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Testing the gel-forming capacity of marine fish muscle proteins is part of the technological effort to improve utilization of our fishery resources.

Gel-Forming Capacity of Washed and Unwashed Flesh of Some Pacific Coast Species of Fish

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ABSTRACT

Several species of Pacific Ocean fish were tested to determine the gel-forming capacity of their proteins when processed into a heat-pasteurized, finely-comminuted fish product ("Kamaboko"). Lingcod, Pacific cod, rockfish, and some sharks had good gel-forming properties, while flounder, hake, and dogfish did not. Washing the comminuted flesh generally improved the gel-forming properties.

INTRODUCTION

Fish is an excellent food because of the high nutritive value of its muscle protein. In addition to their nutritive value, fish muscle proteins are utilized in processed foods for their functional properties. In Japan, for example, the flesh of certain species of fish is used to make fish sausage (Tanikawa, 1963; Amano, 1965) and the Japanese fish cake called "Kamaboko." The gel-forming capacity of the wet fish protein determines its suitability as raw material for fish sausage and "Kamaboko" as described in the preceding papers.

Some of the species caught off the west coast of the United States were tested to determine the gel-forming capacity of their proteins. Included in these tests were several species not utilized for food in the United States. Testing their muscle proteins for functional properties such as gel-forming capacity is part of our effort to develop the technology for utilizing our fishery resources at the highest level of benefit. This gel-forming capacity was evaluated in terms of elasticity, flexibility, firmness, and cohesiveness of the heat-pasteurized fish gel ("Kamaboko") prepared from the flesh of the various species. Thus, the gel-forming capacity of the fish proteins was measured by the quality of the "Kamaboko" prepared. Since washing the flesh to remove fat and water-soluble substances improves the gel-forming capacity (Okada, 1964), washed flesh of all species was tested as well as the unwashed flesh, which was used as control samples. The results of this study are presented here.

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MATERIALS AND METHODS

Fish Samples

Except for the large sharks, caught off the coast of California, the species used in this study (Table 1) were caught off the coast of Washington. All fish were held in ice while aboard the commercial fishing vessels and during shipment to our laboratory except for the sharks, which were frozen aboard ship and thawed just prior to being used. Two lots each of large-size and small size hake taken from Puget Sound were tested.

Preparation of Comminuted Flesh

At our laboratory, the fish were headed, gutted, washed, and passed through a flesh-separator machine as described by Miyauchi and Steinberg (1970). The tension on the rubber belt was adjusted so that when the headed-and-gutted fish were passed through the machine most of the dark flesh remained with the skin and only the light flesh was recovered from the first pass. The separated minced flesh was weighed to determine the yield. The waste from the first pass was sent through the machine again, and the flesh recovered from this operation was also weighed to obtain yield data. Only the first-pass flesh was used in this study.

About half of the first-pass comminuted flesh from the flesh separator was used directly (unwashed). The other half was washed as follows: One part by weight of comminuted flesh and seven parts by weight of water chilled to 32°F were stirred with a large paddle until thoroughly mixed. The flesh was allowed to settle for about 10 minutes; the supernatant containing fat, blood, and water-soluble proteins and minerals was decanted. Washing was repeated four more times. The fifth washing was made with a chilled 0.15 percent salt solution to

Table 1.—Species of fish tested for gel-forming capacity.

Common name	Scientific name	Month caught	Days on ice	Number of fish	Total weight (lb)
Cod, Pacific (true cod)	*Gadus macrocephalus*	Dec.	1	20	130
Dogfish, Spiny	*Squalus acanthias*	Nov.	1	7	32
Flounder, Starry	*Platichthys stellatus*	Oct.	1	58	147
Hake, Pacific (Puget Sound)	*Merluccius productus*				
Lot 1		March	1	35	26
Lot 2		May	1	150	112
Lot 3		Nov.	1	18	39
Lot 4		Jan.	2	24	53
Lingcod	*Ophiodon elongatus*				
Lot 1		Aug.	1	9	51
Lot 2		Sept.	4	3	35
Lot 3		Oct.	4	2	11
Ratfish	*Hydrolagus colliei*	Dec.	1	7	32
Rockfish					
Black	*Sebastes melanops*	Aug.	1	2	7
Bocaccio	*Sebastes paucispinis*	Sept.	5	5	35
Canary	*Sebastes pinniger*	July	3	11	57
Flag	*Sebastes rubrivinctus*	July	4	11	57
Pacific ocean perch	*Sebastes alutus*	Sept.	2	12	24
Silvergray	*Sebastes brevispinis*	Oct.	4	7	44
Sharks					
Blue	*Prionace glauca*	Sept.	F[1]	1	—
Hammerhead, scalloped	*Sphyrna lewini*	Nov.	F	1	—
Whitetip	*Carcharhinus longimanus*	Dec.	F	1	—

[1] Frozen

facilitate the removal of water from the flesh. The mixture was decanted onto cheesecloth to recover the flesh, which was then placed in a hydraulic press, and pressed at up to 20 pounds per square inch for 10 minutes to remove the remaining wash water.

Heat-Pasteurized Fish Gel Preparation

Salt, sugar, and tripolyphosphate were added to both the washed and unwashed flesh at levels of 2.5 percent, 5 percent, and 0.2 percent (W/W), respectively. The mixture was ground for 20 minutes in a prechilled, powered stone mortar operated in a 34°F chilled room in order to minimize the temperature rise of the flesh during grinding. The resulting ground paste was stuffed into polyvinylidene chloride sausage casing 3 cm in diameter. This was heat-pasteurized in a water bath at 180°F for 40 minutes.

Determination of Gel-Forming Capacity

The gel-forming capacity was determined on the "Kamaboko" in terms of flexibility and elasticity by the folding test and on texture by sensory test.

The folding test was made by folding in half a slice of the "Kamaboko" product 3 mm thick by 3 cm in diameter. If no cracking occurred along the fold, the slice was folded again perpendicular to the first fold. The 5-point rating scale of the folding test was based on the grades that were defined by Nishiya (1963) as follows:

Numerical score	Nishiya's grade	Results of folding	Degree of elasticity
5	AA	No cracks on folding into quarters	Extremely elastic
4	A	No cracks on folding in half; cracks on folding into quarters	Moderately elastic
3	B	Some cracking on folding in half	Slightly elastic
2	C	Breaks into pieces on folding in half	Not elastic
1	D	Breaks into fragments with finger pressure	Poor

Texture by Sensory test

The texture of the heat-pasteurized fish gel with respect to its cohesiveness, firmness, and moistness was determined on a slice 2 cm thick by 3 cm in diameter. The texture was rated on the following 10-point scale: 9-10, Excellent; 7-8, Good; 5-6, Standard; 3-4, Substandard; 1-2, Poor.

Expressible Water

Expressible water to measure water-holding capacity was determined as follows: A slice of "Kamaboko" 1 cm in diameter by 0.3 cm thick pressed between four sheets of Whatman No. 1 filter paper (two on each side) for 1 minute under a weight of 8.8 kg. The percent expressible water was based on the difference in weight of the "Kamaboko" before and after pressing.

Determination of Moisture Content

The moisture content of the "Kamaboko" was measured by the rapid moisture determination balance (Ohaus scale. Model 6010)[1] equipped with an infrared lamp. Ten grams of finely chopped "Kamaboko" were spread thin on a flat aluminum dish and placed under the lamp for 25 minutes or until a constant weight was obtained.

RESULTS

Minced Flesh Yield

The minced flesh yields for the first pass and second pass through the flesh separator for the various species are given in Table 2. The difference in the flesh yield between the first and second passes is dependent upon the arbitrary adjustment of the tension exerted by the belt. Somewhat higher or lower yields could be obtained by different adjustments of the tensions. In addition

[1] Use of trade names in this publication does not imply endorsement of commercial products by the National Marine Fisheries Service.

to the flesh yield, those of head and viscera and of skin and bones are given in Table 2.

Gel-Forming Capacity Discussed by Species

Lingcod

Both the washed and unwashed flesh of iced lingcod have good gel-forming capacity for as long as 10 days (Table 3). The "Kamaboko" made from both types of flesh had good color, flavor, and extremely good elasticity and flexibility. Since the gel-forming capacity is not affected by holding the lingcod in iced storage, it is an excellent species for making "Kamaboko" and fish sausage.

Pacific Cod

The unwashed flesh of 1-day iced cod made "Kamaboko" having extremely good elasticity but only average overall texture. "Kamaboko" made from unwashed 5-day iced fish was crumbly and poor in overall quality. On the other hand, the gel-forming capacity of washed flesh was good. The washed flesh of cod iced for 1 day made "Kamaboko" having extremely good flavor, elasticity, and flexibility as determined by the sensory and folding tests (Table 4). The gel-forming capacity of cod decreased with time of iced storage, but the "Kamaboko" made from washed flesh of cod iced for as long as 9 days had good elasticity and flexibility and a slightly higher water-holding capacity than that made from the unwashed flesh. In summary, the gel-forming capacity of washed minced flesh of Pacific cod is good even after 9 days in ice. The gel-forming capacity of washed flesh is better than that of unwashed flesh.

Rockfish

Based on the six species tested (Table 5), rockfish has good gel-forming

Table 2.—Yield of flesh and waste (based on weight of whole fish) from some Pacific Ocean fish passed through a laboratory-model flesh separator.

Species	Weight of fish used	Yield of flesh			Yield of waste		
		1st pass	2nd pass	Total	Head and viscera	Skin and bones	Total
	Kg	*Percent*					
Cod, Pacific	17.4	32.5	5.3	37.8	45.5	16.7	62.2
Dogfish, Spiny	14.5	20.9	16.0	36.9	52.1	11.0	63.1
Flounder, Starry	67.0	27.1	15.8	42.9	46.0	11.1	57.1
Hake, Pacific (Puget Sound)							
Lot 1	11.8	39.0	—	—	45.0	—	—
Lot 2	50.8	41.0	—	—	52.0	—	—
Lot 3	17.7	33.0	16.0	49.0	44.6	6.4	51.0
Lot 4	24.1	37.0	—	—	50.0	—	—
Lingcod							
Lot 1	25.2	41.0	6.9	47.9	40.0	12.1	52.1
Lot 2	15.9	39.0	12.0	51.0	38.0	11.0	49.0
Lot 3	5.1	46.5	11.4	57.9	33.0	9.1	42.1
Rockfish							
Black	33.2	32.4	14.4	46.8	42.7	10.5	53.2
Bocaccio	15.9	27.0	17.7	44.7	43.0	12.3	55.3
Canary	25.9	29.5	11.3	40.8	46.0	13.2	59.2
Flag	25.8	28.0	—	—	49.0	12.6	61.6
Pacific ocean perch	10.9	29.0	10.2	39.2	44.0	16.8	60.8
Silvergray	19.9	35.8	10.7	46.5	42.3	11.2	53.5

Table 3.—Gel-forming capacity of washed and unwashed flesh of lingcod held in ice for varying periods.

Lot	Fish stored in ice	Properties of "Kamaboko" made from: Washed flesh: Texture by sensory test	Washed flesh: Elasticity by folding test	Washed flesh: Moisture content	Unwashed flesh: Texture by sensory test	Unwashed flesh: Elasticity by folding test	Unwashed flesh: Moisture content
Number	*Days*	*10-pt scale*	*5-pt scale*	*Percent*	*10-pt scale*	*5-pt scale*	*Percent*
1	1	9	5	76.5	8	5	72.9
	6	10	5	75.4	8	5	72.9
2	4	8	5	77.3	7	5	73.3
	10	9	5	77.0	7	5	73.2
3	4	7.5	5	79.5	9	5	72.0
	10	9	5	76.8	8	5	74.4

Table 4.—Gel-forming capacity of washed and unwashed flesh of Pacific cod iced for varying periods.

Treatment of flesh	Fish stored in ice	Properties of "Kamaboko": Texture by sensory test	Elasticity by folding test	Expressible water	Moisture content
	Days	*10-pt scale*	*5-pt scale*	*Percent*	*Percent*
Washed	1	9	5	12.8	79.0
	5	6.5	5	11.9	78.1
	9	7.5	5	9.7	76.5
Unwashed	1	6	5	29.5	81.0
	5	3	2	31.7	77.7

capacity and appears to be a good source of raw material for making "Kamaboko"-type products. The unwashed flesh of five species made standard- to good-grade "Kamaboko" having good elasticity, reasonably good flexibility, a light tan to off-white color, and good flavor. The unwashed flesh of only the silvergray rockfish made a soft, substandard-grade "Kamaboko."

The "Kamaboko" made from the washed flesh of all six species were better in quality than those made from the unwashed flesh. Washing the flesh improved the color, flavor, and flexibility of the "Kamaboko."

Holding Pacific ocean perch for as long as 8 days in ice had no effect on its gel-forming characteristics. There was no significant change in color, flavor, elasticity, or flexibility of the "Kamaboko" owing to the storage of fish in ice.

Starry Flounder

The washed flesh of 1-day iced starry flounder had good gel-forming capacity and made "Kamaboko" having good elasticity and excellent flexibility (Table 6). The washed flesh of 6-day iced fish made standard-grade "Kamaboko" having excellent flexibility, but that of 12-day iced fish lost much of its gel-forming capacity and made substandard-grade "Kamaboko" having slight elasticity and flexibility. Thus, the washed flesh of starry flounder iced for as long as 6 days has good gel-forming capacity suitable for making "Kamaboko" and fish sausage. The unwashed flesh of starry flounder, on the other hand, had poor gel-forming capacity even for fish iced 1 day.

Puget Sound Hake

The results of the tests to determine the gel-forming capacity of two lots of large hake and of two lots of small hake are given in Tables 7 and 8, respectively.

Large hake. — The washed flesh of 1-day iced, large-size hake had low gel-forming capacity and made "Kamaboko" having soft-to-mushy texture. However, the gel-forming capacity of the washed flesh of large hake iced for either 5, 7, or 10 days was much better, and the washed flesh made average-grade "Kamaboko" having good elasticity. In comparison, the unwashed flesh had low gel-forming capacity and made a mushy-textured "Kamaboko."

It is difficult to explain why these large-size hake that were iced for longer periods produced better "Kamaboko" than the fresher fish. Although it was difficult to dewater the washed flesh of 1-day iced fish and easier to dewater washed flesh of fish iced for longer periods, there was no clearcut relation between this phenomenon and the amount of expressible water and moisture content of the "Kamaboko" produced. Furthermore, no proteolytic enzymic activity was found in the 1-day iced hake that produced a poor "Kamaboko," and only a small amount of activity was detected in the 10-day iced hake that made an elastic standard-grade "Kamaboko."

Small hake. — For the small-size Puget Sound hake, the washed flesh of the fish caught in March, irrespective of whether they were iced for only 1

Table 5.—Gel-forming capacity of washed and unwashed flesh of rockfish held in ice for varying periods.

Species of rockfish	Fish stored in ice	Properties of "Kamaboko" made from: Washed flesh: Texture by sensory test	Washed flesh: Elasticity by folding test	Washed flesh: Moisture content	Unwashed flesh: Texture by sensory test	Unwashed flesh: Elasticity by folding test	Unwashed flesh: Moisture content
	Days	*10-pt scale*	*5-pt scale*	*Percent*	*10-pt scale*	*5-pt scale*	*Percent*
Black	1	8	5	84	6	4	84
Bocaccio	5	9	5	73.0	7	5	71.2
Canary	3	8	5	75	6.5	5	72
Flag	4	9	5	77	8	5	73
Pacific ocean perch	2	9	5	77.3	8	5	67.7
	5	9.5	5	76.4	8	5	71.0
	8	9	5	76.7	8	5	70.5
Silvergray	4	7.5	5	76.8	3	2	72.7

Table 6.—Gel-forming capacity of washed and unwashed flesh of starry flounder iced for varying periods.

Treatment of of flesh	Fish stored in ice	Properties of "Kamaboko": Texture by sensory test	Elasticity by folding test	Expressible water	Moisture content
	Days	*10-pt scale*	*5-pt scale*	*Percent*	*Percent*
Washed	1	7	5	17.5	78.0
	6	5	5	19.6	76.1
	12	4	3	21.6	77.3
Unwashed	1	4	3.5	33.8	76.0
	6	3	3.5	37.3	76.5
	12	2	2	39.6	78.6

Table 7.—Gel-forming capacity of washed and unwashed flesh of large (50 to 60 cm) Puget Sound hake iced for varying periods.

Month caught	Treatment of flesh	Fish stored in ice	Properties of "Kamboko" Texture by sensory test	Elasticity by folding test	Expressible water	Moisture content
		Days	*10-pt scale*	*5-pt scale*	*Percent*	*Percent*
November	Washed	1	2	2	[1]	78.5
		5	7	5	13.2	77.5
	Unwashed	1	1	1	[1]	79.6
		5	2	2	[1]	79.4
January	Washed	1	4	3	14.0	81.3
		7	7	5	6.4	79.1
		10	6	—	5.5	76.5

[1] Too mushy to determine expressible water.

day or as long as 9 days, made standard-grade elastic "Kamaboko" (Table 8). At each sampling date, fish that were obviously parasitized were segregated and tested separately. Parasitized fish made a slightly less elastic "Kamaboko" than the parasite-free fish; the sensory scores were lower for the "Kamaboko" prepared from the fish with parasites. The protozoan parasites in Puget Sound hake appear to have proteolytic enzyme of relatively low activity and therefore do not adversely affect the "Kamaboko"-forming capacity of parasitized fish. The unwashed flesh of the small hake had low gel-forming capacity and made a mushy-textured "Kamaboko" similar to the unwashed flesh of the large hake.

The results of the washed flesh of the second lot of small hake, which was more limited in scope, were similar to those of the first lot.

Dogfish

One-day iced dogfish had low gel-forming capacity and made poor-grade "Kamaboko" (Table 9). "Kamaboko" made with unwashed flesh was mushy, and that made with washed flesh was crumbly in texture. On the other hand, five-day iced dogfish made a better grade "Kamaboko". The unwashed flesh made a standard-grade "Kamaboko" that was moderately elastic, but the washed flesh made a substandard "Kamaboko" having slight elasticity. Although there were differences in the moisture contents of the "Kamaboko" made from 1-day iced and 5-day iced dogfish (Table 9), their effect on the quality of the "Kamaboko" is not known. A systematic study with respect to effect of size of dogfish, season of catch, iced storage, etc., on the gel-forming capacity of dogfish flesh is needed.

Pelagic Sharks

Blue shark, scalloped hammerhead shark, and whitetip shark, in spite of being frozen and stored at −5°C (23°F) for about 1 month, had good gel-forming capacity and made a very elastic "Kamaboko" (Table 10). The unwashed flesh of the hammerhead and whitetip sharks made good-to-excellent grade "Kamaboko" with excellent elasticity and flexibility, but the unwashed flesh of blue shark produced a very unusual soft and spongy-textured "Kamaboko." The washed flesh of blue shark, however, made an excellent-grade "Kamaboko" with good elasticity and flexibility.

DISCUSSION

After washing and dewatering by pressing, the moisture content of the washed flesh should be brought back to the approximate level of the flesh prior to washing. In practice, the moisture content of the dewatered flesh was usually in the range of 75-85 percent. Difficulty in dewatering the washed flesh was often encountered when the fish was too fresh. Since the moisture content of the washed flesh could not be precisely controlled, the moisture content of the "Kamaboko" produced was determined. Although the moisture content of the

Table 8.—Gel-forming capacity of washed and unwashed flesh of small (20 to 30 cm) Puget Sound hake iced for varying periods.

Month caught	Treatment of flesh	Fish stored in ice	Properties of "Kamaboko" Texture by sensory test	Elasticity by folding test	Expressible water	Moisture content
		Days	*10-pt scale*	*5-pt scale*	*Percent*	*Percent*
March	Washed, normal flesh	1	6.5	5	9.3	83.6
		2	6.5	5	8.3	81.1
		6	6.5	5	5.8	78.0
		9	6.0	5	6.4	77.6
	Washed (parasitized flesh)	1	5.5	5	9.5	79.3
		2	5.0	4.5	10.5	78.3
		6	5.5	5	4.8	74.5
		9	4.5	5	11.1	79.6
	Unwashed	1	1.5	1	31.0	79.1
		2	1.5	1	24.5	79.6
		6	2.0	2	26.5	79.9
May	Washed	1	6.5	5	14.7	78.9
		3	7.5	5	12.8	78.1

Table 9.—Gel-forming capacity of washed and unwashed spiny dogfish iced for 1 and 5 days.

	Properties of "Kamaboko" made from:					
	Washed flesh			Unwashed flesh		
Fish stored in ice	Texture by sensory test	Elasticity by folding test	Moisture content	Texture by sensory test	Elasticity by folding test	Moisture content
Days	*10-pt scale*	*5-pt scale*	*Percent*	*10-pt scale*	*5-pt scale*	*Percent*
1	2	2	72.4	1	2	70.9
5	5	4	67.0	3	3	65.2

Table 10.—Gel-forming capacity of washed and unwashed flesh of blue shark, scalloped hammerhead shark, and oceanic whitetip shark.

	Properties of "Kamaboko" made from:					
	Washed flesh			Unwashed flesh		
Species of shark	Texture by sensory test	Elasticity by folding test	Moisture content	Texture by sensory test	Elasticity by folding test	Moisture content
	10-pt scale	*5-pt scale*	*Percent*	*10-pt scale*	*5-pt scale*	*Percent*
Blue	9	5	73.9	6	5	82.7
Hammerhead, scalloped	8	5	77.0	9.5	5	77.5
Whitetip, oceanic	9	5	72.9	8	5	79.9

"Kamaboko" did vary, there appeared to be no correlation between it and the objective tests used to measure gel-forming capacity of the various samples.

With lingcod, rockfish, hake, and other species that appear to have good gel-forming capacity, systematic studies should be made of the gel-forming capacity in relation to freshness, age or size of fish, the time of year landed and spawning condition, the fishing ground, and the incidence of parasites.

SUMMARY

Preliminary screening of some species of the Pacific Coast for gel-forming capacity was made. The yield of flesh recovered from the first and second passes through the flesh separator ranged from 36.9 percent for spiny dogfish to 57.9 percent for lingcod.

Washing the comminuted flesh with chilled water to remove some of the water-soluble proteins was very effective in improving the gel-forming capacity. Washing also removed blood, fat, small pieces of skin, and any "fishy" odors.

The species studied might be conveniently divided into three groups with regard to stability in gel-forming capacity during ice storage:

1. Lingcod, Pacific cod, Pacific ocean perch produced good- to excellent-grade "Kamaboko" even after 8 to 10 days of iced storage when washed flesh was used. The washed flesh of other rockfish (black, bocaccio, canary, and flag) also produced good- to excellent-grade "Kamaboko."
2. Silvergray rockfish, starry flounder, and hake produced standard- to good-grade "Kamaboko" from washed flesh of fish iced for up to seven days.
3. Dogfish produced substandard- to poor-grade "Kamaboko" from washed flesh.

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