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A Comparison of Body Constituents of Wild and Cultured Red Sea Bream, *Pagrus major* from Different Localities in Japan

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Abstract

Wild and cultured red sea bream, *Pagrus major*, collected from three different localities in Japan were compared for biochemical characteristics that might influence carcass quality of fish. Distinct morphological and anatomical differences were observed between wild and cultured fish. Wild fish were characterized by extremely low concentrations of triglycerides in the muscle and viscera. Muscle RNA/DNA ratio estimated as an index of protein synthetic activity was higher in wild fish. Muscle protein was fractionated into sarcoplasmic, myofibrillar, alkali-soluble and stromal fractions. These protein fractions were highly variable not only between wild and cultured fish, but also among fish from the three localities.

Introduction

Red sea bream, *Pagrus major*, is one of the most common marine fish in Japan on account of its attractive color and excellent flavor. Consumers prefer the wild fish which are thought to have better carcass quality than cultured fish.

It has been reported that, aside from differences in fatty acid composition, the lipid content of cultured fish is much higher than that of wild fish (Chanmugan et al. 1986; Jahncke et al. 1988; Bergström 1989; Aoki et al. 1991).

Muscle protein is an important component of carcass quality. Distinct differences between the protein content of wild and cultured fish are usually not evident (Morishita et al. 1988). However, some notable differences might exist in protein composition (Mustafa et al. 1994).

The present study was therefore designed to compare the body constituents of wild and cultured red sea bream, with special reference to muscle lipid and protein, with a view to obtain basic information on carcass quality of this species.

Materials and Methods

Two year-old wild and cultured red sea bream were collected from the Inland Sea of Japan (Hiroshima Prefecture), the Japan Sea (Shimane Prefecture) and the Ushibuka Bay (Kumamoto Prefecture) between August and September. The age of the fish were determined by scalimetric measurement.

Morphometric data were collected from five to 10 fish from each group. The condition factor (body weight/body length^3 X 10^3), muscle ratio (muscle weight/body weight X 100), hepatosomatic index (liver weight/body weight X 100) and intraperitoneal body fat (IPF) ratio (IPF weight/body weight X 100) were calculated.

Muscle, liver and IPF of five fish from each group were frozen at -20°C until biochemical analysis. Muscle crude protein was determined by the Kjeldahl method. Lipid was extracted with the methanol-chloroform system (Bligh and Dyer 1959). To determine lipid class composition, lipid was loaded on silica rods (Chromarod-S II), developed with the *n*-hexane/diethyl ether/acetic acid (80:20:1, v/v/v/) solvent system, and yielded by an Iatroscan TH-10 (Iatron Co. Ltd.).

The dorsal skeletal muscle was dissected and frozen immediately in liquid nitrogen for protein and nucleic acid analyses. Muscle RNA and DNA were measured as an index of protein synthetic activity in muscle. The nucleic acids were extracted from dorsal white muscle according to Munro and Fleck (1966). Protein was estimated by the Folin method (Lowry et al. 1951). The white muscle of the dorsal part just beneath the dorsal fin was fractionated into sarcoplasmic, myofibrillar, alkali-soluble and stromal fractions according to Hashimoto et al. (1979). The protein content or each fraction was measured by the Folin method.

The data were analyzed for significance using the Student's *t*-test. Probabilities of 0.05 or less were considered statistically significant.

Results

Morphological and anatomical differences between wild and cultured red sea bream were observed (Table 1). Body weight and length were distinctly different among fish from the three localities as well. The amount of IPF in wild fish was very low. The condition factor, muscle ratio and hepatosomatic index showed considerable differences between wild and cultured fish in the Inland Sea of Japan. However, in Ushibuka Bay, the values for cultured fish were higher than for wild fish. The biological characteristics of wild fish from the Japan Sea were similar to that of wild fish from the Inland Sea of Japan. The hepatosomatic index was generally lower in wild than in cultured fish.

Muscle nucleic acids measured as indices of protein synthetic activity and cell volume are given in Table 2. RNA/DNA, RNA/protein and protein/DNA ratios were remarkably higher in larger fish. In the Inland Sea of Japan, the ratios were significantly higher in wild fish than in cultured fish. The ratios among

Table 1. Comparison of morphological and anatomical parameters of wild and cultured red sea bream.

	Inland Sea of Japan		Japan Sea	Ushibuka Bay	
	Wild	Cultured	Wild	Wild	Cultured
Body weight (g)	122 ± 13^{a}	100 ± 18^{a}	224 ± 57^{b}	761 ± 110^{c}	649 ± 102^{c}
Body length (cm)	15.8 ± 0.5^{a}	15.3 ± 0.8^{a}	19.6 ± 1.5^{b}	29.1 ± 2.2^{c}	27.1 ± 1.9^{c}
Condition factor	31.0 ± 1.8^{a}	27.7 ± 1.8^{b}	29.7 ± 2.1^{ab}	30.9 ± 3.2^{ab}	32.6 ± 2.5^{a}
Muscle ratio (%)	41.7 ± 1.9^{a}	34.4 ± 2.6^{b}	36.9 ± 3.6^{b}	38.1 ± 3.8^{ab}	41.2 ± 1.7^{a}
Hepatosomatic index (%)	0.88 ± 0.14^{ab}	1.32 ± 0.18^{c}	0.94 ± 0.10^{ab}	0.84 ± 0.13^{b}	1.00 ± 0.04^{a}
IPF ratio (%)	tr	0.65 ± 0.29^{a}	tr	0.78 ± 1.19^{a}	3.41 ± 0.81^{b}

Mean $\pm$ SD (n=5-10) with different superscripts in the same row are significantly different ($P<0.05$); tr = trace amount; IPF = intraperitoneal body fat.

Table 2. Comparison of muscle nucleic acid and protein in wild and cultured red sea bream.

	Inland Sea of Japan		Japan Sea	Ushibuka Bay	
	Wild	Cultured	Wild	Wild	Cultured
RNA ($\mu g \cdot 100\ mg^{-1}$)	683 ± 56^{a}	487 ± 110^{b}	905 ± 96^{c}	664 ± 58^{a}	551 ± 40^{b}
DNA ($\mu g \cdot 100\ mg^{-1}$)	187 ± 21^{a}	411 ± 94^{b}	186 ± 37^{ac}	124 ± 8.0^{c}	118 ± 3.3^{d}
Protein ($mg \cdot 100\ mg^{-1}$)	17.3 ± 0.9^{a}	18.1 ± 1.3^{ab}	18.1 ± 1.0^{ab}	18.7 ± 1.1^{ab}	19.1 ± 1.5^{b}
RNA/DNA	3.7 ± 0.2^{a}	1.3 ± 0.5^{b}	5.1 ± 0.3^{ac}	5.4 ± 0.7^{c}	4.7 ± 0.4^{c}
RNA/protein ($x10^{2}$)	4.0 ± 0.4^{a}	2.7 ± 0.6^{b}	5.0 ± 0.3^{c}	3.6 ± 0.3^{a}	2.9 ± 0.3^{b}
Protein/DNA	94.2 ± 11.6^{a}	48.4 ± 17.8^{b}	102.1 ± 23.5^{a}	152.0 ± 15.1^{c}	162.1 ± 10.5^{c}

Mean $\pm$ SD (n=5) with different superscripts in the same row are significantly different ($P<0.05$).

wild fish caught in the three different localities were somewhat different. In Ushibuka Bay, wild fish could not be differentiated from cultured fish on the basis of these data. The relationship between body weight and cellular growth parameters is shown in Fig. 1. In small (<300 g) fish, RNA concentration, RNA/DNA and protein DNA ratio tended to increase, and DNA content to decrease with body weight. This trend did not persist in larger (>300 g) fish.

The muscle of wild fish was characterized by extremely low lipid and high moisture content, while crude protein was not different among the groups (Table 3).

The amount of lipid and lipid class composition in the muscle are shown in Fig. 2. Triglycerides (TG) were the major lipid class and were considerably low in wild fish. The distribution of TG in muscle, liver and IPF is shown in Fig. 3. IPF was composed mainly of TG. Wild fish caught in the Inland Sea and Japan Sea retained barely detectable amounts of IPF.

The proportions of sarcoplasmic and myofibrillar protein fractions in the dorsal muscle were not different between wild and cultured fish from the Inland Sea of Japan. Remarkable differences were found in stromal fraction (Table 4). Wild fish of Ushibuka Bay had high stromal fraction. However, the results with fish from the Inland Sea of Japan were completely different. Among wild fish, stroma fraction tended to increase with growth.

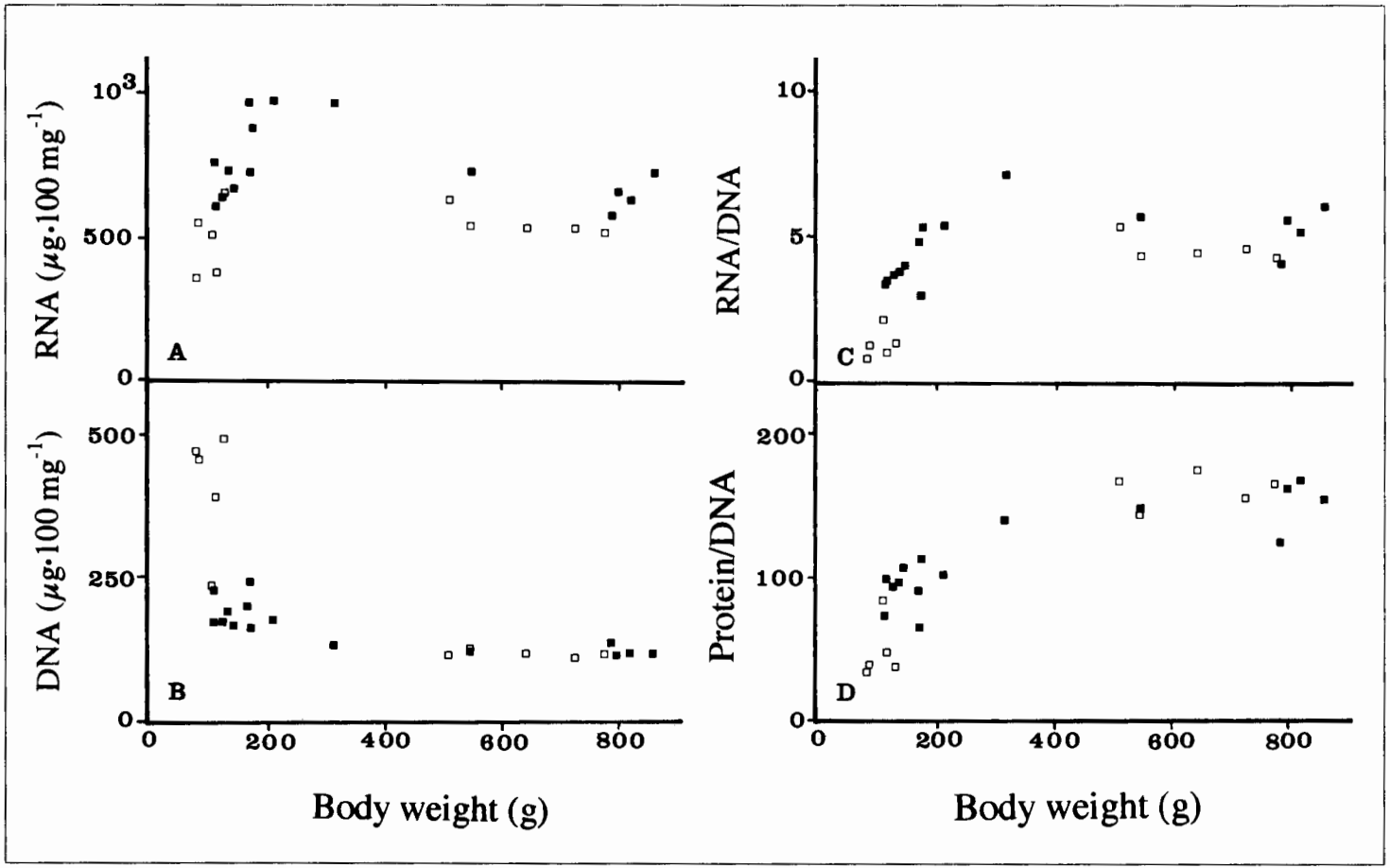

Fig. 1. Relationship between body weight and nucleic acids in wild (■) and cultured (□) fish.

Table 3. Proximate composition (% wet weight) of muscle of wild and cultured red sea bream.

	Inland Sea of Japan		Japan Sea	Ushibuka Bay	
	Wild	Cultured	Wild	Wild	Cultured
Moisture	77.5±0.5^{a}	74.6±0.8^{b}	77.6±1.3^{ac}	76.2±0.8^{c}	71.8±0.6^{d}
Crude protein	19.2±0.9^{a}	19.9±1.3^{ab}	19.5±1.0^{a}	20.4±0.9^{ab}	20.7±0.5^{b}
Lipid	1.8±0.5^{a}	4.1±2.6^{ab}	1.4±0.7^{a}	2.0±0.2^{a}	6.2±0.3^{b}
Ash	1.5±0.1^{a}	1.4±0.1^{ab}	1.5±0.1^{a}	1.4±0.1^{ab}	1.3±0.1^{b}

Mean ± SD (n=5) with different superscripts in the same row are significantly different ($P<0.05$).

Table 4. Comparison of protein composition between wild and cultured red sea bream.

Protein fraction	Inland Sea of Japan		Japan Sea	Ushibuka Bay	
	Wild	Cultured	Wild	Wild	Cultured
Sarcoplasmic (mg·g^{-1})	61.0±2.0^{a} (35.3±0.6)^{ac}	68.0±4.2^{b} (34.1±2.7)^{a}	56.3±1.8^{c} (29.8±1.7)^{b}	65.7±3.9^{ab} (37.7±1.0)^{c}	69.4±2.9^{b} (37.8±2.2)^{c}
Myofibrillar (mg·g^{-1})	38.0±2.5^{a} (22.0±2.0)^{a}	49.4±4.3^{b} (24.7±1.2)^{b}	36.8±4.0^{a} (19.4±1.9)^{ad}	24.7±2.6^{c} (13.1±0.9)^{c}	31.6±7.9^{a} (17.2±4.1)^{cd}
Alkali-soluble (mg·g^{-1})	69.0±5.2^{a} (39.9±1.8)^{a}	67.5±4.1^{a} (33.7±1.0)^{b}	86.8±1.9^{b} (45.9±0.9)^{c}	79.5±5.6^{c} (42.4±3.6)^{ac}	74.3±6.4^{ac} (40.4±2.0)^{a}
Stroma (mg·g^{-1})	4.9±1.0^{a} (2.8±0.5)^{a}	14.9±3.2^{b} (7.4±1.4)^{b}	9.3±1.2^{cd} (4.9±0.6)^{c}	18.2±5.3^{b} (9.6±2.4)^{b}	8.4±4.2^{ad} (4.6±2.4)^{abc}
Total (mg·g^{-1})	173±9.1^{a}	200±6.3^{b}	189±3.7^{c}	188±7.9^{c}	184±7.0^{ac}

Mean ± SD (n=5) with different superscripts in the same row are significantly different ($P<0.05$); values in parentheses represent percentage distribution.

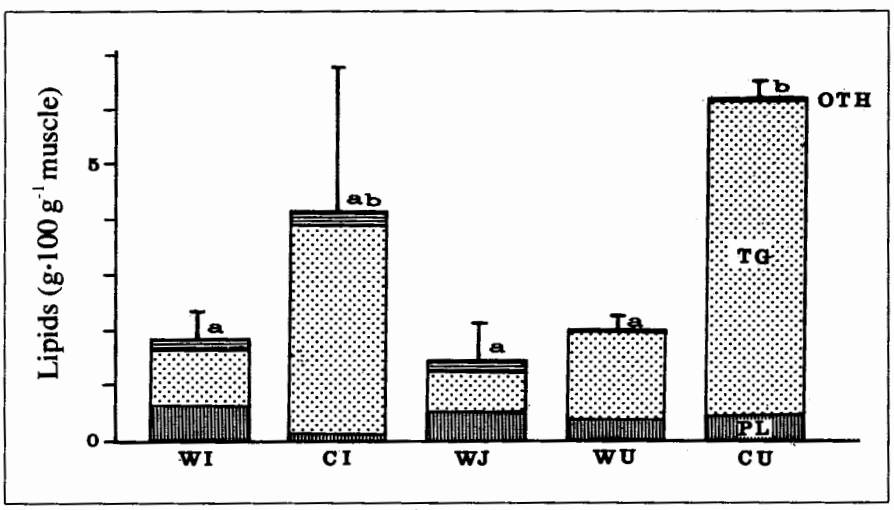

Fig. 2. Lipid and lipid class composition (PL = phospholipids; TG = triglycerides; OTH = others) in muscle of wild and cultured fish; WI = wild fish of the Inland Sea of Japan; CI = cultured fish of the Inland Sea of Japan; WJ = wild fish of the Japan Sea; WU = wild fish of the Ushibuka Bay; CU = cultured fish of the Ushibuka Bay. Vertical lines indicate SD (n=5), different letters on the bar represent significant difference ($P<0.05$).

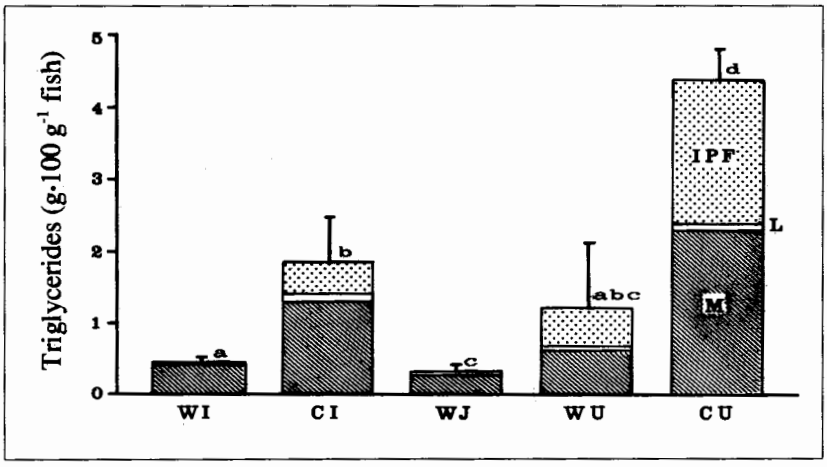

Fig. 3. Distribution of triglycerides in muscle (M), liver (L) and intraperitoneal body fat (IPF) of wild and cultured fish; WI = wild fish of the Inland Sea of Japan; CI = cultured fish of the Inland Sea of Japan; WJ = wild fish of the Japan Sea; WU = wild fish of the Ushibuka Bay; CU = cultured fish of the Ushibuka Bay. Vertical lines indicate SD (n=5), different letters on the bar represent significant difference ($P<0.05$).

Discussion

Cultured red sea bream were distinctly different from wild fish in morphological and anatomical parameters. Body weight was remarkably different among fish from the three localities, although they were determined to be of the same age. It is well known that growth of fish in the Inland Sea of Japan is relatively less than in the open sea (Kitajima 1969) due to lower water temperature during winter in the shallow semi-enclosed sea (min. ca 10°C). The relatively higher RNA/DNA and RNA/protein ratio found in wild fish might be associated with greater efficiency of protein synthesis (Houlihan et al. 1989; Mathers et al. 1993). Environmental factors such as temperature and salinity might also influence RNA/DNA ratio (Jürss et al. 1986, 1987). In fish weighing less than 300 g, environmental factors such as low water temperature might have a greater influence upon protein synthesis.

High lipids in cultured fish is attributed to high energy consumption and limited activity (Phillips 1969; Otwell and Rickards 1981). An inverse correlation between lipid and moisture content was observed in cultured red sea bream, as in other species (Balbontin et al. 1973; Kunisaki et al. 1986; Aoki et al. 1991). TG concentration was lower in wild than in cultured fish. IPF, which is composed mainly of TG, was negligible especially in small wild fish. Reserved lipids should be actively mobilizable as an energy source in order to minimize weight loss during food deprivation (Nakagawa and Kasahara 1986). Therefore the active state of lipid reserves might be considered in the evaluation of the physiological condition.

Differences in muscle protein composition between wild and cultured fish were detected. Stromal fraction is composed mainly of collagen. Thermal processing tenderizes muscle by gelatinization of collagen, and heat toughens

coagulated myofibrillar protein (Sikorski et al. 1984). Collagen contributes to the texture of raw and cooked meat (Feinstein and Buck 1984; Sato et al. 1986). Muscle firmness has been found to be related to the density and arrangement of collagen (Hatae et al. 1986; Ando et al. 1992); it also maintains muscle structure and is considered to be associated with the mode of swimming (Yoshinaka et al. 1988). Exercise has been shown to control the excessive deposition of lipids and increased collagen content in the muscle (Butter 1985; Kovanen and Suominen 1989). Improvement of carcass quality in cultured fish by induced exercise has been practiced (Totland et al. 1987; Tachibana et al. 1988). Collagen content in fish could also vary with dietary and environmental factors (Andrejeva 1971; Lavéty and Love 1972). Stromal fraction was high in larger wild fish, but the reasons for the high stroma content in cultured fish in the Inland Sea of Japan is unknown.

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