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Nutritional Characteristics of Marine Food Fish Carcass Waste and Machine-Separated Flesh

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The yield and nutritional characteristics of whole carcass waste, machine-separated flesh, and bone–skin fractions of six marine food fish were determined. Yields of flesh from whole carcass waste ranged from 48.9 to 60.2% and resulted in a 43.7–55.3% recovery of the total protein, 42.7–66.0% of the fat, and 13.3–21.6% of the ash. Levels of phosphorus, calcium, strontium, manganese, boron, and chromium largely associated with bone and skin were greatly reduced in the flesh fractions over levels found in the whole carcass wastes. Concentrations of potassium, sodium, and iron were higher in the flesh fractions. Calcium/phosphorus and potassium/sodium ratios were generally lower in separated-flesh fractions. Machine separation of bone and skin markedly improved the quality of protein in carcass waste. Protein efficiency ratio values for separated flesh fractions were significantly higher than values for whole carcass waste.

Demersal species of marine food fish represent a sizeable food resource. Oregon landings alone in 1969 amounted to over 21 million pounds of round weight (Fish Commission of Oregon, 1971). Using as a basis an average fillet yield of 30%, the remaining 70% waste would represent 14.7 million pounds of material. At a mean protein content of 14%, the waste from landings in Oregon alone would represent well over 2 million pounds of protein.

Presently, this waste material is being utilized for mink and pet food, for the preparation of low-grade fish meal, and for crab bait. The lower protein and high mineral content of this waste tends to limit its scope of utilization and value.

During the last 20 years machines have been developed in Japan (Tanikawa, 1963) and in the Scandinavian countries which remove edible flesh from bone and skin in a coarsely minced form. More recently, equipment which accomplishes the same objective has been developed in the United States. Machine separators have been recently evaluated as a means of recovering flesh from dressed fish (Miyauchi and Steinberg, 1970) and from dressed and filleted fish carcasses (King and Carver, 1970).

The purpose of this investigation was to determine the yield of flesh which could be obtained from carcass waste by machine separation of bone and skin and to evaluate the effect of machine separation on the composition and nutritional characteristics of the separated fractions. Emphasis was placed on the nutritional characteristics of the protein and mineral fractions.

EXPERIMENTAL

Carcass waste was obtained by random selection from two commercial filleting plants. Approximately 200 lb of carcasses and associated waste was collected for each of six different species of fish that varied greatly in their anatomical features.

A portion (45 lb) was ground through a 0.75-in. plate using a dual-cut meat chopper and then passed through a high-speed mill equipped with a head possessing 0.012-in. openings. The remaining fraction (155 lb) was passed through a Yanagiya Fish Separator ("miny" model) equipped with a perforated rotating drum with 4-mm openings. The head and collar portions of species (rockfish and ling cod) that could not be accommodated by the laboratory scale separator were passed once through a 0.75-in. plate prior to processing. Separated flesh and bone–skin fractions were milled. The three milled samples for each species (whole carcass waste, separated flesh, and bone–skin fraction) were each thoroughly mixed for 20 min with a mechanical mixer. Milled whole carcass waste and the separated flesh fraction were dried using a laboratory atmospheric double-drum drier. Both dry and wet samples were vacuum sealed in moisture vapor-proof packaging material and held at −35°C prior to analysis.

Proximate analyses were carried out on wet, milled samples. Samples for mineral analyses were dried in vacuum at 65°C and passed through a 1-mm sieve of a high speed mill with Dry Ice. Drum-dried samples used to determine protein efficiency ratio (PER) values were mixed with an equal weight of cornstarch and passed through a 0.02-in. sieve of a high speed hammer mill. The use of Dry Ice and the mixing of drum-dried samples with cornstarch was necessary to assure thorough milling of samples high in fat.

Moisture, ash, protein (total N × 6.25), fat, and PER values were determined according to A.O.A.C. procedures (1965a, b, c, d, and e, respectively). Mineral elements were determined by WARF Institute, Inc., Madison, Wis., using direct reading emission spectroscopy methods described by Christensen *et al.* (1968). Data were analyzed by analysis of variance and the differences in PER value means tested by the least significant difference (LSD) method.

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Table I. Yield of Flesh from the Carcasses of Some Food Fish Species Passed Through a Laboratory Model Flesh Separator

Species	Weight processed, kg		Percent recovery from whole carcass waste			
	Carcass waste	Recovered flesh	Flesh	Protein[a]	Ash[a]	Fat[a]
English sole (*Parophrys vetulus*)	70.10	34.66	49.4	43.7	21.6	42.7
Petrale sole (*Eopsetta jordani*)	77.20	45.20	58.6	54.3	17.8	61.6
Orange rockfish (*Sebastodes pinniger*)	76.10	40.88	53.7	48.1	13.3	56.7
Yellowtail rockfish (*Sebastodes flavidus*)	82.25	49.55	60.2	55.3	21.2	66.0
True cod (*Gadus macrocephalus*)	38.45	18.80	48.9	44.1	17.2	44.5
Ling cod (*Ophiodon elongatus*)	50.35	26.50	52.6	45.8	19.7	49.3

[a] Recovery based upon analysis of whole carcass waste and recovered flesh.

Table II. Proximate Composition of Whole Waste and Separated Flesh and Bone–Skin Fractions

	Sample	Species					
		English sole	Petrale sole	Orange rockfish	Yellowtail rockfish	True cod	Ling cod
Moisture, %	Whole waste	79.32	73.44	70.30	71.61	78.92	75.49
	Flesh	83.44	77.12	76.94	73.21	82.90	79.73
	Bone–skin	74.84	67.78	62.14	61.89	74.91	69.71
Fat, %	Whole waste	2.64	7.76	7.26	7.02	2.09	4.57
	Flesh	2.28	8.16	7.66	7.69	1.90	4.28
	Bone–skin	3.04	7.16	5.34	6.41	1.20	3.92
Protein, %	Whole waste	13.40	14.58	16.19	15.79	15.60	17.16
	Flesh	11.84	13.52	14.50	14.48	14.06	14.93
	Bone–skin	15.49	16.69	19.18	19.56	17.87	19.13
Ash, %	Whole waste	4.90	4.42	6.53	5.78	4.33	3.48
	Flesh	2.14	1.34	1.62	2.03	1.52	1.30
	Bone–skin	7.16	8.98	14.64	12.60	7.02	7.98

RESULTS AND DISCUSSION

Yields of flesh, the material less bone and skin recovered by machine separation, ranged from 48.9 to 60.2% (Table I). This resulted in the recovery of 43.7–55.3% of the total protein, 42.7–66.0% of the fat, and 13.3–21.6% of the total ash.

The amount of flesh recovered by machine separation appeared to be related more to the efficiency of hand filleting than to the anatomical features peculiar to the various species of fish investigated. Differences in yield between the species of sole, rockfish, or cod were as great as the differences among the three specie types.

Differences among the six species in the proximate composition of their whole carcass waste and separated flesh and bone–skin fractions were largely related to their respective fat contents and their relationship to moisture and protein content (Table II). The moisture level in the separated flesh fractions from all species was higher than in both the whole carcass wastes or the bone–skin fractions. Fat levels of the flesh fractions were somewhat higher than the respective whole carcass wastes or bone–skin fractions if fat levels were calculated on a dry weight basis. Although the protein content of the flesh fractions was lower than in either the whole carcass wastes or the separated bone–skin fractions, levels on a dry weight basis were generally higher. Ash levels in the separated flesh fractions were greatly reduced over those for respective whole carcass waste samples and reflected the expected concentration of ash in the bone–skin fractions.

Levels of mineral elements largely associated with bone and skin were greatly reduced in the flesh fraction over levels found in the whole carcass waste (Table III). Phosphorus, calcium, strontium, manganese, boron, and chromium levels were substantially reduced. Potassium, sodium, and iron, which are largely associated with muscle and glandular tissues, were concentrated in the flesh fraction. Potassium and sodium levels in the flesh fraction from all species were higher than in respective whole carcass wastes. Flesh iron levels were all higher except for that of yellowtail rockfish. Differences in magnesium, aluminum, barium, copper, and zinc levels between the whole carcass waste and separated flesh fractions were varied and somewhat dependent upon species.

The mineral composition of the separated flesh fractions from the different species varied more than the composition of the various whole carcass wastes. Levels of aluminum, barium, iron, boron, chromium, and magnesium in whole carcass wastes from different species varied considerably. In addition to these mineral elements, levels of calcium, strontium, copper, and zinc also showed a large variation in the separated flesh fractions. Differences in the calcium and strontium levels of the separated flesh probably reflected differences in the efficiency of bone separation among species.

Calcium–phosphorus ratios for the separated flesh fractions were considerably lower than ratios for the whole carcass wastes (Table III). The reduction of the ratios in the flesh fraction resulted from the separation of a proportionally larger amount of calcium than phosphorus from the whole carcass waste into the bone–skin fraction. Ratios in the bone–skin fraction were considerably higher than in the whole carcass waste. Whole English sole waste possessed a lower ratio than all of the other species analyzed. Ratios for the other species were quite consistent. Flesh fraction ratios varied more than ratios for the whole carcass waste. Differences in the efficiency of bone separation and consequently calcium appear to be the most probable reason for this greater variation.

Table III. Mineral Composition[a] of Whole Waste and Separated Flesh and Bone–Skin Fractions

	Sample	English sole	Petrale sole	Orange rockfish	Yellowtail rockfish	True cod	Ling cod
P, %	Whole waste	2.83	2.33	2.95	2.55	2.49	2.13
	Flesh	1.16	0.88	1.05	1.13	1.21	1.02
	Bone–skin	3.42	3.15	3.87	3.26	3.37	3.34
K, %	Whole waste	1.18	1.01	1.12	1.07	1.32	1.19
	Flesh	1.24	1.09	1.16	1.08	1.60	1.42
	Bone–skin	1.04	0.97	1.02	0.86	1.20	1.06
Ca, %	Whole waste	4.05	3.84	4.88	4.08	3.94	3.37
	Flesh	1.00	0.41	0.92	0.98	0.67	0.63
	Bone–skin	6.53	6.30	8.46	7.64	6.13	6.17
Mg, %	Whole waste	0.22	0.18	0.18	0.19	0.22	0.17
	Flesh	0.22	0.14	0.13	0.17	0.19	0.13
	Bone–skin	0.22	0.21	0.23	0.22	0.22	0.20
Na, %	Whole waste	1.03	0.77	0.82	0.82	1.10	0.82
	Flesh	1.22	0.88	0.99	0.89	1.30	0.97
	Bone–skin	0.84	0.70	0.85	0.72	1.06	0.91
Ca/P	Whole waste	1.43	1.65	1.66	1.60	1.58	1.58
	Flesh	0.86	0.46	0.88	0.87	0.55	0.62
	Bone–skin	1.91	2.00	2.18	2.34	1.82	1.85
K/Na	Whole waste	1.14	1.31	1.37	1.30	1.20	1.45
	Flesh	1.02	1.24	1.17	1.21	1.24	1.47
	Bone–skin	1.24	1.38	1.20	1.20	1.13	1.17
Al, ppm	Whole waste	759	225	205	388	488	139
	Flesh	926	121	60	315	402	46
	Bone–skin	466	269	313	357	334	229
Ba, ppm	Whole waste	9.3	3.3	6.0	5.7	4.8	2.0
	Flesh	8.5	2.0	1.9	3.1	3.5	2.0
	Bone–skin	9.8	4.7	9.4	7.3	7.3	4.3
Fe, ppm	Whole waste	860	268	83	739	700	175
	Flesh	1323	397	192	539	906	180
	Bone–skin	435	92	56	129	291	83
Sr, ppm	Whole waste	278	187	213	209	233	147
	Flesh	89	17	47	51	62	22
	Bone–skin	389	254	285	275	296	233
B, ppm	Whole waste	14.0	7.8	8.5	11.7	10.8	6.0
	Flesh	12.1	2.2	2.4	4.1	6.3	0.9
	Bone–skin	14.6	11.4	15.8	13.5	12.7	11.1
Cu, ppm	Whole waste	10.3	8.5	7.5	7.6	9.3	13.4
	Flesh	19.6	8.3	4.9	6.4	20.8	7.8
	Bone–skin	18.7	10.0	12.1	10.8	13.8	10.7
Zn, ppm	Whole waste	88	77	61	71	70	74
	Flesh	106	72	47	57	66	76
	Bone–skin	95	81	78	90	84	77
Mn, ppm	Whole waste	31.6	<1.0	<1.0	5.7	9.9	2.0
	Flesh	25.0	<1.0	<1.0	<1.0	5.5	<1.0
	Bone–skin	36.3	2.3	<1.0	<1.0	7.7	7.6
Cr, ppm	Whole waste	9.3	4.7	8.1	6.7	7.1	4.7
	Flesh	7.2	<1.6	4.7	1.5	<1.1	<1.5
	Bone–skin	15.8	10.9	18.3	14.8	12.5	10.8

[a] Dry weight.

Potassium–sodium ratios in the separated flesh fractions from English and Petrale sole and orange and yellowtail rockfish were somewhat lower than ratios of the respective whole carcass wastes. Recovery of total sodium in the flesh fraction of these species was slightly greater than the recovery of total potassium. Ratios in the flesh fractions from true cod and ling cod were slightly higher as a result of a greater recovery of total sodium in the former and nearly equal recovery in the latter. A greater variation in potassium/sodium ratios was observed between species than between the three samples of each species.

Machine separation of bone and skin markedly improved the quality of carcass waste protein. Combining the results of individual PER determinations for each species listed in Table IV resulted in an average PER value of 3.22 for the separated flesh fraction and 2.70 for the whole carcass waste. This average value for the separated flesh fractions compares favorably with PER values reported for fish protein concentrate prepared from whole red hake (*Urophycis chuss*) (Dubrow and Stillings, 1970) and Atlantic herring (*Clupea harengus*) (Makdani *et al.*, 1971), freeze-dried whole red hake (Dubrow *et al.*, 1971), and phosphate complexed and isopropyl alcohol precipitated sarcoplasmic fish proteins (Spinelli and Koury, 1970).

The PER values for separated flesh fractions from all six species investigated were significantly ($p < 0.05$) higher than those for respective whole carcass wastes (Table IV). The quality of the protein in the flesh fraction of five of the six species was significantly ($p < 0.05$) superior to casein. The PER value for the flesh fraction of true cod did not vary significantly ($p < 0.05$) from the casein reference. Values for the whole carcass waste of four of the six species investigated were significantly ($p < 0.05$) inferior to casein. The PER values for the whole carcass waste of English sole and yellowtail rockfish did not vary significantly ($p < 0.05$) from the casein reference.

Table IV. PER Values for Whole Carcass Waste and Machine-Separated Flesh

Species	Sample	Mean feed consumption, g	Mean weight gain, g	PER	PER ratio × 100[a]
English sole	Whole waste	441.3	124.2	2.83[a,e,f]	97.8
	Flesh	454.8	135.9	3.29[b,c]	113.5
Petrale sole	Whole waste	371.2	89.7	2.64[f,g]	91.2
	Flesh	406.5	106.2	3.15[c]	108.7
Orange rockfish	Whole waste	407.6	100.0	2.67[e,f,g]	92.0
	Flesh	412.1	118.6	3.12[c,d]	107.8
Yellowtail rockfish	Whole waste	418.9	109.2	2.85[a,e]	98.4
	Flesh	426.5	131.8	3.35[b]	115.7
True cod	Whole waste	410.6	104.7	2.70[e,f,g]	93.2
	Flesh	427.6	119.8	2.94[a,d]	101.5
Ling cod	Whole waste	397.9	97.0	2.53[g]	87.4
	Flesh	465.6	150.0	3.49[b]	120.3
	Casein	382.7	110.7	2.90[a]	

[a] PER for sample group/PER for casein reference group × 100. Mean values in a column with same exponent letter did not vary significantly ($p < 0.05$) from each other.

Values for the whole carcass wastes of the different species investigated as well as their respective flesh fractions varied significantly ($p < 0.05$). The relative protein quality of the separated flesh fractions from different species was not related to the quality of the respective whole carcass wastes. The PER value for the whole carcass waste from ling cod was significantly ($p < 0.05$) less than those for the whole carcass wastes of yellowtail rockfish and English sole but not significantly ($p < 0.05$) different from values for wastes of true cod, orange rockfish, and Petrale sole. Conversely, the PER value for the flesh fraction of ling cod waste did not vary significantly ($p < 0.05$) from values for yellowtail rockfish and English sole but was significantly ($p < 0.05$) superior to the flesh fractions from true cod, orange rockfish, and Petrale sole. Differences in the quality of the protein in the whole carcass wastes and separated flesh fractions from different species can probably be accounted for by the differences in the relative quantities of muscle and glandular protein present in the sample. The protein of fish visceral meal has been reported to possess considerably lower gross protein values for chicks and net protein utilization by rats than protein of whole herring meal (Olley *et al.*, 1968).

The reduced total ash content improved protein quality, and more favorable mineral composition of machine-separated flesh shown by this investigation indicates a considerable upgrading in nutritional quality. Removal of bone and skin could greatly widen the market for and increase the value of fish carcass waste.

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