, once-washed and twice-washed samples respectively. For *A. nobilis* surimi, the TBA values were 7.11, 3.78 and 2.14 mg malonaldehyde/kg sample. Washing resulted in a decreased fat level and also resulted in a decrease of the haemoproteins that have a prooxidant effect (Jantawat and Yamprayoon 1990). There were significant increases in TBA values especially in the first 6 weeks where the initial value was 1.67 and increased to 3.87 mg malonaldehyde/ kg sample at week 6 (*S. leptolepis*). From week 9 onwards, TBA values increased but did not show any significant differences. For *A. nobilis* surimi, increases in TBA values were significantly different throughout storage.

From the results in Table 5, TVBN levels for both species showed significant diffences ($P<0.05$). Unwashed samples showed the highest levels of TVBN, followed by the once-washed samples and the twice-washed surimis. These results agree with that of mechanical deboned by-catch where unwashed samples showed significant higher TVBN levels compared to washed samples (Jantawat and Yamprayoon 1990). TVBN levels increased significantly ($P<0.05$) during storage. At week 0, TVBN levels for *S. leptolepis* and *A. nobilis* surimi were 6.92 and 3.87 mg%, respectively. These values increased significantly to 17.20 and 12.23 mg% at week 24. From Figure 2, the levels of TVBN in unwashed *S. leptolepis* surimi at weeks 21 and 24 exceeded the maximum acceptable levels (20 mg%) suggested by Connell (1980).

Table 4. Changes in pH and thiobarbituric acid (TBA) of surimi during storage at -20°C.

Species	Treatment	pH	TBA (mg/kg sample)
S. leptolepis	Number of washing		
	Unwashed	6.79±0.05[c]	6.80±2.54[a]
	Once-washed	6.83±0.04[b]	3.68±0.80[b]
	Twice-washed	6.91±0.04[a]	2.41±0.48[c]
	Time of storage (week/s)		
	0	6.91±0.05[a]	1.67±0.14[d]
	3	6.90±0.05[a]	2.76±0.65[c]
	6	6.88±0.05[b]	3.87±1.59[b]
	9	6.86±0.05[c]	4.54±2.32[ab]
	12	6.83±0.05[d]	4.77±2.46[ab]
	15	6.82±0.05[de]	4.98±2.54[a]
	18	6.81±0.07[ef]	5.23±2.63[a]
	21	6.80±0.05[f]	5.34±2.70[a]
	24	6.80±0.07[f]	5.50±2.81[a]
A. nobilis	Number of washing		
	Unwashed	6.87±0.03[c]	7.11±3.37[a]
	Once-washed	6.88±0.02[b]	3.78±1.48[b]
	Twice-washed	6.92±0.03[a]	2.14±0.66[c]
	Time of storage (week)		
	0	6.93±0.03[a]	1.31±0.10[f]
	3	6.92±0.03[b]	2.05±0.10[ef]
	6	6.91±0.03[c]	2.94±1.11[de]
	9	6.91±0.03[bc]	3.87±1.96[cd]
	12	6.89±0.03[d]	4.99±3.08[bc]
	15	6.88±0.03[e]	5.32±3.04[b]
	18	6.87±0.02[f]	5.85±3.13[ab]
	21	6.87±0.03[f]	6.17±3.22[ab]
	24	6.85±0.02[g]	6.62±3.44[a]

Note: Means within a column with different letters are significantly different ($P<0.05$).
Mean of triplicates

According to Connell (1980), the TMA contents of good-quality cod is around 10 mg%. Results in Table 5 indicate that the TMA contents of unwashed *S. leptolepis* samples were at an unacceptable level (10.37 mg%). However, the TMA values of fresh fish cannot apply to minced products such as surimi as well as processed fish because of the change in concentration of TMA during processing. Minced fish normally contain larger amounts of TMA than do fillets because the process of mincing causes an immediate increase in TMA values (Babbitt *et al.* 1972). Castell *et al.* (1970) explained that blood pigments from fish frames catalyzed the formation of TMA. The relationship between quality and TMA also differs from one species to another (Castell *et al.* 1970). Washing of the minced meats resulted in reduction of TMA as shown in Table 5, in which the once- and twice-washed sample had TMA values of 6.93 mg% and 3.24 mg%, respectively. Licciardello *et al.* (1979) also reported that unwashed minces usually contain large amounts of blood pigments, causing higher levels of TMA. As storage time increases, TMA levels in the samples

Table 5. Changes in total volatile basic nitrogen (TVBN), trimethylamine (TMA) and salt soluble protein (SSP) of surimi during storage at -20°C.

Species	Treatment	TVBN(mg%)	TMA(mg %)	SSP(mg %)
S. leptolepis	Number of washing			
	Unwashed	16.72±4.86^{a}	10.37±2.93^{a}	14.81±5.05^{c}
	Once-washed	12.37±3.03^{b}	6.93±2.05^{b}	17.49±4.31^{b}
	Twice-washed	8.67±1.01^{c}	3.24±0.65^{c}	21.76±2.99^{a}
	Time of storage (week/s)			
	0	6.92±0.10^{f}	2.71±0.01^{e}	24.55±1.65^{a}
	3	10.56±2.17^{e}	5.94±2.92^{d}	22.98±1.86^{b}
	6	11.17±2.85^{e}	6.45±3.46^{cd}	21.15±2.22^{c}
	9	11.72±3.25^{e}	6.65±3.53^{cd}	18.92±2.57^{d}
	12	11.87±3.41^{de}	6.78±3.53^{cd}	17.92±3.42^{e}
	15	13.46±4.06^{dc}	7.54±3.60^{bc}	16.14±3.58^{f}
	18	14.71±4.68^{bc}	8.07±3.55^{ab}	14.84±4.02^{g}
	21	15.66±4.96^{ab}	8.46±3.60^{ab}	13.43±4.03^{h}
	24	17.20±6.04^{a}	9.04±3.72^{a}	12.21±4.00^{i}
A.nobilis	Number of washing			
	Unwashed	10.53±4.42^{a}	N.D.	14.71±5.10^{c}
	Once-washed	8.57±3.39^{b}	N.D.	17.46±4.77^{b}
	Twice-washed	5.20±1.23^{c}	N.D.	21.81±3.34^{a}
	Time of storage (week/s)			
	0	3.87±0.01^{e}	N.D.	25.28±2.10^{a}
	3	4.38±0.29^{e}	N.D.	23.40±2.12^{b}
	6	5.82±1.27^{d}	N.D.	20.88±2.17^{c}
	9	6.90±2.06^{dc}	N.D.	18.79±2.65^{d}
	12	7.77±2.51^{c}	N.D.	17.71±3.51^{e}
	15	9.47±3.55^{b}	N.D.	16.23±3.57^{f}
	18	10.82±3.79^{ab}	N.D.	14.78±3.69^{g}
	21	11.64±3.76^{a}	N.D.	13.02±3.98^{h}
	24	12.23±3.82^{a}	N.D.	11.85±4.26^{i}

$^{a-j}$Means within a column with different letters are significantly different (P<0.05).
Mean of triplicates, N.D. = not detectable.

increased significantly (P<0.05). At week 0, TMA values was 2.71 mg%. At the third week, TMA values increased significantly to 5.94 mg%. However, at weeks 6, 9 and 12, there were no significant differences although values increased. At weeks 15, 18 and 24, increases in TMA values were significantly different. At week 24, the TMA values were as high as 9.04 mg%. The increase indicates that various bacterial enzymic activities still took place (Jantawat and Yamprayoon 1990). For *A. nobilis*, TMA values were not detected as TMA is usually absent in freshwater species (Clucas and Ward 1996).

Sorenson (1976) pointed out that products with good gel forming properties should be produced from minced fish with at least 8.5 - 11 mg% of SSP. From the results in Table 5, the SSP for the different treatments of *S. leptolepis* surimi were significantly different (P<0.05), with the unwashed, once-washed and twice-washed samples having SSP values of 14.81, 17.49 and 21.76 mg% respectively. For the *A. nobilis* samples, the SSP values were 14.71(unwashed), 17.46 (once-washed) and 21.81 (twice-washed) mg%. All the values were greater than the minimum level recommended by Sorenson (1976). Jantawat and Yamprayoon (1990) showed that there were significant increases in SSP concentration in washed samples of mechanically-deboned fish. Babbitt (1986) cited that washing removed fat and other water-soluble substances also increased the concentration of gel-forming proteins essential for producing surimi-based products. SSP values decreased significantly with storage due to the occurrence of protein denaturation during storage. At week 0, the SSP for *S. leptolepis* was 24.55 mg%, while at week 24 , the SSP value was 12.21 mg%, a decrease of 50.3%. SSP values for *A. nobilis* also showed significant differences throughout storage. At week 0, the value was 25.28 mg%, but by week 24, the value decreased to 11.85 mg%, for a 53.1% decrease. Although the SSP values decreased, at week 24, SSP values for washed samples of *S. leptolepis* and *A. nobilis* were still higher than the minimum level recommended by Sorenson (1976). Unwashed samples of *S. leptolepis* and *A. nobilis* showed lower-than-acceptable values.

Conclusion

Results indicated that surimi produced from *S. leptolepis* and *A. nobilis* mince after two washings had better storage stability compared to unwashed and once-washed minces. Therefore, twice-washed mince is more suitable as raw material for surimi production from both species.

References

Anon. 1994a. Perangkaan tahunan perikanan. pp. 70, 96-97. Kementerian Pertanian Malaysia, Kuala Lumpur.

Anon. 1994b. Production of battered and breaded fish products from minced fish and surimi. pp. 56-63. RC-IPD, Kuala Lumpur.

A.O.A.C. 1984. Official methods of analysis of the association of official analytical chemists, 14th Ed. (S. Williams, ed.). Association of Official Analytical Chemists Inc., Virginia.

Babbitt, J.K., D.L. Crawford and D.K. Law. 1972. Decomposition of trimethylamine oxide and changes in protein extractability during frozen storage of minced and intact hake muscle. Journal of Agricultural and Food Chemistry 20:1052-1054.

Babbitt, J.K. 1986. Suitability of seafood as raw materials. Food Technology 40(3): 97-100.

Barae, A.E., B.L. Goodnight, J.P. Sall and J.T. Helwig. 1976. A user guide to the Statistical Analyses System. SAS Institute Inc. Raleigh, N.C.

Bimbo, A.P. 1988. The development of menhaden surimi in the USA. Infofish International. 5/88:22-25.

Castell, C.H., W. Neal and B. Smith. 1970. Formation of trimethylamine in stored frozen seafood. Journal of the Fisheries Research Board of Canada 27(10):1685-1690.

Clucas, I.J. & A.R. Ward. 1996. Postharvest fisheries development: A guide to handling, preservation, processing and quality. p. 391. Chatham Maritime, Kent, United Kingdom.

Connell, J.J. 1980. Control of fish quality. pp. 127. Fish News Book Ltd., Farnham Surrey, England.

Jantawat, P. and J. Yamprayoon. 1990. Effect of washing, chemical additives and storage temperature on quality of mechanically deboned by-catch. Asean Food Journal 5:108-113.

Lee, C.M. 1984. Surimi process technology. Food Technology. 11:69-80.

Lee, C.M. 1986. A pilot plant study of surimi making properties of red hake (Urophycis chuss). In: Proceedings of the International Symposium on Engineered Seafoods Including Surimi. (eds. R.E. Martin and R.L. Collette). pp. 225-243. National Fisheries Institute, Washington, D.C.

Lee, C.M and K.H. Chung. 1989. Analysis of surimi gel properties by compression and penetration tests. Journal of Texture Studies. 20:363-377.

Licciardello, J.J., E.M. Ravest and M.G. Allsup. 1979. Quality aspects of commercial frozen minced fish blocks. Journal of Food Protection 42(1):23-26.

Lim, P.Y. 1987. Measurement of pH. In: Laboratory manual on analytical methods and procedures for fish and fish products (ed. H. Hasegawa). pp. A3.1-3.2. Marine Fisheries Research Department, Southeast Asian Fisheries Development Center, Singapore.

Macdonald. G.A., J. Lelievre and N.D.C. Wilson. 1990. Strength of gels prepared from washed and unwashed minces of hoki (*Macruronus novaezealandiae*) stored in ice. Journal of Food Science 4:976-978.

Macdonald, G.A., J. Lelievre and N.D.C. Wilson. 1992. Effect of frozen storage on the gel-forming properties of hoki (*Macruronus novaezelandiae*). Journal of Food Science 57: 68-71.

Matsuto. S., F. Nagayama and T. Ono. 1967. Volatile monocarbonyls in frozen halibut. Bull. Jap. Soc. Sci. Fish., 33:586-590.

Ng, C.S. 1987a. Determination of trimethylamine oxide (TMAO-N), trimethylamine (TMA-N), total volatile basic nitrogen (TVB-N) by Conway's Method. In: (ed. H. Hasegawa) Laboratory manual on analytical methods and procedures for fish and fish products. pp. B3.1-3.8. Marine Fisheries Research Department, Southeast Asian Fisheries Development Center, Singapore.

Ng, M.C. 1987b. Quality assessment of fish jelly products and raw materials used for production of fish jelly products. In: (ed. H. Hasegawa) Laboratory manual on analytical methods and procedures for fish and fish products. pp. A7.1-7.4. Marine Fisheries Research Department, Southeast Asian Fisheries Development Center, Singapore.

Olley, J., R. Pirie and H. Watson. 1962. Lipase and phospholipids activity in fish skeletal muscle and its relationship to protein denaturation. J Sci. Fd. Agric. 13: 501.

Putro, S. 1989. Surimi-prospects in developing countries. Infofish International. 5:29-32.

Suzuki. T. 1981. Fish and krill protein: Processing technology. Applied Science Publishers Ltd., London.

Sorenson, T. 1976. Effect of frozen storage on functional properties of seperated fish mince. In: (ed. J.N. Keay) Proceedings of the Conference on the Production and Utilization of Mechanically Recovered Fish Flesh (minced fish). pp.56-65. Torry Research Station, Aberdeen.

Tan, S.M., M.C. Ng, T. Fujiwara, K.K. Hooi and H. Hasegawa. 1987. Handbook on the processing of frozen surimi and fish jelly products in Southeast Asia. pp. 6. Marine Fisheries Research Department, Southeast Asian Fisheries Development Center, Singapore.

Tarladgis, B.G., A.M. Pearson and L.R. Dugan. 1964. Chemistry of the 2-thiobarbituric acid tests for determination of oxidative rancidity in food. II. Formation of the TBA-malonaldehyde complex without acid heat treatment. J. Sci. Food Agric. 15(9):602-607.

Manuscript received 11 July 1997; Accepted 12 February 1998.