NOAA TECHNICAL MEMORANDUM
NMFS SEFC-92

Holding Southeast Groundfish (Croaker, Spot, and Weakfish) in Experimental Refrigerated and Chilled Sea Water Systems

Robert C. Ernst, Jr.

June 1982

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Center
Charleston Laboratory
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Malcolm Baldrige, Secretary
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John V. Byrne, Administrator
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ABSTRACT

Atlantic croaker (Micropogonias undulatus), spot (Leiostomus xanthurus), and weakfish (Cynoscion regalis) caught off North Carolina were transferred within 24 hours into experimental refrigerated and chilled sea water (RSW and CSW) systems and held for 15 days compared with icing. Fillets were evaluated every two or three days for salt uptake, pH, total volatile nitrogen (TVN), trimethylamine nitrogen (TMA-N), color, shear values, and sensory tests. Salt uptake was 0.6% in two days and 1.4 to 1.9% in 12 days for fish held in RSW but remained below 0.4% for 10 days in CSW because of sea water dilution by the melting ice. Initial TVN values were 14 to 17 mg N per 100 g and did not significantly increase except for iced fish samples after 13 days. TMA-N values initially at 2 mg N per 100 g did not increase significantly for 13 days. Iced weakfish (gray trout) values reached 10.6 by the 15th day. Spoilage rates appeared about equal for the three species but were affected by the holding method. Spoilage was indicated earlier by the appearance of the whole fish than by test results on the fillets. Results were anomalous but indicated little practical differences among holding methods for the first few days except for salt uptake which may be highly limiting for RSW. Careful consideration is recommended in the selection, design, application and operation f RSW or CSW systems to specific southeast food fish species. Special attention is advised regarding salt uptake, sanitation, low temperature requirements and the heavy chilling loads encountered in southern waters.

INTRODUCTION

Consumer demands and increased costs of harvesting have encouraged the seafood industry to seek more effective and economical handling and holding systems to preserve product quality and reduce costs. Industrial seafood processors (pet food, fish meal, bait, etc.) are also insisting on better quality raw materials which result in higher yields and more uniform products.

Less familiar, lower valued but abundant species of fish are often characterized by their shorter shelf life, stronger flavors, boniness and small size. Consequently, better care in handling and more rapid delivery to markets are necessary. Unfortunately, because of their lower demand and lower price these fish normally are neglected and preference in handling is given to the higher value species.

Traditionally, icing of fish in pens and boxes has been the best method of chilling and holding the catch for market. Rapidly lowering temperatures to as close to freezing as possible without freezing is still the most effective method of reducing and retarding spoilage in the holding of fresh, "wet" fish. Proper handling and holding of fish aboard vessels presents different problems to different fisheries, depending on rate of catching, sorting necessary, and types of handling, e.g. gutting, bleeding, etc. Handling relatively large catches, as in purse seining, presents problems of weight, volume and time that have not been satisfactorily solved by mechanized icing and boxing or other containerization.

Refrigerated sea water (RSW) or chilled sea water (CSW) systems have proven to be effective and economical methods of handling, chilling and holding many species of fish. A number of investigators have reported on different species: ocean perch (Cohen and Peters, 1962); salmon and tuna (Roach, et al., 1967); Danish herring (Hansen, et al., 1974); Atlantic herring (Hulme and Baker, 1977); Atlantic mackerel (Lemon and Regier, 1977); herring, mackerel, spot, capelin, and blue whiting (Kelman, 1977); and walleye pollock (Reppon, et al., 1979).

It has been recommended that several species not be held in RSW or else held for only short periods. Shaw and Botta (1975) recommended that male capelin (Mallotus villosus) caught off Newfoundland not be held in RSW because of softening of the flesh and resulting poor machine processability along with other deterioriative changes. Perigreen, et al., (1975) determined that oil sardines (Sardinella longiceps) held in RSW were inferior to those held on ice after two days of storage. Other investigators have emphasized limiting salt uptake by diluting the sea water, limiting time of holding and keeping the sea water to fish ratio as low as possible. These experiences emphasize the need for investigating the holding qualities of different species before investing in commercial holding systems.

RSW systems appear to have been developed primarily for holding large catches of fish used in the production of canned fish, fish meal and pet foods. They have been used for both low and high valued species. Roach, et al., (1967) reported on the use of RSW in the salmon and tuna industries. These systems greatly reduce damage of fish in bulk handling and holding and permit more rapid and thorough chilling of the catch.

Although some of the first sea water systems used ice for chilling the water (CSW), mechanical refrigeration (RSW) systems have received the most development attention and use. Interest in containerization of the catch has stimulated the further development of CSW systems (Eddie and Hopper, 1974; Kelman, 1977). CSW systems, which require no mechanical refrigeration equipment aboard the vessel, have proved expedient where ice is readily available on shore. Minimal capital investment is required for converting vessels for CSW systems. Space for refrigeration equipment is not required and chilling of the fish can be more rapid than with most RSW systems. Where RSW systems have been underdesigned or conditions changed, ice has been used to supplement the chilling capacity and rates of chilling (Hansen, 1981). CSW systems appear to offer advantages over RSW systems for the smaller vessels, but many considerations must be given to the selection, design, operation, and application of any system.

RSW systems have been used in the Southeast by the industrial fisheries for several decades but have not been used significantly by the food fish industry. Ease of cleaning and sanitation are paramount in food fish systems as well as adequate chilling capacity to obtain low enough temperatures in a reasonable time to retain maximum shelf life.

The need for information on RSW and CSW systems and their applicability to food fish species has been identified in fisheries development programs of the Southeast (Anon., 1980; Anderson, 1982). There has been no published information found on the keeping qualities of Southeast species in RSW or CSW even though the fish meal and pet food industries have used RSW systems for decades. Recent developments, the many design options available for applications, the lack of species specific application information, and the costly errors of misapplication make it necessary to develop more information before commercial applications can be expected.

Utilization of effective RSW and/or CSW systems in the food fish industry is a vital link in the production chain of utilization of available fishery resources. This will permit better quality maintainence at lower cost with concomitant productivity of a variety of quality products leading to increased employment and increased economic stabiltiy of the community.

The objectives of this study were to determine the quality changes of croaker (Micropogonias undulatus), spot (Leiostomus xanthurus) and weakfish (Cynoscion regalis) held in experimental RSW, CSW systems and in ice. These fish were selected as most representative of bottom fish associated with the shrimp by-catch. Since the popular common trade terminology for the weakfish has been gray seatrout, or gray trout, the term trout is generally used thr ughout this report. Results of this study should reduce the risks of applying these methods of holding to these species of fish and better guide users in their applications.

EXPERIMENTAL

Equipment

RSW system — The experimental RSW unit used in this study was designed as an "upward-flow" system and constructed for laboratory and portable shipboard use. The rectangular tank was fabricated of double wall fiberglass filled with 50 mm (two in.) of urethane foam insulation. Total inside dimensions were approximately 74 cm (29 in.) wide, 76 cm (30 in.) high and 122 cm (48 in.) long. The cover was of similar construction hinged in two sections for ease of access. A 61 cm (24 in.) high partition separated the tank into two compartments, one for holding fish and the other for holding the chilling coils. Outlets in the bottom of each section were connected with polyvinyl chloride (PVC) pipe, valves, and a circulating pump permitting flexibility of flow configuration. Nominal operating volumes of the two sections were 3.4 and 2 cu. M (12 and 7 cubic feet). The larger section was used as the fish hold; the smaller section served as the water cooling section. The coils were made in four sections from 61 m (200 feet) of 1/2-inch (13 mm) copper refrigeration tubing. Space between the tubing coils and tank walls permitted the building of ice on the coils or the addition of supplemental ice. This arrangement increased the chilling capacity when loading warm fish or served as reserve chilling when the compressor was off.

The condensing unit consisted of the compressor, a water cooled condenser and a receiving tank. A hot gas by-pass was provided for additional control. The basic unit was a Carrier-Transicold[2/] marine, water cooled condensing unit, Model 07KM002. Its capacity was approximately 4100 J/s (14,000 BTU/hr.) at a saturated suction temperature of -7°C (20°F) but 8800 J/s (30,000 BTU/hr.) at a saturated suction temperature of 7°C (45°F). Freon 22 was the refrigerant.

The circulating pump was a Teel pump (Model 1 P677) with a capacity of about 23 l/min. (6 gallons per minute). This provided a circulation rate of 12 changes of water per hour in the fish holding section when holding fish at a density of 721 kg/cu M (45 pounds of fish per cubic foot of tank volume).

A Kaye Instrument Co. Digistrip II Data Logger with copper-constantan thermocouples was used to monitor temperature of the water and the fish during the experimental runs.

CSW System — A Rubbermaid VersaVat (20 cu. ft. model) with a plywood and styrofoam cover was used. The VersaVat is a commercial, foam-filled plastic vat often used in the meat processing industry. The vat was fitted with a PVC pipe air distributer for mixing the sea water, ice and fish. A Speedaire portable air compressor (Model 2Z628, Dayton Electric Co.) was used to supply air for mixing. Although the previously described RSW system was designed so it could be used as either an RSW or CSW system, the use of this vat permitted simultaneous holding of fish in RSW and CSW for comparative purposes.

Icing — An additional Versa Vat was used to hold iced fish which served as control samples. A drain in the bottom of the vat permitted release of melt water.

2/ The use of trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Procedures

<u>Fish Holding</u> — Three species of underutilized bottomfish were used: croaker, spot and gray trout. The fish were caught off North Carolina, iced and delivered to the laboratory within 24 hours. The fish were small, averaging 142, 121, and 169 g per fish (320, 374, and 269 count per 100 pounds) respectively for the croaker, spot and trout. The whole fish were evaluated for freshness, immediately put into the experimental holding tanks and thermocouples placed in several fish and the medias to monitor temperature during storage. Samples of fillets from the fresh fish were prepared immediately for analyses and as reference samples for sensory evaluations. The three species were held as a mixed catch in RSW, CSW, and ice. Iced fish served as the control. The fish were held a total of 15 days from time of harvest. A 4.5 kg (10 lb.) net bag of each species of fish was accurately weighed and immersed in the RSW tank and in the CSW tank for periodic weighing to determine weight gain or loss.

Seventy-seven kg (170 lbs.) of each of the three species were held in the holding compartment of the RSW tank. The packing density was 721 kg per cu. M (45 pounds of fish per cubic foot) for a fish to water ratio of 2.4:1. Including the additional water in the chilling section of the RSW system, the verall fish to water ratio was approximately 1:1. The fish were introduced into prechilled sea water, and the unit operated with the chilled water flowing up through the bed of fish and down through the water chilling section. Since the RSW system had been designed to initially chill fish, there was no capacity problem keeping these prechilled fish at a low, consistent temperature throughout the holding tank. The temperature of the water was contr lled at $-1^{o}C$ and the water circulated continuously throughout the study.

Seventy-seven kg (170 pounds) of each species of fish (510 pounds total) were initially loaded into the CSW mixture consisting of 77 kg (170 lbs.) each of sea water and ice. This was a seawater:ice:fish ratio of 1:1:3. Air mixing was used one or more times a day to overcome temperature stratification due to lack of continuous water circulation.

Seventy-seven kg (170 pounds) of each species of fish were layered in ice in an insulated tank. Melt water was not allowed to accumulate. The initial ice to fish ratio was approximately 1:1, but ice was added as needed to keep the fish thoroughly iced. Temperatures within the fish held steady at 0°C during the period of testing.

Pr duct Quality Evaluation -- The fish were received within 24 hours of harvesting and icing, transferred to the three holding systems and samples taken immediately for product quality assessment. Standard reference samples for sensory tests were prepared by freezing and holding fillets at -40°C until tested. Whole fish of each species from each holding system were removed periodically for testing. Samples for physical, sensory, and chemical analyses were prepared by filleting and skinning. Fillets for chemical analyses were ground in a meat grinder three times to obtain a homogenous mixture. Whole, skinned fillets were used for physical and sensory tests.

Shear force values (an indication of texture) were obtained on 150 g portions of raw fillets at a product temperature of 6°C using the Food Technology Corporation, TP-2 Texture-press equipped with a CS-2 thin blade, shear compression cell. Fillets were always arranged in the test cell in the same direction in order to measure shear force across the fillet rather than through the weaker longitudinal plane. Peak shear values are expressed in pounds of force and are reported as averages of three samples.

Color measurements of the fillets were made on a Hunterlab, Model D25, color and color difference meter. Fillets were laid side by side, partly overlapping, on a dish with the inside of the fillet exposed. Four measurements were made on each plate of samples and the results averaged. Color was expressed in L, a, b-units.

Chemical analyses for protein, moisture, ash, pH and salt were conducted following standard AOAC methods for fish and fish products (AOAC, 1975). The lipid content was measured according to the Bligh-Dyer method as modified by Smith, et al., (1964). Total volatile nitrogen (TVN) and trimethylamine-nitrogen (TMA-N) were determined as described by Cobb, et al., (1973). Values are reported as an average of three analyses.

Whole fish were evaluated for freshness by a 3-member sensory panel on a scale of 1 to 8; 1 = excellent quality, 8 = spoiled. Raw and cooked fillets were evaluated by an 8-member trained sensory panel. Raw fillets were evaluated for color and odor. Cooked fillets were evaluated for odor, flavor, firmness, saltiness, and overall freshness. Cooked samples were prepared by heating 2 ounce portions in a microwave oven for approximately 40 seconds and the portions served to the panel for evaluation. Panel scores were recorded on a 200 mm open scale as follows: color - 0 = light, 200 = dark; spoiled off-flav r - 0 = none, 200 = strong; firmness - 0 = mushy, 200 = tough; saltiness - 0 = none, 200 = strong; overall freshness - 0 = spoiled, 200 = very fresh. A standard reference sample, previously frozen fresh and held at -40°C, was served simultaneously with the stored samples for comparison.

RESULTS AND DISCUSSION

Fish held in the RSW system were maintained at approximately -1°C. Temperature control was not as close as desired but was reasonable (plus or minus

$1^{\circ}C$). Ice build-up on the cooling coils allowed the compressor to be shut down and the melting ice to maintain the temperature. Withdrawing of samples of fish from the holding tank gradually reduced the fish to sea water ratio and required some addition of sea water in order to maintain an operating water level. Operation was satisfactory, and the fish generally appeared in better condition than those in the CSW or ice.

Fish held in the CSW system were maintained about $-0.5^{\circ}C$ although the water varied plus or minus $1^{\circ}C$. Control of the temperature in this system is only a matter of preventing temperature stratification by occasional mixing with air and the maintainence of sufficient ice. Since ambient air temperatures were often above $32^{\circ}C$ ($90^{\circ}F$) and the units were not always shaded, additional ice was required every few days. The sea water was considerably diluted over the period of holding. This emphasized the need to increase the ice in the seawater:ice:fish ratio for chilling and holding fish in CSW systems in southern climates. A considerable amount of ice is required to maintain low temperatures.

Results verified that 15 days is far too long to reasonably hold these species. Appreciable foaming is usual with air mixed CSW systems and was regularly experienced during mixing. Limited tests with a silicone antifoaming agent indicated effective control was possible.

Croaker -- Results of the chemical analyses of croaker held on ice (c ntrol), in RSW and CSW are shown in Table 1. The moisture content of the croaker held on ice and in CSW increased slightly while the moisture content of those fish held in RSW remained more nearly constant. The lipid, protein and ash contents were determined only at the beginning and end of the study. These remained essentially constant except for reflecting changes due to moisture and salt. The salt content of the croaker held in RSW increased from 0.12% to 1.4% during the 14 days of holding. It did not reach the 1% level until after seven days. Salt content of croaker held in CSW increased to about 0.3% in seven days but was less than 0.5% for the entire study.

The pH of croaker held in all systems remained unchanged during storage indicating minimal protein degradation. The TVN content of the fish held in the three systems decreased slightly during the first ten days from an initial value of 17.6 mg N per 100 g and began increasing thereafter. Only the iced fish exceeded the initial values reaching 20.0. The decrease was possibly due to a leaching effect of the holding waters but the iced samples reflected a similar decrease. The TVN values of the RSW-held fish were slightly lower than for the iced or CSW-held fish. TMA-N values reflected a similar pattern and were generally low. TMA-N values of the iced and CSW-held fish increased significantly the last few days of the holding study rising from an original value of 2.0 to a value of 4.88 mg N per 100 g. It appears the higher salt concentration and slightly lower temperature in the RSW system may have retarded bacterial growth which is responsible for the formation of TMA-N from trimethylamine oxide (TMAO). This effect was indicated in all three species. TMA-N values of CSW-held fish were intermediate between values for the iced and RSW-held fish.

Results of physical measurements on skinned fillets from the croaker held in the three systems are presented in Table 2. The color data indicate there was little change in lightness or color of the fish flesh except for the b-values (yellowness) of the ice-held fish. This increased minimally but consistently with length of holding. Shear values increased the first few days and did not give significant indication of decline until very near the end of the study. Croaker held in RSW and CSW gained about 6% in weight. The major cause was apparently due to increased water content of the fish.

The freshness panel ratings of whole fish are presented in Table 7. Whole croaker from the iced, RSW and CSW systems were rated of borderline quality (4.0) after being held for 8, 10, and 10 days respectively. All were rated as very poor to slightly spoiled by the 15th day. However, the iced and CSW-held croaker appeared a little better (6.5) than the RSW-held croaker (7.0). The sensory panel scores for raw and cooked fillets are presented in Figure 1. The reference sample (fresh, frozen fillets held at -40°C) was served to the panel unidentified. The results are inconsistent but with relatively little differences until beyond ten days when the panel rated the reference samples the freshest. There appear to be little differences among the holding methods other than saltiness.

Spot — Results of the chemical analyses of iced, RSW- and CSW-held spot are shown in Table 3. Similar to croaker the moisture content of spot was lower in RSW but there was an increase in all three holding systems. When proximate analyses are adjusted to constant moisture content there was little change in protein but lipid levels appeared to decrease. Changes in ash levels f RSW-held spot were commensurate with changes in salt content. Salt content of RSW-held spot increased from 0.1% to 0.6% in two days and to a maximum of 1.5% in 12 days. Salt content of CSW-held spot only increased to 0.2% in two days and to 0.5 in 12 days. Salt uptake in spot was similar to that of croaker.

The pH of spot was unaffected by the holding method and storage time. TVN values increased slightly at the beginning of storage, then levelled off except for the ice-held fish which increased substantially after 13 days of storage. The TMA-N content increased three-fold from beginning to end of storage for ice-held fish. RSW-held fish increased about two-fold. These results further indicate that the presence of salt in the CSW and RSW systems retarded bacterial growth during storage.

Results of physical measurements for spot held in ice, RSW, and CSW are shown in Table 4. The color values show that lightness (L-value) of the flesh decreased slightly for ice- and RSW-held fish during storage but increased slightly for the CSW-held fish. The a-values (redness) decreased substantially for fish held in all systems indicating oxidation of the color pigments during storage. The b-values (yellowness) for ice- and RSW-held fish decreased minimally and increased slightly for CSW-held fish. The changes in L- and b-values are minimal but changes in the a-values are important and probably could be minimized with the use of antioxidants.

The shear values remained fairly constant during storage for all holding systems. The results indicate that RSW- and CSW-holding had little affect on texture of the flesh compared with icing. Values for the cumulative weight change show an increase for RSW-held fish. Values for CSW-held fish increased to a maximum at mid-storage time then decreased.

The freshness evaluation panel rated whole, iced (control), RSW-, and CSW-held spot as fair quality (4.0) on the 8th, 10th, and 9th day of storage, respectively (Table 7). They were rated 7.0, 6.5 and 6.5 on the 15th day of storage. Sensory panel scores for raw and cooked fillets are shown in Figure 2. Scores varied among holding methods during storage. By the 15th day, iced fish were judged less acceptable than RSW- and CSW-held fish. Saltiness, scores most closely paralleled chemical values. Freshness scores for fillets from RSW-held fish were low on the 8th day of testing. This was contrary to the assessment of whole fish freshness.

Trout — Results of the chemical analyses for gray trout held in ice (control), RSW and CSW are shown in Table 5. The moisture content increased approximately 1 and 2.5 percentage points for ice- and CSW-held fish respectively during the storage period. Moisture content of the RSW-held trout did not increase. The lipid, protein and ash contents when adjusted for water and salt uptake do not reflect unusual changes. Salt content of the RSW-held tr ut increased from 0.1 to 0.6% in two days and to a maximum of 1.86 in 14 days. Salt content of CSW-held trout increased to 0.3% in two days to a maximum of 0.6% in 14 days.

The pH, TVN and TMA-N values all show little change during the first 8 to 10 days. By the 15th day the ice-held trout were indicating obvious deterioriation with higher pH, TVN and TMA-N values.

The physical measurements of gray trout held in ice, RSW, and CSW are shown in Table 6. The color values show that lightness (L-values) of the flesh varied little, however, some darkening did occur in the RSW-held fish. The a- and b-values varied some during storage. The increases in a-values (redness) reflect occurrences of red discoloration appearing in some specimens f the trout. The increased yellowness (b-values) was not visably apparent. Shear values did not change appreciably, although values for CSW-held fish increased minimally the first few days of storage then lowered to comparable values of the other holding systems. The percent cumulative weight increased and decreased during storage for CSW-held fish but was greatest for RSW-held fish at the end of storage.

The whole fish assessment panel rated ice-, RSW-, and CSW-held trout of fair quality (4.0) on the 8th, 10th, and 9th day of storage respectively (Table 7). The respective scores were 7.0, 7.0, and 6.5 at the end of storage. Sensory scores for raw and cooked fillets are shown in Figure 3. The results indicate that the major overall difference among storage methods was saltiness. The CSW-held fish were slightly more salty than the iced fish but were never considered even "moderately" salty. The RSW-held trout were judged more than "moderately" salty after two days of storage.

General — The proximate composition of fish reflects the characterization of the state of the living animal more than an indicator of deterioration of the dead animal. For example, during holding some protein is lost to the water, the ash content may increase due to salt uptake, and the moisture content may increase or decrease with uptake or loss of water. While these changes are not reliable indicators of product deterioration, proximate analyses can be supportive of the indicies used to assess quality and indicate some of the complex changes taking place in fish during storage. Reduction of proximate analyses to a constant moisture basis with allowance for salt uptake results in an indication of minimal changes in relative compositions.

Total volatile nitrogen determinations have been shown by a number of investigators to be a reasonable indicator of spoilage and protein breakdown (Cobb, et al., 1973; Townley and Lanier, 1981; Waters, 1978). Unfortunately, TVN values do not seem to reflect the same degree of deterioration with all species of fish or reflect the same degree of spoilage at consistent values. The values have often been found to decrease over the first few days of holding and then to increase dramatically when obvious spoilage begins to take place. The point to be made is that TVN values during the early days of holding fish may not give a good indication of the slow deterioration taking place but are more useful as a confirmation of significant spoilage as was the case in this study.

Trimethylamine-nitrogen is a measure of a specific component of the TVN and will always be less than TVN values. Generally, TMA-N values obtained in this study were higher for ice-held fish at end of storage as was indicated in overall freshness scores of cooked fillets. TMA-N formation is considered to be the result of bacterial enzyme action (Castell, et al., 1974) whereas other TVN components are a result of autolytic enzyme and other natural deteriorative breakdown reactions.

Color measurements were made to determine if storage methods affected appearence of the fillets. The cut side was selected for measurement because it was felt that translucency, variations in thickness of the fillets and residual skin tissues on the skin-side of the fillets would not result in consistent and meaningful color measurements of the flesh. The fillets from spot and croaker contained dark lateral striations of tissue predominately on the inside of the fillets. Surprisingly, the measured difference between the trout and croaker (or spot) appears less than one would expect from apparent visual differences. The trout was uniformly light.

The purpose of the shear tests was to evaluate softening or toughening of the fish tissues as may have been influenced by deteriorative changes and/or by method of holding. Earlier tests on fish had established the insignificant effect of reducing the sample size from 250 to 150 grams, consequently 150 gram samples were used. All fillets were loaded in the test cell in the same direction in order to measure shear force across the fillet rather than through the weaker longitudinal plane or an inconsistent mixture of angles. Earlier tests confirmed the direction of greatest force resistance to be across the fillets. No experimental defense is offered at this time other than selection of the direction producing the higher force reading and an argument of consistency. One difficulty encountered in shear tests was the occasional presence of bones. Attempts were made to remove all bones but obviously all were not detected and removed. The smallness of these fish and their natural structure made complete removal of the bones very difficult, particularly the pin bones. The presence of bones and ligament (connective) tissue seemed to cause the erratic shear test results.

CONCLUSIONS

The results obtained from this study of holding croaker, spot and gray trout in experimental RSW and CSW systems, although limited and varied, indicate reasonably similar results to the holding of the fish thoroughly iced except for the uptake of salt from the seawater. The fillets from these small fish (1/4 to 3/4 pound fish) originally contained about 0.15% salt. After holding the fish only two days in RSW the salt content was 0.6% but only 0.2 to 0.3% if the fish were held in CSW. Maximum levels of about 1.5 to 1.8% and 0.5 to 0.6% salt were obtained in 12 to 14 days by the fish held in RSW and CSW, respectively. While salt levels of 0.2 to 0.3% were generally considered slight by the taste panel and should be acceptable for most market uses, higher levels may not be acceptable to the fresh or frozen markets. Higher levels of salt could be acceptable for canning and some processing where brining or additional salt would be acceptable.

Considerable dilution of sea water will occur in CSW systems thus significantly reducing salt uptake. Since the quantities of ice which will melt in a CSW system will vary considerably with water, fish and ambient temperatures, salt concentrations will normally vary much more in CSW systems than RSW systems. Mixed systems such as addition of ice to RSW systems t supplement the refrigeration capacity would result in less predictably c ntrolled and more varied salt concentrations but less salt uptake than in RSW systems. Salt concentration of sea water in RSW systems will decrease significantly as the fish absorb salt from the sea water. Thus, the lower the seawater to fish ratio used in the system, the less and slower the salt uptake by the fish.

Chemical, physical and sensory tests were made on croaker, spot and gray trout held in RSW and CSW systems and thoroughly iced. The data while not all statistically analyzed, appeared to correlate reasonably well and indicated relatively little differences among holding methods except for salt uptake by the fish.

Many factors contribute to the uptake of salt by fish. Salt concentration in the media, time, and size of fish are probably the most important factors. Salt uptake is more rapid and can reach higher levels in RSW systems than CSW systems unless fresh water is used to dilute the sea water or other means found to reduce the salt uptake. RSW or CSW systems can be used to chill and hold croaker, spot, and gray trout but minimizing the time of holding is highly desirable. Time and temperature are major considerations in retarding the spoilage of fish.

It is recommended that careful consideration be given to the selection, operation, and application of RSW or CSW sytems to specific Southeast food fish species. Special attention should be given to salt uptake, sanitation, low temperatures required, and heavy chilling loads encountered in southern temperatures.

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Table 1. Results of chemical analyses of croaker held in ice, RSW and CSW systems.

Caught Age (days)	Holding Method	Moisture (%)	Lipid (%)	Protein (%)	Ash (%)	NaCl (%)	pH	TVN (mg N/ 100 g)	TMA-N (mg N/ 100 g)
1		75.7	4.39	20.0	1.18	0.12	6.42	17.6	2.00
3		76.1	-	-	-	0.14	6.34	18.5	2.51
6		75.1	-	-	-	-	6.36	13.0	1.91
8	Ice	77.7	-	-	-	-	6.42	15.8	1.81
10		76.6	-	-	-	-	6.48	12.3	1.48
13		78.8	-	-	-	-	6.53	12.7	3.03
15		78.1	3.01	18.1	1.04	0.19	6.48	20.0	4.88
1		75.7	4.39	20.0	1.18	0.12	6.42	17.6	2.00
3		76.6	-	-	-	0.56	6.28	16.2	1.76
6		74.9	-	-	-	0.67	6.21	12.2	2.00
8	RSW	75.5	-	-	-	0.86	6.32	14.2	1.85
10		77.3	-	-	-	1.6	6.26	10.8	1.48
13		76.3	-	-	-	1.4	6.30	12.0	3.00
15		75.1	4.27	19.2	2.04	1.4	6.24	11.0	2.93
1		75.7	4.39	20.0	1.18	0.12	6.42	17.6	2.00
3		76.6	-	-	-	0.22	6.34	17.0	1.54
6		75.8	-	-	-	0.26	6.33	12.7	1.69
8	CSW	78.2	-	-	-	0.28	6.42	16.2	2.98
10		78.5	-	-	-	0.32	6.46	12.7	1.33
13		78.1	-	-	-	0.43	6.40	13.6	2.76
15		78.2	3.49	16.3	1.02	0.46	6.42	15.2	4.57

Table 2. Results of physical measurements for croaker held in ice, RSW and CSW systems.

Caught Age (days)	Holding Method	Color Values			Shear Value (lbs.)	Cumulative Weight Changes (%)
		L	a	b		
1		45.3	5.1	6.3	241	-
3		46.2	4.1	6.5	344	-
6		46.3	4.0	6.2	285	-
8	Ice	46.9	5.6	6.4	335	-
10		46.6	3.6	7.0	352	-
13		46.2	6.3	7.5	330	-
15		46.1	4.2	7.3	351	-
1		45.3	5.1	6.3	241	0
3		47.3	4.2	7.2	373	2.80
6		46.7	3.5	6.6	355	4.56
8	RSW	45.2	4.4	6.7	340	-
10		46.8	3.8	6.5	355	4.17
13		45.4	4.5	6.2	314	5.88
15		43.6	4.9	6.6	278	5.79
1		45.3	5.1	6.3	241	0
3		47.2	3.6	6.3	332	4.64
6		47.8	4.0	7.1	311	7.75
8	CSW	50.5	3.6	7.1	293	-
10		47.5	4.1	6.3	340	-1.28
13		47.3	4.5	6.7	364	7.50
15		47.1	4.2	6.8	294	6.07

Table 3. Results of chemical analyses of Spot held in ice, RSW and CSW systems.

Caught Age (days)	Holding Method	Moisture (%)	Lipid (%)	Protein (%)	Ash (%)	NaCl (%)	pH	TVN (Mg N/ 100 g)	TMA-N (Mg N/ 100 g)
1		75.4	4.13	20.4	1.25	0.11	6.44	14.1	2.08
3		78.5	-	-	-	0.16	6.55	23.8	3.97
6		78.2	-	-	-	-	6.53	21.2	5.36
8	ICE	76.7	-	-	-	-	6.61	14.0	2.32
10		80.3	-	-	-	-	6.62	13.1	1.87
13		78.5	-	-	-	-	6.66	14.8	3.20
15		78.4	3.13	18.2	1.02	0.17	6.74	27.1	7.10
1		75.4	4.13	20.4	1.25	0.11	6.44	14.1	2.08
3		76.2	-	-	-	0.61	6.45	23.0	5.61
6		77.6	-	-	-	0.85	6.38	11.7	1.35
8	RSW	78.0	-	-	-	1.08	6.48	12.1	2.60
10		76.0	-	-	-	1.08	6.44	11.9	2.19
13		76.6	-	-	-	1.50	6.36	15.0	4.05
15		77.5	2.84	17.5	2.12	1.50	6.48	12.3	3.65
1		75.4	4.13	20.4	1.25	0.11	6.44	14.1	2.08
3		77.5	-	-	-	0.23	6.51	17.8	5.50
6		77.2	-	-	-	0.31	6.51	14.2	1.58
8	CSW	79.5	-	-	-	0.34	6.49	11.6	1.91
10		79.8	-	-	-	0.33	6.55	11.3	1.41
13		80.9	-	-	-	0.51	6.61	13.4	4.75
15		79.6	2.35	16.7	0.98	0.50	6.60	12.9	5.95

Table 4. Results of Physical Measurements for Spot Held in Ice, RSW and CSW Systems.

Caught age (days)	Holding method	Color values L	Color values a	Color values b	Shear values (lbs.)	Cumulative weight changes (%)
1		46.0	10.5	7.5	246	-
3		47.3	4.2	6.3	294	-
6		46.8	4.4	6.7	272	-
8	ICE	47.4	4.8	7.4	304	-
10		52.7	4.7	7.5	328	-
13		46.3	4.8	7.2	333	-
15		44.2	5.2	6.9	288	-
1		46.0	10.5	7.5	246	0
3		47.8	2.6	6.2	377	2.90
6		47.0	3.5	6.2	282	4.48
8	RSW	45.4	4.7	6.2	281	-
10		43.4	5.4	6.5	273	4.18
13		44.2	4.0	5.3	250	5.76
15		44.5	3.9	6.4	288	6.59
1		46.0	10.5	7.5	246	0
3		47.0	4.1	6.5	277	3.30
6		48.4	4.2	7.7	305	5.10
8	CSW	48.2	4.2	7.1	291	-
10		50.2	5.8	8.1	311	5.35
13		48.6	4.7	7.6	313	4.60
15		49.6	4.9	8.3	298	3.25

Table 5. Results of Chemical Analyses of Gray Trout Held in Ice, RSW and CSW Systems.

Caught age (days)	Holding method	Moisture (%)	Lipid (%)	Protein (%)	Ash (%)	NaCl (%)	pH	TVN (Mg N/ 100 g)	TMA-N (Mg N/ 100 g)
1		79.6	1.22	19.2	1.10	0.12	6.79	14.4	2.56
3		80.5	-	-	-	0.14	6.79	13.2	2.07
6		78.9	-	-	-	-	6.63	10.7	1.33
8	ICE	80.4	-	-	-	-	6.72	12.9	3.07
10		81.2	-	-	-	-	6.84	11.9	1.56
13		82.3	-	-	-	-	6.82	13.2	2.89
15		80.8	1.48	18.4	0.93	0.18	7.11	29.6	10.63
1		79.6	1.22	20.0	1.10	0.12	6.79	14.4	2.56
3		79.6	-	-	-	0.59	6.73	12.6	1.46
6		80.4	-	-	-	1.00	6.56	12.4	1.61
8	RSW	79.5	-	-	-	1.20	6.64	11.2	2.53
10		79.5	-	-	-	1.35	6.63	9.4	1.50
13		78.7	-	-	-	1.80	6.59	9.9	1.83
15		79.8	0.81	17.3	2.52	1.86	6.65	12.7	3.35
1		79.6	1.22	20.0	1.10	0.12	6.79	14.4	2.56
3		80.3	-	-	-	0.28	6.81	13.2	1.69
6	CSW	81.1	-	-	-	0.35	6.66	10.7	1.86
8		81.4	-	-	-	0.33	6.74	10.2	1.55
10		82.2	-	-	-	0.33	6.70	11.9	2.17
13		82.5	-	-	-	0.57	6.77	9.8	3.68
15		82.3	0.98	14.5	1.00	0.59	6.74	13.1	5.18

Table 6. Results of Physical Measurement for Gray Trout Held in Ice, RSW and CSW Systems

Caught age (days)	Holding method	Color Values			Shear values (lbs)	Cumulative weight changes (%)
		L	a	b		
1		48.9	2.5	4.7	184	-
3		50.4	1.7	5.0	185	-
6		50.5	1.6	5.0	212	-
8	ICE	50.5	2.0	6.1	252	-
10		50.1	2.8	6.0	237	-
13		50.7	2.4	6.5	256	-
15		50.0	1.2	6.5	237	-
1		48.9	2.5	4.7	184	0
3		47.3	1.9	4.7	227	3.32
6		46.2	1.5	4.5	245	5.01
8	RSW	-	-	-	178	-
10		51.0	0.9	5.0	224	4.21
13		46.7	2.2	4.8	212	6.79
15		43.7	2.5	4.7	196	6.79
1		48.9	2.5	4.7	184	0
3		51.5	2.3	5.5	286	4.60
6		47.5	2.1	5.3	298	8.59
8	CSW	51.9	0.7	5.4	220	-
10		49.5	1.9	4.9	265	8.54
13		52.4	3.2	6.8	204	5.31
15		50.2	2.1	6.4	272	4.93

Table 7. Whole Fish Sensory Ratings[1/]

Caught age (days)	Croaker			Spot			Trout		
	Iced	RSW	CSW	Iced	RSW	CSW	Iced	RSW	CSW
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
3	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
6	3.5	3.0	3.0	3.5	3.0	3.0	3.5	3.0	3.0
8	4.0	3.5	3.5	4.0	3.5	3.5	4.0	3.5	3.5
10	5.0	4.0	4.0	5.0	4.0	4.5	5.0	4.0	4.5
13	5.5	6.0	5.0	6.0	5.0	5.0	6.5	6.0	5.5
15	6.5	7.0	6.5	7.0	6.5	6.5	7.0	7.0	6.5

[1/] 1 = Excellent, 2 = very good, 3 = good, 4 = fair, 5 = poor, 6 = very poor, 7 = slightly spoiled, 8 = spoiled.

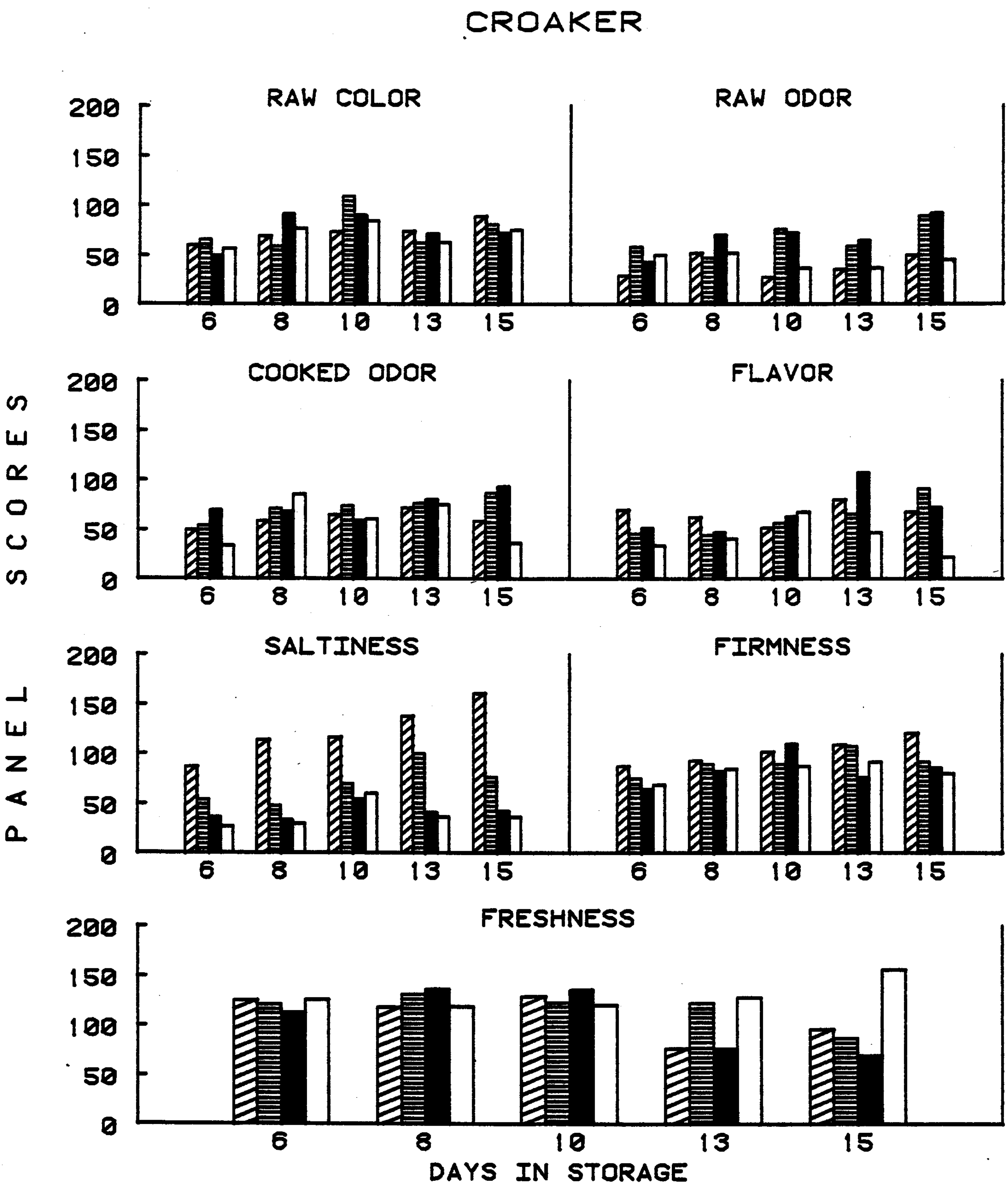

Figure 1. Sensory panel scores for raw and cooked croaker fillets held in RSW (hatched), CSW (striped), ice (solid) and for a reference (open) sample.

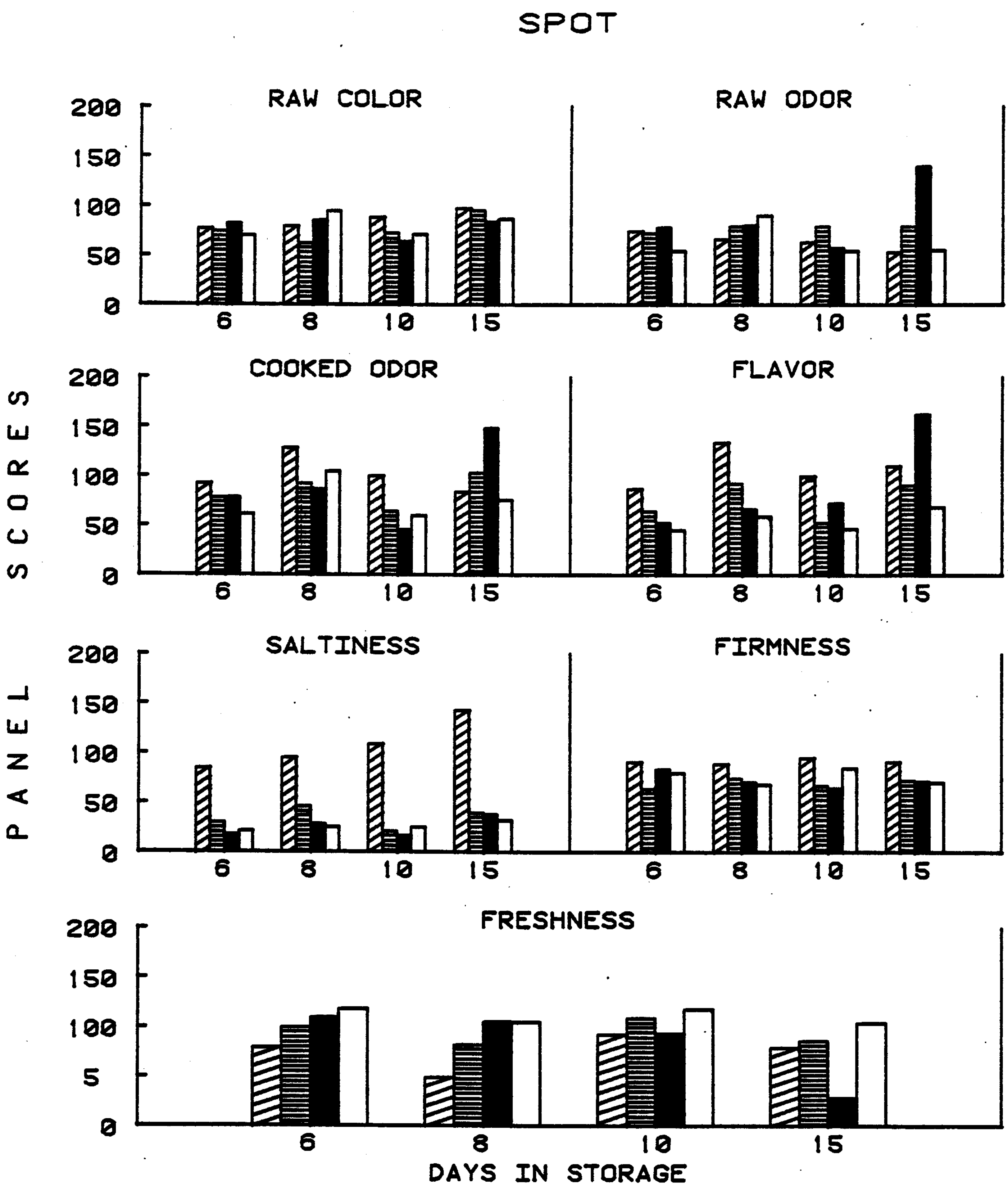

Figure 2. Sensory panel scores for raw and cooked spot fillets held in RSW (hatched), CSW (striped), ice (solid) and for a reference (open) sample.

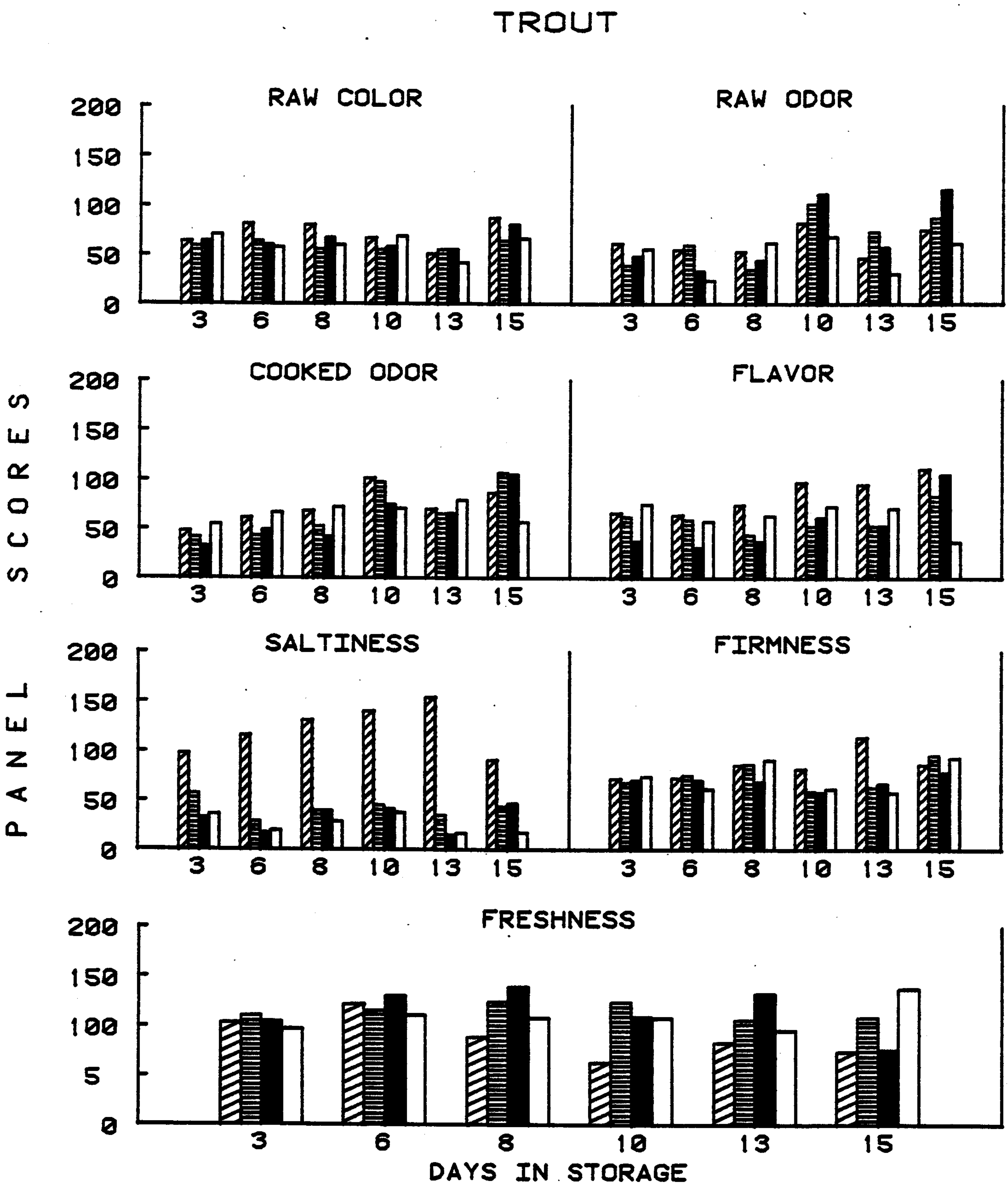

Figure 3. Sensory panel scores for raw and cooked gray trout fillets held in RSW [hatched], CSW [striped], ice [solid] and for a reference [open] sample.