EXPERIMENTAL PRODUCTION OF FISH PROTEIN CONCENTRATE (FPC) FROM MEDITERRANEAN SARDINES

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Early in 1967 the National Center for Fish Protein Concentrate (NCFPC) undertook to cooperate with the United Nations Industrial Development Organization (UNIDO)/FAO mission to the plant of the Société Nationale Farine Alimentaire Poisson (SONAFAP) at Agadir, Morocco. This plant had been set up some years before to manufacture FPC by solvent extraction of a press cake made by wet reduction of sardines. However, the plant had encountered production difficulties involving, among other problems, variability in the quality of the product. The quality was so low that its addition to foods was unacceptable. The objective of the FAO mission was to investigate the problems encountered by SONAFAP and to assist the plant in resuming production and distribution of FPC.

The first step was to determine whether a satisfactory FPC could be made from the available fish. NCFPC, at the request of UNIDO/FAO, prepared FPC from Mediterranean sardines shipped from Morocco, using the isopropyl alcohol (IPA) extraction process. This process had already produced stable products of reproducibly uniform quality with other fish. The Center's FPC program, having provided the technical information needed to obtain U.S. Food and Drug Administration approval of FPC as a food additive, had begun to broaden its investigations beyond the use of lean fish, such as red hake to the much more abundant fatty fishes. Investigation of the use of Mediterranean sardines fitted well into the Bureau of Commercial Fisheries' program. The information developed in this investigation would assist the Moroccan project--and support Bureau efforts to broaden the base of raw material permitted for FPC.

The use of other varieties of fatty fish will be the subject of a forthcoming publication.

NCFPC is continuing to cooperate with the UNIDO project by examining further samples of FPC produced in recent trials at the Agadir plant.

STUDY MATERIALS AND METHODS

Three shipments of Mediterranean sardines--one from Portugal, one from Yugoslavia, and one from Morocco--were received by NCFPC and processed into FPC. Although the species was not absolutely established when received, the point of origin of the fish identified reasonably well two shipments as Clupea pilchardus and one as Sardinia pilchardus. The fish, frozen immediately after capture, were flown to the laboratory at College Park, Maryland. Composition of the raw fish is given in Table 1.

Table 1 - Proximate Composition of Mediterranean Sardines (Percent by Weight)

Country of origin. . . . . Species	Portugal Sardine (Clupea pilchardus)	Yugoslavia Sardine (Clupea pilchardus)	Morocco Sardine (Sardinia pilchardus)
Date received	Dec. 1967	Dec. 1967	April 1968
Crude protein (N x 6.25)	16.7	16.8	19.1
Lipid	17.7	13.4	3.18
Ash	2.95	2.75	4.36
Volatiles (moisture). . .	63.7	68.6	73.3
Ca	0.68	0.61	0.35
P	0.57	0.51	0.28

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Note: Fig. 1, Tables 3 and 4 are in the appendix in reprint (Sep. No. 851) of this article. For a free copy of the Separate, write Division of Publications, U.S. Department of the Interior, Fish and Wildlife Service, BCF, 1801 N. Moore St., Arlington, Va. 22209

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Processing Details

In 1967, the laboratory procedure for making FPC from lean fish was a modified "crosscurrent" batch extraction consisting of the following steps:

1. A batch of fish was comminuted (ground to a hamburger-like consistency) and mixed with azeotropic isopropyl alcohol (AIPA) at room temperature, with a ratio of solvent to fish of 2:1 by weight.

2. After 30 minutes of agitation, the solids and liquid (miscella) were separated in a 12-inch basket centrifuge.

3. The wet solids were then re-slurried with fresh AIPA and extracted continuously for 2 hours at ca. 155° F. (70° C.) in a system where the extract (miscella) was continuously drawn off, filtered, evaporated, and the condensed overheads pumped back into the extractor. (All the nonvolatile solubles--proteins, lipids, etc.--remained in the evaporator and the condensed overheads became somewhat richer in water than the AIPA.)

4. The solids were then separated from the miscella in the 12-inch basket centrifuge.

5. The solids were desolventized (dried) in a vacuum oven (pressure ca. 2 inches of mercury, i.e., 50 mm) at 160° F. (71° C.) for 18-22 hours.

Since the sardines were expected to contain much more lipid than the lean fishes for which this procedure had been developed, the procedure had been modified (for sardines from Yugoslavia and Portugal) to include one or two additional hot extractions to determine the effect, if any, on residual lipid content. In the process outlined above, this was done by repeating stages 3 and 4 once (Procedure A) or twice (Procedure B).

By the time the Moroccan sardines were received (April 1968), the laboratory had shifted its extraction procedure to a countercurrent system (Procedure C) so that processing information obtained would be directly applicable to larger-scale systems likely to be used for industrial production. Consequently, the sardines received from Morocco were processed in a manner closely approximating a commercial batch countercurrent process, using a 4-stage countercurrent procedure with an overall ratio of solvent to fish of 2:1. (This represents between one-third to one-fifth the total solvent used in Procedures A and B.) This procedure is outlined schematically in Figure 1 (in appendix). The first stage was performed at room temperature (with no added heat), the second, third, and fourth stages at about 155° F. (70° C.). The solid liquid slurry from each stage was separated, as in step 4 of the procedure outlined above. The final solids were desolventized as in step 5.

Theoretically, the processing of a large number of batches of fish would be required before this countercurrent system would attain steady-state operating conditions--that is, before the compositions of the miscellae and solids in each stage do not change from batch to batch. However, detailed analysis of the composition of the materials in each stage shows that, as a practical matter, the system essentially will have reached steady-state conditions after the fourth batch, and definitely after the fifth stage. Only the FPC produced by countercurrent extraction of Moroccan sardines (Sardinia pilchardus) was subjected to the complete processing procedure now used for FPC produced in this laboratory. Furthermore, because the fifth batch was most likely to represent steady-state conditions, fluorine analysis and nutritive evaluation were performed only on this batch of FPC.

Results

The results obtained with the three shipments of fish received are listed in Tables 2, 3, and 4. (Tables 3 and 4 are in appendix.) The proximate composition and amino acid pattern obtained for a sample of FPC made at Agadir in 1966 also are shown. In addition, average values are listed for proximate analyses, PERs, and a typical amino acid pattern for FPC made from hake by standard crosscurrent batch extraction process using AIPA. This process (Procedure "D") consists of a four-stage AIPA extraction using 2 parts of fresh IPA to one part of fish at each stage. Solid-liquid separation is accomplished in a 6-inch continuous solid bowl centrifuge and desolventization (drying) is performed in a 6-cubic-foot, double cone, tumbling vacuum dryer.

DISCUSSION

It is apparent from the data in the tables that no basic problem exists in processing sardines into FPC by the IPA extraction

Table 2 - Chemical Composition of FPC Produced from Mediterranean Sardines and Red Hake

Country of Origin . . . . . Species	PORTUGAL Sardine (Clupea pilchardus)		YUGOSLAVIA Sardine (Clupea pilchardus)		MOROCCO Sardine (Sardinia pilchardus)							U.S. Red Hake (Urophycis chuss)	
Sample (FPC)	Sp-1	Sp-2	Sy-1	Sy-2	Sm-1[a]	Sm-2[a]	Sm-3[a]	Sm-4[a]	Sm-5[a] (b)	Sm-5[a] (c)	SONAFAP FPC (Lot 39)	BCF FPC Typical Values	
Extraction procedure (h)	A	A	B	B	C	C	C	C	C	C	?	D	D
Date processed	1-3-68	1-4-68	1-9-68	1-10-68	7-23-68	7-24-68	7-25-68	7-26-68	7-29-68	7-29-68	8-9-68	(f)	(g)
Proximate composition (percent by weight)													
Crude protein (N x 6.25)	81.2	82.0	83.3	84.5	77.0	79.6	78.8	80.8	79.7	77.7	85.3	85.0	89.2
Lipid	0.70	0.90	0.56	0.23	0.5	0.15	0.24	0.23	0.22	-(e)	0.79	0.15	0.16
Ash	14.1	14.3	13.6	13.3	17.3	16.6	17.3	16.3	17.0	17.4	12.50	10.97	11.55
Volatiles (moisture) . .	4.8	3.8	3.6	3.7	7.0	4.8	5.5	4.6	4.4	8.2	4.0	4.50	0
Ca	3.5	3.8	3.9	3.8	4.9	4.7	4.8	4.5	4.8	-(d)	3.8	2.95	3.10
P	2.4	2.4	2.4	2.2	3.0	2.9	3.0	2.5	2.9	-(d)	2.3	1.79	1.88
F (ppm)	-(d)	-(d)	-(d)	-(d)	-(d)	-(d)	-(d)	-(d)	-(d)	70.2	-(d)	-(d)	-(d)
IPA (ppm)	-(d)	-(d)	-(d)	-(d)	120(e)	311(e)	124(e)	200(e)	-(e)	103	-(d)		

(a) These samples are the results of each batch of the five-batch countercurrent extraction.
(b) Before steam-stripping to reduce the residual IPA content.
(c) After steam-stripping to reduce the residual IPA content.
(d) This analysis not performed on this sample.
(e) This analysis was performed after the sample was steam-stripped. All other analyses on this sample were performed before steam-stripping.
(f) Average values for 10 samples, calculated on "as is" basis.
(g) Average values for 10 samples individually calculated on dry weight basis.
(h) See text for explanation of procedure.

process although considerable engineering modifications of the lean fish process may be needed. The only significant distinguishing factor among the three batches of sardines processed is the relatively high residual lipid content of the FPC made from the Portuguese and Yugoslav sardines. It was unfortunate, for the purposes of comparison, that these fish initially contained much more oil than the Moroccan sardines (perhaps a result of seasonal variation) and were not extracted in a countercurrent system as were the latter. However, previous work in this laboratory on the countercurrent extraction of fish with initial lipid contents as high as 20 percent has shown the residual lipid of the resultant FPC to range from 0.10 to 0.29 percent. This experience leaves little doubt that these sardines would have yielded an FPC with residual lipid contents of the same order if they had been extracted by the same procedure. The nutritive values of both SONAFAP FPC and Sample Sm-5 are comparable to FPC made from red hake, and all are at least equal to that of casein. The fluoride content of Sm-5 is well below the 100 ppm. now required by the U.S. Food and Drug Administration.

SUMMARY

NCFPC's investigation on production of fish protein concentrate (FPC) by isopropyl alcohol extraction of Mediterranean sardines indicates that the products meet all present U.S. Food and Drug Administration requirements on chemical composition and nutritive value. The products were made both by laboratory procedures involving combinations of cross-current and continuous batch extraction, and by countercurrent extraction procedures that approximate commercial production methods. It is particularly significant that, in agreement with results obtained for FPC made from other species of fatty fish in this laboratory, a satisfactory FPC can be produced from Mediterranean sardines by this prototype commercial process.