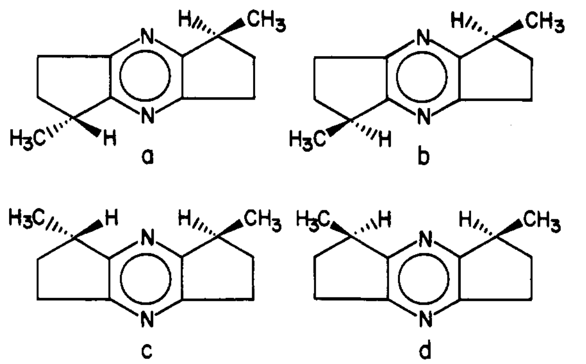

Figure 1. Possible structures of 1,5(or 7)-dimethyl-2,3,6,7-tetrahydro-1*H*,5*H*-biscyclopentapyrazine: (a) *trans*-1,5-dimethyl-2,3,6,7-tetrahydro-1*H*,5*H*-biscyclopentapyrazine, (b) *cis*-1,5-dimethyl-2,3,6,7-tetrahydro-1*H*,5*H*-biscyclopentapyrazine, (c) *trans*-1,7-dimethyl-2,3,6,7-tetrahydro-1*H*,5*H*-biscyclopentapyrazine, and (d) *cis*-1,7-dimethyl-2,3,6,7-tetrahydro-1*H*,5*H*-biscyclopentapyrazine.

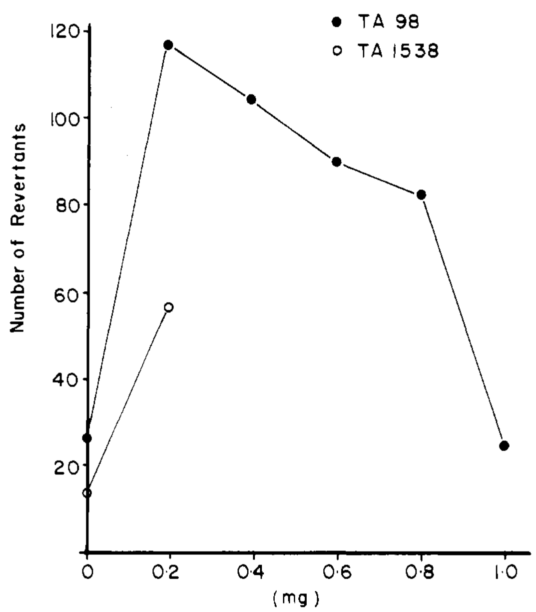

Figure 2. Mutagenicity of 1,5(or 7)-2,3,6,7-tetrahydro-1*H*,5*H*-biscyclopentapyrazine toward *S. typhimurium* strains TA 1535 and TA 98 without metabolic activation by S-9 mix.

gation of its mutagenicity. If the dose exceeded 1 mg, all bacteria were killed. I showed positive response only toward strains TA 1538 and TA 98 (frameshift mutants) without S-9 mix. No appreciable activity was observed with TA 1535, TA 100, or TA 1537 at any dose level of I. This lack of activity is of interest because other reported browning products were more mutagenic toward the base-pair mutation strain (TA 100) than toward the frameshift mutation strain (TA 98) (Mihara and Shibamoto, 1980). The dicarbonyl compounds, which are precursors of pyrazines, also responded positively toward TA 100, but not toward TA 98 (Bjeldanes and Chew, 1979).

It has been proposed that heat treatment causes the production of mutagens in food (Sugimura and Nagao, 1979). Sugimura et al. (1977) obtained some polycyclic nitrogen-containing compounds, which showed strong mutagenic activity toward TA 98 and TA 100, from a tar formed by pyrolysis of tryptophan. Their method was, however, much more vigorous than ordinary cooking conditions. Pyrazine I was obtained under much milder conditions, closer to normal cooking conditions.

Polycyclic pyrazines have not as yet been found in foods, but are formed in certain model systems (Rizzi, 1972; Nishimura et al., 1980). A large number of alkylpyrazines have been found in food products (Maga and Sizer, 1973). These pyrazines have, however, been reported as nonmutagenic (Spingarn and Garvie, 1979). More work is necessary to discover the formation mechanism of mutagenic polycyclic pyrazines in cooked food.

LITERATURE CITED

Ames, B. N., McCann, J., Yamasaki, E., *Mutat. Res.* **31**, 347 (1975).
Bjeldanes, L. F., Chew, H., *Mutat. Res.* **67**, 367 (1979).
Hodge, J. E., *Symp. Foods: Chem. Physiol. Flavors*, [*Proc.*] *1965*, 472 (1967).
Maga, J. A., Sizer, C. E., *CRC Crit. Rev. Food Technol.*, 39 (1973).
Mihara, S., Shibamoto, T., *J. Agric. Food Chem.* **28**, 62 (1980).
Nishimura, O., Mihara, S., Shibamoto, T., *J. Agric. Food Chem.* **28**, 39 (1980).
Rizzi, G. P., *J. Agric. Food Chem.* **20**, 1081 (1972).
Sakaguchi, M., Shibamoto, T., *Agric. Biol. Chem.* **43**, 667 (1979).
Shibamoto, T., Bernhard, R. A., *J. Agric. Food Chem.* **26**, 183 (1978).
Shibamoto, T., Russell, G. F., *J. Agric. Food Chem.* **25**, 109 (1977).
Spingarn, N. E., Garvie, C. T., *J. Agric. Food Chem.* **27**, 1319 (1979).
Sugimura, T., Kawachi, T., Tsuji, K., Wakabayashi, K., Iitaka, Y., Itai, A., *Proc. Jpn. Acad.* **53**, 58 (1977).
Sugimura, T., Nagao, M., *CRC Crit. Rev. Toxicol.*, 189 (1979).
Umezawa, K., Sawamura, M., Matsushima, T., Sugimura, T., *Cancer Res.* **38**, 1782 (1978).
Wilson, R. A., Katz, I., *J. Agric. Food Chem.* **20**, 741 (1972).

Takayuki Shibamoto
Department of Environmental Toxicology
University of California
Davis, California 95616

Received for review November 26, 1979. Accepted February 19, 1980.

Protein and Amino Acid Composition of Select Freshwater Fish

The protein content and amino acid composition of six species of freshwater fish [white sucker (*Catostomus commersoni*), burbot (*Lota lota*), black crappie (*Pomoxis nigromacultatus*), rainbow trout (*Salmo gairdneri*), walleye pike (*Stizostedion vitreum*), and yellow perch (*Perca flavescens*)] were determined. Little variation in composition was found among species.

Because of their abundance and their possible utilization as a source of food, freshwater fish species are being studied for the fabrication of new products (March et al., 1967; Lantz, 1966). Knowledge of the amino acid composition of freshwater fish is limited (March et al., 1967). In conjunction with product development we are concurrently determining the nutrient composition of several freshwater fish species (Kinsella et al., 1977a,b; Mai et al.,

Table I. Protein Content and Amino Acid Composition of Different Species of Freshwater Fish

	fish species					
	white sucker (*Catostomus commersoni*)	burbot (*Lota lota*)	black crappie (*Pomoxis nigromaculatus*)	rainbow trout (*Salmo gairdneri*)	walleye pike (*Stizostedion vitreum*)	yellow perch (*Perca flavescens*)
protein content (g/100 g of fish)	15.83[b]	17.40	17.96	18.29	17.68	17.11
amino acid[a] (g/100 g of fish protein)						
tryptophan[b]	1.01	1.00	1.00	0.96	0.76	1.06
aspartic acid	9.46	10.25	8.34	7.74	8.10	8.13
threonine	3.94	4.14	3.28	3.23	3.50	3.19
serine	3.81	4.49	3.03	3.18	3.18	3.31
glutamic acid	14.57	15.67	12.12	11.69	12.53	12.23
proline	3.85	4.26	2.96	2.79	2.97	3.10
glycine	3.65	4.56	3.18	3.04	3.05	3.20
alanine	5.05	5.67	4.43	4.25	5.29	4.37
valine	4.93	5.09	3.93	4.13	3.99	4.12
methionine	2.67	3.21	2.27	2.42	2.52	2.46
isoleucine	3.71	4.27	3.42	3.26	3.47	3.43
leucine	8.03	8.54	6.93	6.56	6.78	6.82
tyrosine	3.39	3.63	2.75	2.80	2.96	2.97
phenylalanine	3.95	4.19	3.66	3.28	3.36	3.38
histidine	2.16	2.49	1.82	1.22	2.05	2.07
lysine	8.46	8.34	6.94	6.61	7.00	6.06
arginine	6.01	6.72	4.80	4.78	5.09	5.03
NH_3	0.71	0.17	0.14	0.14	0.16	0.14

[a] Value of single determination. [b] Mean of duplicate.

1979). In this communication the protein content and amino acid composition of white sucker (*Catostomus commersoni*), burbot (*Lota lota*), black crappie (*Pomoxis nigromaculatus*), rainbow trout (*Salmo gairdneri*), walleye pike (*Stizostedion vitreum*), and yellow perch (*Perca flavescens*) are reported.

MATERIALS AND METHODS

The fish were caught locally (Cayuga Lake, Ithaca, NY), filleted, and cut into cubes (1.5 cm^3). These pieces from each species were randomized and dried in a forced air oven at 90 °C to constant weight. The nitrogen content of randomly chosen samples were determined in duplicate by the micro-Kjeldahl procedure and a conversion factor of 6.25 was used to calculate protein from nitrogen content (AOAC, 1975). The amino acid composition was determined following the hydrolysis of the dried fish in 6 N hydrochloric acid in an evacuated tube at 110 °C for 24 h using a Beckman 119-CL automatic amino acid analyzer according to the procedure of Spackman et al. (1958). Norleucine was used as an internal standard. The procedure of Spies (1967) was used to determine the tryptophan content.

RESULTS AND DISCUSSION

The protein content (Table I) of the different species of fish studied ranged from 15.83 to 18.29 g/100 g with white sucker and rainbow trout containing the lowest and the highest amount of protein, respectively. The amino acid analyses showed no significant variation in the concentration of each amino acid in the different species (Table I). Glutamic acid, aspartic acids, arginine, lysine, leucine, and valine were the major amino acids. Aspartic acid, glutamic acid, histidine, and arginine showed the greatest variation whereas methionine, threonine, serine, isoleucine, tyrosine, and phenylalanine showed the least variation. Burbot contained a higher concentration of amino acids than the other species. The essential amino acids in white sucker and burbot were higher compared to the other species.

These data revealed that no major differences exist between the amino acid composition of the freshwater fish compared to those of marine fish (March et al., 1967). On the basis of amino acid composition, the nutritional quality of these freshwater fish is apparently equivalent to marine fish assessed by biological tests with chicks (Jangaard et al., 1974).

LITERATURE CITED

Association of Official Analytical Chemists, "Official Methods of Analysis", 12th ed, Washington, DC, 1975.
Jangaard, P. M., Regier, L. W., Claggett, F. G., March, B. E., Biely, T., *J. Fish Res. Board Can.* **31**, 141 (1974).
Kinsella, J. E., Shimp, J. L., Mai, J., Weihrauch, J., *J. Am. Oil Chem. Soc.* **54**, 424 (1977a).
Kinsella, J. E., Shimp, J. L., Mai, J., Weihrauch, J., *J. Food Biochem.* **1**, 131 (1977b).
Lantz, A. W., *Bull. Fish. Res. Board Can.* **45**, 151 (1966).
Mai, J., Shimp, J., Weihrauch, J., Kinsella, J. E., *J. Food Sci.* **43**, 1669 (1979).
March, B. E., Biely, J., Bligh, E. G., Lantz, A. W., *J. Fish Res. Board Can.* **24**, 1291 (1967).
Spackman, D. H., Stein, W. H., Moore, S., *Anal. Chem.* **30**, 1190 (1958).
Spies, P. G., *Anal. Chem.* **39**(12), 1412 (1967).

Jimbin Mai
Jayarama K. Shetty
Tze-Ming Kan
John E. Kinsella*

Institute of Food Science
Cornell University
Ithaca, New York 14853

Received for review September 10, 1979. Accepted January 15, 1980. Supported in part by the New York State Sea Grant Program.