BLACK ROCKFISH, *SEBASTES MELANOPS*: CHANGES IN PHYSICAL, CHEMICAL, AND SENSORY PROPERTIES WHEN HELD IN ICE AND IN CARBON DIOXIDE MODIFIED REFRIGERATED SEAWATER

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ABSTRACT

The purpose of this study was to determine changes in various properties of fillets, minced flesh, and washed minced flesh from black rockfish, *Sebastes melanops*, as affected by time of holding in ice or carbon dioxide modified refrigerated seawater and frozen storage at -18° C. Fish were held up to 14 days in the holding mediums and removed periodically and analyzed for changes in physical, chemical, and sensory properties. The yield of fillets calculated from the initial whole weight was unaffected by time of holding in either system. Subjective observations made during the holding periods indicated that fillets of good quality could be prepared from rockfish held for 10 days in either system. These observations were confirmed in a later series by sensory evaluation of cooked portions from the frozen blocks of fillets prepared at intervals during an 11-day holding period. The chemical analyses for trimethylamine, total volatile acid, and total volatile base were of no use to measure spoilage. Washing the minced flesh resulted in a reduction of solids, trimethylamine oxide, and salt and a reduction in yield when expressed on a salt-free constant, 18% solids basis. The extractable protein nitrogen of minced flesh decreased with time of frozen storage at -18° C and was strongly influenced by the length of holding period for the fresh whole fish.

Several papers have been published on the fresh or frozen characteristics of fillets or minced flesh from rockfishes. Different species of rockfishes gave products having different fresh acceptability and frozen storage life (Miyauchi and Stansby 1952). Stansby and Dassow (1949) found that the frozen storage quality of fillets from yellowtail rockfish, *Sebastes flavidus*, could be improved by removing part of the dark flesh along the lateral line. Barnett et al. (1971) compared yellowtail rockfish held in refrigerated seawater (RSW) and RSW modified with the addition of CO_2 (MRSW). The fresh storage life was extended 1 wk in MRSW over RSW. Teeny and Miyauchi (1972) increased the frozen life of minced flesh of yellowtail rockfish and silvergray rockfish, *S. brevispinis*, by using various additives. Additional improvements in storage life were obtained by washing the minced muscle of black, silvergray, and yellowtail rockfishes (Miyauchi et al. 1975.)

The objectives of this study were generally to characterize and compare the changes that occur in black rockfish with time of holding in ice and in MRSW, to determine sensory properties of fillets as affected by fresh holding time, and to determine the changes in amine content and extractable protein nitrogen with time of frozen storage of washed and unwashed minced flesh.

EXPERIMENTAL PROCEDURES

Sampling

Two groups of fish were used in this study. Lot 1 was used to determine physical and chemical properties and Lot 2 was used for formal sensory evaluation. The fish were caught over a 2-h period with hook and line, with or without bait. These fish are found locally on exposed, highly sloped rocky shores with strong currents where trawling gear cannot be used. A sporadic local fishery has employed the same fishing technique. Lot 1 fish (154 fish, 265 kg, 0.2 kg SD) were captured 2 July 1977 at the Triplets, 20 mi northwest of Kodiak, Alaska, and delivered to the laboratory about 2 h later. The fish were individually tagged and weighed before placing in the previously described ice and MRSW holding systems (Bullard and Collins 1978). The raw fish handling and sample preparation were similar to that previously reported for walleye pollock (Reppond et al. 1979), and are briefly described here. Fish were sampled according to weight classes to give an average of

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1.8 kg/fish for an 11-fish sample at holding periods of 0, 4, 6, 8, 10, 12, and 14 days. When removed from the holding systems, the fish were washed briefly to remove slime or ice, drained on a rack for 5 min, and individually weighed. The fish were filleted by hand and the fillets were rinsed briefly, drained on an inclined screen for 5 min, and weighed. Notes were made on the appearance of the round fish and the condition of the gills, viscera, and fillets. The fillets were ground using the coarse blade of an Oster[2] food grinder, and a portion was washed with cold water (1 part flesh: 2 parts water) for 15 min on a reciprocating shaker. The flesh was drained for 30 min on an inclined 16-mesh plastic screen then weighed. Composite portions of both washed and unwashed meats were frozen at -34° C for chemical tests. Other portions were sealed in polylaminated pouches and stored at -18° C for 2, 4, 6, and 9 mo.

Sensory

Lot 2 fish (184 fish, 258 kg) were used for formal sensory testing and were caught in the same location 1 mo later, on 26 August. These fish were held in ice and in MRSW in the same manner as Lot 1 and at 0, 3, 6, 8, and 11 days were filleted. The fillets were packed into blocks and held at -34° C for sensory evaluation several months later. The blocks were sawed into portions measuring 80 × 50 × 12 mm and thawed at room temperature. The control sample and samples from fish held in ice were salted by immersion in a 5% solution for 1.5 min to minimize differences in salt content with samples from fish held in MRSW. The portions were cooked in individual sealed aluminum pans at 232° C for 20 min in a commercial oven. Because of the difficulty in equalizing the salt content, samples from the two holding systems were not directly compared. The results of the sensory test were evaluated by analysis of variance. If analysis of variance indicated a change had occurred with time of holding, the Student-Newman-Keuls test was used to determine which samples were different.

Analyses

The frozen samples for chemical tests (Lot 1) were tempered overnight in a refrigerator at 3° C and ground twice using the fine blade of an Oster food grinder. Analyses were carried out for total nitrogen, total solids, chloride (Horwitz 1975: 15, 309, 310), total volatile acid (TVA, Friedemann and Brook 1938), total volatile base (TVB, Stansby et al. 1944), and extractable protein nitrogen (EPN, Dyer et al. 1950). Analyses for trimethylamine oxide (TMAO, Bystedt et al. 1959), nonprotein nitrogen (NPN, Nikkilä and Linko 1954), and trimethylamine (TMA, Tozawa et al. 1971) were carried out on a 5% trichloroacetic acid extract. An aliquot of the extract was neutralized and analyzed for dimethylamine (DMA) by Dowden's method (1938) modified by increasing the time of extraction to 15 min on a mechanical shaker.

RESULTS AND DISCUSSION

Physical Appearance and Yield

At each period of sampling, informal subjective observations were made on the whole fish and their raw fillets. We noted differences in gills, fins, and slime between the two holding systems. In ice, the gills were bright red to day 6 but discolored quickly in MRSW. Cloudiness of the eyes started at day 8 in ice but the eyes were white in a day or two in MRSW. The beginning of off-odors in the fillets, softening of flesh, and gut decompostion was observed in both holding systems at 10 days and worsened thereafter. At day 14, the odor of the fillets was objectionable and mincing intensified the odor. The quality of fillets from the fish held in MRSW were generally judged better than from fish held in ice for the same time. As noted later in this paper, neither formal sensory nor chemical tests detected the changes observed on the 10th day of holding in ice or MRSW. Chemical tests could not confirm the poor raw quality at 12 and 14 days which was so obvious that we would not serve these fillets to a taste panel. Consequently, we concluded that experienced observers could subjectively judge the various stages of raw quality, namely: good quality (0-8 days), onset of spoilage (10 days), and unacceptable quality (12 days).

Whole fish gained weight with time of holding in either system (Table 1). Fish held for 14 days in ice gained half as much weight as those held in MRSW, about 3% and 6%, respectively. The yield of fillets increased slightly with time of holding in ice but was constant with time of holding in MRSW. The average yield of fillets was slightly

[2]Reference to trade names here does not imply endorsement by the National Marine Fisheries Service, NOAA.

higher from fish held in ice than from fish held in MRSW, 31.7% and 30.5%, respectively. When yield data are converted to a salt-free, 18% solids basis however, equal yields of fillets were obtained in both systems (34%). The solids content of the fillets decreased slightly in ice but increased in MRSW because of the increase in salt content (Table 1). The absorption of salt from the MRSW system is not a problem because rockfish have thick flesh and skin.

TABLE 1.—Initial round weight and change in yield, salt, and total solids content of fillets and washed ground flesh from black rockfish (Lot 1) with time of holding in ice and in modified refrigerated seawater.

Time of holding (days)	Round wt[1] (kg)	Gain in wt (%)	Fillets			Washed ground flesh		
			Yield (%)	Salt (%)	Solids (%)	Yield[2] (%)	Salt (%)	Solids (%)
			Ice					
0	18.35	0.00	30.7	0.03	20.2	40.5	0.05	15.0
4	19.09	1.15	31.0	0.07	19.2	36.5	0.04	14.6
6	18.88	1.51	31.5	0.09	19.5	38.5	0.06	13.8
8	19.48	2.08	31.8	0.10	19.4	38.9	0.08	13.5
10	19.51	2.15	31.2	0.10	19.3	38.5	0.06	13.3
12	19.66	2.74	32.1	0.09	19.1	39.3	0.04	13.1
14	21.49	2.75	32.7	0.08	19.1	40.0	0.07	13.0
			Modified refrigerated seawater					
0	18.35	0.00	30.7	0.03	20.2	40.5	0.05	15.0
4	19.90	2.56	30.4	0.20	20.2	36.8	0.08	14.2
6	19.35	3.89	30.6	0.28	20.6	34.7	0.11	15.0
8	19.26	4.25	30.0	0.36	20.4	34.0	0.14	14.8
10	18.93	4.40	30.4	0.48	20.7	34.2	0.20	15.3
12	19.48	6.27	30.8	0.57	20.9	33.5	0.22	16.1
14	18.81	5.65	30.6	0.76	20.9	32.9	0.27	16.8

[1]Total round weight of fish that composed the sample.
[2]Yield of washed ground flesh if no portion had been reserved for analysis of fillets.

TABLE 2.—Change in mean sensory analysis scores ± standard deviations for baked portions of blocks of fillets from black rockfish (Lot 2) with time of holding in ice and in modified refrigerated seawater (MRSW). Panel had 12 judges. Flavor and texture scores were on the following scale: 5-Very good, 4-Good, 3-Fair, 2-Borderline, and 1-Poor. Preference scores were on a 9-point scale: 9-Like extremely, 8-Like very much, 7-Like moderately, 6-Like slightly, 5-Neither like nor dislike, 4-Dislike slightly, 3-Dislike moderately, 2-Dislike very much, and 1-Dislike extremely.

Time of holding (days)	Flavor		Texture		Preference	
	Ice	MRSW	Ice	MRSW	Ice	MRSW
0	3.5±0.7		4.1±0.6		6.3±1.4	
3	3.1±0.4	3.8±0.6	3.9±0.7	4.1±0.3	5.8±0.7	6.4±1.3
6	3.4±0.7	3.6±0.5	4.1±0.5	4.0±0.4	6.3±1.2	6.3±0.9
8	3.6±0.6	2.9±0.8	4.3±0.5	3.8±0.6	6.5±1.0	5.2±1.3
11	3.5±0.8	3.1±0.5	4.0±0.5	3.8±0.6	6.4±1.3	5.4±1.2

Sensory Evaluation

No significant ($P<0.05$) change in flavor, texture, or preference was noted between the zero time control and any sample from either holding system (Table 2). No significant differences in sensory scores occurred among the ice-held samples but the differences in flavor and preference scores between samples held 3 days and 8 days in MRSW were significant. However, these differences were probably circumstantial since neither the 3- nor 8-day MRSW sample differed from any of the other samples from that holding system.

The bland flavor of rockfish flesh was reflected in the preference scores which ranged from "like slightly" to "neither like nor dislike." The sensory data indicate that when held in ice or in MRSW this species of rockfish will maintain its acceptability during commercial holding periods of at least 8 to 10 days.

Chemical Analyses

The protein content of fillets (Table 3) was unaffected by time of holding but was slightly lower from fish held in ice than in MRSW. The nonprotein nitrogen content decreased slightly with time of holding in both holding systems.

Several chemical tests were performed to measure spoilage. TVA values increased from 0.07 at 8 days in ice to 0.10 meq/100 g at 10 days which may indicate a change in quality at 10 days. No change was noted in fillets from the MRSW system. TVB values were constant and low (about 4 mg N/100 g). As with walleye pollock, TVB data were not useful to indicate spoilage. TMA values increased

TABLE 3.—Change in analytical values of fillets from black rockfish (Lot 1) with time of holding in ice and in modified refrigerated seawater.

Time of holding (days)	Ice						Modified refrigerated seawater					
	Protein[1] (%)	NPN (%)	TVA (meq H^+/100g)	TVB (mgN/ 100 g)	TMA (mg N/ 100 g)	DMA (mg N/ 100 g)	Protein[1] (%)	NPN (%)	TVA (meq H+/100 g)	TVB (mg N/ 100 g	TMA (mg N/ 100 g)	DMA (mg N/ 100 g)
0	18.3	0.34	0.06	3.9	0.20	0.20	18.3	0.34	0.06	3.9	0.20	0.20
4	18.5	0.33	0.06	3.6	0.41	0.30	18.8	0.32	0.06	3.3	0.37	0.23
6	18.8	0.31	0.06	—	0.41	0.24	19.0	0.31	0.07	—	0.43	0.23
8	18.3	0.31	0.07	—	0.49	0.27	19.0	0.30	0.06	2.8	0.49	0.29
10	18.4	0.31	0.10	—	0.59	0.29	19.2	0.30	0.06	—	0.56	0.18
12	18.2	0.30	0.11	—	0.62	0.30	19.1	0.30	0.07	2.9	0.67	0.37
14	18.4	0.30	0.10	3.9	0.82	0.24	19.0	0.27	0.08	—	0.69	0.29

[1]6.25 N.

in an equal, gradual and linear manner with time of holding in both systems. DMA values did not change with time of holding or system (0.3 mg DMA-N/100 g).

Effects of Washing Minced Flesh

Washing the minced flesh of black rockfish resulted in a reduction in salt and solids content (Table 1), in slightly lower EPN values (Table 4), and a big drop in TMAO content (Table 5). Washing increased the apparent yield of minced fillets from 32 to 38% (ice) and from 32 to 33% (MRSW). When yield data of fillets and minced, washed flesh are placed on a comparable basis by converting to a salt-free, constant 18% solids basis however, the washing procedure reduced the yield in both systems from 34 to 28%.

Frozen Storage

A number of research papers have been published on the general subject of toughness of fish flesh and the relationship (or not) of free fatty acids, formaldehyde, and EPN (Mills 1975). The tough texture that develops in frozen fish is always accompanied by a decrease in EPN (Castell et al. 1973) but texture and EPN are not necessarily equated. It is generally accepted that reduced EPN occurs with increased fatty acid content and formaldehyde content (sometimes indirectly measured as DMA). The extractable protein nitrogen (Table 4) of minced flesh from ice-held fish decreased slightly at 2 and 4 mo of frozen storage, decreased to about 50% at 6 mo, and decreased to about 35% at 9 mo. The same general trend was observed with MRSW-held fish except EPN values

TABLE 4.—Change in extractable protein nitrogen content (percent) of minced flesh (unwashed and washed) from black rockfish (Lot 1) with time of holding in ice and in modified refrigerated seawater.

Time of holding (days)	Ice					Modified refrigerated seawater				
	Months of frozen storage at -18° C					Months of frozen storage at -18° C				
	0	2	4	6	9	0	2	4	6	9
	Minced flesh					Minced flesh				
0	85	87	70	60	32	85	87	70	60	32
4	83	83	68	64	42	85	—	73	70	31
6	80	72	78	46	42	80	63	64	59	24
8	87	74	73	54	37	86	53	73	42	26
10	78	70	77	53	34	78	56	65	38	30
12	82	69	72	33	35	73	56	60	49	24
14	86	73	64	48	27	74	48	39	26	22
	Washed minced flesh					Washed minced flesh				
0	90	79	63	56	30	90	79	63	56	30
4	77	79	75	59	33	78	61	58	57	32
6	83	76	74	62	29	75	65	63	42	28
8	81	69	70	38	34	79	71	60	28	26
10	77	75	62	49	34	83	45	54	27	19
12	83	77	66	31	26	67	44	44	23	21
14	74	70	63	42	26	68	40	47	23	15

TABLE 5.—Change in trimethylamine oxide content (milligrams TMAO-N/100 g) of minced flesh (unwashed and washed) from black rockfish (Lot 1) with time of holding in ice and in modified refrigerated seawater.

Time of holding (days)	Ice					Modified refrigerated seawater				
	Months of frozen storage at -18° C					Months of frozen storage at -18° C				
	0	2	4	6	9	0	2	4	6	9
	Minced flesh					Minced flesh				
0	136	100	68	69	74	136	100	68	69	74
4	130	97	56	66	70	145	98	70	67	69
6	128	96	66	65	66	140	93	68	63	66
8	129	92	66	60	64	127	86	63	66	62
10	125	86	64	60	66	126	85	63	58	62
12	143	84	64	60	66	121	83	62	58	59
14	143	86	63	63	61	120	83	59	61	56
	Washed minced flesh					Washed minced flesh				
0	36	—	37	36	39	36	—	37	36	39
4	30	—	29	28	29	27	—	30	25	27
6	28	—	26	28	26	24	—	25	23	23
8	25	—	26	25	26	25	—	26	24	26
10	26	—	27	24	26	24	—	25	23	24
12	24	—	26	26	24	22	—	25	26	23
14	22	—	25	25	23	20	—	23	22	22

were slightly lower. Although EPN did not change significantly with time of fresh holding in ice and only slightly in MRSW, the effect of the length of time of fresh holding on EPN became apparent in samples held at -18° C for 6 to 9 mo. If EPN is related to the texture of black rockfish, the data in Table 4 suggest that 6 mo of frozen storage at -18° C was too long for minced flesh at any level of fresh quality and that various periods of frozen storage would give acceptable texture depending on the level of fresh quality when frozen.

The TMAO content of the unwashed minced flesh was unaffected by time of holding in ice but decreased slightly in MRSW (Table 5). Although not expected to change with the frozen storage of this non-gadoid fish, amine data were obtained since no data on TMA and DMA and only one value for TMAO (93 mg N/100 g, Dyer 1952) have been reported in the literature for *S. melanops*. There was a strong reduction in TMAO content of the unwashed minced flesh with time of frozen storage to 4 mo with little change thereafter. TMA and DMA values were not affected by frozen storage (data not included in tables). Consequently, the substantial reduction in EPN was not caused by formaldehyde. We cannot explain either the observed loss of TMAO without a concomitant increase in either TMA or DMA content or the lack of change in TMAO content with time of frozen storage of the unwashed minced flesh.

SUMMARY

Black rockfish was held in the round in ice or MRSW to 14 days. The yield of fillets was not affected by time of holding but fish held in ice gave slightly higher yields than fish held in MRSW, 32 and 31%, respectively. The usual chemical spoilage tests (TMA, TVA, TVB) were of little or no use as indicators of spoilage. Observations of the beginning of off-odors, softness of flesh, and decomposition of viscera at 10 days were not confirmed by sensory evaluation of the cooked portions. For this species, early changes in quality were best judged subjectively on the raw, whole fish and fillets. Formal sensory evaluation was less sensitive than informal evaluation to change in quality, and chemical spoilage tests were not sensitive to obviously advanced spoilage. Washing the minced flesh resulted in a reduction in salt, solids, and TMAO content. The yield increased with washing because of increased water content but when calculated on a salt-free, constant 18% solids basis, the yield decreased in both systems to 28% when minced and washed. The EPN values of minced flesh from ice-held fish decreased during frozen storage at -18° C from about 80 to 35% after 9 mo and MRSW-held fish gave similar but slightly lower EPN values. The degree of fresh quality strongly influenced EPN values during frozen storage indicating that the time of holding in ice or MRSW should be considerably less than 10 days to maintain good quality for any reasonable period of frozen storage.

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