Processing Yields and Composition of Paddlefish (*Polyodon spathula*), a Potential Aquaculture Species†

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Paddlefish (*Polyodon spathula*) were processed and analyzed to determine yields and chemical composition. Dressed paddlefish yields with and without tails were 47.3% and 45.0%, respectively, and fillet yields were 33.5%. The lipid concentration of whole fillets was 1.53%, while white muscle fillets were 0.27% lipid. Nonpolar lipids from whole fillets contained 71.37% unsaturated fatty acids of which 78.62% were monounsaturated. Polar lipids were composed of 60.92% unsaturated fatty acids of which 79.58% were monounsaturated. The $\omega - 3$ fatty acid concentrations were 9.9% and 10.9% of the nonpolar and polar lipids, respectively. The production of thiobarbituric acid reactive substances was greater in whole fillets then in white muscle fillets during frozen storage (−15 °C), suggesting that the removal of red muscle could decrease lipid oxidation in paddlefish fillets.

INTRODUCTION

Aquacultural production of finfish and shellfish in the United States has increased from 200 million pounds in 1980 to over 790 million pounds in 1988 (Harvey, 1990). The rapid growth of aquaculture can be attributed primarily to increased consumer demands for seafood and the inability of wild catches to meet this demand. Catfish is the major aquacultural species, contributing over 45% of the total U.S. aquacultural production in 1988. Other major species include trout, salmon, and crawfish.

Interest in paddlefish (*Polyodon spathula*) as an aquacultural species has increased in recent years. Paddlefish are desirable in polyculture systems because they are indiscriminate filter feeders on primarily zooplankton and will not readily compete with primary species for prepared diets (Rosen and Hale, 1981; Kirkendall, 1983). Polyculture of paddlefish with channel catfish has been the most extensively studied system (Burke and Bayne, 1986; Semmens and Shelton, 1986; Kirkendall, 1983). Feeding catfish results in pond fertilization which increases zooplankton abundance and carrying capacity to produce paddlefish at no extra feed costs. Paddlefish fry stocked at 1500/ha can produce 0.5 kg of fish in polyculture with catfish after 180 culture days under optimum conditions (Semmens and Shelton, 1986).

Paddlefish meat has excellent potential as a marketable product. Fillets consist of primarily white muscle and are firm and boneless. Most paddlefish are currently wild-caught and not raised commercially. The objectives of this research were to determine processing yields and proximate and fatty acid composition of cultured paddlefish. In addition, the effects of processing on the frozen shelf life of paddlefish fillets were investigated.

METHODS

Paddlefish were spawned and raised at the Kentucky State University Aquaculture Research Center. Seventeen-month-old fish (stocked at 1235 fish/ha) were harvested in September 1989. Fish ranging in size from 394.4 to 666.5 g were sacrificed by deheading. The fish were mechanically skinned by a Jet mini-skinner (Fayetteville, AR) and filleted. Paired fillets were prepared from the same fish by leaving one fillet intact (whole fillet), while the other had the outer 3–6 mm of the fillet removed to eliminate the red muscle (white muscle fillet). White muscle fillets were prepared in this manner to ensure the removal of all red muscle to determine the role of the red muscle in the storage stability of the fillets. No efforts were made to quantitate the amount of red muscle in the fish since much of the red muscle was lost during the skinning process. The paired fillets were individually placed into Whirlpak bags (500-g capacity) and stored at −15 °C.

Proximate analysis was performed in triplicate on three paired filets. Protein (Kjeldahl), fat (Soxhlet), moisture (drying oven), and ash were evaluated according to AOAC methods of analysis (AOAC, 1987).

Lipid extraction was performed by using a 1:10 ratio of muscle to chloroform/methanol (2:1) (Folch et al., 1957). The mixture was homogenized in a blender for 1 min, filtered through Whatman No. 1 paper, and evaporated on a Büchi rotovapor-revaporator to isolate the lipid.

Lipid fractions were separated by using heat activated (2 h, 100 °C) 100-mesh silicic acid (Rouser et al., 1976). A slurry of 15 g of silicic acid and chloroform was poured into a 33 cm × 1 cm glass column containing glass wool. The silicic acid column was washed with 3 column volumes of chloroform. The final washing of chloroform was allowed to descend to the top of the gel, and 200 mg of lipid/10 mL of chloroform was applied with a Pasteur pipet. Once the lipid descended into the silicic gel, the lipid fractions were eluted at a rate of 3 mL/min. Ten column volumes of chloroform (nonpolar) and methanol (polar) were used to elute the lipid fractions. Washings were collected in preweighed round-bottom flasks and evaporated on a rotovap. The percent of the nonpolar lipid fractions was determined gravimetrically, and the lipids were resolubilized in petroleum ether, flushed with nitrogen, and stored at −15 °C until analyzed.

The fatty acids of the lipid fractions were methylated as described by Ackman and Eaton (1971). The lipid/petroleum ether fractions were evaporated to dryness under nitrogen at 40 °C. Boron trifluoride/methanol (5 mL) was added to 50 mg of lipid and sealed tightly in screw-capped test tubes. The samples were placed into a boiling water bath for 60 min and cooled, and 2 mL of petroleum ether was added to extract the fatty acid methyl esters. Samples were centrifuged at 2000*g* for 5 min, the petroleum ether layer was collected, and the extraction was repeated. The pooled petroleum ether/fatty acid methyl esters were evaporated under nitrogen (40 °C) to approximately 0.5 mL. All samples contained heptadecanoic acid as an internal

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† This paper (90-5-121) is published with the approval of the Director of the University of Kentucky Agricultural Experiment Station.

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0021-8561/91/1439-0686$02.50/0

Table I. Processing Yields of Paddlefish

	wt, g	% yield
	Dressed[a]	
whole fish	531.6 ± 95.0	
with tail	253.3 ± 57.1	47.3 ± 2.3
without tail	240.3 ± 54.8	45.0 ± 2.3
	Fillets[b]	
whole fish	517.8 ± 70.7 g	
fillets	87.2 ± 16.4 g	33.5 ± 2.3

[a] Skin, dorsal fin, head, and viscera removed. [b] Skinned.

standard. Fatty acid analysis was performed by injecting 1–5 μL of the fatty acid methyl esters into a Hewlett-Packard 5880A gas chromatograph equipped with a flame ionization detector and a 2.0 m × 3.0 mm glass column packed with 100/200 Chromosorb, 10% SP2300 (Supleco). The gas chromatograph conditions were as follows: injector temperature 220 °C, detector tempertaure 220 °C, and oven temperature 200 °C, with nitrogen as the carrier gas (40 mL/min). Fatty acid methyl ester standards were solubilized in petroleum ether and injected under the same conditions as the samples. Fatty acid concentrations were quantitated by peak area ratios.

Atomic absorption was used to determine iron concentration of the paired paddlefish fillets. Fish samples (20 g) were digested in concentrated H_2SO_4 (20 mL) with 6% H_2O_2 (10 mL) for 8 h at 400 °C. Samples were read at 248.3 nm by using a slit width of 0.2 nm.

Susceptibility to oxidative rancidity in frozen fillets was determined on whole and white muscle fillets by analyzing three sets of paired fillets every 6 weeks for 6 months. Frozen fillets were thawed under cold running tap water and finely chopped in a food processor. The extent of lipid oxidation in muscle was determined by measuring thiobarbituric acid reactive substances (TBARS). TBARS were calculated as micrograms of malonaldehyde/gram of muscle (Sinnhuber and Yu, 1977).

RESULTS AND DISCUSSION

Paddlefish used in this study (approximately 0.5 kg, Table I) were smaller than paddlefish of a similar age (2.3 kg) reported by Semmens and Shelton (1986). The smaller size of the fish used in this study could be due to several factors including stocking density. Fish in this study were stocked at 1235 fish/ha for the entire 17-month growth period. Semmens and Shelton (1986) stocked fish at 1500/ha for the first 6 months and then thinned fish to 250/ha for the remaining 11 months. Small fish size could also be attributed to available feed; however, the relationship between pond fertility and growth rate of paddlefish is not well understood. Fish growth rates are also affected by climatic conditions which might be partially responsible for the small size of the fish raised in Kentucky versus the size of the fish raised in southern Alabama (Semmon and Shelton, 1986). While the paddlefish used in this study might not be the maximum size that can obtain after 17 months of culture, they were not in a nutritionally depleted state since this size is typical of 17-month-old paddlefish raised at the Kentucky State University Aquaculture Center (data not shown). Therefore, the composition, processing yields, and storage stability of the meat obtained from these fish should be representative of similar sized paddlefish.

The processing yields for paddlefish were slightly lower than for other species of fish. The yield for skinned, dressed paddlefish with tails was 47.3% (Table I) compared to 58.5–62.9% for catfish (Walker and Ammerman, 1976; Russell, 1972; Lovell and Ammerman, 1974). Fillet yields for paddlefish (33.5%, Table I) were lower than for aquacultured striped bass (Hodson et al., 1987), catfish (Ammerman, 1985), and rainbow trout (Smith et al., 1988), which had dressed fillets yields of 40%, 45.7%, and 57.5%, respectively. The low yields in paddlefish could be due to the paddle, which contributes to 40% of the total length of the fish (data not shown).

Table II. Proximate Composition of White and Whole Muscle Fillets (Grams/100 g)

	whole	white
moisture	81.90 ± 0.25	83.80 ± 0.40
fat	1.53 ± 0.35	0.27 ± 0.21
nonpolar lipids	1.28	
polar lipids[a]	0.25	
protein	15.80 ± 0.32	15.90 ± 0.14
ash	0.93 ± 0.06	1.00 ± 0.00
iron, ppm	19.80	6.40

[a] Calculated by difference.

Table III. Fatty Acid Composition of the Polar and Nonpolar Lipid Fractions of Whole Paddlefish Fillets

	nonpolar, %	polar, %
14:0	3.37 ± 0.04	4.91 ± 0.17
16:0	21.28 ± 0.08	26.09 ± 1.27
18:0	3.46 ± 0.07	6.78 ± 1.58
22:0	0.36 ± 0.18	1.38 ± 1.38
total saturates	28.47	39.16
14:1	2.07 ± 0.13	3.55 ± 0.62
16:1	14.18 ± 0.42	13.09 ± 1.89
18:1	37.24 ± 0.57	22.80 ± 1.16
20:1	1.02 ± 0.30	1.79 ± 0.40
22:1	1.60 ± 0.04	2.25 ± 1.32
total monounsaturates	56.11	43.48
18:2	4.95 ± 0.04	4.46 ± 0.33
18:3n3	5.86 ± 0.03	5.70 ± 0.06
20:2	0.37 ± 0.04	0.96 ± 0.60
20:4		0.44 ± 0.44
20:5n3	1.10 ± 0.08	0.77 ± 0.77
22:2		0.67 ± 0.67
22:3n3	2.98 ± 0.22	4.45 ± 0.95
total polyunsaturates	15.26	17.44
total unsaturates	71.37	60.92
ω − 3	9.90	10.90

The lipid content of foods is important from both a nutritional and a sensory standpoint. Fatty acids can have both deleterious and beneficial effects on human nutrition (Kinsella, 1986). Current recommendations of the Surgeon General suggest that fat consumption be limited to 30% of total caloric intake and that the amount of saturated fatty acids in the diet be decreased. The paddlefish used in this study had a low fat content with skinned whole and white muscle fillets containing 1.53% and 0.27%, respectively (Table II). The higher fat content in the whole fillets could be due to the red muscle, which can have up to 5 times the concentration of lipid of white muscle (Ackman, 1980; Mitchell, 1986). This suggests that removal of the red muscle could substantially decrease the fat content of the paddlefish fillets. However, the low fat content of both whole or white muscle fillets suggests that aquacultured paddlefish would be classified as low-fat fish species (Nettleton, 1985) which could be included in low-fat diets.

The type and amount of unsaturation of the fatty acids in foods also has nutritional implications. The nonpolar fatty acids in the paddlefish were 71.4% unsaturated, and the polar lipids were 60.9% unsaturated (Table III). The concentration of unsaturated fatty acid in the nonpolar lipids was similar to the unsaturated fatty acid content of the total lipids in catfish (71.4% vs 73%, respectively; Ammerman, 1985). Nonpolar lipids were approximately 85% of the total lipids in paddlefish (Table II). Monoun-

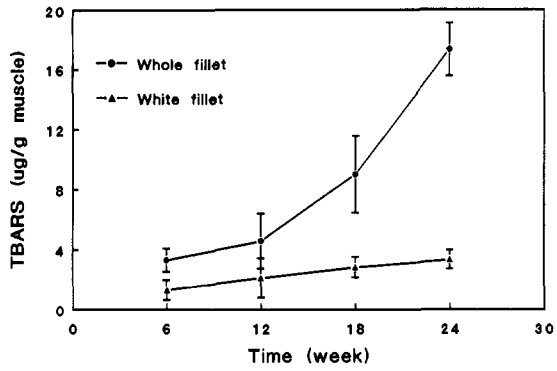

Figure 1. Production of thiobarbituric acid reactive substances (TBARS) in whole and white muscle paddlefish fillets stored at −15 °C. TBARS are expressed as micrograms of malonaldehyde/gram of muscle.

saturates made up 78.6% of the total unsaturated fatty acids in the nonpolar lipids and 71.4% of the polar lipids. While slight variations were observed in the fatty acid profiles of the nonpolar and polar lipids, the major fatty acids in these two fractions were similar. Hexadecanoic (palmitic) acid was the major saturated fatty acid. The major monounsaturated fatty acids were 9-hexadecenoic (palmitoleic) acid and 9-octadecenoic (oleic) acid. The major polyunsaturated fatty acids were 9,12-octadecadienoic (linoleic) acid, 9,12,15-octadecatrienoic (linolenic) acid, and 13,16,19-docasatrienoic acid.

The total $\omega - 3$ fatty acid content (9,12,15-octadecatrienoic acid, 5,8,11,14,17-eicosapentaenoic acid, and 13,16,19-docosatrienoic acid) was 9.9% in the nonpolar lipids and 10.9% in the polar lipids. While the proportion of $\omega - 3$ fatty acids in the paddlefish lipids was relatively high, it was low in 5,8,11,14,17-eicosapentaenoic acid (1.1% nonpolar and 0.8% polar) and absent in 4,7,10,13,16,19-docosahexaenoic acid. Both of these fatty acids are believed to play an important role in the prevention of heart disease (Kinsella, 1986).

A problem with muscle foods that are high in unsaturated fatty acids is their susceptibility to lipid oxidation. Therefore, the frozen storage stability of the whole and white muscle paddlefish fillets was examined. Lipid oxidation was more rapid in whole fillets with TBARS increasing 5.2-fold compared to 2.5-fold increase after 24 weeks in white muscle fillets (Figure 1). The increased lipid oxidation in the whole fillets could be due to the red muscle. The presence of the red muscle attributed a 5-fold higher lipid and a 3-fold higher iron content to the whole fillets compared to the white muscle fillets (Table II). Higher fat and iron concentrations of muscle foods will result in increased susceptibility to lipid oxidation due to increased substrate and prooxidant concentrations (Dawson and Gartner, 1983). Removal of the red muscle from the fillets decreases the rate of lipid oxidation, suggesting that this could be an effective method of prolonging the frozen shelf life of paddlefish fillets. However, no attempts were made in this study to determine yields of paddlefish that had red muscle removed; therefore, the economic feasibility of the removal of red muscle from paddlefish is not known.

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Received for review July 2, 1990. Revised manuscript received October 8, 1990. Accepted November 12, 1990.

Registry No. Fe, 7439-89-6.