Chemical Composition and Frozen Storage Stability of Weakfish, *Cynoscion regalis*

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ABSTRACT—Weakfish, Cynoscion regalis, *were harvested seasonally for a 12-month period to determine the chemical composition and frozen storage (−18°C) stability of fillets, minced flesh, and washed minced flesh. One-pound blocks were prepared, frozen, and evaluated after 0, 3, 6, and 12 months of storage. The results showed that harvesting season and frozen storage had little effect on the chemical properties of the flesh. However, TBA values (rancidity) increased slightly during 6 months of storage, then decreased. Mincing increased rancidity during storage, but the rancidity was minimized by washing. Total volatile nitrogen and trimethylamine-nitrogen values indicated that the fish were of good quality when processed. No clear-cut trends existed in the fatty acid composition during storage, though there was some suggestion of a slight loss of 22:6ω3 in the minced form after 12 months. Washing the minced flesh improved its storage stability, color, flavor, odor, and overall appearance.*

Sensory scores showed that weakfish fillets were preferred over the washed and unwashed minced forms due to better texture, flavor, odor, and lighter color. Lighter color was primarily responsible for the preference of fillets over other products. Instrumental results showed comparable L-values (lightness) between fillets and washed mince, but both were notably higher than those for unwashed mince. Processing yields for weakfish were 37 percent for hand-processed fillets and 49 percent for the minced flesh. Washing the flesh resulted in 3-4 percent loss of solids and accounted for decreased values for the fat and protein content of the minced product.

Introduction

Weakfish, *Cynoscion regalis*, is a species important to both recreational and commercial fisheries in the United States and is grouped under the general category of groundfish. They are found along the Atlantic coast from southern Florida to Massachusetts Bay, straying occasionally to Nova Scotia (Wilk, 1979). Occasionally they are caught off Marco Island, Fla. (Weinstein and Yerger, 1976) proving the presence of this species in the Gulf of Mexico. Spawning, hatching, and early larval development take place in the near-shore and estuarine zones along the coast from May to October with peak production during late April through June (Wilk, 1978).

Weakfish are harvested principally with fish traps (pound nets) and secondarily with hook and line, haul seines, and purse seines (Wilk and Brown, 1982). The bulk of the catch is made in the Mid-Atlantic and southern New England regions. Weakfish are also caught incidentally in the shrimp fishery. The sizes of weakfish found in the average commercial catch range from about 200 g to about 2,300 g. Wilk (1979) reported that weakfish can reach 17 pounds (7,718 g), and he examined a 9-year-old fish weighing approximately 13 pounds (5,902 g). Pellegrin (1981) reported that 5 of the top 10 fish species harvested annually by the shrimp fleet in the South Atlantic are sciaenids, predominately spot, croaker, and weakfish. Keiser (1977), evaluating the incidental catch from commercial shrimp trawlers of the South Atlantic states, showed that small weakfish (less than 250 g) accounted for 3.9, 3.0, and 6.9 percent of the shrimp by-catch discarded at sea by vessels operating from North Carolina, South Carolina, and Georgia ports, respectively. Market-sized fish harvested with the shrimp catch are separated and sold dockside as food fish. Considering that 5 percent of the reported 66 million pounds of the discarded by-catch in the South Atlantic area are weakfish, 3.3 million additional pounds of this species could be made available for human consumption with little additional effort and cost to the fishermen.

Landing of weakfish contributes substantially to the U.S. economy. A considerable number are caught by recreational fishermen, according to available statistics, but the number is believed to be conservative due to an inadequate reporting system. In 1979 (latest data available), the U.S. recreational catch totaled 4.5 million fish and the 1981 commercial catch totaled 26.5 million pounds valued at $9.1 million; the 5-year average (1977-81) totaled 26.4 million pounds (USDC, 1982).

Weakfish are highly perishable and must be handled expeditiously, even when properly stored, to maintain good quality at the retail level. The texture of the flesh is soft and the fish feed on highly proteolytic material, resulting in a short shelf life after capture. These factors probably play a major role in the underutilization of the species. On the positive side, however, the flesh is relatively light in color (compared with other groundfish species), is considered

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low to medium oily, and possesses a pleasant fish flavor when fresh. Weakfish are readily available in restaurants and seafood markets in coastal areas where landed.

Mincing technology, introduced to the United States about 1970, offers a unique opportunity to utilize the smaller weakfish (shrimp fishery discards), and to use the oversupply of larger fish in fabricated and reshaped products. These product forms can take advantage of the characteristic soft texture of the weakfish where different textural properties can be expected. However, fabricated and reshaped products should not be used as an escape route for utilizing soft-textured weakfish caused by low quality fish.

Investigations in the use of weakfish in minced food products have not been reported, yet this species may offer good potential, economically and technologically, due to its availability, high yield of minced flesh, ease in processing, and favorable minced product characteristics. Preliminary investigations in our laboratory indicated that weakfish possess several characteristics that are desirable in minced fish products. To further determine if this species is a suitable candidate for minced fish products, expanded investigations were required. The purpose of this study was to determine the seasonal chemical composition of weakfish and evaluate the effect of composition on the frozen storage stability of fillet blocks and washed and unwashed mince blocks as an intermediary for further processing.

Materials and Methods

Sample Preparation

Fresh, iced weakfish were obtained during March, May, July, September, and December 1980 and January 1981 from a commercial seafood dealer in North Carolina. In each sampling period, 150 pounds were obtained dockside, reiced, and transported to the NMFS Southeast Fisheries Center's Charleston Laboratory for processing. The fish were caught off the coast of Morehead City, N.C., 36-48 hours before sample preparation. They ranged in size from 326 to 789 g with an average weight of about 495 g.

Preparation of fillet and mince blocks began immediately upon arrival of the fish at the laboratory. The fish were washed, divided into two groups, and weights obtained for subsequent calculation of product yield. The first group (60 pounds) was hand filleted and skinned; fillets were weighed, rinsed in ice water, and drained 5 minutes. The fillets (F) were packed in 1-pound, wax-coated food cartons (7.5 × 21.5 × 3 cm). The second group (90 pounds) was mechanically scaled, headed, gutted, and deboned, and the resulting minced flesh weighed. The minced flesh was divided equally into two lots, one of which was packed in 1-pound waxed food cartons and designated as unwashed mince (UWM). The second lot was washed in cold tap water (8°C) according to the procedure outlined by Rasekh et al. (1980). The washed flesh was pressed to remove the wash water to equal the initial prewashed weight. The washed flesh was packed in 1-pound waxed food cartons and designated as washed mince (WM). The fillet and minced fish blocks were frozen in a plate freezer at −40°C under pressure, overwrapped with polyvinyl chloride (PVC) packaging material and stored at −18°C for 12 months. Ten 1-pound fillet blocks were stored at −40°C as a reference for sensory evaluations.

Product Evaluation

Three blocks each of filleted, UWM, and WM weakfish were evaluated organoleptically, physically, and chemically after 0, 3, 6, and 12 months of storage at −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, UWM, and WM blocks and reference samples, which were battered, breaded, and fried approximately 1.5 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 from 1 = most acceptable to 5 = least acceptable.

The reference samples, used as the sensory control, were stored at −40°C to minimize sensory changes due to storage. Reference samples were prepared each sample period and compared to stored samples of that sampling period so as to be more nearly representative of those samples.

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[1] 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 of the extracting solution. Samples for the remaining 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 determina-

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

tions 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). Thiobarbituric acid 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 (Metcalfe et al., 1966).

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 $\times$ 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 before 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.—Mean and range of values for proximate composition of filleted, washed mince (WM), and unwashed minced (UWM) weakfish stored 12 months at −18°C.

Month and year harvested	Product form	Mean Range	Proximate composition (%)				
			Moisture	Protein	Fat	Ash	NPN
March 1980	Fillet	Mean	80.54	17.62	1.87	1.12	0.06
		Range	80.39-80.82	17.06-18.06	1.38-2.21	1.00-1.38	0.01-0.13
	WM	Mean	83.41	14.18	2.30	0.49	0.04
		Range	81.64-84.52	13.19-15.63	1.78-2.67	0.46-0.52	0.01-0.06
	UWM	Mean	80.41	16.85	2.56	1.02	0.09
		Range	80.20-80.69	16.50-17.34	2.32-2.74	0.95-1.07	0.01-0.18
May 1980	Fillet	Mean	80.02	18.58	1.45	1.15	0.06
		Range	79.65-80.62	18.21-18.94	0.99-1.65	1.03-1.46	0.02-0.12
	WM	Mean	83.35	15.69	1.67	0.56	0.08
		Range	82.69-84.65	15.39-16.25	1.38-1.88	0.48-0.63	0.02-0.23
	UWM	Mean	79.24	18.14	2.50	1.05	0.11
		Range	78.44-80.29	17.72-18.55	1.76-2.86	0.96-1.22	0.02-0.31
July 1980	Fillet	Mean	78.83	18.47	2.81	1.00	0.05
		Range	78.35-79.30	17.60-19.34	2.57-3.18	0.92-1.06	0.02-0.11
	WM	Mean	82.14	15.90	2.22	0.48	0.06
		Range	81.70-82.48	15.41-16.13	2.13-2.31	0.44-0.51	0.02-0.10
	UWM	Mean	79.09	18.34	2.59	1.02	0.05
		Range	78.85-79.29	17.98-18.69	2.47-2.75	0.98-1.06	0.02-0.09
September 1980	Fillet	Mean	80.87	18.27	1.01	1.05	0.07
		Range	80.68-81.32	17.93-18.49	0.81-1.24	1.00-1.07	0.02-0.15
	WM	Mean	82.81	16.15	1.43	0.82	0.07
		Range	80.47-83.85	15.33-18.07	1.32-1.64	0.47-1.21	0.01-0.14
	UWM	Mean	80.97	17.67	1.52	0.95	0.08
		Range	80.43-82.05	16.93-18.41	1.33-1.68	0.57-1.15	0.02-0.18
December 1980	Fillet	Mean	76.54	17.81	5.35	0.94	0.06
		Range	75.74-77.24	17.44-18.25	4.96-5.95	0.88-0.99	0.02-0.08
	WM	Mean	81.00	13.92	4.55	0.45	0.04
		Range	80.62-81.23	13.22-14.65	4.34-4.89	0.41-0.49	0.01-0.06
	UWM	Mean	76.08	18.23	5.36	1.02	0.07
		Range	75.67-76.30	17.84-18.71	5.07-5.55	0.96-1.05	0.02-0.10
January 1981	Fillet	Mean	77.74	18.10	4.27	1.02	0.06
		Range	77.48-77.92	17.41-18.52	3.84-4.76	0.96-1.07	0.01-0.10
	WM	Mean	81.14	15.37	3.80	0.54	0.05
		Range	80.58-81.65	15.01-15.73	3.55-4.00	0.51-0.60	0.01-0.10
	UWM	Mean	77.37	17.61	4.61	1.07	0.07
		Range	76.76-78.05	16.64-18.28	4.26-5.09	0.98-1.24	0.02-0.13

Results and Discussion

Processing yields for weakfish were 37 percent for hand-processed fillets and 49 percent for the minced flesh.

The proximate composition of fillet, WM, and UWM 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 fish, i.e., when the moisture was highest, the fat content was minimal. The moisture content of fillets and UWM closely paralleled each other during seasonal harvest, and values were highest in September, toward the end of spawning, and lowest in December after spawning. Conversely, the fat content was highest in December and lowest in September for all three product forms. The moisture content of WM was somewhat higher than the other forms (2-4 percent) reflecting the loss of solids and its replacement with moisture. In a preliminary experiment, it was determined that washing minced flesh removed from 3 to 4 percent of the solids (proteins, fat, etc.). This was replaced by water when the flesh was pressed to the prewashed weight. This loss in solids accounts for the lower fat and protein content of the WM samples. The fat content of fillet blocks was slightly less than that of the other forms in March, May, and September. This could be attributed to the concentration of depot fat, adjacent to the skin during these months, which was removed during the skinning process. Eide et al. (1982), investigating methods for gutting, skinning, and removing the fat from small fatty fish, referenced work that showed most of the depot fat in fat cells of capelin is concentrated in the peritoneum and beneath the skin. The protein and ash content remained fairly stable throughout all months of harvest. The ash content was least for the WM samples due to leaching of minerals, the washing out of scales and small bone particles, and the increase in moisture content. The nonprotein nitrogen (NPN) content generally remained below 0.1 percent except for the May sample stored for 3 months. Values for all proximate composition factors did not vary appreciably during storage.

The TBA, TVN, and shear values for fillet, WM, and UWM blocks are shown in Table 2. Overall, TBA values were lowest in fish obtained in September and remained low during the storage period. The low TBA values corresponded well with the low fat content for September. Thiobarbituric acid values were least for fillet blocks, followed by WM blocks, and highest for UWM fish, corresponding well with the fat content of these forms. The TBA values of all product forms during storage was somewhat erratic; values for December and January fish peaked at 12 months, others peaked at 6 months.

Total volatile nitrogen values fluctuated somewhat between months of harvest and during storage. The slight increase during storage is evidence of only minor proteolytic activity at $-18°C$ as was expected. The TVN content was noticeably lower in the WM form (corresponding with removal of water soluble protein) and about equal in the other forms; maximum values did not exceed 16 mg N/100 g sample. Phillips and Cobb (1977) showed that 30 mg N/100 g fish is the maximum acceptable TVN level for edible quality iced fish.

The shear values for all products remained relatively stable between months of harvest and during the storage period. Shear values were greater for the fillet blocks reflecting the presence of connective tissue; values for the WM were consistently higher than those for the UWM. Fluctuation in values for fillets during storage may be attributed to the amount of connective tissue in the sample and age of the fish from which the fillets were derived. The lower values for the mince forms, as compared with the fillets, were due to the loss of tissue integrity during mincing.

Table 2.—The TBA, TVN, and shear values of filleted, washed mince (WM) and unwashed mince (UWM) blocks of weakfish stored 12 months at $-18°C$.

Month and year harvested	Product form	TBA (mg MA/kg)				TVN (mg N/100g)				Shear force (lb force)			
		Months in storage				Months in storage				Months in storage			
		0	3	6	12	0	3	6	12	0	3	6	12
March 1980	Fillet	0.58	0.84	2.06	2.36	6.75	8.50	8.89	10.56	422	382	345	500
	WM	2.30	2.00	3.01	2.01	3.09	6.74	4.12	6.26	87	125	168	143
	UWM	1.71	2.01	5.67	3.66	6.66	8.57	8.82	9.98	66	78	103	111
May 1980	Fillet	0.51	0.72	0.62	0.56	9.92	9.95	15.01	13.05	565	243	485	337
	WM	0.87	1.30	1.22	0.97	7.37	5.95	8.18	7.85	105	143	151	157
	UWM	2.86	2.02	2.83	2.40	9.98	9.78	12.82	12.00	70	83	84	93
July 1980	Fillet	2.17	1.04	2.23	1.16	10.75	11.37	11.40	12.93	388	495	555	508
	WM	2.10	1.36	3.20	1.43	5.69	8.08	8.23	9.96	107	117	118	131
	UWM	3.44	1.76	5.86	2.34	10.63	12.27	14.54	15.84	77	78	79	86
September 1980	Fillet	0.70	0.30	0.68	0.33	12.92	13.20	13.74	11.77	583	680	592	693
	WM	0.77	0.96	0.82	0.37	7.70	7.41	8.23	6.68	156	216	139	137
	UWM	0.79	0.84	1.27	0.43	12.13	13.32	13.20	11.38	100	102	87	86
December 1980	Fillet	1.00	1.39	1.49	1.47	10.52	10.21	12.40	9.13	413	593	635	460
	WM	1.94	1.59	1.23	2.69	7.20	6.57	6.24	5.43	85	113	116	105
	UWM	2.70	4.03	2.86	4.80	11.95	11.26	12.16	9.64	66	62	71	67
January 1981	Fillet	0.87	0.91	0.76	3.73	12.27	14.70	12.56	9.08	450	485	525	503
	WM	1.48	0.93	1.71	2.35	12.71	11.35	10.63	5.78	95	115	121	121
	UWM	1.23	1.98	2.68	3.04	7.28	10.87	16.36	9.09	84	86	81	94

The pH of weakfish was highest in March and lowest in July, approximately 7.0 and 6.5, respectively. Values decreased slightly during storage and values were always highest for the WM followed by the UWM.

Trimethylamine-nitrogen values for all product forms were low (0-2 mg N/100 g) for fish harvested during March, May, July, and September; values were slightly higher (2-4 mg N/100 g) for fish collected in December and January. Values remained fairly consistent during storage. Trimethylamine-nitrogen values of frozen fish indicates the extent of microbial spoilage before the muscle was frozen (Castell et al., 1974) and should not increase measurably during storage. The higher values for December and January may be due to improper handling and storage of the whole fish before preparation and freezing the samples.

The color values (L, a, b) for all product forms did not change significantly between months of harvest or during storage. The L values (lightness) for the fillet and WM forms were about the same and substantially higher than the UWM form. The a values (redness) for the UWM form were notably higher than the other forms, except in a few obvious isolated cases where the skin side of fillets contained dark flesh not removed during the skinning procedure. The red-brown color of the UWM flesh was due to the presence of oxidized blood pigments not removed before mincing. The b values (yellow) for all product forms were virtually unchanged and revealed no particular pattern of differences.

Sensory panel scores revealed that, in general, the color of the fillet form was most acceptable while the UWM form was least acceptable as compared with the reference sample (fillet blocks held at $-40°C$). The flavor and odor scores showed much the same consensus as the color while the firmness scores showed the panel's greatest acceptance for the fillet form followed by the UWM form. The WM form was slightly rubbery in texture and deviated considerably from that of the reference sample. Overall acceptability scores showed that the fillet form was equal to the reference sample and both were more acceptable than the WM and UWM forms. Only slight inconsistencies existed between acceptability scores for the WM and UWM forms and, generally speaking, the two

Table 3.—Percent amino acid and ammonia composition of proteins in filleted, washed, and unwashed minced weakfish harvested on a seasonal basis.

Amino acid and ammonia	Fillet						Washed mince						Unwashed mince					
	Mar.[1]	May	July	Sept.	Dec.	Jan.	Mar.	May	July	Sept.	Dec.	Jan.	Mar.	May	July	Sept.	Dec.	Jan.
Tryptophan		1.13	1.14	1.02	1.04	1.15	1.20	1.03	1.04	1.09	1.13	1.19	1.14	1.00	1.12	1.05	1.09	1.04
Lysine		9.25	9.49	9.19	9.57	9.16	9.58	9.98	10.04	9.75	9.60	10.46	9.90	9.60	9.58	10.36	9.44	9.84
Histidine		1.82	2.28	1.72	2.05	2.01	2.01	2.01	2.04	1.85	2.02	2.12	2.09	2.07	2.04	2.02	1.82	2.03
Ammonia		1.13	1.19	1.02	1.29	1.52	1.01	1.07	1.07	1.08	1.22	1.17	1.09	1.13	0.99	1.02	1.09	1.17
Arginine		5.84	6.17	5.93	6.37	6.22	6.35	6.53	6.60	6.87	6.40	6.52	6.47	6.33	6.38	6.64	5.81	6.50
Aspartic acid		10.43	9.68	10.49	10.90	10.67	11.07	10.70	10.57	10.38	10.59	10.03	10.54	10.87	10.67	10.01	10.40	10.82
Threonine		4.73	4.49	4.87	4.64	4.63	4.87	4.76	4.68	4.77	4.75	4.71	4.79	4.70	4.66	5.02	4.82	4.68
Serine		4.31	3.98	4.40	4.09	4.09	4.22	4.25	4.22	4.19	4.11	4.20	4.17	4.27	4.15	4.16	4.37	4.24
Glutamic acid		16.29	15.88	16.61	16.47	16.67	15.94	17.33	17.47	16.99	17.13	15.57	15.98	17.00	17.11	15.78	16.77	16.68
Proline		3.63	6.32	3.88	3.39	3.34	3.28	3.28	3.43	3.33	3.50	3.59	3.24	3.28	3.63	3.58	3.77	3.10
Glycine		4.46	4.39	4.38	4.50	4.45	4.18	4.03	4.25	4.03	4.09	4.23	4.03	4.23	4.44	4.27	4.42	4.22
Alanine		6.17	5.74	6.16	6.05	6.11	6.01	6.04	6.00	6.01	5.92	6.22	5.89	5.92	5.87	6.35	6.11	6.07
Cystine		1.18	1.05	1.16	1.11	1.30	1.05	1.15	1.16	1.09	1.06	1.07	1.35	1.17	1.22	1.06	1.16	1.14
Valine		4.83	4.65	4.45	4.55	4.62	4.59	4.38	4.24	4.88	4.69	4.67	5.06	4.57	4.50	4.80	4.85	4.61
Methionine		3.59	3.19	3.64	3.24	3.48	3.37	3.53	3.59	3.57	3.29	3.29	3.54	3.49	3.42	3.43	3.49	3.40
Isoleucine		4.70	4.35	4.69	4.45	4.38	4.58	4.50	4.41	4.60	4.57	4.72	4.51	4.55	4.48	4.74	4.58	4.49
Leucine		8.59	8.20	8.60	8.21	8.19	8.38	8.39	8.31	8.41	8.31	8.51	8.50	8.42	8.48	8.47	8.43	8.40
Tyrosine		3.37	3.54	3.44	3.62	3.53	3.59	3.39	3.41	3.53	3.84	3.32	3.32	3.25	3.27	3.36	3.27	3.28
Phenylalanine		3.88	3.80	3.79	3.96	3.98	4.03	3.37	3.46	3.32	3.76	3.66	3.78	3.52	3.46	3.55	3.78	3.68
Taurine		0.66	0.47	0.55	0.50	0.52	0.69	0.27	Trace	0.28	Trace	0.75	0.61	0.63	0.54	0.31	0.53	0.63
Total		99.99	100.00	100.00	100.00	100.02	100.00	99.99	99.99	100.02	99.98	100.00	100.00	100.00	100.01	99.98	100.00	100.02

[1]Samples lost during storage.

forms were considered acceptable (score of 3.0) by the taste panel. The color and firmness attributes contributed the greatest toward lower acceptability of the UWM and WM, respectively.

The concentration of essential amino acids and ammonia of fillet, WM, and UWM weakfish is listed in Table 3 and expressed as a percentage of the protein content. Amino acid values were obtained only at 0 months of storage since these values should not change measurably when stored at $-18°C$. Values varied little between months of harvest and between product forms. Detailed analyses of values for four amino acids (arbitrarily selected) for the three product forms revealed that the tyrosine content was generally highest in the fillet and WM forms and lowest in the UWM form, while the phenylalanine and glycine content was highest in the fillet form and least in the UWM form; again variation in values were minimal. The threonine content was about equal in all forms. Mincing or washing the minced flesh did not seriously affect the amino acid content as compared with fillets.

Fatty acid values (seasonal mean and range for 12 months of storage) of fillet, WM, and UWM blocks are shown in Tables 4, 5, and 6, respectively, expressed as a percentage of total fatty acids. Although a complete profile was obtained, only the biochemically important components are shown. In examining the data, no clear-cut trends could be detected between the fatty acid composition of the filleted and minced forms of weakfish. Additionally, only minor differences existed between samples stored for various periods of time (i.e., 0, 3, 6, and 12 months). Consequently, values for the storage periods were combined and the mean and range are shown. There was, however, some suggestion of a slight loss of $22{:}6\omega3$[2] in the minced forms after 12 months of storage, primarily for fish obtained during March, May, and September. A number of factors could explain the apparent seasonal differences in composition. These include differences in average weight/length ratios and sexual composition of each population, the areas of capture, and the time-span between capture and processing. The fatty acid profile of weakfish is similar to that of spot, *Leiostomus xanthurus*, as shown by Waters (1982).

[2]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.

Conclusions

Based on the results of this study, I concluded that the moisture and fat content of weakfish were inversely proportional and reached maximum values in September and December, respectively. Washing the minced flesh improved the color, decreased the fat and protein content, and resulted in a 3-4 percent loss of solids. Mincing weakfish promoted rancidity development during frozen storage; rancidity was minimized by washing. Minimal TVN and TMA-N values indicated high-quality raw fish as experimental material and indicated minor proteolytic activity during storage. Seasonality of harvest had little affect on color, shear values, and amino acid content; fatty acid content varied somewhat and may or may not be a seasonal effect. Washing of the minced flesh did not appreciably affect its nutritional value and, was an overall improvement (flavor, color, and odor) over the unwashed flesh. Taste panelists preferred filleted weakfish over the WM and UWM forms. The greatest advantages to be gained in washing the mince are better

Table 4.—Mean and range of values for the more important components of the fatty acid profile (weight percent composition) of filleted weakfish 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
March 1980	14:0	2.27	2.05 - 2.54	July 1980	14:0	2.23	2.11 - 2.53	December 1980	14.0	2.18	1.87 - 2.34
	16:0	23.68	22.74 - 24.39		16:0	27.12	26.34 - 28.47		16:0	24.88	24.17 - 26.13
	16:1	10.82	10.14 - 11.52		16:1	13.89	13.41 - 14.25		16:1	13.43	12.30 - 14.47
	18:0	6.31	5.58 - 6.91		18:0	6.95	6.59 - 7.31		18:0	6.30	6.06 - 6.60
	18:1ω9	19.64	19.64 - 20.39		18:1ω9	23.93	22.72 - 24.50		18:1ω9	22.49	21.81 - 23.80
	18:2ω6	1.08	0.94 - 1.23		18:2ω6	1.31	1.16 - 1.51		18:2ω6	1.33	0.72 - 1.88
	18:3ω3	0.78	0.59 - 1.03		18:3ω3	0.80	0.52 - 1.12		18:3ω3	0.88	0.55 - 1.41
	18:4ω3	1.80	1.65 - 1.98		18:4ω3	1.32	0.70 - 1.64		18:4ω3	1.57	0.34 - 2.59
	20:4ω6, 20:3ω3	1.88	1.63 - 1.98		20:4ω6, 20:3ω3	1.48	1.22 - 1.59		20:4ω6, 20:3ω3	1.73	1.28 - 2.19
	20:5ω3	4.61	3.99 - 5.56		20:5ω3	2.28	2.06 - 2.47		20:5ω3	3.64	2.68 - 4.11
	22:5ω3	1.33	0.38 - 1.79		22:5ω3	1.13	0.99 - 1.25		22:5ω3	1.53	1.06 - 1.93
	22:6ω3	15.20	13.09 - 16.09		22:6ω3	8.28	7.45 - 9.17		22:6ω3	8.89	8.30 - 10.07
May 1980	14:0	2.49	2.24 - 2.71	September 1980	14:0	1.16	1.29 - 2.06	January 1981	14:0	2.33	2.05 - 2.66
	16:0	22.71	21.51 - 23.82		16:0	25.54	22.48 - 27.98		16:0	24.79	23.90 - 25.56
	16:1	10.38	9.96 - 10.57		16:1	9.57	7.64 - 12.24		16:1	12.65	12.13 - 13.42
	18:0	6.90	5.78 - 7.77		18:0	9.02	7.21 - 9.58		18:0	5.97	5.85 - 6.24
	18:1ω9	18.83	17.79 - 20.49		18:1ω9	18.12	15.97 - 21.21		18:1ω9	23.07	21.34 - 26.86
	18:2ω6	1.09	0.95 - 1.35		18:2ω6	1.20	0.68 - 1.81		18:2ω6	1.30	1.06 - 1.60
	18:3ω3	0.72	0.58 - 0.87		18:3ω3	0.49	0.28 - 0.68		18:3ω3	1.04	0.72 - 1.29
	18:4ω3	1.62	0.59 - 2.08		18:4ω3	1.14	0.92 - 1.45		18:4ω3	1.05	0.46 - 1.97
	20:4ω6, 20:3ω3	1.60	1.40 - 1.83		20:4ω6, 20:3ω3	2.53	2.32 - 2.90		20:4ω6, 20:3ω3	1.42	1.11 - 1.98
	20:5ω3	4.84	4.37 - 5.23		20:5ω3	2.16	1.61 - 2.70		20:5ω3	4.03	3.57 - 4.50
	22:5ω3	1.84	1.60 - 1.96		22:5ω3	1.10	0.86 - 1.23		22:5ω3	1.44	1.27 - 1.54
	22:6ω3	15.70	14.77 - 16.61		22:6ω3	15.74	11.86 - 21.17		22:6ω3	10.44	10.17 - 10.58

Table 5.—Mean and range of values for the more important components of the fatty acid profile (weight percent composition) of washed minced weakfish 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
March 1980	14:0	2.18	2.05 - 2.29	July 1980	14:0	2.23	2.06 - 2.18	December 1980	14.0	2.32	2.21 - 2.43
	16:0	24.62	23.75 - 25.50		16:0	27.66	27.28 - 28.27		16:0	24.45	23.44 - 25.05
	16:1	11.65	11.09 - 12.19		16:1	13.34	12.28 - 13.71		16:1	12.35	11.94 - 13.07
	18:0	6.34	6.03 - 6.59		18:0	7.17	6.70 - 7.57		18:0	6.21	5.76 - 6.53
	18:1ω9	22.11	21.52 - 22.80		18:1ω9	23.50	23.02 - 23.81		18:1ω9	23.76	20.42 - 29.70
	18:2ω6	1.04	0.89 - 1.26		18:2ω6	1.29	1.16 - 1.51		18:2ω6	1.28	0.89 - 1.47
	18:3ω3	0.76	0.51 - 1.11		18:3ω3	0.74	0.55 - 0.82		18:3ω3	1.08	0.89 - 1.43
	18:4ω3	1.63	1.53 - 1.78		18.4ω3	1.16	0.62 - 1.38		18:4ω3	1.40	0.36 - 2.21
	20:4ω6, 20:3ω3	1.70	1.51 - 2.04		20:4ω6, 20:3ω3	1.62	1.48 - 1.70		20:4ω6, 20:3ω3	2.04	1.54 - 2.64
	20:5ω3	4.38	4.08 - 4.71		20.5ω3	2.37	2.26 - 2.61		20:5ω3	4.12	3.37 - 5.06
	22:5ω3	1.24	0.23 - 1.69		22:5ω3	1.10	0.96 - 1.18		22:5ω3	1.66	1.56 - 1.79
	22:6ω3	12.71	11.54 - 13.62		22:6ω3	8.92	7.98 - 9.66		22:6ω3	8.23	7.68 - 9.01
May 1980	14:0	2.82	2.68 - 2.89	September 1980	14:0	1.39	1.28 - 1.48	January 1981	14:0	2.78	2.37 - 2.67
	16:0	22.62	22.17 - 23.12		16.0	27.51	24.51 - 28.93		16:0	25.16	24.41 - 26.46
	16:1	10.99	10.58 - 11.21		16:1	11.86	10.79 - 12.50		16:1	12.41	12.00 - 13.38
	18:0	6.72	5.66 - 7.56		18.0	7.06	5.62 - 7.92		18:0	6.11	5.94 - 6.21
	18:1ω9	19.81	19.42 - 20.05		18:1ω9	21.50	19.91 - 22.92		18:1ω9	23.09	20.97 - 27.98
	18:2ω6	1.09	0.87 - 1.37		18:2ω6	0.99	0.59 - 1.20		18:2ω6	1.11	0.97 - 1.21
	18:3ω3	0.82	0.46 - 1.05		18:3ω3	0.65	0.48 - 0.77		18:3ω3	0.96	0.45 - 1.17
	18:4ω3	1.86	1.00 - 2.41		18:4ω3	1.35	1.15 - 1.67		18:4ω3	0.84	0.35 - 2.05
	20:4ω6, 20:3ω3	1.65	1.35 - 1.80		20:4ω6, 20:3ω3	2.66	2.23 - 3.68		20:4ω6, 20:3ω3	1.54	1.22 - 2.11
	20:5ω3	5.01	4.56 - 5.40		20:5ω3	2.29	1.16 - 3.35		20:5ω3	4.43	4.04 - 4.95
	22:5ω3	1.89	1.82 - 1.96		22:5ω3	1.01	0.83 - 1.16		22:5ω3	1.51	1.39 - 1.57
	22:6ω3	12.81	12.03 - 13.85		22:6ω3	10.72	9.73 - 11.15		22:6ω3	10.29	9.76 - 10.73

storage stability and improved flavor, odor, and appearance. Minced weakfish provides a good source of protein for the human diet. The minced form (intermediate product) offers many opportunities for further processing.

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Table 6.—Mean and range of values for the more important components of the fatty acid profile (weight percent composition) of unwashed minced weakfish 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
March 1980	14:0	2.23	2.02 - 2.36	July 1980	14:0	2.03	2.01 - 2.07	December 1980	14:0	2.28	2.19 - 2.39
	16:0	24.49	23.69 - 25.87		16:0	21.01	26.74 - 27.91		16:0	24.28	23 19 - 24.74
	16:1	11.63	10.92 - 12.06		16:1	13.07	12.76 - 13.42		16:1	12.35	11.57 - 13.57
	18:0	4.76	5.92 - 6.11		18:0	7.28	6.75 - 7.72		18:0	6.14	5.82 - 6.44
	18:1ω9	21.90	21.02 - 23.06		18:1ω9	23.91	23.32 - 24.26		18:1ω9	24.30	20.62 - 29.29
	18:2ω6	1.00	0.84 - 1.23		18:2ω6	1.40	1.18 - 1.62		18:2ω6	1.26	0.87 - 1.45
	18:3ω3	0.72	0.42 - 1.05		18:3ω3	0.80	0.74 - 0.90		18:3ω3	1.06	0.96 - 1.17
	18:4ω3	1.52	1.46 - 1.68		18:4ω3	1.30	0.78 - 1.49		18:4ω3	1.58	0.60 - 2.46
	18:4ω6 } 20:3ω3 }	1.77	1.63 - 2.01		20:4ω6 } 20:3ω3 }	1.56	1.31 - 1.75		20:4ω6 } 20:3ω3 }	2.09	1.45 - 2.92
	20:5ω3	4.64	4.28 - 5.47		20:5ω3	2.33	2.13 - 2.48		20:5ω3	3.84	3.15 - 5.17
	22:5ω3	1.30	0.30 - 1.82		22:5ω3	1.07	1.01 - 1.14		22:5ω3	1.54	1.43 - 1.76
	22:6ω3	13.27	12.85 - 14.67		22:6ω3	8.70	8.06 - 9.56		22:6ω3	7.63	7.00 - 8.33
May 1980	14:0	3.53	3.29 - 3.78	September 1980	14:0	1.51	1.48 - 1.56	January 1981	14:0	2.43	2.29 - 2.55
	16:0	22.79	22.45 - 23.26		16:0	28.66	27.95 - 29.87		16:0	25.25	24.65 - 26.33
	16:1	12.57	12.19 - 12.97		16:1	12.53	12.06 - 13.10		16:1	13.17	12.77 - 13.69
	18:0	6.59	5.88 - 6.94		18:0	7.11	6.38 - 7.48		18:0	6 16	6.07 - 6.31
	18:1ω9	20.49	20.09 - 20.84		18:1ω9	22.72	22.14 - 23.39		18:1ω9	22.37	21.73 - 23.18
	18:2ω6	1 19	0.98 - 1.32		18:2ω6	0.75	0.62 - 0.89		18:2ω6	1.19	1.07 - 1.31
	18:3ω3	0.78	0.49 - 0.94		18:3ω3	0.47	0.17 - 0.65		18:3ω3	0.90	0.62 - 1.16
	18:4ω3	1.90	1.41 - 2.14		18:4ω3	0.99	0.32 - 1.39		18:4ω3	0.87	0.45 - 1.82
	20:4ω6 } 20:3ω3 }	1.34	1.24 - 1.47		20:4ω6 } 20:3ω3 }	2.39	2.08 - 2.77		20:4ω6 } 20:3ω3 }	1.47	1.34 - 1.72
	20:5ω3	5.55	4.59 - 6.52		20:5ω3	2.04	1.80 - 2.26		20:5ω3	4.03	3.78 - 4.26
	22:5ω3	1.84	1.62 - 2.08		22:5ω3	1.02	0.93 - 1.12		22:5ω3	1.53	1.53 - 1.63
	22:6ω3	9.56	9.00 - 9.91		22:6ω3	11.40	10.24 - 12.55		22:6ω3	9.55	8.79 - 10.54

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