derstood as regards the presence of added ammonium hydroxide, may be the basis of this difference.

The use of material of batch 1 which was undried, partly dried, or partly dried plus water affected the chemical composition of the silage at postfermentation. A lower conversion of insoluble nonammonium nitrogen to soluble nonammonium nitrogen was evident with partly dried material (40% dry matter) than with undried material (30% dry matter) as shown with control (untreated) samples. Also, higher pH values and lower lactic and acetic acid contents were shown with the partly dried material than with the undried material, either in the absence or in the presence of a nitrogen addition. Water addition to the partly dried material to restore the moisture content to that of the undried material was not completely effective against the effects from drying. Furthermore, an abnormal butyric acid production in samples containing 30% dry matter and 1.24% added nitrogen was not evident when the dry matter content was at 40%. Other investigators (Huber et al., 1973) have reported higher pH values and lower lactic acid contents with silage of high dry matter content.

ACKNOWLEDGMENT

Appreciation is expressed to W. L. Tucker, Experiment Station Statistician, for the statistical analysis and to Nancy Thiex for supplying the chopped corn plants.

LITERATURE CITED

Association of Official Agricultural Chemists "Official Methods of Analysis", 7th ed.; AOAC: Washington DC, 1950; pp 12–14.
Barker, S. B.; Summerson, W. H. *J. Biol. Chem.* **1941**, *138*, 535.
Barnett, A. J. G. "Silage Fermentation"; Academic Press: New York, 1954; p 128.
Bergen, W. G.; Cash, E. H.; Henderson, H. E. *J. Anim. Sci.* **1974**, *39*, 629.
Henderson, H. E.; Bergen, W. G. "Treating corn silage with gaseous-ammonia for feedlot-cattle"; Department of Animal Husbandry and Beef Cattle, Michigan State University: East Lansing MI, 1972; Report No. 712-A.
Huber, J. T.; Foldager, J.; Smith, N. E. *J. Anim. Sci.* **1979**, *48*, 1509.
Huber, J. T.; Lichtenwalner, R. E.; Thomas, J. W. *J. Dairy Sci.* **1973**, *56*, 1283.
Huber, J. T.; Santana, O. P. *J. Dairy Sci.* **1972**, *55*, 489.
Huber, J. T.; Smith, N. E.; Stiles, J. *J. Amin. Sci.* **1980**, *51*, 1387.
Pennington, R. J.; Sutherland, T. M. *Biochem. J.* **1956**, *63*, 353.
Steel, R. G. D.; Torrie, J. H. "Principles and Procedures of Statistics"; McGraw-Hill: New York, 1960.

Received for review July 7, 1981. Revised manuscript received December 21, 1981. Accepted January 12, 1982. Published with the approval of the Director of the South Dakota Agricultural Experiment Station as publication no. 1773 of the Journal Series.

Nutritive Value of Fillets and Minced Flesh from Alaska Pollock and Some Underutilized Finfish Species from the Gulf of Mexico

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The nutritional properties of fillets and minced flesh from Alaska pollock and nontraditional finfish species from the Gulf of Mexico were investigated. Based on protein efficiency ratio, net protein ratio, amino acid chemical score, and protein digestibility, the data indicated that minced fish flesh, prepared by proper mechanical deboning of dressed carcasses, contained protein of equal nutritional properties to that of fillets. Significantly lower PER and NPR values were obtained for minced flesh produced by mechanical deboning of croaker filleting waste under high pressure. From a nutritional point of view, this study has shown that mechanical deboning is a suitable technology for converting the shrimp by-catch into products for human consumption.

During commercial trawling for shrimp in the Gulf of Mexico, a large amount of small bottom fish are caught with the shrimp. Even though this incidental catch, referred to as by-catch, represents a significant amount of protein, it is presently discarded back into the water. Bullis and Carpenter (1968) stated that a latent sustainable catch of 2.6 million metric tons per year of trawl fish is available from Gulf Coast waters. They estimated a total discarded by-catch of 592000 tons during the 1967 shrimping season.

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One major obstacle for the development of the by-catch as a food resource is the size and shape of the fish species normally caught in shrimp trawls. Meinke (1974) reported that landed fish average 17 cm in length and weigh around 60 g. These fish are too small to be processed by traditional techniques, and special processing procedures will be required to produce products for human consumption.

Mechanical deboning equipment currently used to recover edible flesh from poultry, meats, and fish can also be used for species which are typical for the shrimp by-catch. Mechanical deboners are not only ideal for handling these small fish, but product yield as compared to that from conventional ways of processing fresh fish is also high (Finch, 1970; Miyauchi and Steinberg, 1970; Rasekh and Waters, 1979). Finne et al. (1980) described a potential processing scheme for minced fish flesh from Gulf of Mexico finfish species.

0021-8561/82/1430-0477$01.25/0

Much work has been reported in the literature on deboning equipment, yields, and frozen storage stability of deboned fish. No information is available on the nutritional quality of deboned flesh as compared to that of fish fillets from the same species. The objectives of this research were 2-fold: (1) to determine proximate and amino acid composition of fillets and minced flesh of by-catch species; (2) to compare nutritive values (protein efficiency ratio (PER), net protein ratio (NPR), chemical score (CS), and protein digestibility) of fillets and minced flesh of the commercial sample (Alaska pollock) and one of the underutilized species (croaker). These methods were chosen because they represent the most common ways of expressing nutritive values.

EXPERIMENTAL PROCEDURES

Preparation of Fish Samples. The by-catch species spot (*Leiostomus xanthurus*), silver sea trout (*Cynoscion nothus*), and croaker (*Micropogon undulatus*) were obtained from vessels trawling for shrimp off the Texas coast. After being landed and separated from the shrimp, the fish were immediately put on ice and stored in ice chests overnight for processing the next day. Upon arrival at the Texas Agricultural Experiment Station in Corpus Christi, the fish were scaled, beheaded, and eviscerated as described by Finne et al. (1980). After evisceration, half of the catch of each species was filleted while the other half was mechanically deboned by using a Bibun Model 16 deboner with a drum opening holes of 3 mm. The waste material left after filleting croaker was passed twice through the deboner under high pressure (maximum belt tightening). All experimental minced fish preparations were frozen as 1-lb blocks in a wax-coated cardboard box by using a plate freezer. The boxes were wrapped in Saran [poly(vinylidene chloride)] wrapping and stored in a chest freezer at −30 °C until prepared for compositional analyses or feeding studies. The samples were kept in frozen storage no longer than 2 months. Boneless and skinned fillets and minced (deboned) flesh from Alaska pollock (*Theragra chalcogramma*) were prepared and provided by a commercial fish processing plant. Alaska pollock was included in the study because this species has been suggested as ideal for minced fish products.

Analytical Procedures. (*a*) *Proximate and Amino Acid Composition.* Samples of the raw frozen fish preparations were lyophilized, ground into fine powders, and immediately analyzed for proximate and amino acid composition. The proximate composition of the samples was determined according to AOAC (1975) procedures. For determination of amino acids other than tryptophan and cystine, the powders were digested in 6 N hydrochloric acid in a stream of dry nitrogen. The amino acid composition of the hydrolysates was determined by using a Beckman 150 C amino acid analyzer. Cystine was determined as cysteic acid by the method of Moore (1963) and tryptophan from barium hydroxide hydrolysates according to Slump and Schreuder (1969).

(*b*) *Protein Efficiency Ratio.* Protein efficiency ratio (PER) assays were conducted by using 10 rats per sample with a 4-week growth period. The basal diet contained 80% starch, 10% combined corn oil plus fish oil supplied by the test samples, 5% Alphacel, 4% mineral mixture (USP XIV), and 1% vitamin mixture (General Biochemicals). Diets containing 10% protein ($N \times 6.25$) from lyophilized fish flesh or casein were prepared at the expense of the corn starch of the basal diet.

Experimental PER values were calculated as grams of weight gain per gram of protein intake over a 28-day feeding period.

Table I. Proximate Composition of Fillets and Minced Flesh[a]

fish	flesh	% protein	% oil	% ash	% moisture
pollock	fillet	13.56	0.11	1.01	85.48
pollock	minced	13.97	0.15	0.78	85.37
spot	minced	17.97	6.04	1.15	73.86
trout	minced	17.95	0.56	1.10	80.38
golden croaker	fillet	18.36	1.24	0.99	79.53
golden croaker	minced	17.89	1.73	1.03	78.81
golden croaker	minced filleting waste	16.80	2.30	1.20	78.27

[a] Average values based on a minimum of four and a maximum of six assays for each constituent.

Table II. Amino Acid Composition of the Fish Flesh Preparations[a]

	g of amino acid/16 g of nitrogen							
	pollock		spot,	trout,	golden croaker			
amino acid	F	M	M	M	F	M	MW	av[b]
Ile	4.2	4.2	4.8	4.9	4.4	4.7	4.4	4.5
Leu	7.7	8.0	8.3	9.0	7.9	8.3	7.9	8.2
Lys	8.7	9.1	10.3	10.6	9.3	9.8	9.1	9.6
Phe	3.7	4.0	4.2	4.3	3.9	4.0	3.9	4.0
Tyr	3.6	3.8	4.0	3.8	3.5	3.7	3.5	3.7
Phe + Tyr	7.3	7.8	8.2	8.1	7.4	7.7	7.4	7.7
Cys	1.1	1.1	1.1	1.1	0.9	0.9	1.2	1.0
Met	2.9	3.1	3.3	3.5	3.3	3.5	3.2	3.3
Cys + Met	4.0	4.2	4.4	4.6	4.2	4.4	4.4	4.3
Thr	4.0	4.2	4.5	4.7	4.4	4.6	4.4	4.4
Trp	1.1	1.2	1.3	1.1	1.2	1.3	1.3	1.2
Val	4.7	4.8	5.2	5.5	4.9	5.2	5.0	5.0

[a] Average of single runs on duplicate hydrolysate preparations. F = fillet, M = minced, and MW = mince produced from filleting waste. [b] Average of the means of the seven different samples.

(*c*) *Net Protein Ratio.* Net protein ratio (NPR) assays were based on the first 14 days of growth of the rats on the protein efficiency ratio determinations. The data were supplemented with a subsequent 14-day weight loss study for rats on a protein-free diet. Net protein ratios were calculated according to

$$\text{NPR} = (\text{test group wt gain} + \text{wt loss of protein-free group})/\text{protein ingested by test group} \quad (1)$$

Experimental NPR values were corrected to casin as 100%.

(*d*) *Protein Digestibility.* For determination of the digestibility of the protein from the different fish preparations, the second week data for the NPR tests were used. Protein digestibilities were calculated from the data according to equation:

$$\text{digestibility (\%)} = [\text{N intake} - (\text{fecal N} - \text{fecal nonprotein N}) \times 100]/\text{N intake} \quad (2)$$

(*e*) *Chemical Scores.* The chemical scores (CS) of the lyophilized fish powders were calculated from the amino acid composition. The CS for the individual amino acids were based on whole egg protein amino acid composition according to

$$\text{CS} = (\text{concentration in protein test sample} \times 100)/\text{concentration in whole egg protein} \quad (3)$$

RESULTS AND DISCUSSION

The proximate compositions of the various fish flesh preparations are shown in Table I. For both pollock and

Table III. Chemical Scores[a] of the Fish Flesh Preparations[b]

	pollock				golden croaker			
amino acid	F	M	spot, M	trout, M	F	M	MW	FAO data[c]
Ile	67	67	76	78	70	74	70	76
Leu	87	91	95	103	89	94	90	88
Lys	124	130	147	151	133	140	130	130
Phe	65	70	74	75	69	71	69	68
Tyr	85	91	95	91	83	87	83	88
Phe + Tyr	73	79	83	82	75	77	75	77
Cys	44	46	44	44	38	39	51	50
Met	86	91	96	103	96	103	95	85
Cys + Met	69	72	75	79	72	77	77	71
Thr	78	82	88	92	86	89	85	90
Trp	73	80	87	73	80	87	87	80
Val	68	70	75	79	71	75	73	90

[a] Based on whole egg amino acids (FAO, 1970). [b] F = fillet, M = minced, and MW = mince produced from filleting waste. [c] Calculated from amino acid data on edible fish portions (FAO, 1970).

Table IV. Protein Efficiency Ratios of the Fish Flesh Preparations[a]

protein source	protein intake, g	weight gain, g	expt PER
casein	38.6 ± 2.4	110.4 ± 9.8	2.86 ± 0.22
casein	36.2 ± 2.5	103.1 ± 14.0	2.85 ± 0.24
casein	39.6 ± 2.9	119.9 ± 8.0	3.03 ± 0.11
pollock (F)[b]	38.7 ± 2.4	135.8 ± 12.7	3.51 ± 0.15
pollock (F)	38.8 ± 3.0	132.0 ± 12.8	3.38 ± 0.13
pollock (M)[b]	40.8 ± 2.4	144.2 ± 9.2	3.53 ± 0.13
pollock (M)	40.8 ± 3.0	139.9 ± 18.1	3.42 ± 0.29
spot (M)	45.3 ± 2.9	164.6 ± 11.8	3.63 ± 0.28
trout (M)	43.5 ± 2.1	152.8 ± 9.3	3.51 ± 0.16
croaker (F)	44.9 ± 2.2	162.8 ± 11.0	3.63 ± 0.30
croaker (M)	45.7 ± 3.2	162.2 ± 13.6	3.55 ± 0.09
croaker (MW)[b]	45.9 ± 2.9	157.6 ± 12.3	3.43 ± 0.12

[a] As supplied by 10% protein diets; 10 rats for the 4-week test. [b] F = fillet, M = minced, and MW = mince produced from filleting waste.

croaker, there was no difference between the proximate composition of fillets and minced flesh produced from eviscerated fish. Minced flesh from croaker filleting waste, however, had lower protein and higher ash and oil content as compared to fillets and minced flesh from the same species.

Both fillets and minced flesh from Alaska pollock had low protein and oil content. In contrast, typical Gulf of Mexico by-catch species contained approximately 30% more protein than pollock but had variable oil content with spot being the highest at 6.04% while trout had only 0.56% oil.

The concentration of essential amino acids together with tyrosine and cystine is shown in Table II. The total contents of these acids in the various flesh samples ranged from 41.6 to 48.6 g/16 g of sample nitrogen. This range of assay values compares to 51.3 g for whole egg protein (FAO, 1970). The lysine contents for all the flesh preparations ranged from a low of 8.7 to a high of 10.6 g/16 g of nitrogen. Minced flesh produced from croaker filleting waste gave an amino acid profile similar to the overall average profile obtained for the other six sample preparations listed in Table II. However, the sample produced from filleting waste was inferior because of bone fragments and discolorations.

The chemical sources (CS) for the different amino acids of the fish flesh preparations together with average scores for edible fish portions as published by FAO (1970) are given in Table III. In all of the fish samples, tryptophan, cystine, phenylalanine, valine, and isoleucine comprised a group with the lowest chemical scores. By use of whole egg protein as the reference, the average chemical scores for these amino acids ranged from less than 50% for cystine to 73% for valine. Intermediate CS values in a range from 79 to 89% included threonine, total sulfur, total aromatic, and tyrosine. Nonlimiting character with values from 93 and higher was found for leucine, methionine, and lysine.

The protein efficiency ratios (PER) shown in Table IV are the result of 28-day feeding tests with diets containing reference ANRC casein or lyophilized raw fish flesh powder. The average starting weight of the rats, Sprague-Dawley strain, varied from 56 to 61 g. During the 4-week test period, the three groups of animals on the casein diet ingested 36.2–39.6 g of protein ($N \times 6.25$) as 10% protein diets and gained from 103.1 to 119.9 g. The overall average experimental PER for the three casein feedings was 2.91 with no statistical difference between them ($P > 0.05$). The protein intake of the rats on the lyophilized fish flesh diets was lowest for the pollock preparations, ranging on an average from 38.7 to 40.8 g. Weight gains for the same

Table V. Corrected PER Values for the Fish Flesh Preparations[a]

	pollock				golden croaker			
	F[c]	M	spot, M	trout, M	F	M	MW	av
cor PER[b]	3.1[x] 3.0[x]	3.1[x] 3.0[x]	3.2[x]	3.1[x]	3.0[x]	2.9[x]	2.8[x]	3.0
SD	0.27 0.26	0.27 0.36	0.37	0.29	0.26	0.13	0.14	0.26
calcd PER[c]	3.0	3.0	2.9	3.1	2.9	3.0	2.9	2.9

[a] F = fillet, M = minced, and MW = mince produced from filleting waste. [b] Experimental PER corrected to casein at 2.5. Values with the same superscript, x or y, are not significantly different at the 95% confidence level by Duncan's Multiple Range test. [c] Alsmeyer et al. (1974).

Table VI. Net Protein Ratio (NPR) of the Fish Flesh Preparations

protein source	exptl NPR	corrected NPR[a]	corrected PER[a]
casein	4.16 ± 0.20	100	100
casein	4.21 ± 0.33	100	100
casein	4.39 ± 0.27	100	100
pollock (F)[b]	4.87 ± 0.23	117[y]	123[x]
pollock (F)	4.86 ± 0.13	115[y]	119[x]
pollock (M)[b]	4.86 ± 0.25	117[y]	124[x]
pollock (M)	4.90 ± 0.31	116[y]	120[x]
spot (M)	5.20 ± 0.24	124[x]	127[x]
trout (M)	4.91 ± 0.27	117[y]	123[x]
croaker (F)	4.82 ± 0.19	110[y]	120[x]
croaker (M)	4.82 ± 0.40	110[y]	117[x]
croaker (MW)[b]	4.57 ± 0.31	104[z]	113[y]

[a] Values in the same column having the same superscript are not significantly different at the 95% confidence level. [b] F = fillet, M = minced, and MW = mince produced from filleting waste.

Table VII. Digestibility of the Fish Flesh Preparations[a]

fish flesh	protein[b] digestibility, %[c]
pollock (F)[d]	95.4
pollock (F)	93.2
pollock (M)[d]	94.6
pollock (M)	95.8
spot (M)	96.6
trout (M)	98.1
croaker (F)	95.9
croaker (M)	96.1
croaker (MW)[d]	96.0

[a] 10% protein diets. Data from the second week of the PER tests. [b] Nitrogen × 6.25. [c] Averages of duplicate runs on each feces collection. [d] F = fillet, M = minced, and MW = mince produced from filleting waste.

animals ranged from 132.0 g for diets made from fillets to 144.2 g for similar diets made from minced flesh. Animals receiving protein as supplied by lyophilized by-catch species ingested on an average from 43.5 to 45.9 g of protein which gave weight gains from 152.8 to 164.6 g for the 4-week test period.

The corrected PER values for the fish preparations equivalent to casein at 2.5 are listed in Table V. When using a Duncan's Multiple Range analysis, there was no significant difference ($P > 0.05$) between species of fish or between fillets and minced flesh preparations. However, the minced flesh prepared from croaker filleting waste was significantly inferior to the other six fish preparations. Table V also shows PER values as calculated by the method of Alsmeyer et al. (1974) which is based on the leucine and proline content of the samples. By use of Alsmeyer's suggested standard deviation of 0.2 PER unit, no significant difference between the fish flesh samples was evident.

For accurate representation of actual protein retained, net protein ratio (NPR) was also calculated. This test of protein quality is being widely evaluated since it reflects the maintenance potential of a protein, is less time consuming, and is less expensive (Lachance et al., 1977). NPR was calculated as the overall difference in weight gain (gain in weight of the test group plus loss in weight of the protein-free group) divided by the amount of protein uptake. The data in Table VI shows the experimental NPR values for the fish flesh preparations, along with NPR and PER values corrected to casein at 100. The NPR for minced flesh produced from spot was significantly ($P > 0.05$) better than the NPR values for the other samples. The minced flesh produced from croaker filleting waste has an NPR value significantly ($P < 0.05$) inferior to that of all the other samples.

Differences in the digestibility of the proteins in the diet supplements may be a factor that can influence the PER and NPR. The protein digestibility for the samples used during this study is shown in Table VII. As is evident from the data, the digestibility values for the raw lyophilized fish samples were high and essentially equal. Actual values ranged from 93.2% for pollock fillet flesh to 98.1% for spot minced flesh.

From a nutritional point of view, this study has shown that mechanical deboning is a suitable technology for converting the shrimp by-catch into products for human consumption.

LITERATURE CITED

Alsmeyer, R. H.; Cunningham, A. E.; Happich, M. L. *Food Technol. (Chicago)* **1974**, *28* (7), 34.
AOAC "Official Methods of Analysis", 12th ed.; Horwitz, W., Ed., Association of Official Agricultural Chemists: Washington, DC, 1975.
Bullis, H. R.; Carpenter, J. S. *Univ. Wash. Publ. Fish.* **1968**, *4*, 61.
FAO *FAO Nutr. Meet. Rep. Ser.* **1970**, *No. 24*.
Finch, R. *CRC Crit. Rev. Food Technol.* **1970**, *1* (4), 519–580.
Finne, G.; Nickelson, R.; Quimby, A.; Connally, N. *J. Food Sci.* **1980**, *45*, 1327.
Lachance, P. A.; Bressani, R.; Elias, L. G. *Food Technol. (Chicago)* **1977**, *31* (6), 82.
Meinke, W. W. In "Fishery Products"; Kreuger, R., Ed.; Fishing News (Books), Ltd.: London, 1974; p 233.
Miyauchi, D.; Steinberg, M. *Fish. Ind. Res.* **1970**, *4* (6), 165.
Moore, S. *J. Biol. Chem.* **1963**, *238*, 235.
Rasekh, J.; Waters, M. *Food Prod. Dev.* **1979**, *13*, 46.
Slump, P.; Schreuder, H. A. W. *Anal. Biochem.* **1969**, *27*, 182.

Received for review August 31, 1981. Revised manuscript received December 11, 1981. Accepted December 11, 1981. Technical Article 17140 of the Texas Agricultural Experiment Station. This work was supported by a grant from the National Fisheries Institute.