SALMON QUALITY

The Effects of Ice and Chilled Seawater Storage

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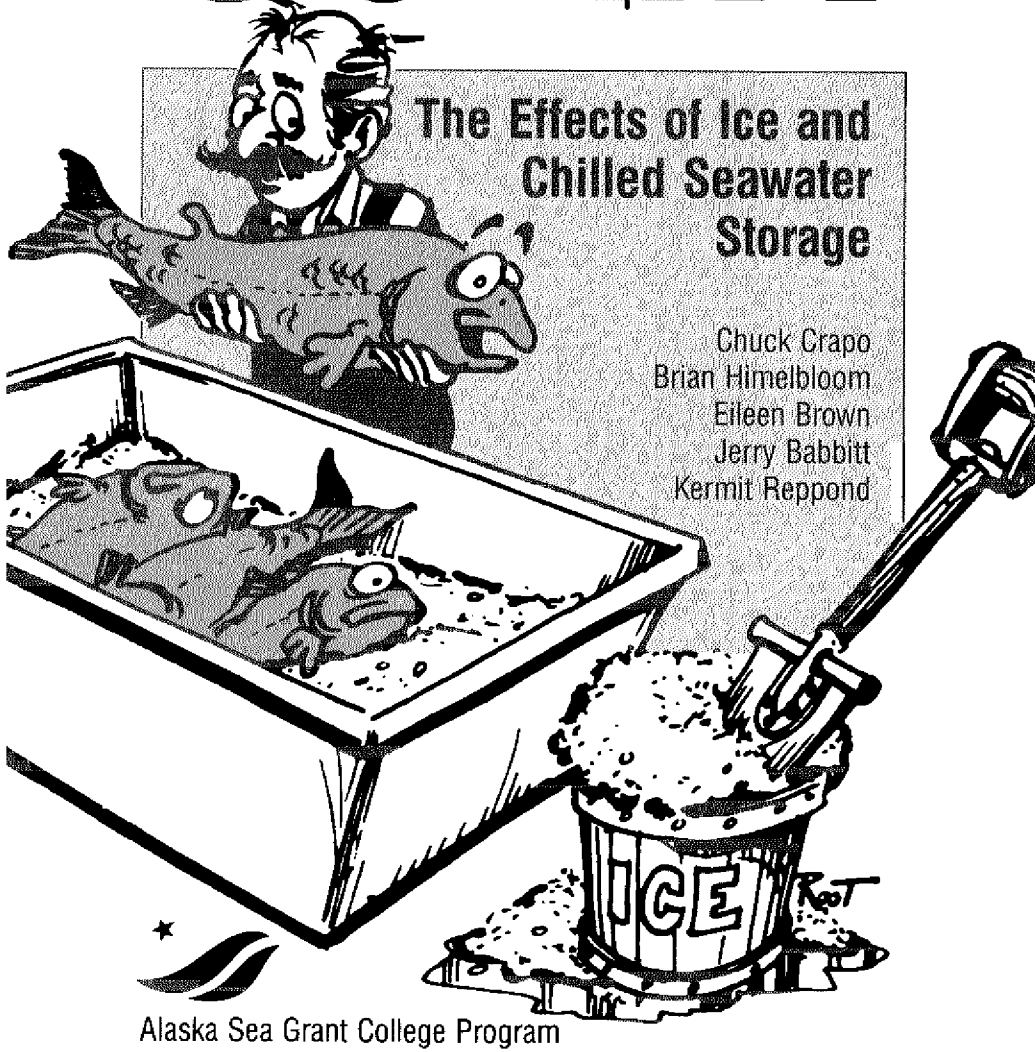

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Introduction

The Alaska seafood industry is increasingly dependent on chilled seawater (CSW) and refrigerated seawater (RSW) systems to hold salmon on tenders and fishing vessels. These systems are excellent for rapid chilling of the fish and maintenance of quality.

Fish received at processing plants are transferred to either onshore CSW/RSW systems or iced totes. It is felt that salmon transferred from CSW/RSW to ice often lose their quality much faster than those maintained on ice prior to processing. These fish appear more fragile, lose scales easier, and must be handled carefully and processed quickly.

Are quality changes in the fish associated with transfers between liquid and solid chilling systems? Are there bacteriological changes? Or do other factors, such as handling and sanitation, affect fish quality? This publication reports on an investigation of the quality changes in pink salmon when the fish are transferred between chilling systems (chilled seawater and ice).

The Experiment

Two hundred forty freshly caught pink salmon were held in ice or CSW totes aboard tenders and delivered within 12 hours. These fish were ocean-fresh and caught in the same area. At the dock, they were transferred into fresh ice and CSW and held for up to ten days at 32°F and 31°F, respectively.

Three days after catch, one hundred iced salmon were transferred to a fresh CSW system and one hundred CSW-held salmon were transferred to fresh ice. These fish were then held for seven days.

At periods of 1, 2, 3, 4, 6, 8, and 10 days after catch, salmon were removed from each system for evaluation. Fish were examined

for visual changes, microbiological growth, salt uptake, and weight and texture changes. After examination, fish were dressed, plate frozen at -40°F and held in 0°F storage for three to six months prior to taste panel evaluation, chemical analysis, and texture change determination.

Results and Discussion

Visual Changes

On each sampling day, ten salmon were graded as excellent, good, fair, or poor according to specific criteria (Appendix). As expected, significant changes occurred throughout the ten-day storage period (Table 1). Initial quality for both the iced and CSW fish was graded excellent to good, with firm flesh, bright skin, and fresh odor. Some fish showed slight flesh softness.

Iced salmon retained excellent quality during the first three days. Noticeable changes started to occur at day four, with 40% of the salmon judged good to fair. At day six, only 20% of the fish were still in excellent condition. By day 10, iced salmon were rated fair to poor, with 50% of the fish showing significant decomposition.

CSW-held salmon deteriorated faster than the iced fish. By day three, fish were graded mostly good to fair. At day four, all salmon were in fair condition, showing strong slime odor and moderate softness. By day eight, 80% of the fish were in poor condition, and at the tenth day of holding, all salmon were judged to be of poor quality with significant spoilage.

Salmon transferred from CSW to ice maintained better condition than the fish held exclusively in CSW. At day four, 40% of the fish were still judged in good condition, with neutral odor and slight flesh softening. By day six, or three days after the transfer, significant decomposition developed.

Table 1. Visual Quality* of Pink Salmon Held in CSW and Ice

Storage Time (days)	Storage Conditions			
	CSW	Ice	CSW to Ice	Ice to CSW
1	E (80%) G (20%)	E (90%) G (10%)	--	--
2	E (60%) G (40%)	E (90%) G (10%)	--	--
3	G (70%) F (30%)	E (80%) G (20%)	--	--
4	F (100%)	E (60%) G (30%) F (10%)	G (40%) F (60%)	E (20%) G (60%) F (20%)
6	F (70%) P (30%)	E (20%) G (60%) F (20%)	F (100%)	G (70%) F (30%)
8	F (20%) P (80%)	G (40%) F (60%)	F (40%) P (60%)	G (20%) F (50%) P (30%)
10	P (100%)	F (50%) P (50%)	F (20%) P (80%)	F (40%) P (60%)

* See Appendix for descriptions of grading criteria.
E = Excellent G = Good F = Fair P = Poor

Fish transferred from ice to CSW deteriorated faster than the iced salmon but slower than the fish held exclusively in CSW. At day six, most of the salmon (70%) were in good condition. However, rapid quality loss was experienced between days eight and ten. At day eight, only 20% of the fish were judged good. By day ten, 60% of the salmon were in poor condition, with dark roe and noticeable decomposition.

Microbiological Changes

Bacterial levels in seawater and salmon were monitored for each system (Table 2). During each sampling day, CSW, ice, and swab samples from the salmon were collected for aerobic plate counts and identification. Pink salmon held in ice had the highest microbial counts reaching 3,000,000 bacteria per cm^2 after ten days storage. By contrast, the CSW-held fish had only 59,000 bacteria per cm^2. This large difference was due in part to the initial bacterial loads of iced fish being almost seventy times greater than CSW fish. This difference was a result of initial holding conditions on the tenders. Therefore, CSW-held salmon maintained lower bacterial levels throughout the storage period. Similarly, bacterial counts were also lower for the CSW chilling system during the ten days of storage when compared to the counts for ice.

Fish transferred from ice to CSW resulted in an initial reduction in bacterial counts. Some of the adhering bacteria apparently had sloughed off after contact with fresh CSW. Thus, the transfer of three-day iced salmon resulted in an initial bacterial count of 100,000 per gram for the CSW chilling system. After the bacteria had acclimated to this new environment the counts on the salmon reached 210,000 per cm^2 at ten days of storage.

Table 2. Aerobic Plate Counts of Pink Salmon Held in Ice and CSW

Storage Time (days)	CSW	Ice	CSW to Ice	Ice to CSW
		Bacteria per cm^2		
Salmon:				
1	480	35,000	--	--
2	70	6,300	--	--
3	450	18,000	150	400
4	1,200	130,000	2,400	3,800
6	800	190,000	2,200	11,000
8	5,900	1,900,000	14,000	20,000
10	59,000	3,000,000	240,000	210,000
Chilling System:		Bacteria per gram		
1	1,700	460,000	--	--
2	6,000	1,400,000	--	--
3	13,000	220,000	100	100,000
4	16,000	570,000	9,700	120,000
6	39,000	1,200,000	15,000	510,000
8	130,000	6,800,000	43,000	640,000
10	110,000	39,000,000	180,000	540,000

Table 3. Bacteria Found on Salmon Held in CSW and Ice

Storage Time and bacteria	% of Bacterial Flora			
	CSW	Ice	CSW to Ice	Ice to CSW
Day 1				
Moraxella	43	85	--	--
Pseudomonas	4	6	--	--
Flavobacterium	26	7	--	--
Other bacteria	27	2	--	--
Day 4				
Moraxella	15	76	8	59
Pseudomonas	20	0	26	11
Flavobacterium	40	22	23	5
Acinetobacter	25	2	36	9
Other bacteria	0	0	7	16
Day 8				
Moraxella	19	66	63	29
Pseudomonas	73	0	25	65
Flavobacterium	8	32	9	6
Other bacteria	0	2	3	0

Fish transferred from CSW to fresh ice resulted in bacterial counts intermediate between those for CSW-held and iced salmon. Ice, containing the three-day CSW-held salmon, had 180,000 bacteria per gram by ten days of storage.

While the bacterial levels found in the iced fish were much higher than those found in CSW, the iced fish maintained better quality. This was due to the type of bacteria present in each system. Identification of the bacteria revealed some interesting differences between chilling systems (Table 3). *Moraxella* species dominated in pink salmon stored in ice or transferred from CSW. These

Table 4. Salt Content (in %) of Pink Salmon Held in Ice and CSW

Storage Time (days)	CSW	Ice	CSW to Ice	Ice to CSW
1	0.23	0.11	--	--
2	0.37	0.11	--	--
3	0.39	0.11	--	--
4	0.47	0.11	0.39	0.26
6	0.52	0.12	0.34	0.29
8	0.51	0.13	0.36	0.30
10	0.48	0.12	0.33	0.35

bacteria are not food spoilage organisms. The *Pseudomonas* species that predominated in the CSW systems is a potent spoiler of food and produces objectionable odors and flavors that taint the salmon during storage.

Salt Uptake

One of the concerns with CSW during extended storage is the potential for increased salt content in the flesh. Levels greater than one percent are undesirable because salt accelerates the development of rancidity and may affect the flavor during frozen storage. None of the treatments in this experiment resulted in salt content more than one percent (Table 4). As expected, the salmon either stored in or transferred to CSW had higher salt contents than the iced fish. Salt levels of fish held in CSW doubled from 0.23% to 0.52% during the storage period. Salt content of fish transferred from CSW to ice was slightly reduced, presumably due to the leaching by melting ice. Salt levels of salmon held in ice did not change, remaining between 0.11% and 0.13%.

These salt levels compare favorably with values from other investigations. For cod stored in CSW, Tertnes, et al. (1984) recorded values as high as 0.7% salt after six days. Tomlinson, et al. (1974) reported salt contents of 0.56% in sockeye salmon held in RSW and 0.14% for salmon held in ice for eight days.

Weight Changes

Another drawback of chilled storage is the weight change sometimes experienced during long holding periods. In this experiment, ten salmon in each system were tagged and weighed at each sampling period to determine the extent of the changes (Figure 1). Weight gains occurred in all systems. Weight gain of salmon held in ice was about one percent while CSW-held fish increased almost five percent during the storage period. These weight gains are from water absorption in the flesh and result in salmon that are more fragile and difficult to handle.

Fish transferred from ice to CSW experienced weight increase similar to CSW-held fish, gaining almost four percent. Salmon transferred from CSW to ice gained weight in CSW and then lost weight when placed in ice.

Texture Changes

The texture of fresh and thawed frozen salmon was determined using an Instron Universal Testing Machine. This machine, specifically designed to measure food texture, recorded the force needed for a four blade shear to cut through a sample. The greater the force needed to cut the fish, the firmer the sample.

Results from fresh salmon (Figure 2) showed very little texture difference between treatments. CSW-held fish were slightly softer

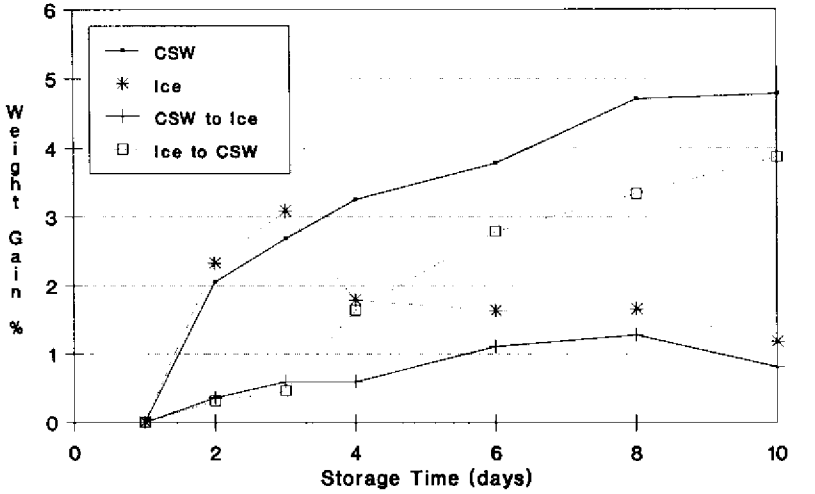

Figure 1. Weight gain of pink salmon held in ice and CSW.

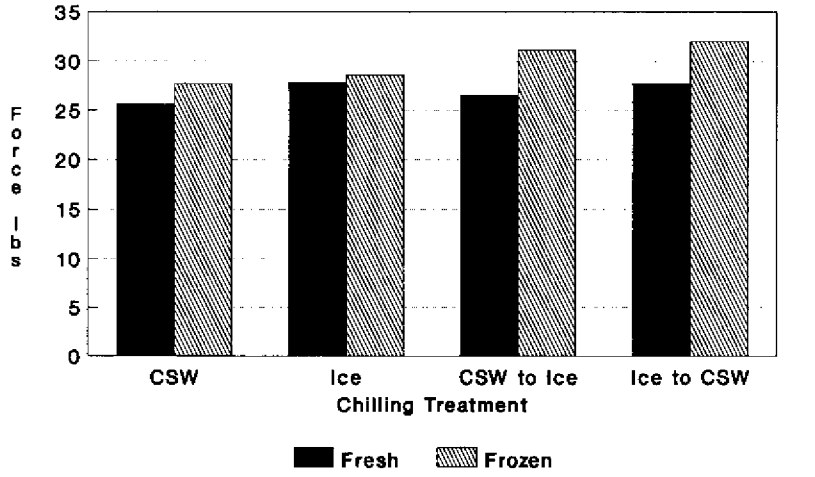

Figure 2. Texture changes of pink salmon held in ice and CSW. Values are the average firmness over the ten-day storage period.

than those stored in ice, but not significantly. Transferring salmon from CSW to ice and from ice to CSW did not affect overall flesh texture.

Texture of the salmon held in frozen storage for six months at 0°F (Figure 2) showed significant differences among the treatments. After six months of frozen storage, iced and CSW-held fish had very similar textures, slightly firmer than the fresh samples. Those fish that were transferred from one chilling system to another showed a large increase in firmness. The fish transferred from ice to CSW had toughened considerably. Handling during transfer may have had an adverse effect on flesh texture in frozen storage.

Another measurement of texture changes that occurred was the amount of expressible moisture in the fresh salmon. Expressible moisture is the water that can be forced from a sample by applying pressure. It was measured by placing a fish sample under an 11-pound weight for two minutes and collecting free water in weighed filter paper. It was expected that as the flesh softened during storage, more moisture could be squeezed from the flesh. The results (Figure 3) showed that expressible moisture increased noticeably in the CSW-held salmon and those transferred from CSW to ice. There was no difference in fish held in ice. The fish transferred from ice to CSW showed a slight decrease in expressible moisture.

Biochemical Indices of Quality

A standard measure of fish quality is the nucleotide levels found in the flesh. Nucleotides are biochemicals essential to the living fish. Once the fish dies, these chemicals degrade as part of the process that leads to less desirable quality. Measuring one of these compounds, hypoxanthine, provides a relative gauge of fish quality.

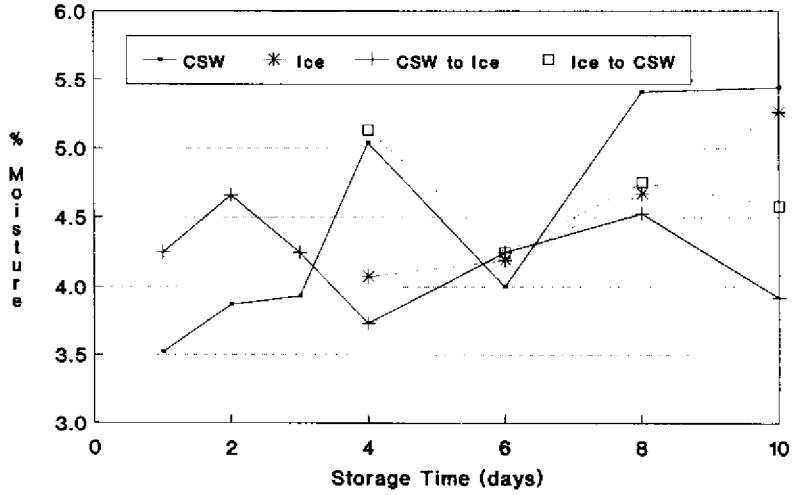

Figure 3. Expressible moisture from pink salmon held in ice and CSW.

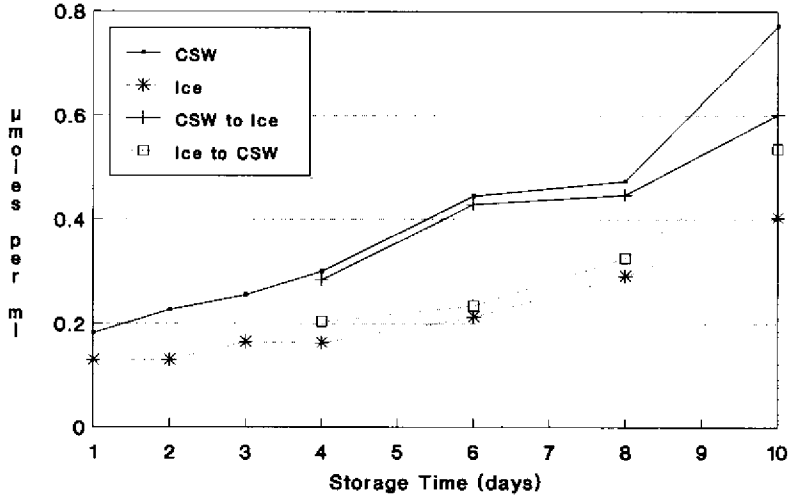

Figure 4. Hypoxanthine levels in pink salmon held in ice and CSW.

Table 5. Flavor Scores of Pink Salmon Held in Ice and CSW

Storage Time (days)	CSW	Ice	CSW to Ice	Ice to CSW
2	5.45	5.36	--	--
3	5.82	5.63	--	--
4	5.00	4.91	5.73	4.55
6	3.33	4.75	4.50	4.75
8	1.45	4.27	4.09	4.64
10	*	4.82	4.09	3.27

* 10 Day CSW was spoiled.
Higher scores indicate more desirable samples.
Scores: 1 = Bad Flavor, 7 = Excellent Flavor.

Hypoxanthine levels were monitored and, as expected, increased in all chilling systems over the storage period (Figure 4). Salmon held in CSW developed higher levels of hypoxanthine than those held the other chilling systems. The amounts of hypoxanthine increased four-fold in CSW-held fish and in salmon held on ice. Fish that were transferred between chilling systems experienced three-fold increases.

Based on hypoxanthine levels, holding fish in CSW resulted in the fastest quality deterioration while iced fish experienced the slowest rate. Salmon transferred into ice or CSW had rates of quality loss intermediate between CSW-held and iced salmon.

Taste Panel Results of Frozen Fish

Salmon were held in frozen storage at 0°F for three months before taste panel evaluation of moistness, flavor, and overall desirability.

Results showed that flavor and desirability scores changed with storage time and chilling system.

The best flavor was found in salmon held less than four days. Salmon held more than six days suffered a noticeable decrease in flavor. Significant flavor loss (Table 5) occurred in the CSW-held fish and those transferred from CSW to ice and ice to CSW. Fish held in ice maintained acceptable flavor throughout the storage period; no significant changes occurred.

Among the chilling treatments, CSW-held salmon deteriorated fastest, followed by fish transferred from ice to CSW. Fish transferred from CSW to ice held up slightly better, and those stored in ice maintained the best flavor of all samples.

Conclusions

This experiment revealed several potential causes for quality loss when salmon are either held in CSW or transferred from CSW to ice. When compared to iced fish, salmon held in CSW experienced greater weight gain, higher salt levels, higher expressible moisture levels, and higher nucleotide levels. Greater weight gain meant more water was absorbed into the flesh, making the fish more fragile. Higher levels of hypoxanthine indicated faster deterioration of nucleotides and a more rapid quality loss. Although the bacterial counts were lowest for salmon held in CSW systems, the predominant bacteria were potent food spoilers belonging to the genus *Pseudomonas*. All these conditions resulted in salmon that were more susceptible to spoilage and handling damage. These changes occurred within four days after catch, a typical length for a tender trip.

Salmon transferred from CSW/RSW vessels to ice are much more fragile when compared to iced fish. Typical handling procedures could easily reduce quality much faster. From the experimental

results, it is probable that handling is a major influence in the rapid deterioration of these fish.

The recommendation from this experiment is to hold salmon less than four days in CSW/RSW systems. This is in agreement with other RSW/ice studies conducted with salmon. Tomlinson, et al. (1974) and Bronstein, et al. (1985) recommended salmon should be stored no longer than four days in RSW. The fish must also be handled carefully when transferred from the fishing vessels and tenders to iced totes. Iced storage remains the best method for maintaining fish quality.

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Appendix: Salmon Grading Criteria

	Excellent	Good	Fair	Poor
Odor	Fresh, seaweedy	No odor, neutral	Strong slime odor	Decomposing, acrid odor
Eyes	Bright, clear	Flat, slightly opaque	Opaque, slight reddening	Opaque, red, sunken
Skin	Bright, no bleaching	Slightly dull, wavy	Dull, some bleaching	Dull, bleached
Gills	Bright red, no odor	Pink, slight odor	Green-brown, strong slime odor	Brown-white, decomposed
Flesh	Firm	Slightly soft	Moderately soft	Severely soft
Gut	Firm, bright, no decomposition	Softening, no decomposition, slight discoloration	Slightly liquid, slight decomposition, darkening	Very liquid, noticeable decomposition dark

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