Storage of Dressed Chinook Salmon, *Oncorhynchus tshawytscha*, in Refrigerated Freshwater, Diluted Seawater, Seawater, and in Ice

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Introduction

In the past, ice was routinely used to preserve dressed Pacific salmon, *Oncorhynchus* spp., on commercial salmon trollers. Due to increasing ice costs, its limited availability in some ports, and the time and effort required to ice fish at sea, some fishermen have adopted chilled water systems to preserve dressed salmon at sea. These systems include refrigerated freshwater, refrigerated mixtures of seawater and freshwater, refrigerated seawater, and chilled mixtures of seawater and ice (Melvin et al., 1983).

Although water chilling systems provide ease of handling and rapid cooling, an excessive uptake of water, an increase in total salt content, and bacterial growth in water systems have been identified as potential problems (Barnett et al., 1971; Roach et al., 1967; Tomlinson et al., 1974). Fishermen and salmon buyers have also asked if fish become shorter, bleached, or discolored during storage in chilled water systems, and if fish lose weight when transferred from these systems to iced storage during distribution on land.

This study was conducted to compare the effects of several chilled water systems on selected physical, chemical, microbial, and sensory changes occurring during the storage of dressed chinook salmon, *Oncorhynchus tshawytscha*, at 0°C. Chilling systems investigated were: 1) Refrigerated freshwater (RFW); 2) refrigerated diluted seawater (1/3 RSW); 3) refrigerated seawater (RSW); and 4) ice. Also investigated were the effects of transferring fish from chilled water systems to ice after 7-day storage.

ABSTRACT—Dressed chinook salmon, Oncorhynchus tshawytscha, *were held at 0°C in refrigerated freshwater, diluted seawater, and seawater for 7 days, and then in ice for 9 days. Another group was held in ice for the entire 16-day period, and the effects of chilling media on selected physical, chemical, microbial, and sensory changes were compared.*

Chilled water systems appeared to retard bacterial growth slightly, an advantage over ice, and fish held in diluted seawater gained less weight than fish held in freshwater and absorbed less salt than fish held in seawater. Seawater-held fish became shorter during storage. Iced storage offers several advantages over the water chilling systems, including little weight change during the first nine days and, thereafter, better appearance of belly flaps, eyes, dorsal skin color, and better belly cavity odor. Salt levels in fish stored in seawater solutions decreased by 25 percent within four days after transfer to ice, and weight gained during water storage was lost after transfer to ice.

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Materials and Methods

For the first phase of the study, 60 chinook salmon, weighing an average of 3.95 ± 0.57 kg, were obtained from commercial salmon trollers at Albion and Drakes Bay, Calif. The fish were eviscerated at sea, packed in ice, and transported to the University of California Food Science & Technology Department in Davis. Upon arrival and within 18 hours of capture, fish weights and total lengths were determined. Length measurements were from the tip of the snout to the extreme tip of the tail. Forty-six of the salmon were randomly transferred into 55-gallon plastic drums containing the following refrigerated storage media: RFW (20 fish); 1/3 (v/v) RSW (20 fish); and RSW (6 fish). The seawater was obtained from the University of California Bodega Marine Laboratory, Bodega Bay, Calif. The remaining 14 fish were iced in insulated containers. The plastic drums contained storage media to within 10 cm of the rim of the drum, and were loosely covered during storage at 0° ± 0.6°C. Temperatures of the storage media, the air in the cold storage room, and of two fish in each storage condition were monitored throughout the study. On day 7 of the study, eight fish from the 1/3 RSW and the RFW storage media were transferred to ice for the remainder of the experiment.

The salmon were sampled on days 0, 4, 7, 9, 11, 14, and 16. Fish held in RSW were only sampled until day 7. On each sampling day, two fish from each storage condition were randomly removed. Each fish's weight and length were recorded. A 4 cm steak was aseptically removed just anterior to the dorsal fin for bacterial examination and salt analysis.

In the second phase of the study, 27 chinook salmon, weighing an average of 1.71 ± 0.55 kg, were caught off San Francisco Bay, Calif. Following capture, the fish were immediately eviscerated and iced. Within 12 hours of capture, the fish were transported to Davis, tagged, weighed, and measured. Twenty-four fish were randomly distributed into 55-gallon plastic drums containing refrigerated storage media: RFW (7 fish), 1/3 RSW (8 fish), and RSW (9 fish). The remaining three fish were repacked in ice. The plastic drums contained storage media to within 10 cm of the rim of the drum, and were loosely covered during storage at 0° ± 0.6°C. On day 7 of the study, fish in chilled water systems were transferred to ice.

All fish were weighed and measured at 2- or 3-day intervals during the 16 days of chilled storage, and two fish were temporarily removed from each of the storage conditions for sensory evaluation. The same fish were used for each of the sensory sessions.

Bacteriological Measurements

Aerobic plate counts (APC) of the salmon were done as follows: 21 g of fish flesh were aseptically removed from the dorsal half of the sample steak and blended with 400 ml of sterile 0.1 percent peptone water in a Waring[1] blender for 2 minutes. Duplicate 0.1 ml aliquots from appropriate serial dilutions (0.1 percent peptone water) were spread-plated on Standard Methods Agar with 0.5 percent NaCl, as suggested by Liston and Matches (1976), and incubated for 3 days at 20°C.

NaCl Analysis

The salt content of the ventral half of the sample steak was quantified using Quantabs chloride titrators (Ames Division, Miles Laboratories, Inc.). The salt content is reported as percent NaCl of wet weight. Analyses were conducted in triplicate.

Sensory Analysis

Sensory assessment of the general appearance of the whole fish was made by a trained panel of eight judges. At each judging, the panelists were presented with duplicate sets of four fish, each set containing a representative of the four storage conditions. The panelists were asked to rank the fish from most to least for the following attributes: Browning of gill cavity, discoloration of belly-flap cuts, darkness of dorsal skin color, cloudiness of eyes, and off-odor of belly cavity. Both sets of four fish were judged three times.

Statistical Analysis

Statistical differences between treatment groups were determined by analysis of variance for all the chemical and physical tests. Significance was determined using least significant difference test. The sensory data were analyzed for significant differences using the Kramer ranked two-factor analysis of variance test (Kramer, 1960; 1963).

Results and Discussion

APC results are presented in Table 1. Although differences between storage media were not consistently statistically significant, bacterial growth in fish held on ice appeared to be more rapid than in fish held in chilled water systems. Since the chilled-water fish and the iced fish were held at the same temperature, this difference may be due to more aerobic conditions present during iced storage, allowing the normal aerobic spoilage flora (Shewan, 1961) to grow more rapidly. Tomlinson et al. (1974) found RSW at −0.6° ± 0.6°C to be much more effective than ice in controlling bacterial growth with lingcod, *Ophiodon elongatus,* and sockeye salmon, *Oncorhynchus nerka.* Tomlinson's findings, and similar reports by others (Roach et al., 1961), are probably due to the lower temperature (−1.1° to −0.6°C) for the RSW-held fish.

APC data has been used to provide an index of quality in fresh raw seafoods (Liston and Matches, 1976). Good quality fish will have counts of less than 10^5/g, and acceptable quality fish will have counts of less than 10^6/g. Counts in excess of 10^6/g indicate the onset of spoilage, and counts in excess of 10^7/g are considered unacceptable for fresh raw fish (International Commission on Microbiological Specifications for Foods, 1974). Using these criteria, iced salmon had acceptable quality at day 4, marginal quality at day 7, and were unacceptable at day 11. Salmon

Table 1.—Aerobic plate counts in chinook salmon stored in ice and water systems at 0°C (32°F); mean values are for cell forming units per gram[1].

Days in storage	Storage media					
	RFW	RFW/ice[2]	1/3 RSW	1/3 RSW/ice[2]	RSW	Ice
0						$^a4.0 \times 10^3$
4	$^a6.5 \times 10^3$		$^a3.6 \times 10^4$		$^a2.0 \times 10^4$	$^a2.4 \times 10^5$
7	$^a4.4 \times 10^5$		$^a6.7 \times 10^5$		$^a8.5 \times 10^4$	$^a4.4 \times 10^6$
9	$^a7.2 \times 10^5$	$^a5.3 \times 10^6$	$^a4.0 \times 10^5$	$^a5.9 \times 10^5$	$^a3.2 \times 10^5$	$^a2.5 \times 10^6$
11	$^b1.6 \times 10^6$	$^b2.2 \times 10^6$	$^b1.2 \times 10^6$	$^b3.4 \times 10^5$		$^a1.8 \times 10^7$
14	$^a1.0 \times 10^7$	$^a2.1 \times 10^7$	$^a4.9 \times 10^6$	$^a2.1 \times 10^7$		$^a8.1 \times 10^7$
16	$^c5.8 \times 10^6$	$^{bc}1.9 \times 10^7$	$^{bc}1.3 \times 10^7$	$^b2.7 \times 10^7$		$^a5.4 \times 10^7$

[1] Means within the same horizontal row preceded by different letters (a,b,c) are significantly (P>0.05) different.
[2] Transferred from liquid media to ice at day 7

[1]Mention of trade names or commercial firms does not imply endorsement by the authors or the National Marine Fisheries Service, NOAA.

in RFW and 1/3 RSW had good quality at day 4, acceptable quality at day 7, marginal quality at day 11, and were unacceptable at day 14 (RFW) or day 16 (1/3 RSW). Salmon in RSW had good quality at day 7, and acceptable quality at day 9.

The results of NaCl determinations on salmon flesh are shown in Table 2. By day 4, the RSW fish had at least a twelvefold higher concentration of salt than either the iced or RFW fish. Based on an acceptable upper limit of 0.75 percent salt[2], the RSW fish had unacceptable (1.06 percent) salt levels after only 4 days. Fish stored in 1/3 RSW had about a fourfold higher concentration of salt than the iced or RFW-held fish at day 4. When transferred to ice, about 25 percent of the salt in the flesh of the 1/3 RSW-held fish was leached out within 4 days of iced storage. A similar observation was made by Thurston and Groninger (1959) with pink salmon, *O. gorbuscha,* that were placed on ice following 8 days storage in 3 percent brine. After 6 days on ice, the sodium content in these fish was found to drop by an average of 47 percent.

NaCl uptake in fish held in water media depends on such factors as species, size, fish:RSW ratio, length of storage, and whether or not the fish are gutted (Roach et al., 1967; MacLeod et al., 1960; Wekell, et al., 1983). Salt distribution within the fish can be very uneven. Thurston and Groninger (1959) compared the salt content of the light meat, dorsal, ventral, and belly flap portions of pink salmon that had been held in brine for 8 days. The inner light meat was found to be lowest in sodium (520 mg/100 g), while the most exposed tissue, the belly flap, displayed the highest sodium content (794 mg/100 g). The tissue sampled for NaCl in this study included the belly flap, and the values reported are probably higher than the average flesh salt content.

[2] "Salt absorption of fish held in refrigerated sea water (RSW)" Activities Report, Utilization Research Division, Northwest and Alaska Fisheries Center, NMFS, NOAA, Seattle, Wash., 25 April 1980.

Table 2.—Percent salt content in the flesh of chinook salmon stored in ice and water systems at 0°C (32°F)[1].

Days in storage	Storage media					
	RFW	RFW/ice[2]	1/3 RSW	1/3 RSW/ice[2]	RSW	Ice
4	[a]0.072 ± 0.008		[b]0.327 ± 0.068		[c]1.058 ± 0.057	[a]0.081 ± 0.000
7	[a]0.084 ± 0.008		[a]0.357 ± 0.051		[b]1.137 ± 0.250	[a]0.096 ± 0.021
9	[a]0.104 ± 0.011	[a]0.084 ± 0.008	[a]0.371 ± 0.155	[a]0.436 ± 0.176	[b]1.004 ± 0.295	[a]0.120 ± 0.000
11	[a]0.098 ± 0.011	[a]0.084 ± 0.000	[b]0.657 ± 0.238	[a]0.270 ± 0.013		[a]0.102 ± 0.004
14	[a]0.105 ± 0.064	[a]0.094 ± 0.006	[c]0.522 ± 0.000	[b]0.368 ± 0.023		[a]0.120 ± 0.030
16	[a]0.106 ± 0.011	[a]0.096 ± 0.025	[b]0.652 ± 0.167	[a]0.270 ± 0.013		[a]0.147 ± 0.006

[1] Means within the same horizontal row preceded by different letters (a,b,c) are significantly (P>0.05) different.
[2] Transferred from liquid media to ice at day 7

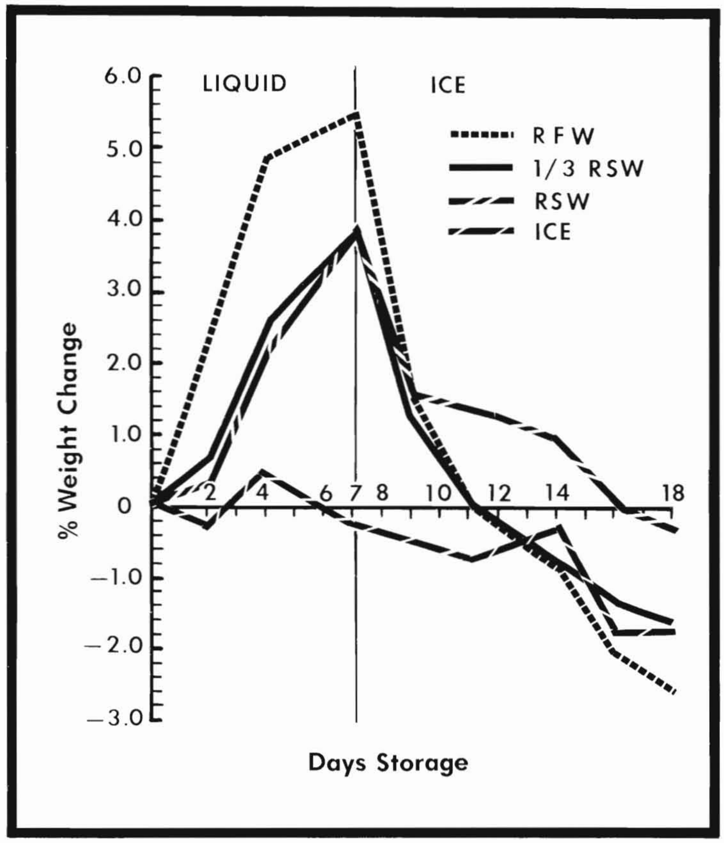

Figure 1.—Percent weight changes for salmon stored in ice and water systems at 0°C (32°F). All fish were transferred to ice at day 7.

Weight data are presented in Figure 1. Fish held in RFW, 1/3 RSW, and RSW all displayed a significant weight gain during the storage period. Within 7 days, the average weight gain was 5.45 percent for the RFW fish and 3.8 percent for the 1/3 RSW and the RSW fish. The RFW fish took up water at a much faster rate than either the 1/3 RSW or the RSW fish. The

Table 3.—Sensory evaluation of salmon stored in ice and water systems at 0 °C (32 °F). For each of the sensory attributes, fish are listed from least to most, left to right.

	Sensory attributes				
Days in storage	Discoloration of belly flap cuts	Browning of gill cavity	Darkness of dorsal skin	Cloudiness of eyes	Off-odor in belly cavity
4	Ice, RSW, RFW, 1/3 RSW	1/3 RSW, Ice, RFW, RSW	RFW**, 1/3 RSW, Ice, RSW··	1/3 RSW*, Ice, RSW·, RFW·	RFW*, 1/3 RSW, Ice, RSW·
7	Ice, 1/3 RSW, RFW, RSW	1/3 RSW, RFW, Ice, RSW	RFW**, 1/3 RSW, Ice, RSW··	Ice**, 1/3 RSW**, RFW··, RSW··	Ice*, 1/3 RSW*, RFW, RSW··
9	Ice**, 1/3 RSW, RSW, RFW··	Ice*, RSW, RFW, 1/3 RSW·	RFW**, 1/3 RSW, RSW, Ice··	Ice**, 1/3 RSW, RFW·, RSW··	1/3 RSW*, Ice, RSW·, RFW·
11	Ice**, RSW, 1/3 RSW, RFW··	Ice, RFW, 1/3 RSW, RSW	RFW**, 1/3 RSW, RSW, Ice··	Ice**, 1/3 RSW, RFW·, RSW··	Ice**, RFW, RSW, 1/3 RSW·
14	Ice*, RSW, 1/3 RSW, RFW·	Ice, RFW, 1/3 RSW, RSW	RFW**, 1/3 RSW, RSW, Ice··	Ice**, 1/3 RSW, RSW·, RFW··	Ice**, RFW, RSW, 1/3 RSW··
16	Ice**, 1/3 RSW, RSW, RFW··	Ice**, RFW, RSW, 1/3 RSW·	1/3 RSW, RFW, RSW, Ice··	Ice**, 1/3 RSW, RSW··, RFW··	Ice**, RFW, RSW·, 1/3 RSW··

*Significantly less (P< 0.05).
**Significantly less (P< 0.01).
·Significantly more (P< 0.05).
··Significantly more (P< 0.01).

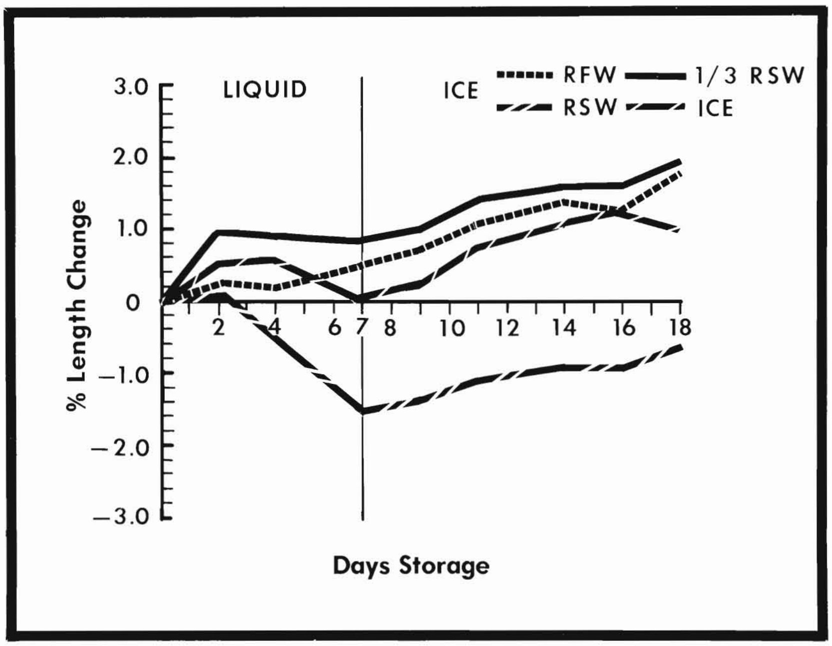

Figure 2.—Percent length changes for salmon stored in ice and water systems at 0°C (32°F). All fish were transferred to ice at day 7.

1/3 RSW and the RSW fish gained weight at a similar rate. After transfer to ice at day 7, the water taken up during water storage was quickly lost. The weight of the iced fish remained relatively constant through the first 14 days of storage. Toward the end of the study, all fish demonstrated a significant weight loss.

MacLeod et al. (1960) and Barker and Idler (1955) observed a similar weight gain for fish held in RSW. Tomlinson et al. (1965) and Roach et al. (1966), however, reported that RSW stored fish lose weight during the first 1-2 days of storage, before gaining weight. If the fish were held for several hours before being placed in RSW, they did not always demonstrate this weight loss. The salmon used in this study were held on ice for about 12 hours prior to immersion, and 2 days elapsed before the first weighing. This may account for a weight loss at day 2 for only 2 of the 17 fish stored in RSW and in 1/3 RSW.

Length data are presented in Figure 2. The 1/3 RSW and the RFW fish displayed a significant gradual increase in length over the entire storage period. The iced fish demonstrated a similar trend, although not significant due to the small (n = 3) sample size.

In contrast, fish held in RSW shrank significantly during the first 7 days of storage. When transferred to ice, this trend gradually reversed, but after 11 days in ice, the RSW fish were still significantly shorter than on day 0.

The results of the sensory evaluation are presented in Table 3. After 9 days storage, iced fish were judged as having less discoloration of the belly flap cuts, browning of the gill cavity, cloudiness of the eyes, and off-odor of the belly cavity than fish held in water solutions. Fish held in ice were also judged as having the darkest dorsal skin color. This indicates that skin color undergoes less bleaching when fish are stored in ice, and substantiates previous reports that chilled water systems bleach skin pigment (Ronsivalli and Baker, 1981).

Sensory data indicate significant differences between iced fish and fish held in chilled water systems; however, differences between fish held in the three water systems were not as apparent. RFW fish displayed the most discoloration of the belly flap cuts and fading of the dorsal skin color. Both RFW and RSW fish demonstrated significant clouding of the eyes. After 11 days storage, 1/3 RSW fish were judged to smell significantly worse than the other fish.

Conclusions

Chilled water systems appear to slightly retard bacterial growth, offering a potential advantage over ice. The 1/3 RSW system is recommended over RSW or RFW, because it results in fish with less salt uptake than RSW, and less weight gain than RFW. Foul odors in RSW tanks, reported in other studies (Barnett et al., 1971; Roach et al., 1966; Peters and Dassow, 1965), were not a problem in our study.

Iced storage appears to offer several advantages over chilled water systems. Fish held in ice show little weight change during the initial 9 days of storage. Thereafter, the appearance of iced fish is significantly better in: Belly flap color, eye clarity, belly cavity odor, and dorsal skin color.

If acceptable quality throughout the typical distribution chain and at point of consumption is to be achieved, dressed chinook salmon should be held in 1/3 RSW, ice, or RFW no longer than 4 days at 0°C. Fish stored in RSW should be held no longer than 3 days.

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Literature Cited

Barker, R., and D. R. Idler, 1955. Transport and storage of fish in refrigerated sea water. IV. Preliminary report on nitrogen loss, weight changes, and proteolysis (belly-burn). Fish. Res. Board Can., Pac. Coast Sta. Progr. Rep. 104:16-18.

Barnett, H. J., R. W. Nelson, P. J. Hunter, S. Bauer, and H. Groninger. 1971. Studies on the use of carbon dioxide dissolved in refrigerated brine for the preservation of whole fish. Fish. Bull., U.S. 69(2):433-442.

International Commission on Microbiological Specifications for Foods. 1974. Microorganisms in foods 2, sampling for microbiological analysis: Principles and specific applications. Univ. Toronto Press, Toronto, 213 p.

Kramer, A. 1960. A rapid method for determining significance of differences from ranked sums. Food Technol. 14(11):576-581.

________. 1963. Revised tables for determining significance of differences. Food Technol. 17(12):1596-1597.

Liston, J., and J. R. Matches. 1976. Fish, crustaceans, and precooked seafoods. *In* M. L. Speck (editor), Compendium of methods for the microbiological examination of foods, p. 507. Am. Public Health Assoc., Inc., Wash., D.C.

MacLeod, R. A., R. E. E. Jonas, and J. R. McBride. 1960. Sodium ion, potassium ion, and weight changes in fish held in refrigerated sea water and other solutions. Agric. Food Chem. 8(2):132-136.

Melvin, E. F., B. B. Wyatt, and R. J. Price. 1983. Recommended procedures for handling troll-caught salmon. Univ. Calif. See Grant Mar. Advisory Program, UCSG-MAP-17, 8 p.

Peters, J. A., and J. A. Dassow. 1965. Improved methods of handling fresh fish in the United States. Part III - Use of refrigerated sea water. Proc. Indo-Pac. Fish Counc. 11(III):254-262.

Roach, S. W., J. S. M. Harrison, and H. L. A. Tarr. 1961. Storage and transport of fish in refrigerated sea water. Fish. Res. Board Can., Bull. 126, 61 p.

________. H. L. A. Tarr, N. Tomlinson, and J. S. M. Harrison. 1967. Chilling and freezing salmon and tuna in refrigerated sea water. Fish. Res. Board Can., Bull. 160, 40 p.

________, N. Tomlinson, S. E. Geiger, and E. Dollinger, 1966. Partial freezing as a means of preserving various species of groundfish. J. Fish. Res. Board. Can. 23(5):701-713.

Ronsivalli, L. J., and D. W. Baker, II. 1981. Low temperature preservation of seafoods: A review. Mar. Fish. Rev. 43(4):1-15.

Shewan, J. M. 1961. The microbiology of seawater fish. *In* G. Borgstrom (editor), Fish as food, vol. 1, p. 487. Acad. Press, Inc., N.Y.

Thurston, C. E., and H. S. Groninger. 1959. Composition changes in Puget Sound pink salmon during storage in ice and in refrigerated brine. J. Agric. Food Chem. 7(4):282-284.

Tomlinson, N., S. E. Geiger, J. W. Boyd, B. A. Southcott, G. A. Gibbard, and S. W. Roach. 1974. Comparsion between refrigerated sea water (with or without added carbon dioxide) and ice as storage media for fish to be subsequently frozen. Bull. Int. Inst. Refrig. Annex 1974-1:163-168.

________, ________, and W. W. Kay. 1965. Sodium, potassium and magnesium concentration and weight changes in fish stored in refrigerated sea water in relation to biochemical changes associated with rigor mortis. J. Food Sci. 30:126-133.

Wekell, J. C., F. M. Teeny, E. J. Gauglitz, Jr., L. Hathorn, and J. Spinelli. 1983. Implications of reduced sodium usage and problems in fish and shellfish. Food Technol. 37(9):51-63.