Fatty Acids and Lipid Classes of Three Underutilized Species and Changes Due to Canning

MALCOLM B. HALE and THOMAS BROWN

ABSTRACT—Canned products were prepared from three underutilized species that are abundant in the Gulf of Mexico: Spanish sardine, Sardinella aurita; *thread herring,* Opisthonema oglinum; *and chub mackerel,* Scomber japonicus. *Proximate chemical compositions, fatty acid profiles, and lipid class compositions are reported for both raw and canned products. Results indicate that heat processing in sealed cans has no significant effect on the fatty acid profile or lipid class composition. The use of vegetable oil as a packing medium, however, has major effects on the product fatty acid profile. Linoleic acid (18:2ω6) is greatly increased and the concentrations of long-chain polyunsaturated fatty acids decreases.*

Introduction

The coastal herrings are, in general, small, bony fishes of the family *Clupeidae* which regularly occur in large schools and have the highest potential yield of any fishery resource in the west-central Atlantic Ocean and Gulf of Mexico. Houde (1976) estimated that the resource in the eastern Gulf alone could probably support a 500,000 metric ton (t) annual yield. Several species have been utilized to some extent as bait fish and menhaden have been fully exploited for fish meal, but the untapped potential of small herrings and related species for food use is great.

The coastal herrings are not suitable for the traditional fresh or frozen markets because of their small size, bony structure, and readily oxidizable fat content. Several species have a good potential as canned products, however, since the bones are softened during heat processing and sealed cans prevent lipid oxidation during storage.

In recent years, there has been much interest in the effect of diet on the risk of coronary heart disease (CHD). Several studies have demonstrated that the consumption of fish or fish oils lowers serum lipid levels in both human subjects and experimental animals. Von Lossonczy et al. (1978) showed that both serum cholesterol and triglycerides (triacylglycerols) were reduced in healthy human subjects by ingestion of a controlled diet based on mackerel. Truswell (1978) stated, "It is firmly established that plasma total cholesterol is positively related to the risk of subsequent CHD." In addition, eicosapentaenoic acid (EPA, 20:5ω3), a major fatty acid in marine fish, also protects against CHD by acting as a precursor for a prostaglandin which slows the rate of blood clotting (Rawls, 1981).

Coastal herrings and other underutilized species from southeastern U.S. coastal waters have relatively high contents of the highly unsaturated fatty acids (HUFA) containing five or six double bonds. Processing or storage conditions, however, could potentially result in undesirable changes to these labile compounds. Although the effects of frozen storage on fatty acid composition of fish has been widely studied and reported, the effects of processing in general and canning in particular are not well known. Dudek et al. (1981) reported fatty acid data on six seasonal samples each of Atlantic mackerel and sockeye salmon. Their data indicated that neither canning, broiling, baking, nor microwave cooking had a significant effect on total polyunsaturated fatty acids (PUFA) or the five and six double-bonded HUFA. Giddings and Hill (1975) heat processed blue crab for 10 minutes at 121 °C and found that PUFA losses were not excessive and changes in lipid fractions were slight.

In this paper we present fatty acid, lipid class, and proximate composition data on some abundant but generally unfamiliar species and indicate whether nutritionally desirable polyunsaturated fatty acids are affected by the canning process.

Materials and Methods

The fish samples used for the primary study were collected in May and June 1982, from the vicinity of Panama City, Fla. Spanish sardines, *Sardinella aurita*, and chub mackerel, *Scomber japonicus*, were harvested by beach seine; thread herring, *Opisthonema oglinum*, was harvested by purse seine. Samples were frozen into ice blocks in polyethylene containers at the Southeast Fisheries Center's Panama City Laboratory and later transported to the SEFC Charleston

Malcolm B. Hale and Thomas Brown are with the Charleston Laboratory, Southeast Fisheries Center, National Marine Fisheries Service, NOAA, P.O. Box 12607, Charleston, SC 29412-0607. This paper is Contribution No. 83-30C, Southeast Fisheries Center.

Laboratory in Styrofoam[1] boxes. On arrival, the plastic containers were sealed in Cryovac bags and stored at −30 °C until processed (within 2 weeks).

The individual fish were separated from ice blocks in cold tap water after partial thawing in a chilled room overnight. Length and weight measurements were made on a representative sample of each lot. A subsample of approximately 500 g was dressed, comminuted in a food processor, sealed in plastic sample cups and frozen for later analysis.

Fish for processing were washed after removal of heads, tails, and viscera. The dressed fish were immersed in a 60 degree brine (15.8 percent NaCl) for 15 minutes, drained, lightly rinsed, and refrigerated for 1-2 hours before packing. The dressed thread herring and chub mackerel were packed into 307 × 409 (No. 2) cans and the Spanish sardines were cut into chunks and packed into 307 × 113 (No. ½ tuna) cans. Needle-type copper-constantan thermocouples were centered in several cans in each run using Ecklund receptacles and connectors. The packed fish were steam precooked to a temperature of about 190 °F (88 °C). Free liquid was drained from the cans and a hot 2 percent brine was added. Lids were applied to the cans and sealed with a Rooney can sealer. Cans of each species were processed in two batches in a RDTI-3 steam retort (Dixie Canner Equipment Co.). One batch was processed to the normal sterilization level (F_0 = about 12) and the second batch to an F_0 value (total heat exposure) about 50 percent greater. The F_0 value is a measure of total heat exposure at the center of the can, including heat-up, processing, and cool-down. An F_0 value of 12 indicates a degree of sterilization equivalent to that obtained during 12 minutes at a constant 250 °F (121 °C). The thermocouples inside the cans were connected to a data logger (Kaye Instrument Co.) for automatic print-out of temperatures and computed F_0 values at 2-minute intervals. Samples for chemical analysis consisted of the drained solids contents from the individual cans for which the specified F_0 values were determined.

Table 1.—Size data for whole fish and proximate chemical compositions for dressed, H&G fish, both raw and canned.

Item	Size data (whole fish)		
	Spanish sardine	Thread herring	Chub mackerel
Mean weight (g ± SD)	71.5 ± 23.8	108.4 ± 12.6	78.8 ± 13.5
Mean length (cm ± SD)	16.9 ± 1.7	18.2 ± 0.56	18.8 ± 0.77

	Proximate composition (dressed, H&G)					
	Raw	Canned	Raw	Canned	Raw	Canned
Moisture (%)	75.41	69.63	75.22	70.81	73.73	69.77
Protein (%)	20.09	24.52	20.05	23.21	21.08	24.79
Lipid (%)	3.22	4.21	2.71	3.41	3.07	3.30
Ash (%)	1.75	1.90	3.04	3.21	2.66	3.03

Spanish sardines, harvested in September 1981, from the vicinity of Port St. Joe, Fla., were canned in an earlier processing study. The dressed fish were heat processed to the normal level ($F_0 = 12$) in two groups: 1) With a 2 percent brine packing medium and 2) with soybean oil as a packing medium. Raw dressed samples and drained solids from each canned product were comminuted and analyzed for proximate chemical compositions and fatty acid profiles.

Protein, moisture, and ash contents were determined by AOAC methods (AOAC, 1975) and the lipid content was determined by a chloroform-methanol extraction method (Smith et al., 1964).

Fatty acid methyl esters were prepared from extracted lipids by the method of Metcalfe and Schmitz (1961) and were analyzed with a Hewlett-Packard 5830A gas chromatograph equipped with a 50 m flexible fused silica capillary column coated with Carbowax 20-M. Separation was isothermal at 210 °C with injector and detector at 300 °C. The individual fatty acid esters were identified by means of a computer program containing equivalent chain length (ECL) values of authentic standards and those of esters of cod liver oil (Ackman and Burgher, 1965).

Lipid classes were quantified using an automated system of thin layer chromatography (TLC) with flame ionization detection (Iatroscan Laboratories, Tokyo, Japan) of the type described by Sipos and Ackman (1978). Type S (II) chromarods were spotted with 10-20 μg of lipid dissolved in heptane:chloroform (1:1 by volume) and developed for 30 minutes in hexane:diethylether:acetic acid (85:15:0.02) to separate triglycerides, free fatty acids, sterols, and total polar lipids. Detector peaks were quantified with a Hewlett-Packard 3390A reporting integrator.

Results and Discussion

Length, weight, and proximate composition data for the lots of Spanish sardine, thread herring, and chub mackerel used in this study are listed in Table 1. Both protein and lipid concentrations increase during canning due to moisture losses. Relative to other fish, these species rate high in protein and moderate in fat content.

The major fatty acids, as determined for raw and canned samples, are listed in Table 2 for Spanish sardine, Table 3 for thread herring, and Table 4 for chub mackerel. The 16:0 and 22:6ω3 fatty acids predominate in all three species. There are minor variations in the analytical results for individual fatty acids, but no definite pattern is apparent. The oxidation of fish lipids normally results in a decrease in the polyunsaturated fatty acids (PUFA) and particularly those

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

Table 2.—Major fatty acids of raw and canned Spanish sardines, *Sardinella aurita* (weight percent composition).

Fatty acid	Sample form: Raw	Canned (F_0 = 13.3)	Canned (F_0 = 17.7)
14:0	3.9	3.5	4.1
16:0	22.2	21.8	22.8
17:0	1.6	1.5	1.5
18:0	7.5	7.7	7.3
16:1	5.7	5.4	6.1
18:1	11.3	10.2	11.4
20:1	1.3	1.2	1.1
22:1	0.1	—	0.1
18:2ω6	1.2	1.3	1.4
18:3ω3	0.7	0.8	0.8
18:4ω3	0.7	0.6	0.8
20:4ω6	1.8	1.9	1.8
20:5ω3	8.1	7.8	9.4
22:5ω6	1.2	1.4	1.2
22:5ω3	1.4	1.2	1.3
22:6ω3	22.7	25.1	22.1
Total saturated	37.7	37.3	39.0
Total monoenes	19.4	17.8	19.5
Total PUFA	42.9	44.9	41.6
Total HUFA	33.6	35.6	33.9

Table 3.—Major fatty acids of raw and canned thread herring, *Opisthonema oglinum* (weight percent composition).

Fatty acid	Sample form: Raw	Canned (F_0 = 12.1)	Canned (F_0 = 17.3)
14:0	5.7	4.6	5.1
16:0	23.5	23.5	23.0
17:0	1.9	1.8	1.8
18:0	7.8	7.8	7.5
16:1	5.8	5.2	5.0
18:1	11.0	9.7	9.6
20:1	2.0	1.8	1.6
22:1	0.1	0.2	0.2
18:2ω6	1.7	1.7	1.9
18:3ω3	0.7	0.8	0.9
18:4ω3	0.5	0.6	0.6
20:4ω6	3.1	3.2	3.7
20:5ω3	6.7	6.9	6.7
22:5ω6	1.3	1.5	1.7
22:5ω3	1.9	1.6	1.6
22:6ω3	17.2	19.3	20.6
Total saturated	43.2	42.0	41.3
Total monoenes	19.2	17.5	16.5
Total PUFA	37.6	40.5	42.2
Total HUFA	27.7	29.5	30.6

Table 4.—Major fatty acids of raw and canned chub mackerel, *Scomber japonicus* (weight percent composition).

Fatty acid	Sample form: Raw	Canned (F_0 = 13.3)	Canned (F_0 = 18.8)
14:0	2.8	2.3	2.8
16:0	18.5	17.3	17.6
17:0	1.6	1.8	1.7
18:0	8.4	9.4	8.3
16:1	3.9	3.6	4.0
18:1	14.5	12.1	13.7
20:1	2.7	2.4	2.7
22:1	0.7	0.7	0.8
18:2ω6	1.4	1.3	1.4
18:3ω3	0.7	0.6	0.8
18:4ω3	0.6	0.4	0.6
20:4ω6	3.2	4.1	3.2
20:5ω3	5.3	5.4	5.5
22:5ω6	2.2	2.8	2.1
22:5ω3	2.7	3.0	2.8
22:6ω3	21.1	24.1	22.2
Total saturated	34.8	34.2	33.9
Total monoenes	22.5	19.0	22.2
Total PUFA	42.7	46.9	44.0
Total HUFA	31.3	35.3	32.6

Table 5.—Effect of packing media on concentrations of total lipids and selected fatty acids for canned Spanish sardines.

Item	Sample: Raw, headed and gutted	Canned in 2% brine	Canned in soybean oil
		Percent	
Total lipids	1.3	2.05	9.64
		Fatty acids (% of total)	
16:0	25.18	25.38	13.81
18:0	8.09	8.48	5.04
18:1	9.71	11.74	21.42
18:2ω6	1.06	1.32	43.50
20:5ω3	4.86	4.29	0.84
22:6ω3	29.46	25.50	4.34

Table 6.—Lipid class composition of raw and canned Spanish sardines.

Lipid class	Sample form: Raw	Canned (F_0 = 13.3)	Canned (F_0 = 17.7)
		Percent of total	
Triglycerides	67	55	66
Free fatty acids	7	7	5
Sterols	2	3	2
Polar lipids	22	35	26
Unidentified	2	—	—

Table 7.—Lipid class composition of raw and canned thread herring.

Lipid class	Sample form: Raw	Canned (F_0 = 12.1)	Canned (F_0 = 17.3)
		Percent of total	
Triglycerides	61	65	61
Free fatty acids	4	4	5
Sterols	2	3	4
Polar lipids	32	28	31
Unidentified	1	—	—

Table 8.—Lipid class composition of raw and canned chub mackerel.

Lipid class	Sample form: Raw	Canned (F_0 = 13.3)	Canned (F_0 = 18.8)
		Percent of total	
Triglycerides	64	51	65
Free fatty acids	6	6	5
Sterols	2	4	2
Polar lipids	27	40	28
Unidentified	—	—	—

with five or six double bonds (HUFA). However, neither docosahexaenoic acid (22:6ω3) nor other HUFA showed any consistent pattern of change due to heat processing in this study.

Shown in Table 5 is the effect that packing media can have on the fatty acid profiles of canned fish. Lipid content and selected fatty acids are listed for the Spanish sardines harvested in September 1981. Headed and gutted (H&G) fish were analyzed both raw and as the drained solids after canning in either 2 percent brine or in soybean oil. Fat content of these Spanish sardines was low, and a significant amount of the soybean oil was absorbed. Consequently, the fatty acid profile showed a much higher level of 18:2ω6 and much lower 22:6ω3, since soybean oil contains about 65 percent 18:2 and no 22:6ω3 at all.

The lipid class compositions as determined by the automated TLC system, for Spanish sardine, thread herring, and chub mackerel appear in Tables 6, 7, and 8, respectively. All the raw samples have a similar pattern. Triglycerides predominate with polar lipids a strong second. An apparent shift from triglycerides to polar lipids was indicated by analyses of two of the canned samples. This shift did not show up in the corresponding samples canned at higher

F_0 values, however, and was probably an artifact.

Conclusions

Lipid characteristics of these samples of Spanish sardines, thread herring, and chub mackerel are fairly similar, with relatively high levels of highly unsaturated fatty acids and a predominance of triglycerides as a lipid class. No significant changes in PUFA concentrations or lipid class distributions due to heat processing in sealed cans were demonstrated. The use of oil as a packing medium can have great effects on the lipid content and fatty acid profile of the final product. The positive medical benefits of the highly unsaturated fatty acids contained in marine lipids could be more fully realized with a fish oil packing medium rather than vegetable oils. The present food regulations would probably limit usage to oil recovered from precooking of the same species, however.

Acknowledgments

We thank Gloria Seaborn for performing the lipid class analyses, Jim Bonnet for the proximate composition data, Rick Dufresne (Panama City) for collecting the fish, and John Goodwin for assistance in processing and sample preparation.

Literature Cited

Ackman, R. G., and R. G. Burgher. 1965. Cod liver oil fatty acids as secondary reference standards in the GLC of polyunsaturated fatty acids of animal origin: Analysis of a dermal oil of the Atlantic leatherback turtle. J. Am. Oil Chem. Soc. 42:38-42.

AOAC. 1975. Official methods of analysis of the Association of Official Anal. Chem. 12th ed. Assoc. Off. Analytical Chem., Wash. D.C.

Dudek, J. A., B. A. Behl, E. R. Elkins, Jr., R. E. Hagen and H. B. Chin. 1981. Determination of effects of processing and cooking on the nutrient composition of selected seafoods. Natl. Food Processors Assoc., Wash., D.C.

Giddings, G. G., and L. H. Hill. 1975. Processing effects on the lipid fractions and principal fatty acids of blue crab (*Callinectes sapidus*) muscle. J. Food Sci. 40:1127-1129.

Houde, E. D. 1976. Abundance and potential for fisheries development of some sardine-like fishes in the eastern Gulf of Mexico. Proc. Gulf Caribb. Fish. Inst. 28:73-82.

Metcalfe, L. D., and A. A. Schmitz. 1961. The rapid preparation of fatty acid esters for gas chromatographic analysis. Anal. Chem. 33:363-364.

Rawls, R. 1981. Fatty acid source a factor in heart disease. Chem. & Eng. News 59(6): 24 (Feb. 9).

Sipos, J. C., and R. G. Ackman. 1978. Automated and rapid quantitative analysis of lipids with chromarods. J. Chromatogr. Sci. 16:443-447.

Smith, P., Jr., M. E. Ambrose, and G. M. Knobl, Jr. 1964. Improved rapid method for determining total lipids in fish meal. Commer. Fish. Rev. 26(7):1-5.

Truswell, A. S. 1978. Diet and plasma lipids - a reappraisal. Am. J. Clin. Nutr. 31:977-998.

Von Lossonczy, T. O., A. Ruiter, H. C. Bronsgeest-Schoute, C. M. Van Gent, and R. J. J. Hermus. 1978. The effect of a fish diet on serum lipids in healthy human subjects. Am. J. Clin. Nutr. 31:1340-1346.