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Nutrient composition of mechanically separated and surimi-like seal meat

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The nutritional value of mechanically separated seal meat (MSSM) and MSSM washed with water or a sodium bicarbonate solution was compared with that of beef, pork, mechanically separated chicken meat (MSCM) and cod. The unwashed MSSM had a higher crude protein content (23·2%) and calculated PER (protein efficiency ratio) value (2·99) than other muscle foods. However, its essential amino acid index (EAA) value was similar to other meats. The caloric values of MSSM, MSCM, beef, pork and cod were 528, 612, 481, 479 and 344 kJ/100 g meat, respectively. Unwashed MSSM had a much larger content of B vitamins than meat from other animals. Calcium (591 mg%) and phosphorus (504 mg%) were the main minerals in MSSM, perhaps due to the presence of small bone particles in the samples. MSSM was a rich source of nutritionally available iron (18·5 mg%). Washings with water or a sodium bicarbonate solution increased the moisture and reduced the crude protein content of the resultant wet tissues. However, the protein content calculated on a dry weight basis was increased from 79·6% in unwashed MSSM to 82·2 and 80·1% after aqueous and bicarbonate washings, respectively. Meanwhile, the collagen content of MSSM was increased due to the above washings from 0·92% to 1·65 and 1·09% and the EAA values of products decreased from 116 to 104 and 113, respectively. The removal of lipids during washings with water or a sodium bicarbonate solution reduced the caloric value of the meat to 282 and 247 kJ/100 g sample.

INTRODUCTION

The population of Harp seal (*Phoca groenlandica*) in Newfoundland-Labrador waters has increased from 1·25 million in 1960 (Mansfield, 1967) to about 3·5–5·0 million at the present time. Uncontrolled increase of the seal population has resulted in a decrease of over 5 million metric tons of fish, such as cod, herring, capelin and salmonids. In 1971, a quota system for seal hunting was introduced. Although the first quota in 1971 was 245 000, this has been changed several times and it has been set at 186 000 in recent years. However, only 50 000–70 000 animals have annually been hunted during the last few years. This provides approximately 1·2–2·1 million kilograms of meat in Newfoundland each year (Synowiecki & Shahidi, 1991). Generally manual separation of meat from flippers, rumps and flanks is practical. Recovery of the residual tissues on bones and connective tissues is difficult. Therefore, mechanical separation of seal meat is preferred. Mechanical separation of meat from carcasses increased the recovery yield of seal meat from about 22% for manual separation to over 80% (Shahidi *et al.*, 1990). Synowiecki & Shahidi (1991) have shown that the dark colour of mechanically separated seal meat (MSSM) may be improved by partial extraction of haemoproteins with water or a sodium bicarbonate solution. However, very little is known about the quality, nutritional value and technological properties of seal meat.

The objectives of the present study were to examine the nutritional value of minced seal meat and washed products obtained by aqueous or sodium bicarbonate washings.

MATERIALS AND METHODS

Harp seals (*Phoca groenlandica*) from 1 to 4 years of age hunted in the coastal areas of Newfoundland during the month of April, were bled, skinned, blubber fat removed and eviscerated. The carcasses after the removal of blubber, weighing up to 30 kg without head and flippers as compared with 80 kg for the original animal, were placed inside plastic bags and stored on ice for up to 3 days. Each carcass was then washed with a stream of cold water (+10°C) for about 15 s to remove most of the surface blood. Mechanical separation of meat from the carcasses of 15 seals was carried out using a Poss deboner (Model PDE500, Poss Limited, Toronto, Ontario). Small portions of mechanically separated seal meat (MSSM) were vacuum-packed in

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polyethylene pouches and kept frozen at −20°C before use. Samples of MSSM were washed one to three times with water (pH = 5·9–6·0) using a water to meat ratio of 3 : 1 (v/w). Other samples were washed with water and then with 0·5% sodium bicarbonate solution at a solvent to meat ratio of 3 : 1 (v/w). Each washing was done at a temperature of 2°C for 10 min while stirring manually. The washed meat was then filtered through two layers of cheesecloth with 1 mm size holes.

Analyses

Crude protein was calculated from the total nitrogen (N) content determined according to the AOAC (1990) method (i.e. N × 6·25). Total lipids were extracted by a chloroform–methanol–water mixture as described by Bligh & Dyer (1959).

Total lipids extracted according to Bligh & Dyer (1959) from unwashed and washed seal meat were subjected to transmethylation in acidified methanol for analysis of fatty acids. Methyl heptadecanoate was used as an internal standard. Recovered fatty acid methyl esters from approximately 100 μg lipids were then separated on a 30 m × 0·25 mm i.d., fused silica SP-2330 capillary column (Supelco Inc., Bellefonta, PA) using a Perkin Elmer 8500 gas chromatograph. The oven temperature was initially 180°C for 12 min and was then increased to 200°C at 20°C/min and held there for 8 min. The injection port and flame ionization detector temperatures were 230°C. The caloric value of the samples was calculated by the Atwater conversion method (Bogert *et al.*, 1973) using their protein and lipid contents.

The individual amino acids in freeze-dried samples were determined after their digestion in 6 N HCl at 110°C according to the method of Blackburn (1978). The HCl was then removed under vacuum, and dried samples were reconstituted using a lithium citrate buffer at pH 2·2. The amino acid composition of the hydrolysate was determined using a Beckman 121 MB amino acid analyser (Beckman Instruments Inc., Palo Alto, CA). Cysteine and methionine were determined by performic acid oxidation prior to their digestion in 6N HCl and were measured as cysteic acid and methionine sulphone, respectively (Blackburn, 1978). Analysis of tryptophan was carried out by hydrolysis of the sample under vacuum in 3 M mercaptoethanesulphonic acid at 110°C, as described by Penke *et al.* (1974).

The collagen content in the samples was calculated from their hydroxyproline content as given by Goll *et al.* (1963). The essential amino acid index (EAA) value was calculated according to the equation:

$$EAA = 100 \sqrt[n]{\frac{X_1}{X_{s1}} \cdot \frac{X_2}{X_{s2}} \cdot \ldots \cdot \frac{X_n}{X_{sn}}}$$

where X_n and X_{sn} are the contents of leucine, isoleucine, lysine, threonine, (phenylalanine + tyrosine), tryptophan, (methionine + cysteine) and valine in each sample and protein (FAO/WHO) standard (Sikorski *et al.*, 1988).

The amount of haeme iron was determined after three extractions of meat samples with acidified 80% acetone according to the method of Hornsey (1956). After 1 h, the absorbance of the extract was read at 640 nm using a Hewlett Packard 8452A diode array spectrophotometer. Haeme iron, expressed as micrograms per gram of sample, was calculated by multiplying the absorbance of the acetone extract at 640 nm by a factor 60·18 and taking into consideration the size of the sample.

The amounts of individual minerals and vitamins in the samples were determined according to AOAC (1990) procedures except for riboflavin and thiamine which were analysed by an improved HPLC assay method described by Reyes & Subryan (1989). Determinations were carried out by an outside firm (Diversified Research Laboratories, Toronto, ON).

Statistical analysis

Analysis of variance and Tukey's studentized range test (Snedecor & Cochran, 1980) were used to determine differences in mean values based on the data presented in the tables. Significance was determined at 95% probability.

RESULTS AND DISCUSSION

The nutrient composition and caloric values of MSSM as well as meats from other species are given in Table 1. The amount of crude proteins in unwashed MSSM was 23·2% which is more than that in beef (22·0%), pork (22·0%), MSCM (14·6%) and cod (17·8%). Washing of MSSM twice with water or once with water and then with 0·5% sodium bicarbonate solution increased the water content of the product, and consequently decreased the amount of proteins (Table 2). However, the protein content, calculated on a dry weight basis, increased from 79·6 ± 0·44% in unwashed MSSM to 82·2 ± 1·20% after aqueous washings or to 80·1 ± 0·52% after washing with a sodium bicarbonate solution. The increase in the protein content despite the removal of the sarcoplasmic proteins during the washing process is caused by extraction of lipids and water-soluble minerals from the meat (Synowiecki & Shahidi, 1991). Proteins in MSSM contained 3·96% collagen which, upon washing with water or a bicarbonate solution, was increased to 12·5% and 8·95%, respectively. Bicarbonate solution removed only the less cross-linked part of the collagen and thus the increase in the collagen content of the resultant meat was less pronounced. The amount of essential amino acids in unwashed MSSM proteins was 43·5%, similar to that in beef (41·8%) and pork (42·5%). Two washings with water or with water and a sodium bicarbonate solution decreased the total amount of the essential amino acids in MSSM to 37·5 and 40·8%, respectively. Seal proteins in comparison with beef and pork (Schweigert, 1987) contained 2·1 and 1·8% more histidine and 0·7 and 1·3% more lysine,

Table 1. Nutritional quality of MSSM as compared with meat from other sources[a]

Constituents in 100 g meat	Dimension	MSSM	Beef[b]	Pork[b]	MSCM[c]	Cod[d]
Total protein	g	23·2 ± 0·13	22·0	22·0	14·6	17·8
Collagen	g	0·92 ± 0·11	0·51[e]	0·671[e]	1·15	0·48
EAA value	—	116 ± 1·61	117	119	117	119
PER value	—	2·99 ± 0·09	2·85	2·52	2·84	2·90
Caloric value	kJ	528 ± 31	481	479	612	344
Lipids	g	3·69 ± 0·02	1·90	1·86	9·81	0·67
Fatty acids:[f] saturated	Area (%)	17·6 ± 0·61	46·7	37·0	31·0	26·0
monounsaturated	Area (%)	56·5 ± 0·48	47·1	52·6	52·1	20·9
polyunsaturated	Area (%)	24·6 ± 0·23	6·21	10·4	16·9	53·1
total ω-3	Area (%)	17·4 ± 0·10	1·10	1·63	2·92	51·3
total ω-6	Area (%)	7·20 ± 0·07	4·50	8·81	14·0	2·8
Calcium	mg	591 ± 9·21	3·50	3·20	78·4	24·0
Phosphorus	mg	504 ± 5·03	194	204	195	184
Potassium	mg	288 ± 9·15	370	418	229	356
Sodium	mg	159 ± 4·30	57·0	56·0	86·8	72·0
Iron	mg	64·6 ± 2·21	1·90	1·01	1·80	0·44
Magnesium	mg	34·2 ± 1·16	21·0	27·1	17·7	25·0
Zinc	mg	2·80 ± 0·53	4·20	1·90	2·20	0·50
Copper	mg	0·10 ± 0·03	0·06	0·05	0·10	0·23
Manganese	mg	<0·10	0·02	0·08	<0·10	0·02
Riboflavin (B2)	mg	0·35 ± 0·02	0·26	0·23	0·23	0·05
Thiamine (B1)	mg	0·11 ± 0·01	0·23	0·90	0·09	0·06
Niacin (B3)	mg	6·10 ± 0·04	7·50	5·00	4·50	2·30
Pantothenic acid	mg	0·89 ± 0·05	0·60	0·70	1·60	0·12
Vitamin B6	mg	0·23 ± 0·02	0·40	0·50	0·26	0·20
Vitamin B12	μg	7·70 ± 0·13	5·00	5·00	0·81	0·53
Folic acid	μg	3·30 ± 0·11	15·3	6·00	11·5	12·0

[a] Results are mean values of three determinations ± standard deviation.
[b] Scherz & Senser (1989).
[c] Shahidi & Onodenalore (unpublished data).
[d] Shahidi *et al.* (1991).
[e] Lawrie (1979).
[f] Shahidi & Synowiecki (1991).

Table 2. Effect of washing on nutritional quality of seal meat[a]

Constituents in 100 g meat	Dimension	Unwashed MSSM	MSSM washed	
			2 × H_2O	1 × H_2O then 1 × $NaHCO_3$
Total protein	g	23·2 ± 0·13	13·2 ± 0·36	12·2 ± 0·14
Collagen	g	0·92 ± 0·11	1·65 ± 0·15	1·09 ± 0·09
EAA value	—	116 ± 1·61	104 ± 0·53	113 ± 1·09
PER value	—	2·99 ± 0·09	2·67 ± 0·07	2·81 ± 0·05
Caloric value	g	3·69 ± 0·02	1·61 ± 0·07	1·15 ± 0·10
Lipids	kJ	528 ± 31	282 ± 25	247 ± 17
Fatty acids: saturated	Area (%)	17·6 ± 0·61	20·9 ± 0·38	21·8 ± 0·25
monounsaturated	Area (%)	56·6 ± 0·48	58·7 ± 0·47	59·1 ± 0·52
polyunsaturated	Area (%)	24·6 ± 0·23	20·4 ± 0·19	19·0 ± 0·26
total ω-3	Area (%)	17·4 ± 0·10	15·6 ± 0·12	14·2 ± 0·09
total ω-6	Area (%)	7·20 ± 0·07	4·89 ± 0·09	4·97 ± 0·05
Calcium	mg	591 ± 9·21	1 330 ± 13·20	991 ± 8·36
Phosphorus	mg	504 ± 5·03	560 ± 4·22	565 ± 7·13
Potassium	mg	288 ± 9·15	24·5 ± 1·14	22·2 ± 2·10
Sodium	mg	159 ± 4·30	36·4 ± 0·51	174 ± 1·26
Iron	mg	64·6 ± 2·21	28·9 ± 1·16	11·9 ± 2·05
Magnesium	mg	34·2 ± 1·16	33·3 ± 1·17	21·9 ± 0·92
Zinc	mg	2·80 ± 0·53	3·00 ± 0·44	2·05 ± 0·13
Copper	mg	0·10 ± 0·03	0·20 ± 0·05	0·10 ± 0·02
Manganese	mg	<0·10	0·10 ± 0·02	<0·10
Riboflavin (B2)	mg	0·35 ± 0·02	0·23 ± 0·01	0·10 ± 0·01
Thiamine (B1)	mg	0·11 ± 0·01	0·02 ± 0·01	0·02 ± 0·00
Niacin (B3)	mg	6·10 ± 0·04	0·40 ± 0·03	0·40 ± 0·02
Pantothenic acid	mg	0·89 ± 0·05	0·27 ± 0·02	0·19 ± 0·06
Vitamin B6	mg	0·23 ± 0·02	0·06 ± 0·01	0·02 ± 0·00
Vitamin B12	μg	7·70 ± 0·13	4·50 ± 0·09	2·40 ± 0·07
Folic acid	μg	3·30 ± 0·11	2·50 ± 0·07	1·70 ± 0·05

[a] Results are mean values of three determinations ± standard deviation.

respectively. Differences in the amounts of other amino acids did not exceed 0·9%. The essential amino acid index (EAA) value for MSSM was 116, almost the same as that for beef (117) and MSCM (117) and slightly lower than that for pork (119) and cod (119). These results indicate that seal meat could be used as a rich source of essential amino acids in food products. During washings, proteins, mostly sarcoplasmic, are extracted from MSSM. This could in turn increase the concentration of myofibrillar and connective tissue proteins in washed meat and influence the amino acid composition of their protein fraction (Table 3).

Washed MSSM contained more alanine, glycine, proline, hydroxyproline and hydroxylysine which are characteristic of collagenous proteins and less tryptophan and histidine which are generally scarce in collagen. The enhanced collagen content in washed MSSM corresponds with the amino acid pattern observed for these samples (Table 2) and also decreased the EAA value of seal proteins due to washings with water or a sodium bicarbonate solution from an initial value of 116 to 104 and 113, respectively. Thus, a smaller drop in EAA values due to sodium bicarbonate washing makes this processing method more attractive for commercial exploitation. The nutritional quality of seal meat proteins was also expressed as protein efficiency ratio (PER) values calculated from equations developed by Lee *et al.* (1978) as follows:

$$\text{PER value} = 0{\cdot}0632 \sum_{i=1}^{k} Xi - 0{\cdot}1539$$

where $\sum Xi$ = isoleucine + leucine + lysine + methionine + phenylalanine + threonine + valine + arginine + histidine + tryptophan.

The calculated PER values were used as relative indicators of the nutritional quality of MSSM in comparison with the washed sample (Table 2) as well as meat from other species (Table 1). The PER value for unwashed MSSM was 2·99 as compared with that for beef (2·85), pork (2·52), MSCM (2·84) and cod (2·90). After washing with water or a sodium bicarbonate solution a minor decrease in the respective PER values, from 2·99 to 2·67 and 2·81, was observed. The decrease in the PER values corresponds well with the increase in the collagen content of the products. However, PER values for both unwashed and washed MSSM proteins were higher than the 2·50 set as the American Standard Requirements for mechanically deboned meats (Federal Register, 1976). Washing with a sodium bicarbonate solution allowed the production of a better quality product with a higher PER value than that produced from washings with water (Table 2).

The caloric value of unwashed MSSM was 528 kJ/100 g meat, more than that for beef (481 kJ/100 g), pork (479 kJ/100 g), cod (344 kJ/100 g) and less than that for MSCM (612 kJ/100 g). The presence of excessive amounts of fat in MSCM was responsible for its higher caloric value. Washing with water or a sodium bicarbonate solution decreased the caloric value of MSSM to 282 and 247 kJ/100 g, respectively (Table 2). Removal of lipids and enhanced water content in the products was responsible for this observation (see below). The initial total lipid content of MSSM, on a dry basis, was 12·65 ± 0·07%. Washing with water or a sodium bicarbonate solution decreased this to 7·85 ± 0·42% and 7·56 ± 0·22%, respectively.

Seal lipids were somewhat similar to those of fish but were different from those of the land-based animals. The total amount of unsaturated fatty acids in manually separated seal meat lipids was 74·3% (Shahidi & Synowiecki, 1991) which is similar to that of cod lipids (74·0%) and is more than that in pork (63·0%) and beef

Table 3. Amino acid composition of raw and washed MSSM, as % of total proteins[a]

Amino acid	Unwashed MSSM	Washed 2 × H_2O	Washed 1 × H_2O then 1 × 0·5% $NaHCO_3$ sol.
Alanine	5·88 ± 0·03[a]	6·05 ± 0·01[b]	5·58 ± 0·03[c]
Arginine	6·21 ± 0·05[a]	7·06 ± 0·04[b]	6·20 ± 0·04[a]
Aspartic acid	8·23 ± 0·15[a]	8·55 ± 0·12[a]	8·80 ± 0·01[b]
Cysteine	0·87 ± 0·01[a]	0·95 ± 0·01[b]	1·49 ± 0·01[c]
Glutamic acid	11·5 ± 0·03[a]	11·3 ± 0·14[a]	13·5 ± 0·021[b]
Glycine	4·47 ± 0·05[a]	6·17 ± 0·02[b]	5·47 ± 0·02[c]
Histidine	5·01 ± 0·09[a]	2·88 ± 0·12[b]	3·31 ± 0·04[c]
Hydroxylysine	0·10 ± 0·01[a]	0·40 ± 0·01[b]	0·18 ± 0·01[c]
Hydroxyproline	0·55 ± 0·01[a]	1·73 ± 0·14[b]	1·24 ± 0·09[c]
Isoleucine	4·58 ± 0·04[a]	4·59 ± 0·01[a]	4·83 ± 0·02[b]
Leucine	7·44 ± 0·03[a]	6·33 ± 0·21[a]	8·15 ± 0·01[b]
Lysine	8·72 ± 0·06[a]	7·82 ± 0·13[b]	8·50 ± 0·07[c]
Methionine	1·64 ± 0·07[a]	1·49 ± 0·08[a]	1·93 ± 0·01[b]
Phenylalanine	4·57 ± 0·05[a]	4·09 ± 0·02[b]	4·00 ± 0·01[c]
Proline	3·89 ± 0·04[a]	5·24 ± 0·05[b]	4·12 ± 0·05[c]
Serine	3·98 ± 0·02[a]	3·72 ± 0·01[b]	3·58 ± 0·05[c]
Threonine	4·53 ± 0·06[a]	3·83 ± 0·09[b]	4·00 ± 0·01[c]
Tryptophan	1·20 ± 0·01[a]	1·06 ± 0·01[b]	1·05 ± 0·01[b]
Tyrosine	2·85 ± 0·01[a]	2·90 ± 0·02[b]	3·07 ± 0·01[c]
Valine	5·80 ± 0·07[a]	5·46 ± 0·04[b]	5·04 ± 0·02[c]

[a] Results are mean values of three determinations ± standard deviation. Values in each row carrying identical superscripts are not significantly ($p > 0{\cdot}05$) different from one another.

(53·3%). Mechanical deboning enhanced the amount of unsaturated fatty acids by about 7%. Incorporation of bone marrow lipids into the meat might be responsible for this observation. The dominant fatty acids in seal lipids were oleic acid (29·7%) and gondoic acid (15·9%). However, essential fatty acids (linoleic, linolenic and arachidonic) constituted only 6·7% of the total fatty acids fraction. About 30·3% of the unsaturated fatty acids were polyunsaturated compounds, more than that in beef (11·6%) and pork (16·5%) and less than that in cod lipids (71·7%). Fatty acids from seal intramuscular lipids contained about 5·7% of eicosapentaenoic (EPA), 3·4% of docosapentanenoic (DPA) and 5·5% of docosahexaenoic (DHA) acids. However, these values depend on both the hunting season and living conditions of the animals. Possible lowering of serum cholesterol due to the intake of long-chain ω-3 fatty acids may influence the nutritional significance of marine lipids (Krzynowek, 1985). The absence of DHA in the human diet has been associated with multiple sclerosis (Bernsohn & Stephanides, 1967). The total amounts of EPA and DHA in unwashed MSSM were similar to those in herring (9·1%) and cod (12·3%) lipids (Sikorski *et al.*, 1988). After washing of MSSM with water, the amount of EPA and DHA decreased by 38·6 and 18·2%, respectively (Shahidi & Synowiecki, 1991).

The amount of minerals in MSSM in comparison with meat from other species is given in Table 1. The major mineral components of MSSM were calcium (591 mg/100 g sample) and phosphorus (504 mg/100 g sample). The calcium content in MSSM was 169, 185, 24·6 and 7·5 times higher than that in beef, pork, cod and MSCM, respectively. The inclusion of small particles of bones in mechanically processed meat may be partially responsible for this observation. However, the phosphorus content in MSSM was only 2·5–2·7 times higher than that in other meats (Table 1). Enhancement of the calcium content due to washing may arise from the concentration of bone residues caused by the removal of sarcoplasmic and possibly some contractile muscle tissue components. MSSM contained over 140 times more iron as compared with that in cod and over 35 times more than that present in MSCM. The iron present in seal meat is in the haeme form, which is readily absorbable upon consumption. Washing of MSSM resulted in a considerable decrease in the amount of haeme iron in the products (Fig. 1). However, even after most effective washing with a sodium bicarbonate solution, the amount of haeme iron in the product was 3·4 and 7·8 times greater than that in beef and pork, respectively. Washings with water or a sodium bicarbonate solution also decreased the amounts of other minerals in the sample (Table 2). The observed increase in the sodium content of meat washed with a 0·5% $NaHCO_3$ solution was perhaps due to the retention of some sodium bicarbonate in the muscle tissues.

The amount of vitamins in MSSM as well as those from other species is also listed in Table 1. In general, the total amount of B vitamins in seal meat

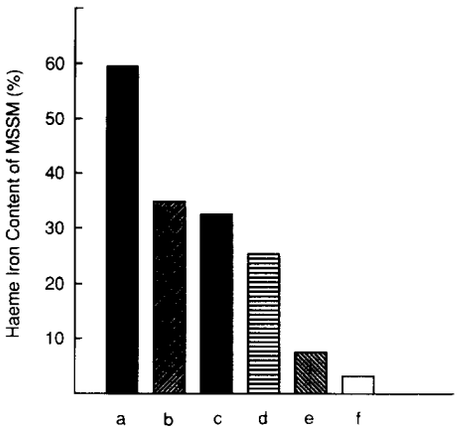

Fig. 1. Percentage of haeme iron remaining in MSSM after washing with: a, 1 × H_2O; b, 2 × H_2O; c, 3 × H_2O; d, 1 × H_2O then a 0·5% bicarbonate solution, as compared with e, beef *Longissimus dorsi*; and f, pork *Biceps femoris*. Standard deviations did not exceed 0·8% of each value.

(14·5 mg%) was higher than that in beef (13·4 mg%), pork (11·6 mg%), MSCM (5·89%) and cod (3·14 mg%). The amount of pantothenic acid was similar to that in beef and pork and was over three times higher than that in cod (Table 1). The amounts of vitamins were reduced after aqueous or bicarbonate washings (Table 2). Of particular interest is the removal of thiamine, which is considered as a flavour precursor in meat products. Its degradation and further interaction with other meat volatiles is responsible for development of desirable meaty aromas in heat-processed products (Shahidi, 1989). Therefore, as expected, the removal of flavour precursors such as free amino acids and thiamine by a washing process affords a more bland product.

CONCLUSIONS

Based on the data presented in this paper, the nutritional value of MSSM was somewhat superior to that of pork, beef, MSCM and cod. Washing with a sodium bicarbonate solution produced a more bland product with a lighter colour. Therefore, the washed, surimi-like products, may be used in the preparation of seafood hybrid products. The washed MSSM so produced fulfils the nutritional criteria set by the American Standard Requirements for mechanically deboned meats.

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