CHEMICAL AND NUTRITIONAL CHARACTERISTICS OF FISH PROTEIN CONCENTRATE PROCESSED FROM HEATED WHOLE RED HAKE, *Urophycis chuss*

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ABSTRACT

This study was to determine whether cooking lean, whole fish before they are extracted by solvent affects the chemical and nutritional characteristics of the resulting fish protein concentrate. When red hake were heated at 100° and 109° C for as long as 80 min, the chemical and nutritional properties of the fish protein concentrate were not adversely affected significantly. The nutritional quality was slightly lower, however, in fish protein concentrate produced from red hake that were heated at 121° C for 10 to 80 min.

Fish protein concentrate (FPC) contains protein that is high in quality. It therefore can be used to supplement diets that contain inadequate amounts of high-quality protein.

Fish protein concentrate is prepared by removing most of the lipids and water from whole fish. Several methods for preparing FPC have been investigated. They can be classified as chemical, biological, and physical. Most investigators have used chemical methods in which solvents extract the lipids and water from whole fish.

In the United States, two processes for making FPC have been approved by the Food and Drug Administration. Both of these are chemical processes in which solvents are used. In the overall program of the National Marine Fisheries Service National Center for Fish Protein Concentrate, various approaches to processing are being investigated. One such approach is cooking and pressing fish prior to solvent extraction. This procedure would tend to reduce the volume of solvent required for extraction, inasmuch as water and lipids would be expressed during the pressing stage.

Raw fish are difficult to press because of their physical consistency. The processor can overcome this problem by cooking the fish before pressing them. If he subjects the fish to a high temperature for a long time, however, undesirable chemical reactions may occur that decrease the quality of the protein.

The purpose of this study therefore was to find whether or not the chemical composition and nutritional quality of fish protein concentrate are altered when the FPC is produced by solvent extraction of fish that have been cooked at different temperatures for varying periods of time.

CHEMICAL COMPOSITION

Reported here are both the proximate composition and amino acid composition of the FPC produced from cooked fish.

PROXIMATE COMPOSITION

We used red hake, *Urophycis chuss*, which are lean fish. They were caught off the coast of New England in the area of Block Island, situated south southwest of Point Judith, R.I. The hake were iced on board the vessel and were then frozen in 25-lb. wax laminated cartons at the dock. The hake were kept frozen while being shipped to the National Marine Fisheries Service National Center for Fish Protein Concentrate in College Park, Md. The shipment contained about 96 cartons. From these 96 boxes, 15 cartons (375 lb.) were picked at random for the investigation and were stored

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at —20° C (The other cartons were used in another experiment.) The hake were used within 1 month after storage.

About 17 to 18 hr before studying each processing variable, we placed one carton of fish in a refrigerated room at a temperature of 5° to 6° C. This treatment allowed the fish to thaw sufficiently so that they could be handled individually. The fish were ground through a Hobart meat grinder,[2] which was equipped with an end plate containing holes that were one-quarter inch in diameter. After the hake were ground, they were thoroughly mixed, and a sample that weighed 20 lb was removed. The sample was divided into three equal portions, and each portion was placed in a 2-inch-deep tray lined with aluminum foil. (This procedure was used in order to permit existing equipment to be used.)

The trays were placed in an autoclave and were heated at 100°, 109°, or 121° C for 10, 20, 40, or 80 min. Thermocouples were used to measure the temperature of the samples. After being heated, the trays were removed from the autoclave, were covered with aluminum foil, and were cooled in a refrigerated room at 5° to 6° C. A control sample was also prepared, which consisted of raw, unheated ground hake.

The entire contents of the trays were mixed with solvent at a 2:1 (w/w) ratio of solvent to solid. The samples were extracted by the "cross-current" batch-extraction procedure described by Brown and Miller (1969). The solvent used for extraction was 91%, by volume, isopropyl alcohol.

The extracted and dried samples of FPC were ground in a Rietz Disintegrator.

The samples were analyzed for crude protein, volatiles, and ash by the methods described by Horwitz (1965). Lipids were determined by the method of Smith, Ambrose, and Knobl (1964).

Table 1 shows the concentrations of crude protein, ash, and lipids found.

The concentration of crude protein in the samples that were heated was slightly lower than in the sample that was not heated. The concentration of crude protein, however, was not significantly affected by the temperature at which the samples were heated. Also, the time of heating did not significantly affect the concentration of crude protein in the samples, except for the 20-min treatment. The samples that were heated for 20 min had a slightly lower concentration of crude protein than did those that were heated for the other intervals of time.

TABLE 1.—Proximate composition, expressed on a moisture-free basis, of samples of FPC prepared from hake that were heated for varying times and temperatures before being extracted with solvent.

Sample	Crude protein	Ash	Lipid
	%	%	%
Nonheated control	88.7	13.8	0.16
Heated samples:			
100° C for:			
10 min	86.0	15.3	0.16
20 min	85.3	15.4	0.16
40 min	86.3	15.0	0.20
80 min	85.9	15.5	0.15
Mean	85.9	15.3	0.17
109° C for:			
10 min	87.5	14.4	0.12
20 min	85.6	15.8	0.12
40 min	86.8	15.7	0.21
80 min	87.4	13.8	0.15
Mean	86.8	14.9	0.15
121° C for:			
10 min	87.3	13.6	0.12
20 min	85.9	15.2	0.14
40 min	86.5	13.7	0.16
80 min	86.8	14.3	0.16
Mean	86.6	14.2	0.14

The concentration of ash was slightly higher in the samples that were heated than in the sample that was not heated. The concentration of ash in the heated samples was not affected by either the temperature of heating or the length of time of heating.

The concentration of lipid in the samples was somewhat variable, but it was not significantly affected by the treatments.

AMINO ACID COMPOSITION

Essential amino acids, except for tryptophan, were determined with an automatic amino acid analyzer by the method described by Moore, Spackman, and Stein (1958). Tryptophan was determined chemically by the method of Spies and Chambers (1949). Cystine was determined

[2] The use of trade names is merely to facilitate descriptions; no endorsement is implied.

microbiologically by the method of Henderson and Snell (1948). Available lysine was determined by the method described by Carpenter (1960).

We found only slight changes in the concentrations of amino acids in the samples (table 2). The treatments that we used did not consistently affect the concentrations of amino acids, except for cystine and available lysine. The concentration of cystine was reduced in the sample heated at 121° C for 80 min. The concentrations of available lysine were slightly lower in the samples heated at 100° and 109° C for 20 min. The reason for these decreases is not apparent to us.

Evans and McGinnis (1948) previously reported that cystine was reduced when soybeans were autoclaved at 130° C for 60 min.

NUTRITIONAL QUALITY

The nutritional quality of the samples was determined in a feeding study using rats. Diets were prepared that contained 10% protein from the heated samples, the nonheated sample, or casein. The diet that contained the nonheated sample served as a control, and the one that contained casein served as a reference standard. The composition of the basal diet was described earlier by Stillings, Hammerle, and Snyder (1969).

Male weanling rats of the Carworth Farms CFE strain were received when they were 22 days old. The rats were housed individually in cages with screen bottoms and were kept in an air-conditioned room maintained at about 23° C. During the first 2 days, the rats were fed a basal diet containing 15% casein. They were then allotted to groups on the basis of weight, and the groups were randomly assigned to different diets. Each group contained 10 rats, and the rats were offered feed and water *ad libitum* for 4 weeks.

The amount of feed consumed was recorded three times each week, and the gains in weight were determined once each week. At the end of the experiment, the protein efficiency ratio was determined by dividing the gain in weight by the weight of protein consumed.

The data were analyzed statistically. Differences between means were determined by Tukey's procedure as described by Steel and Torrie (1960: 109).

Table 3 shows the data on the nutritive quality of the FPC samples. Based on the gain in weight, intakes of feed, and protein efficiency ratios, the quality of the samples that were heated at 100° and 109° C was not significantly different from the quality of the control, which was not heated. Samples that were heated at 121° C, however, had a lower quality than the control sample. In general, the quality of the samples heated at 100° and 109° C was equal to that of casein or was slightly higher than

TABLE 2.—Amino acid composition of FPC samples prepared from hake that were heated for varying times and temperatures before being extracted with solvent.

Amino acid	Concentration of amino acid in:											
	Unheated control sample	Samples heated at:										
		100° C for:				109° C for:				121° C for:			
		10 min.	20 min.	40 min.	80 min.	10 min.	20 min.	40 min.	80 min.	10 min.	20 min.	40 min.	80 min.
	Grams per 16 grams of nitrogen												
Arginine	6.2	6.7	6.4	6.8	6.4	5.7	7.0	6.1	6.4	6.9	6.1	6.6	6.3
Histidine	1.8	2.0	1.9	1.9	1.8	1.7	1.9	1.7	1.8	2.1	1.9	1.8	2.0
Isoleucine	4.5	4.3	4.4	4.5	4.3	4.3	4.6	4.5	4.5	4.9	4.6	4.4	4.8
Leucine	7.4	7.2	6.9	7.1	6.9	7.0	7.5	7.0	7.2	8.0	7.2	7.3	7.6
Lysine	7.7	8.3	7.8	8.0	7.4	7.1	7.7	7.1	7.5	8.4	7.5	7.9	7.6
Methionine	3.2	3.1	3.1	3.1	3.0	3.0	3.0	3.1	3.0	3.6	3.1	3.1	3.4
Phenylalanine	4.1	4.1	4.0	4.1	4.0	4.0	4.2	4.1	4.1	4.5	4.1	4.2	4.3
Threonine	4.3	4.2	4.1	4.2	4.0	4.0	4.4	4.2	4.0	4.6	4.1	4.2	4.4
Tryptophan	1.0	1.2	1.2	1.0	1.3	1.2	1.1	1.1	1.2	1.1	1.2	1.3	1.2
Valine	5.1	4.9	5.0	5.0	5.1	4.8	5.2	4.6	5.0	5.5	5.0	5.0	5.3
Cystine	0.9	1.2	1.2	1.2	0.9	1.1	1.1	1.1	1.1	1.1	1.1	--	0.7
Available lysine	7.9	7.8	6.9	7.2	7.9	7.7	6.9	7.2	7.6	7.8	7.1	7.2	7.6

TABLE 3.—Weight gain, feed intake, and protein efficiency ratio of groups of 10 rats fed diets of FPC samples prepared from red hake that were heated for varying times and temperatures before being extracted with solvent.

Sample	Average daily weight gain	Average daily feed intake	Protein efficiency ratio
	Grams	*Grams*	
Nonheated control	4.85	13.8	3.37
Heated samples:			
100° C for:			
10 min	4.96	14.0	3.41
20 min	4.37	13.0	3.25
40 min	4.50	13.1	3.37
80 min	4.29	13.3	3.16
Mean	4.53	13.4	3.30
109° C for:			
10 min	4.37	12.7	3.35
20 min	4.31	13.1	3.11
40 min	4.45	13.4	3.20
80 min	4.20	12.6	3.28
Mean	4.34	13.0	3.24
121° C for:			
10 min	3.21	10.6	3.01
20 min	4.01	12.2	3.13
40 min	3.52	11.1	3.10
80 min	3.20	10.3	3.02
Mean	3.49	11.0	3.07
Casein	3.85	12.0	3.18
Tukey's W ($P<0.05$)	0.81	2.0	0.26

that of casein. When the temperature was increased to 121° C, the quality of the samples was slightly lower than that of casein but not significantly so. At each temperature, the temperature at which the samples were heated had a more significant effect on the quality of the samples than did the length of time of heating.

SUMMARY AND CONCLUSIONS

We conducted a study to determine the chemical composition and nutritional quality of FPC produced from fish that are heated before they are extracted with solvent. Red hake, which are lean fish, were heated at 100° C for 10, 20, 40, or 80 min. Other samples were heated for these same lengths of time at 109° or 121° C. The samples were then extracted with isopropyl alcohol. The FPC produced from the samples of hake that were heated contained slightly less crude protein and more ash than did the FPC produced from the samples that were not heated. The amino acid composition of samples that had been heated did not differ markedly from the composition of those that were not heated. The nutritive quality of the samples that were heated at 100° and 109° C was not significantly affected. Samples heated at 121° C, however, were lower in quality than was the control sample.

We conclude that red hake can be heated at temperatures of 100° and 109° C for as long as 80 min before being extracted by solvent without the quality of the protein being affected significantly.

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