Chemical Composition and Frozen Storage Stability of Spot, *Leiostomus xanthurus*

MELVIN E. WATERS

ABSTRACT—Spot, Leiostomus xanthurus, *was harvested seasonally for a 12-month period to determine the chemical composition and frozen storage (–18°C) stability of the filleted and minced forms of flesh. One-pound blocks were prepared, frozen, and evaluated after 0, 3, 6, and 12 months of storage. The results indicated that maximum nutritional values and frozen storage stability are obtained from spot harvested from October to February. During this period, the protein content was at its maximum, the fat content decreased to a minimum, and the fatty acids were relatively stable. Amino acid values varied minimally throughout the harvesting period.*

Sensory scores showed that filleted spot were preferred over the minced form due to flavor, odor, and color but primarily to the color of the mince. The low level of acceptability of spot (any form) is due to its strong flavor and dark colored flesh. Thiobarbituric acid (TBA) values increased with an increase in fat content and during storage. TBA values were highest for the minced form, however, the sensory panel did not report rancid flavor or odor. Total volatile nitrogen (TVN) values indicated minimal proteolysis during frozen storage.

Introduction

Spot, *Leiostomus xanthurus,* is one of the more abundant finfish inhabiting coastal waters of the southeastern United States. They are bottom dwellers to depths of over 100 fathoms and range from Massachusetts Bay south to the Bay of Campeche (Dawson, 1958; Parker, 1971). In the mid- and south-Atlantic, the commercial fishery is centered in the Chesapeake Bay area and in the Carolinas, where the fish are harvested mainly for food.

Spot are harvested in the Carolinas by beach seine during September and October (Dawson, 1958). In the Gulf of Mexico they are harvested from inshore waters (out to 50 fathoms), principally by otter trawls in a mixed catch, as a directed fishery for petfood, and to a lesser extent as foodfish. Additionally, a large number of spot are harvested as a by-catch of the shrimp fishery and discarded at sea. Spot is estimated at 8 percent of the shrimp by-catch (Juhl et al.[1]).

In the northern Gulf of Mexico, spot, croaker, and seatrout are the most important finfish in both the commercial and spot fisheries and contribute to the major portion of the industrial bottomfish and foodfish catches (Gutherz et al., 1975). An accurate assessment of the MSY (maximum sustainable yield) of spot is not available but the potential is believed to be substantial. In 1979, the U.S. recreational catch totaled 2.1 million pounds (NMFS, 1981) and the 1980 commercial catch totaled 10.2 million pounds valued at $2.3 million (Thompson[2]).

The average marketable (foodfish) size of spot is about 227 g, ranging from about 113 to 454 g. Hildebrand and Cable (1930) reported a record size of 34.5 cm weighting 624 g and stated, "apparently spot grows larger in the more northern parts of its range than it does farther south and although a common species on the Texas Coast, spot does not attain a sufficiently large size there to be of much commercial value."

Spot is commonly regarded as an underutilized species because of its 1) small size, 2) limited acceptance as a food fish in the market place and 3) primary use in low valued animal food. Spot is generally available as fresh whole fish in retail markets along the mid- and south-Atlantic coasts during the harvesting season and as frozen-thawed fish during the off-season. The nutritional value of spot compares favorably with traditionally-consumed species. The flesh possesses a strong, distinctive fish flavor, is firm, and contains a considerable amount of dark meat along the lateral line, which contributes to the development of rancidity during frozen storage.

The low acceptance of spot in the market place is due primarily to its strong flavor, dark colored flesh and product form (whole) in which it is presented. Preparation of additional forms (headed and gutted, fillets, portions, etc.) have not been attempted because of the high labor costs involved in hand processing small fish. Mechanical processing of small fish in the southeastern United States for human consumption has been minimal in the past but may offer an opportunity to utilize the spot resource economically. Mechanical equipment is available commercially to process this species effectively.

Mechanically deboned fish (mince) has the potential of becoming a major

[1] Juhl, R., S. B. Drummond, E. J. Gutherz, C. M. Roithmayr, J. A. Benigno, and J. A. Butler. 1976. Oceanic resource surveys and assessment task. A status report presented to the technical coordinating committee of the Gulf States Marine Fisheries Commission, October 1976. On file at National Marine Fisheries Service, Mississippi Laboratories, Pascagoula Facility, Pascagoula, Miss.

[2] B. G. Thompson, National Marine Fisheries Service, NOAA, Office of Science and Environment, Washington, DC 20235. Pers. commun., 20 August 1981.

Melvin E. Waters is with the Charleston Laboratory, Southeast Fisheries Center, National Marine Fisheries Service, NOAA, Charleston, SC 29412-0607. This paper is contribution number 82-26C, Southeast Fisheries Center, National Marine Fisheries Service, NOAA, Charleston, SC 29412-0607.

source of high quality fish protein in the United States (Decker, et al.[3]). Minced croaker is currently being produced commercially as surimi in substantial quantities on the Alabama coast (Thrash[4]). Although croaker is the species of choice in the production of surimi because of its unique physical and chemical properties, species with similar characteristics, such as spot, may be substituted if the croaker resource decreases significantly. Substitution of spot for croaker in the production of surimi is speculation (similarities between species) and requires further research to determine its suitability. Additionally, spot may be used in the mince form in the preparation of fish cakes, fish sticks and portions, seafood stuffings, chowders, and many other products where integrity of the flesh is unimportant. Fillets packaged in small portions (454-908 g) could be used by consumers similarly to other species currently on the market; however, this marketing form is yet to be established.

The frozen storage stability of the various product forms of spot is little known and must be determined if this species is to be effectively used. Chemical composition has been reported by Sidwell (1981) only as a guide to the ranges of nutritional values, but seasonal data are unavailable. It is important to determine the chemical composition and storage characteristics of spot on a seasonal basis to provide the necessary information to produce and process fish of optimum nutritional value and storage stability. The objectives of this study were to: 1) Determine the chemical composition of spot on a seasonal basis for fish harvested from one location and 2) determine the storage stability of fillet and mince blocks held at − 18 °C for 12 months.

Materials and Methods

Sample Preparation

Fresh, iced spot were obtained during May, July, October, and November, 1979 and February 1980 from a commercial seafood dealer in North Carolina. In each sampling period, 150 pounds were obtained dockside, re-iced, and transported to the Charleston Laboratory for processing. The fish were caught off the coast of Morehead City, N.C., 36-48 hours prior to sample preparation. The fish ranged in size from 113 to 340 g and averaged about 227 g each.

Preparation of fillet and mince blocks began immediately upon arrival of the fish at the laboratory. The fish were washed, divided equally into two groups, and weights obtained for product yield. The first group was hand filleted and skinned; fillets were weighed, rinsed in ice water, and drained 5 minutes. The fillets were packed in 1-pound, wax-coated food cartons (7.5 × 21.5 × 3 cm). The second group was mechanically scaled, headed, gutted, and deboned, and the minced flesh weighed and packed in 1-pound, waxed food cartons. The fillet and mince blocks were frozen in a plate freezer at − 40 °C under pressure, overwrapped with PVC (polyvinyl chloride) packaging material and stored at − 18 °C for 12 months. Twelve 1-pound fillet blocks were stored at − 40 °C as a reference for sensory evaluations.

Product Evaluation

Three blocks each of filleted and minced spot were evaluated organoleptically, physically, and chemically after 0, 3, 6, and 12 months of storage (− 18 °C). Two fillet blocks stored at − 40 °C were used as a reference sample for sensory comparison. Physical and chemical values are reported as an average of three analyses.

Sensory Evaluation

Sticks (1.3 × 7.6 × 3 cm) were cut from frozen fillet blocks, mince blocks, and reference samples, then battered, breaded, and fried approximately 1½ minutes in vegetable oil at 182 °C. The sticks were cooled, wrapped in aluminum foil, and frozen at − 18 °C. They were removed from storage the next day, cooked approximately 15 minutes in an oven heated to 204 °C and served to a 12-member taste panel.

The panel rated the samples for color, flavor, firmness, odor, and overall acceptability on a scale of 1-5. Sensory attributes were rated as: Color, 1 = white, 5 = dark; firmness, 1 = soft, 5 = firm; flavor, 1 = bland, 5 = strong; odor, 1 = mild, 5 = strong; and acceptability, 1 = acceptable, 5 = unacceptable).

The reference samples, used as the sensory control, were stored at − 40 °C to minimize sensory changes due to storage and to be more nearly representative of seasonal sensory attributes of samples under evaluation.

Physical Measurements

Color values (L = lightness, a = redness, b = yellowness) were determined on a 6.5 cm^2 portion from each block, using a Hunter-lab[5] color and color-difference meter. Two values were obtained from each of two sides of the portion by rotating the portion 90° after the first reading. The color value for each portion is, therefore, an average of four readings.

Shear force (texture) values were obtained on 110 g portions of each block at a product temperature of 6 °C, using the Kramer Shear press (Kramer and Twigg, 1966). Values are reported as total pounds of shear force.

Chemical Analyses

Samples used for thiobarbituric acid (TBA) analyses were cut from near the center of each frozen block so as to be truly representative of the total exposed area; samples were homogenized only after addition to the extracting solution. Samples for the remaining

[3]Decker, C. D., S. K. Holt, and D. B. Westerling. 1980. Ingredients for product development. 4 gelling proteins. Presented at the Third National Technical Seminar on Mechanical Recovery and Utilization of Fish, December 1980, Raleigh, N.C.: Ralston Purina Company, St. Louis, Mo.

[4]Thrash, B. 1980. Surimi production in the United States. Presented at the Third National Technical Seminar on Mechanical Recovery and Utilization of Fish, December 1980, Raleigh, N.C.: Production Manager, Nichibei Fisheries, Inc., Bayou LaBatre, Ala.

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

chemical analyses were passed through a meat grinder three times to obtain a homogeneous mixture. Ground samples for proximate composition, amino acid, and fatty acid analyses were placed separately in vapor-proof containers, frozen, and held at −40 °C until analyzed. Proximate analyses and pH determinations were conducted according to the AOAC method (AOAC, 1975). Fat was measured according to the Bligh-Dyer method as modified by Smith et al. (1964). TBA determinations were performed as a measure of oxidative rancidity, using Vyncke's direct extraction method (Vyncke, 1972), and results are expressed as mg malonaldehyde (MA)/kg tissue. Total volatile nitrogen (TVN) and trimethylamine-nitrogen (TMA-N) were determined as described by Cobb et al. (1973). Fatty acid profiles were obtained by gas chromatography on methyl esters of the extracted lipids (Gauglitz and Lehman, 1963).

Samples for amino acid analysis were prepared initially by drying duplicate samples 2 days in a Virtis model FFD-15-W5 freeze dryer. Moisture-free samples were then extracted with petroleum ether for 8 hours in a Soxlet extraction apparatus to remove the lipids. The dry, lipid-free samples were ground to pass a 40-mesh screen in a Cyclo-Tech sample grinding mill. Crude protein (N × 6.25) was determined on the ground samples by the Kjeldahl method (AOAC, 1975). Amino acids, other than methionine, cystine, and tryptophan, were determined by the method of Spackman et al. (1958). Ground samples were weighed into hydrolysis tubes containing 6 N hydrochloric acid, evacuated, sealed, and hydrolyzed 22 hours with rotation in a 110 °C forced air oven. Contents of each tube were evaporated to dryness on a Buchler rotary evaporator and diluted to volume with sodium citrate buffer. The samples were then analyzed for total amino acid content on a Dionex Amino Acid/Peptide Analyzer Kit, Model MBN/SS. Methionine and cystine content were determined with a performic acid oxidation pretreatment prior to normal hydrolysis as described above and according to the method of Moore (1963). Tryptophan content was determined by hydrolysis as described above, except that 4 N methane-sulfonic acid containing 0.2 percent 3-(2 aminoethyl) indole was substituted for the 6 N hydrochloric acid. These samples were then chromatographed on the basic column of a Phoenix Amino Acid analyzer, Model K-8000 VG.

Table 1.—The mean and range of values for proximate composition of mince and fillet blocks of spot stored 12 months at −18°C.

Month and year harvested	Product form	Mean/range	Proximate composition (%) Moisture	Protein	Fat	Ash	NPN
May 1979	Mince	Mean	75.33	17.25	6.44	0.86	0.02
		Range	73.38-76.09	16.70-18.56	5.12- 7.36	0.82-0.89	0.02-0.03
	Fillet	Mean	74.25	18.50	6.73	0.89	0.03
		Range	72.94-75.20	18.08-19.64	6.16- 7.81	0.86-0.93	0.02-0.03
July 1979	Mince	Mean	72.36	18.35	9.29	1.03	0.02
		Range	71.76-72.73	17.23-19.24	8.34-10.06	0.97-1.09	0.01-0.03
	Fillet	Mean	72.64	18.63	8.69	1.04	0.03
		Range	71.74-73.32	17.68-20.28	8.11- 9.84	0.99-1.12	0.02-0.04
October 1979	Mince	Mean	74.47	19.56	5.45	1.17	0.03
		Range	73.84-74.99	18.76-20.49	4.96- 5.71	1.04-1.26	0.02-0.04
	Fillet	Mean	73.34	19.73	6.51	1.09	0.04
		Range	72.65-74.42	19.30-20.54	5.50- 7.57	1.04-1.13	0.02-0.04
November 1979	Mince	Mean	76.55	19.04	4.31	1.11	0.03
		Range	76.10-77.22	18.45-19.76	4.08- 4.46	1.06-1.16	0.02-0.06
	Fillet	Mean	76.94	19.14	3.84	1.00	0.04
		Range	76.50-77.44	18.61-19.64	3.44- 4.25	0.93-1.06	0.02-0.07
February 1980	Mince	Mean	82.36	17.27	0.72	1.08	0.03
		Range	81.25-83.75	16.75-17.71	0.49- 0.85	1.04-1.16	0.02-0.04
	Fillet	Mean	82.04	17.79	0.60	1.04	0.03
		Range	81.29-83.88	17.20-19.10	0.37- 0.71	1.00-1.10	0.01-0.04

Results and Discussion

Processing yields for spot were 29 percent for hand-processed fillets and 41 percent for the minced flesh.

The proximate composition of mince and fillet blocks is presented in Table 1. The mean and range of values are shown for the 12-month storage period. An inverse relationship exists between the moisture and fat content of seasonally harvested samples, i.e., when the moisture was highest, the fat content was lowest. The fat content peaked in July and dropped to a low in February. Overall, the protein content peaked in October and dropped to a low in May. Both fat and protein content were lowest during the post-spawning period (February-May). Dawson (1958) reported that spawning occurs during the winter, usually reaching its peak from December to February. The ash content was lowest in May samples and about equal in other monthly samples. The NPN (nonprotein nitrogen) content was low and varied little for all samples. Values for all proximate composition factors did not vary appreciably during storage.

The pH and shear values for mince and fillet blocks are shown in Table 2. The pH of spot harvested throughout the year did not change significantly. The lowest values were obtained in October and November just prior to the spawning season. The pH decreased slightly at 12 months of storage for both product forms.

The shear values for the minced form remained relatively stable throughout the year, except the February sample was inexplicably about double that of the others and the October sample about one-half that of the others. The values for fillets increased progressively from May 1979 through February 1980, possibly reflecting a physiological change in the muscle tissue during the life cycle and spawning period. The shear values for both forms increased during storage, indicating an increase in firmness of the flesh. The lower values for the mince, as compared with fillets, were

Table 2.—The pH, shear, TVN, TMA-N, and TBA values of mince and fillet blocks of spot stored 12 months at −18°C.

Month and year harvested	Product form	pH				Shear force (lb.)				TVN (mg N/100 g)				TMA-N (mg N/100 g)				TBA (mg MA/kg)			
		0	3	6	12	0	3	6	12	0	3	6	12	0	3	6	12	0	3	6	12
May 1979	Mince	6.89	6.88	6.75	6.76	64	65	60	82	12.5	10.3	11.3	10.2	2.1	1.9	0.8	1.0	1.7	4.6	3.3	7.0
	Fillet	6.88	6.84	6.70	6.70	35	138	112	218	16.7	10.9	11.3	12.3	3.3	1.6	1.2	1.6	1.7	4.2	3.3	6.7
July 1979	Mince	6.91	6.76	6.68	6.57	69	71	77	83	8.7	9.4	10.7	8.4	0	1.2	1.0	1.0	3.6	2.2	5.3	4.4
	Fillet	6.92	6.76	6.56	6.51	167	283	311	343	8.0	8.7	11.3	8.8	0	1.3	1.0	1.0	3.4	1.4	3.9	4.5
October 1979	Mince	6.67	6.59	6.61	6.39	38	63	84	88	10.5	13.0	11.5	13.3	0	0	0	0	0.7	3.0	3.2	2.2
	Fillet	6.67	6.64	6.62	6.44	281	356	470	353	11.2	12.0	10.4	12.0	0	0	0	0	0.4	3.4	2.8	1.3
November 1979	Mince	6.71	6.73	6.71	6.48	67	100	93	105	9.6	10.0	10.1	14.3	1.3	1.7	0	1.8	0.3	1.1	3.8	3.3
	Fillet	6.66	6.75	6.71	6.45	434	398	532	343	10.3	9.7	9.3	13.8	1.3	1.8	0	2.1	0.6	1.6	2.3	2.0
February 1980	Mince	6.98	6.97	6.89	6.76	124	116	142	113	8.6	8.1	9.1	11.4	2.0	0	0	2.3	0.7	1.9	1.0	1.1
	Fillet	7.16	6.95	6.95	6.71	622	886	860	850	7.9	7.4	8.3	10.8	1.9	0	0	2.2	0.7	1.3	1.2	0.7

due to the loss of tissue integrity during mincing.

The TVN, TMA-N, and TBA values are also shown in Table 2. TVN values of the seasonal harvest fluctuated minimally and highest values were obtained from May samples. Generally, values increased only slightly during storage for both product forms and the increase may be due to sample variability rather than real increases. Significant increases during storage were not expected since freezing immobilizes most proteolytic enzymes. An increase in TVN content indicates the occurrence of proteolysis, resulting from the activity of proteolytic enzymes. The primary concern with frozen fish, however, is the prevention of oxidative rancidity, dehydration, and textural changes. The slight increase in TVN did not correspond with the slight decrease in pH, but again these changes may be due to sample variations and not real changes.

TMA-N values for both product forms were relatively low at 0-months of storage, indicating minimal preprocessing spoilage due to bacterial activity. Castell et al. (1974) stated that measurements of TMA-N are useful in estimating the quality of frozen, stored gadoid fillets, and that the TMA-N value indicates the extent of microbial spoilage before the muscle was frozen. TMA-N values remained relatively unchanged during storage.

TBA values for seasonally harvested fish varied at 0-storage time. The values peaked in July (midway between spawning seasons) and decreased to a minimum in November and February (peak of spawning). There is good correlation between increased TBA values and high fat content (Table 1). In general, TBA values increased with storage and peaked at 6 months except the May samples which peaked at 12 months.

Table 3.—Color values of mince and fillet blocks of spot stored 12 months at −18°C.

Month and year harvested	Product form	0 L	0 a	0 b	3 L	3 a	3 b	6 L	6 a	6 b	12 L	12 a	12 b
May 1979	Mince	47.5	2.5	8.4	50.3	1.9	8.8	50.1	3.2	8.8	48.7	2.6	9.8
	Fillet	51.7	2.5	9.2	54.9	2.7	9.5	53.9	3.4	9.6	51.9	2.4	10.2
July 1979	Mince	51.6	5.9	8.5	47.9	4.3	9.9	48.7	3.6	9.6	50.4	−0.2	10.8
	Fillet	54.6	4.5	8.0	49.6	4.3	9.4	52.2	3.3	9.4	51.7	0.5	10.4
Oct. 1979	Mince	46.7	7.4	8.6	45.5	4.9	8.9	45.1	4.2	9.3	44.9	3.2	9.8
	Fillet	52.7	4.9	8.0	50.3	4.1	9.5	51.9	3.0	8.9	51.5	2.6	9.7
Nov. 1979	Mince	42.7	8.0	8.4	42.7	5.4	9.7	40.5	5.4	9.0	42.1	3.5	9.2
	Fillet	50.1	6.8	8.8	49.7	5.2	10.5	48.8	4.3	10.0	49.2	3.4	9.7
Feb. 1980	Mince	36.9	7.5	8.6	34.5	6.2	8.1	36.8	6.2	6.4	34.4	5.4	7.9
	Fillet	41.7	6.8	8.8	42.7	6.1	8.6	40.3	7.0	6.8	44.0	4.1	8.4

Values for the minced form were slightly higher than the filleted form, for stored samples, possibly due to oxidation of the lipids as a result of the incorporation of oxygen into the flesh during the mincing process. Metal ions from the mincing equipment may have enhanced this effect (Lee and Toledo, 1977; Castell, 1971; Castell and Spears, 1968). The moderate increase in values indicated that some rancidity occurred during storage. However, rancid flavors or odors, which may have been masked by the strong fishy flavor and odor, and flavor of the batter and breading, were not reported by the sensory panel.

The color values for mince and fillet blocks are presented in Table 3. The L-values (lightness) for seasonally harvested samples (mince and fillets) varied moderately and followed similar changes as the fat content and TBA values, i.e. highest TBA, fat, and L-values in July and lowest values in February. L-values for mince blocks were lower than fillet blocks due to uniform dispersement of the dark flesh (and residual blood) during the mincing process. The a-values (redness) were lowest for May samples (about one-half that of the others) and highest for November and February samples (0-months of storage). Values for May samples remained stable through 12 months of storage; July samples decreased significantly at 12 months and all other samples decreased rather consistently during storage. The b-values (yellow) remained relatively unchanged for all samples throughout the storage period. Overall, the color of minced and filleted spot appears to be only slightly affected by season of harvest and frozen storage.

Sensory scores for acceptability, color, flavor, firmness, and odor of spot, harvested seasonally and stored 12 months, are shown in Figures 1-5, respectively. Generally, the minced form was less acceptable to the panel for all months of harvest (and storage) due to the color, flavor, and odor of the mince but primarily due to the dark color of the flesh. The color of minced fish flesh can be improved by washing with cold water as shown by Rasekh et al. (1980). Firmness scores varied the least (seasonally and during storage) among product forms and the reference sample was preferred (in most attributes tested) over the minced and filleted forms held at −18 °C. Season of harvest and time in storage had little affect on sensory judgement of both product forms.

The concentration of essential amino acids of minced and filleted spot is shown in Table 4 and expressed as a percentage of the protein content. Amino acid values were obtained only at 0-months of storage. Monthly values varied little between the mince and fillet forms except for histidine, which was about 23 percent lower for the fillet form of the February sample. Appreciable seasonal fluctuations are apparent only for histidine (February: fillet), glutamic acid (February: mince), and taurine (October: mince). All values, however, are comparable to those reported by Sidwell (1981).

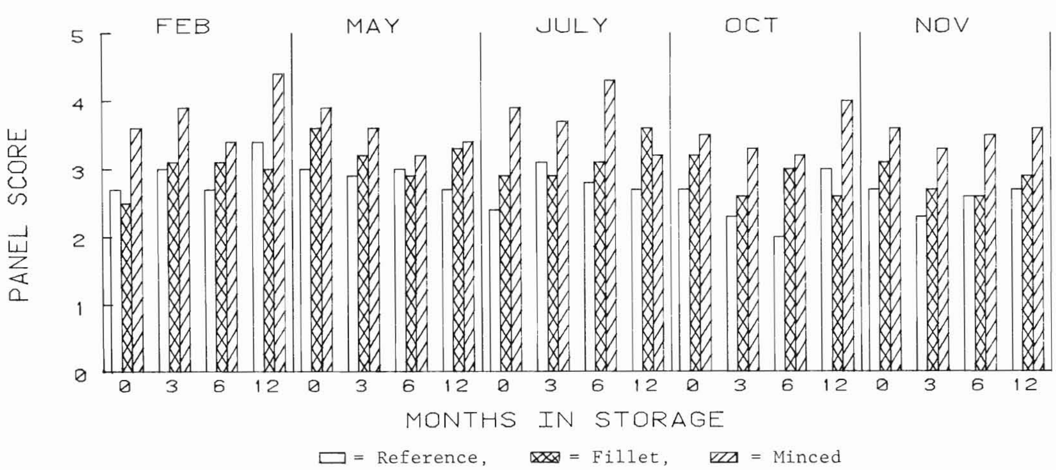

Figure 1.—Sensory panel scores for overall acceptability of minced and filleted spot harvested seasonally and stored 12 months at −18°C. 1 = acceptable; 5 = unacceptable.

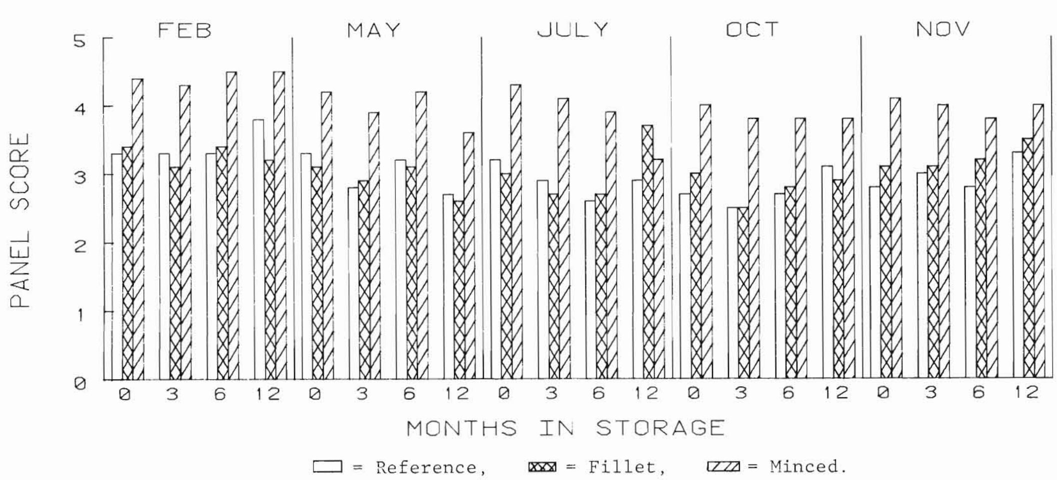

Figure 2.—Sensory panel scores for color of minced and filleted spot harvested seasonally and stored 12 months at −18°C. 1 = white; 5 = dark.

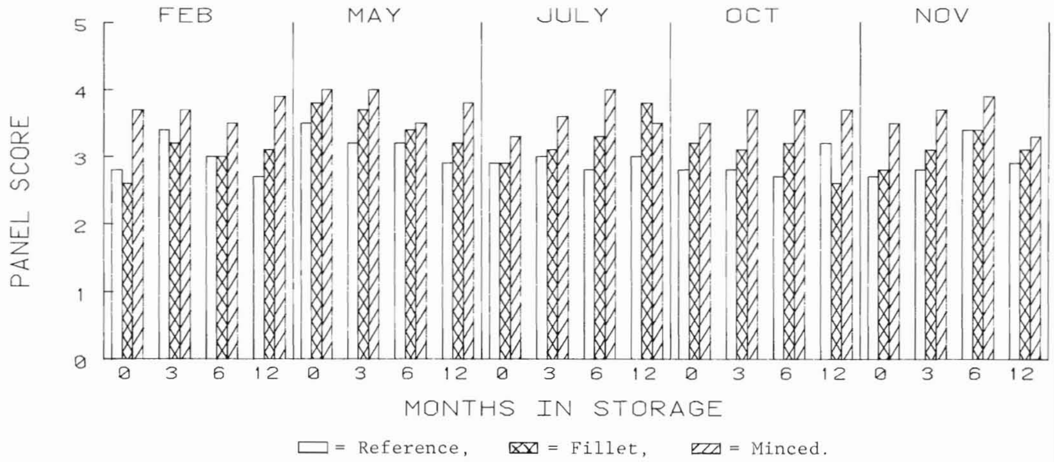

Figure 3.—Sensory panel scores for flavor of minced and filleted spot harvested seasonally and stored 12 months at −18°C. 1 = bland; 5 = strong.

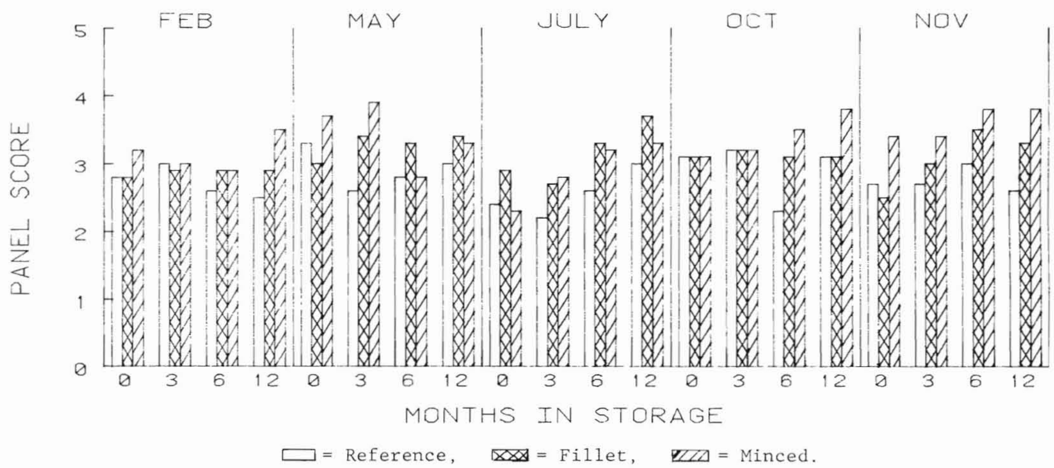

Figure 4.—Sensory panel scores for firmness of minced and filleted spot harvested seasonally and stored 12 months at −18°C. 1 = soft; 5 = firm.

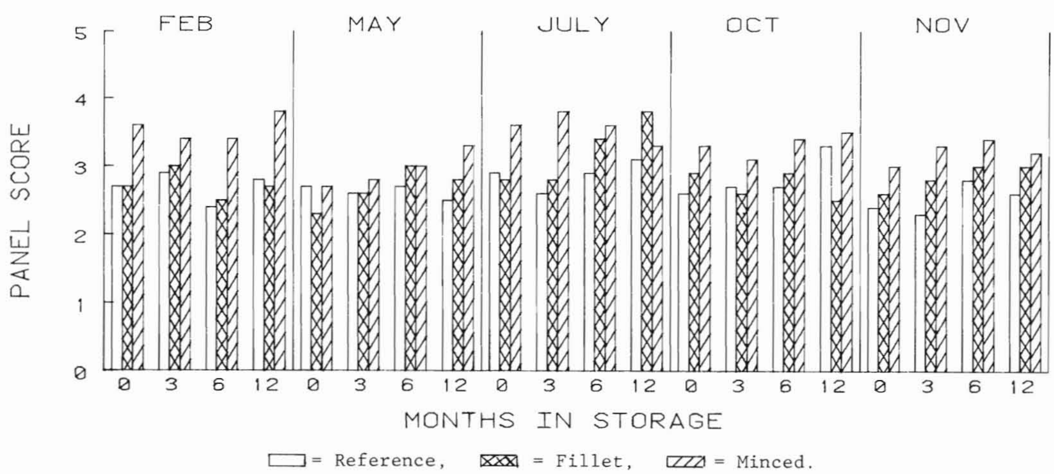

Figure 5.—Sensory panel scores for odor of minced and filleted spot harvested seasonally and stored 12 months at −18°C. 1 = mild; 5 = strong.

Fatty acid values (seasonal mean and range for 12 months of storage) of minced and filleted spot are shown in Tables 5 and 6, respectively, and are expressed as a percentage of total fatty acids. Although a complete profile was obtained, only the more important components are shown. At the mid-winter minimum (0.7 percent fat), this fat must be virtually all membrane phospholipids, a conclusion supported by the elevated percentages of 20:4ω6[6] and 22:6ω3, both of which are important membrane fatty acids. Both saturates (16:0 and 18:0) and monoenes (16:1 and 18:1) declined seasonally in both product forms, from mid-summer to mid-winter. This may be a real change in fatty acid composition of the fish or may simply be a reflection of the increasing percentages of the poly-

[6]Notation indicates the number of carbon atoms in the molecule and the number of double bonds. The number following the ω-symbol indicates the position of the final double bond with respect to the terminal methyl group of the molecule.

Table 4.—Percent composition of amino acids of minced and filleted spot harvested on a seasonal basis.

	Product form/month of harvest									
	Fillet					Mince				
Amino acid	May	July	Oct.	Nov.	Feb.	May	July	Oct.	Nov.	Feb.
Tryptophan	1.07	1.22	1.07	1.21	0.96	1.13	1.13	1.06	1.05	1.05
Lysine	9.71	9.70	10.00	9.99	9.26	9.77	9.79	9.88	9.53	9.98
Histidine	2.20	2.25	2.34	2.10	1.61	2.42	2.54	1.99	2.05	2.10
Ammonia	1.19	1.01	1.09	1.00	1.14	1.12	1.06	1.14	0.90	1.02
Arginine	6.41	6.42	6.39	6.47	6.66	6.53	6.47	6.53	6.23	6.70
Aspartic acid	10.15	10.27	10.22	10.30	10.38	10.28	10.06	10.05	10.22	10.27
Threonine	4.65	4.75	4.64	4.63	4.76	4.57	4.63	4.58	4.63	4.64
Serine	4.18	4.17	4.12	4.12	4.22	4.15	4.11	4.18	4.19	4.11
Glutamic acid	15.68	15.40	15.56	15.84	16.36	15.72	15.12	15.49	15.93	16.57
Proline	3.40	3.40	3.45	3.34	3.44	3.45	3.61	3.80	3.69	3.10
Glycine	4.95	5.14	5.05	4.82	4.73	4.76	5.38	4.97	4.89	4.21
Alanine	6.11	6.40	6.22	6.34	6.46	6.05	6.34	6.18	6.28	6.16
Cystine	1.43	1.26	1.11	1.06	1.02	0.87	1.20	1.03	1.37	0.96
Valine	4.64	4.76	4.62	4.79	4.94	4.55	4.83	4.81	4.90	4.75
Methionine	3.56	3.39	3.51	3.53	3.11	3.06	3.21	3.45	3.57	3.40
Isoleucine	4.50	4.56	4.54	4.51	4.63	4.58	4.38	4.62	4.42	4.64
Leucine	8.41	8.37	8.35	8.21	8.55	8.37	8.22	8.40	8.40	8.46
Tyrosine	3.31	3.29	3.22	3.22	3.49	3.77	3.13	3.31	3.37	3.34
Phenylalanine	3.60	3.48	3.65	3.61	3.36	3.90	3.82	3.77	3.42	3.61
Taurine	0.87	0.77	0.85	0.92	0.93	0.94	0.98	0.75	0.94	0.94
Total	100.02	100.01	100.00	100.01	100.01	99.99	100.01	99.99	99.98	100.01

Table 5.—The mean and range of values for the fatty acid profile (weight percent composition) of minced spot harvested on a seasonal basis and stored at –18°C for 12 months.

Date harvested	Fatty acid	Weight percent Mean	Weight percent Range	Date harvested	Fatty acid	Weight percent Mean	Weight percent Range	Date harvested	Fatty acid	Weight percent Mean	Weight percent Range
May 1979	14:0	2.539	2.512- 2.576	October	14:0	2.528	2.252- 2.943	February	14:0	1.816	1.566- 2.375
	16:0	25.617	24.686-26.735	1979	16:0	23.496	22.045-24.162	1980	16:0	19.409	18.165-20.745
	16:1	12.482	12.306-12.821		16:1	10.611	9.801-11.671		16:1	6.126	5.368- 7.472
	18:0	5.756	4.696- 6.364		18:0	6.724	6.163- 7.111		18:0	8.571	6.671- 9.614
	18:1ω9	21.890	21.123-22.958		18:1ω9	20.847	20.279-21.434		18:1ω9	15.406	15.026-15.753
	18:2ω6	1.434	1.310- 1.552		18:2ω6	1.089	0.867- 1.670		18:2ω6	1.023	0.654- 1.336
	18:3ω3	0.797	0.746- 0.904		18:3ω3	0.613	0.294- 0.998		18:3ω3	0.600	0.365- 0.788
	18:4ω3	2.834	2.529- 3.206		18:4ω3	4.945	4.147- 5.479		18:4ω3	3.312	2.835- 3.802
	20:4ω6 + 20:3ω3	1.224	1.021- 1.577		20:4ω6 + 20:3ω3	2.466	2.203- 2.741		20:4ω6 + 20:3ω3	4.785	4.306- 5.212
	20:5ω3	2.751	2.490- 2.999		20:5ω3	4.710	4.321- 5.314		20:5ω3	6.123	5.566- 7.220
	22:5ω3	1.250	1.064- 1.424		22:5ω3	2.527	2.267- 2.685		22:5ω3	4.119	3.674- 4.382
	22:6ω3	9.207	8.466-10.071		22:6ω3	5.826	5.434- 6.595		22:6ω3	15.348	14.217-16.568
July 1979	14:0	4.017	3.287- 5.395	November	14:0	3.169	2.917- 3.578				
	16:0	24.377	23.931-24.828	1979	16:0	23.397	21.810-24.940				
	16:1	13.814	12.448-16.475		16:1	11.198	10.598-12.110				
	18:0	5.921	4.332- 6.994		18:0	6.719	6.161- 7.294				
	18:1ω9	20.429	18.606-20.753		18:1ω9	20.690	19.651-22.023				
	18:2ω6	0.551	0.478- 0.612		18:2ω6	0.750	0.504- 1.353				
	18:3ω3	0.453	0.227- 0.844		18:3ω3	0.540	0.283- 0.866				
	18:4ω3	2.460	1.075- 4.775		18:4ω3	5.309	4.720- 5.748				
	20:4ω6 + 20:3ω3	2.052	1.747- 2.244		20:4ω6 + 20:3ω3	2.561	2.408- 2.972				
	20:5ω3	6.527	5.527- 8.509		20:5ω3	4.458	3.720- 4.928				
	22:5ω3	2.304	2.129- 2.421		22:5ω3	2.858	2.520- 3.027				
	22:6ω3	4.785	4.453- 5.318		22:6ω3	5.989	5.307- 6.715				

unsaturates, which is, almost certainly, a real seasonal change in composition since the polyunsaturates of the cellular lipids become more prominent in the fatty acid profile as the depot fats are utilized by the fish.

No significant decreases in the polyunsaturates were apparent in any of the groups of fillets over the 12 month storage period, suggesting minimal lipid oxidation in the fillets. In the minced fish, significant decreases in 20:4ω6, 20:5ω3, and 22:6ω3 over 12 months of storage were observed only in those samples from fish harvested in February 1980. This may be due to the absence of natural antioxidants, such as the tocopherols, which are derived from food and carried in the depot fat, but it is equally possible that mincing introduced atmospheric oxygen which oxidized the highly labile polyunsaturates.

Conclusions

Based on the results of this study, it is concluded that spot harvested from early fall (October) to mid-winter (February) contain optimum nutritional values and exhibit good frozen storage stability. During this period, the protein content is at its maximum, the fat content is decreasing to a minimum, and the fatty acids are fairly stable. Changes in other characteristics, such as the functional properties and chemical quality indices, are minimal during this period. Although the suggested harvesting period is during the early spawning and spawning season, and at a time of maximum physiological stress of the animal, the results indicate the overall utilization quality characteristics are maximum between October and February.

The overall quality of spot, particularly the minced form, could be significantly enhanced through the use of physical and chemical treatments. Washing the minced flesh with cold water would improve the color (and possibly the flavor and texture); treatment of the mince and fillets with antioxidants may minimize oxidative rancidity even when the lipids are at a minimal level in the fish.

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Table 6.—The mean and range of values for the fatty acid profile (weight percent composition) of filleted spot harvested on a seasonal basis and stored at – 18°C for 12 months.

Date harvested	Fatty acid	Weight percent		Date harvested	Fatty acid	Weight percent		Date harvested	Fatty acid	Weight percent	
		Mean	Range			Mean	Range			Mean	Range
May 1979	14:0	2.527	2.452- 2.630	October	14:0	2.569	2.356- 2.824	February	14:0	1.388	0.717- 2.481
	16:0	25.677	24.834-26.563	1979	16:0	23.594	22.569-24.670	1980	16:0	19.247	18.746-20.316
	16:1	12.246	11.585-12.509		16:1	11.158	10.720-12.048		16:1	5.232	3.408- 8.772
	18:0	6.044	5.559- 6.327		18:0	6.767	6.402- 6.950		18:0	9.279	6.740-10.372
	18:1ω9	22.091	21.501-22.519		18:1ω9	20.468	19.404-21.305		18:1ω9	13.447	11.227-15.665
	18:2ω6	1.402	1.218- 1.520		18:2ω6	1.059	0.770- 1.657		18:2ω6	1.156	0.821- 1.521
	18:3ω3	0.751	0.628- 0.821		18:3ω3	0.619	0.243- 0.944		18:3ω3	0.466	0.396- 0.560
	18:4ω3	2.728	2.485- 3.039		18:4ω3	5.143	4.376- 5.856		18:4ω3	2.592	1.853- 3.349
	20:4ω6+	1.051	0.963- 1.131		20:4ω6+	2.562	2.253- 2.873		20:4ω6+	5.579	4.910- 6.578
	20:3ω3				20:3ω3				20:3ω3		
	20:5ω3	2.645	2.534- 2.857		20:5ω3	4.557	4.467- 4.742		20:5ω3	6.289	6.096- 6.510
	22:5ω3	1.228	1.194- 1.305		22:5ω3	2.389	2.193- 2.602		22:5ω3	4.136	3.656- 4.673
	22:6ω3	9.602	9.104-10.114		22:6ω3	6.019	5.706- 6.327		22:6ω3	18.966	14.217-21.702
July 1979	14:0	3.275	3.275- 4.139	November	14:0	2.908	2.506- 3.988				
	16:0	24.943	24.148-25.668	1979	16:0	23.235	22.137-24.286				
	16:1	13.078	12.256-14.473		16:1	10.633	9.793-12.694				
	18:0	6.422	6.298- 6.647		18:0	6.775	5.266- 7.565				
	18:1ω9	21.098	20.707-21.626		18:1ω9	20.700	18.780-22.716				
	18:2ω6	0.537	0.494- 0.556		18:2ω6	0.847	0.441- 1.455				
	18:3ω3	0.299	0.162- 0.757		18:3ω3	0.560	0.217- 0.894				
	18:4ω3	2.532	1.795- 4.045		18:4ω3	4.861	3.352- 5.676				
	20:4ω6+	2.014	1.795- 2.213		20:4ω6+	2.544	1.874- 2.942				
	20:3ω3				20:3ω3						
	20:5ω3	6.083	5.435- 6.587		20:5ω3	4.833	3.914- 6.170				
	22:5ω3	2.272	2.034- 2.405		22:5ω3	3.116	2.796- 3.359				
	22:6ω3	5.156	4.619- 5.824		22:6ω3	6.799	6.154- 8.296				

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