Comparative Studies on Physico-chemical Properties of the Muscle between Wild and Cultured Red Sea Bream (*Pagrus major*) Obtained in Kagoshima, Southern Japan

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**Abstract:** This study was aimed to investigate the physico-chemical property differences of the muscles in wild and cultured red sea bream obtained from Kagoshima region, southern Kyushu of Japan. Twenty live fish samples comprising 10 wild fish and 10 cultured fish (mean weight 1380 ± 40.0 g) were obtained from the Kagoshima Bay fishery and the Azuma Marine Fish hatchery, Kagoshima. All specimens were slaughtered by hypothermia, divided into dorsal and ventral fillets and maintained under 0°C for 48 hours wrapped in aluminium foil. Monitoring of k-value, pH and muscle rheology was conducted by using the fillets at 6-hour intervals for 48 hours and sensory analyses were conducted by using samples prepared for Japanese sashimi. Approximately 200 g samples from dorsal and ventral fillets were then freeze-dried for proximate analysis. In the dorsal muscles, k-values at 24, 30 and 36 h increased to 5.6, 5.5 and 6.4% respectively in culture fish compared to 3.1, 3.5 and 3.8% respectively in wild fish. The k-value at 48 h was significantly higher (*P* < 0.05) in cultured (17.5%) than that in wild (4.5%) ones. Ventral muscles showed slightly higher k-value at 0 hr in both cultured and wild fish, increasing significantly with time. Accordingly, deterioration rate of sashimi was faster in cultured than wild fish. On the contrary, at 36 h the pH values were significantly lower in cultured fish (6.0 in dorsal; 6.0 in ventral) compared to wild fish (6.5 in dorsal; 6.9 in ventral). Water and fat losses in ventral muscles in both wild and cultured fish were higher compared to those of dorsal muscles. The data of muscle rheology indicated textures of wild fish were harder than those of cultured fish. However, all samples deteriorated at 48h. Sensory scores for dorsal freshness, taste, odor and texture were generally similar and product acceptance of sashimi from both wild and cultured fish was not significantly different. Cultured fish showed significantly higher lipid in dorsal and ventral than in wild. Lipid contents were higher in dorsal muscles than in ventral muscles for both wild and cultured fish. Results demonstrated that physico-chemical properties differences between wild and cultured red sea bream were attributed to higher fat accumulation in cultured fish than in wild fish. Other parameters indicated no big differences between dorsal and ventral muscles of both wild and cultured fish within 48 h after slaughter. It can be concluded that wild and cultured red sea bream demonstrated similar quality characteristics within 48 hours after slaughter.

**Key words:** Red sea bream; K-value, Rheological analyses; Wild and cultured fish

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Introduction

Red sea bream (*Pagrus major*) is one of the most important cultured marine species in Japan (Kato et al. 2002). As the natural supply of captured fish continues to decline, aquaculture has often been looked at as the most promising “aqua-based” source. Fish quality in terms of freshness determines the quality of the final fish product (Ólafsdóttir et al. 1997). Consequently, the quality of cultured fish in terms of composition (Robb et al. 2002) should be similar or higher compared to fish caught from the wild. The perishable nature of fish and fish products (Ólafsdóttir et al. 2004) therefore calls for clear understanding of the factors, which determine quality characteristics and the deterioration mechanism after harvest. General quality indexes such as the level of freshness, sensory properties (flavor, smell and taste), water-holding capacity and texture determine reasonable evaluations of quality for both wild and cultured based fishes.

Saito et al. (1959) recommended k-value as one of the superior criteria for rapid assessment of fish freshness, and it has been widely used in related areas (Özogul et al. 2006). The k-value is a practical biochemical index (Va’zquez-Ortiz et al. 1997) and has been adapted in grading sashimi (Kaminishi et al. 2000; Hamada-Sato et al. 2005), with k-values below 20% regarded as acceptable for human consumption (Ohashi et al. 1991). However, the k-value varies with fish species, slaughter techniques and preservation temperature as well as the duration of storage. Sensory attribute is also used to evaluate acceptability of fish and fish products ensuring quality assurance during processing (Cardello et al. 1982), and fish texture is mainly determined by water holding capacity in fish muscle. Although numerous studies have been conducted to evaluate fatty acid compositions, rigor mortis and freshness of wild and cultured fish (Morishita et al. 1989; Iwamoto and Yamanaka 1986; Hatae et al. 1989), very limited updated information exists on the comparative variations in physico-chemical properties of edible muscles from wild and cultured fish fed using dry or extruded diets. Fish quality of cultured species largely depends upon the dietary treatments. Although there has been much information available in the past on the quality of cultured species (Kunisaki et al. 1985; Morishita et al. 1988; Ohashi et al. 1991) due to the technological progress dietary formulation has been drastically improved. Therefore, quality evaluation of cultured fish should be conducted with present time period.

The objective of this study was therefore to compare the physico-chemical variations in edible muscles obtained from wild and cultured red sea bream from Kagoshima area. Specifically, the study focused on k-value, pH, water-holding capacity, texture properties in relation to storage time, proximate composition, fatty acid composition and sensory evaluation. This evaluation on red sea bream is hoped to give an updated awareness on impacts of aquaculture to fish quality and can be used as guidelines in enhancing high quality aquafeeds in future.

Materials and methods

Experimental fish

A total of 20 fish of mean weight 1380 ± 40 g were used in the current study; 10 wild fish sampled from the Kagoshima Bay during June 2006 and 10 cultured from Azuma Marine Fish Hatchery, Kagoshima Prefecture. The cultured fish, reared in cages, were fed with a commercial diet (Higashimaru Co., Ltd. Kagoshima, Japan, 40–50% crude protein; 11% lipid). The experimental fish were transported alive in High Density Polyethelene (HDPE) tanks with oxygen aeration and held in a flow-through system tank on arrival at Kamoike Marine Production Laboratory, Faculty of Fisheries, Kagoshima University. All fish were acclimatized without feeding for 7 days prior to slaughter using hypothermia method, by immersion into slurry-ice cold marine water prepared and maintained at 3 ppt and 0°C according to method adapted from Losada et al. (2005). The slurry ice mixture was renewed every 30 min to maintain salinity. After acclimatization, the fish were transferred in insulated polystyrene box with water drainage,
weighted, eviscerated and filleted within 6 hrs after slaughter. The weights of the sampled fish varied from 1450 to 1500g in the wild captured specimens and 1210 to 1330 g in hatchery cultured fish with a pooled mean of 1380 ± 40.0 g for all the 20 specimens. Filleting was conducted by separating the dorsal and ventral flesh according to Japanese standards to obtain approximately 500 g fillets from each specimen for analyses in the current study. The fillets were wrapped in aluminum foil and chilled in ice at 0°C during analyses. Ice changed every 6 hours.

**Physico-chemical properties**

Monitoring of physico-chemical properties (pH, k-value and muscle rheology) of the dorsal and ventral fillets was conducted at 6 h-intervals for a period of 48 h. The pH measurements were conducted by insertion of an electronic pH meter probe (IQ150 pH meter, IQ Scientific Instruments, Inc. California) into both dorsal and ventral fillets muscles at 6 hr intervals over a 42 hr period.

White muscles (3 – 4 g) were digested with 5 ml of 10% trichloroacetic acid (TCA), supernatant was collected, filtered through a filter paper (Advantec no.1, Toyo Roshi Kaisha, Ltd., Tokyo, Japan) and neutralized using 10 M KOH and collected as filtrate 1 (S1). Filtrate 2 (S2) was prepared by mixing 50 ml S1 with 50 ml alkaline phosphatase (P) and incubated in water bath (37°C) for 20 min. Prior to injection of samples, the Super Freshness Meter reaction cell was prepared by filling 1 ml of air saturated 0.1 M PBS (phosphate buffer saline) into reaction cell and by injecting 10 ml S1 (before digestion, total ATP), 10 ml E₀ (Xanthine oxidase + Nucleoside phosphorylase) and 20 ml S2 (S1+Alkaline phosphatase = dephosphorylated ATP). The k-value was then measured using freshness meter (model KV-202, Central Kagaku Corp., Tokyo, Japan) according to the following formula.

\[ k\text{-value} = \frac{\text{100} \times (\text{Inosine}+\text{Hypoxanthine})}{(\text{ATP}+\text{ADP}+\text{AMP}+\text{IMP}+\text{Inosine}+\text{Hypoxanthine})} \]

The quality deterioration ratio (QDR) was calculated using the formula \( QDR = K/H \), where K is the k-value of fillet and H is the total storage period after slaughter.

**Water-holding capacity (WHC)**

Water-holding capacity of fillet samples was measured according to Gomez-Guillen et al. (2000). Five grams of sample and a filter paper (Advantec no.1, Toyo Roshi Kaisha, Ltd., Tokyo, Japan) were placed into a centrifuge tube (15 ml) and centrifuged at 7000 rpm for 10 min (10°C), and then the filter paper containing aqueous fatty fraction were weighed. Percentage of water loss (WL) from the samples was calculated as follows:

\[ WL\ (\%) = 100 \times \frac{(V^2-V^1)}{W_s} \]

The wet filter paper was then dried to a constant weight at 50°C in an oven, and percentage of fat loss (FL) was calculated as FL (\%) = 100 \times \frac{(V^3-V^1)}{W_s} , where V^1 is the weight of filter paper (g), V^2 is the weight of filter paper containing aqueous fatty fraction (g) and Ws is the sample weight (g).

**Rheological (texture profiles) analyses**

Texture profiles of the fish fillets were measured on a Rheonier II Creep (model RE-2-33005B, Yamaden, Co, Japan) consisting of four components: a detector (model RE2-33005B-2), measurement meter (model REZ-OP18-01), a cooler (model ETC-3305-1) and a computer auto-analyzer (Model CA-3305) installed with Texture Analysis Program (TAP ver.1.2-a). Samples were obtained from fillet according to Fig. 1. The temperature of the fresh samples was maintained at 4°C throughout the analyses and measurements were set in the central part of fillet. Analyzed parameters included maximum hardness force and adhesiveness of samples for a period of 48 hrs. Texture profiles were expressed in Fig. 2. Maximum hardness force is expressed as (H) maximum height of force in first plunge (Newton) and adhesiveness is the total area of A3 (J/m²).

**Sensory Analyses**

Sensory analyses were conducted at 6 h after slaughter. 500 g fillets from both wild and
cultured fish were cross-divided into dorso-ventral sections and sliced to obtain uniform sized sashimi of about 30-mm thickness. The slices were hygienically wrapped in aluminum foil and refrigerated at 4°C for 30 minutes before served to non-trained panelists comprising of 16 students from the Faculty of Fisheries, Kagoshima University. Sensory evaluation was conducted in a 25°C air-conditioned room. All panelists were lined 1 m apart and asked to taste and assess the sashimi slices according to odor, texture, freshness and taste scores based on method adapted from Amerine et al. (1965). The scores were then graded as 10 = excellent, 9 = very good, 7 = good, 5 = medium, 3 = poor, 1 = very poor and 0 = not acceptable.

Proximate analyses

Homogenized samples of dorsal and ventral muscle were analyzed in duplicates for protein, lipid, ash, and moisture. Protein determination was conducted according to the AOAC method (1990). Lipid content was analyzed according to the method adapted from Bligh and Dyer (1959), while ash content was obtained by combustion in muffle furnace at 550°C. Moisture, on a 5 g sample of freeze-dried fillet muscle, was determined by oven-drying at 110°C to constant weight.

Fatty acid composition analyses

Fatty acid composition was analyzed based on the study of Querijero et al. (1997) with slight modifications. Total lipid (TL) was extracted by homogenizing 0.2 g sample according to Bligh and Dyer (1959). Fatty acid esters were then produced from total lipids aliquots. Samples were then methylated with boron trifluoride (BF₃) in methanol. Methyl tricosanoate (Nu-Chek Prep. Inc) was used as internal standard at 1.000 mg/ml hexane. Fatty acid methyl ester was analyzed with a gas chromatograph (Shimadzu GC 17A) with flame ionization detector temperature maintained at 260°C; carrier gas He at 1 ml/min; column temperature at 200°C; injector temperature at 250°C and helium (He) served as the carrier gas. The samples (1.0 μl) were manually injected into injection port and identified fatty acids were presented as area percentage of total fatty acids.

Statistical Analysis

Statistical analyses on the physico-chemical parameters were conducted using One-Way Analysis of Variance (ANOVA) and posthoc tests were done using the Tukey-HSD for differences among treatments. Two-way analysis of variance (ANOVA) was used to analyze proximate composition and fatty acid composition of dorsal and ventral parts in wild and cultured fish. Data were expressed as means ± S.E (n = 3×3 individual fish muscles samples). All tests were considered significant at P<0.05.

Results

Physico-chemical properties; pH, k-value, and k-value QDR of fillet samples

The pH of dorsal and ventral samples
decreased with storage time as shown in Fig. 3. In the dorsal samples, there were no significant differences in pH between wild and cultured fish at 0, 6 and 12 h, in which pH ranged from 6.4 to 6.6. The pH decreased gradually until 42 h for both wild and cultured fish. Results skewed a little at 24 h and 30 h in which wild dorsal pH suddenly increased significantly to 6.8 and dropped to 6.1 respectively. Wild dorsal samples indicated significant higher pH value as compared to cultured dorsal ones at 18, 24 and 36 h. In ventral area, pH in wild was also significantly higher than that of cultured samples from 0 to 36 h, in which pH ranged from 5.6 to 6.9. There were no significant differences at 42 h for both groups.

The k-value in wild and cultured fish samples during cold storage (0°C) is presented in Fig. 4. In dorsal muscle, the k-value increased from a level of 1.6% to 4.5% in wild fish and 1.6% to 17.5% in cultured fish. The values of dorsal muscles from cultured fish showed significantly higher than those of wild ones after 24 h. At 42 h, k-value increased suddenly to 17.5% in cultured muscles. In ventral muscles, k-values gradually increased in both wild and cultured muscles up to 36 h. However, at 42 h, a sudden increase of k-value to 23.6% occurred in cultured muscles, which was significantly higher than that of wild ones.

In terms of QDR (Fig. 5), dorsal and ventral...
muscles of cultured fish showed higher level of deterioration ratio as compared to wild dorsal and ventral muscles. At 6 h after slaughter, QDR was high in all samples without significant differences among them. Ratio gradually decreased and remained at constant level up to 36 h for all treatments. At 42 h, QDR of cultured fish samples from both dorsal and ventral muscles escalated to 0.41 and 0.56%/h respectively and were significantly higher than those of wild ones.

**Water-holding capacity (WHC)**

WHC was represented by water loss (WL) and fat loss (FL) in muscle samples, and the changes of dorsal muscles are illustrated in Fig. 6. The pattern of WL between wild and cultured dorsal was similar up to 24 h. However, at 36 h WL value of cultured samples increased but that of wild ones dropped to 5.7%. FL values of cultured dorsal were significantly higher than those of wild dorsal at all sampling points. Comparatively, WL and FL in ventral fillets of both wild and cultured fish were higher compared to those of dorsal fillets (Figs. 6 and 7). Although no clear pattern in WL was observed between two groups, FL in ventral fillets of wild fish differed significantly from that of cultured one in all periods.

**Rheological (texture profiles) analyses**

Fig. 8 illustrated maximum hardness force in dorsal and ventral muscle fillets of wild and cultured fish. In ventral muscles, the values of wild fish were significantly higher than those of cultured ones from 6 h to 24 h, but were similar at 30 and 36 h. Those were leveled up to 48 h in cultured samples whereas it dropped zero in wild muscles at 42 h. In dorsal muscle, the values of wild fish was significantly higher than those of cultured ones at 0, 6, 12, 18, 24, 42 and 48 h but became similar at 30 and 36 h.

Dorsal and ventral muscles differed in terms of adhesiveness or gumminess of muscles as expressed in Fig. 9. Dorsal muscle fillets of both wild and cultured showed more adhesiveness throughout 48 h with some fluctuations than ventral muscles. Adhesiveness was more pronounced at 0 h for both samples obtained from dorsal areas. Apparently, the values of dorsal muscles decreased drastically to less than 5000 J/m³ after 18 h. In comparison, ventral areas for both groups were less adhesive and continued at low level until the end of analyses.

**Sensory Analyses**

The sensory scores from wild and cultured red sea bream are demonstrated in Fig. 10. In both dorsal and ventral muscles, freshness, taste, odor and texture scores were good in average without significant differences \( P > 0.05 \) among all treatments. Results indicated that quality of both specimens was well accepted by panelists.
Proximate analyses and fatty acid composition

Proximate composition of wild and cultured fish is presented in Table 1. There were no significant differences ($P > 0.05$) in crude protein and ash in both dorsal and ventral muscles between wild and cultured fish. Moisture had inverse relationship with lipid content in which higher lipid content decreased moisture level in all fish samples. Results indicated that cultured fish had significantly higher amounts of lipid in both dorsal and ventral areas as compared to wild fish. Lipids contents in dorsal muscles were relatively lower than those in ventral ones in both wild and cultured fish.

![Graph](image1)

**Fig. 6.** Changes of water holding capacity (fat and water loss) according to time series (h) in dorsal muscle fillets of wild and cultured fish.

![Graph](image2)

**Fig. 7.** Changes of water holding capacity (fat and water loss) according to time series (h) in ventral muscle fillets of wild and cultured fish.

![Graph](image3)

**Fig. 8.** Maximum hardness force pattern in dorsal and ventral muscle fillets of wild and cultured fish.
### Table 1. Proximate composition (%) and major fatty acids contents (μg/mg dry sample) of wild and cultured fish muscles

<table>
<thead>
<tr>
<th>Proximate composition (%)</th>
<th>Dorsal muscle</th>
<th>Ventral muscle</th>
<th>Dorsal muscle</th>
<th>Ventral muscle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude lipid$^2$</td>
<td>2.8 ± 0.2$^a$</td>
<td>9.3 ± 0.3$^c$</td>
<td>4.9 ± 0.5$^b$</td>
<td>14.2 ± 0.0$^d$</td>
</tr>
<tr>
<td>Crude protein$^2$</td>
<td>20.9 ± 0.2</td>
<td>21.7 ± 0.3</td>
<td>22.2 ± 0.3</td>
<td>21.2 ± 0.4</td>
</tr>
<tr>
<td>Ash$^2$</td>
<td>1.4 ± 0.0$^a$</td>
<td>1.3 ± 0.0$^b$</td>
<td>1.5 ± 0.0$^b$</td>
<td>1.4 ± 0.0$^a$</td>
</tr>
<tr>
<td>Moisture</td>
<td>74.9 ± 0.1$^d$</td>
<td>67.6 ± 0.1$^b$</td>
<td>72.3 ± 0.1$^c$</td>
<td>63.9 ± 0.1$^a$</td>
</tr>
<tr>
<td>Major fatty acids (μg/mg dry)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C18 : 2n-6</td>
<td>0.77 ± 0.13$^a$</td>
<td>6.73 ± 0.36$^b$</td>
<td>1.03 ± 0.07$^a$</td>
<td>8.04 ± 0.06$^c$</td>
</tr>
<tr>
<td>C18 : 3n-3</td>
<td>0.18 ± 0.02$^a$</td>
<td>1.31 ± 0.04$^b$</td>
<td>0.28 ± 0.01$^a$</td>
<td>1.43 ± 0.25$^b$</td>
</tr>
<tr>
<td>C20 : 5n-3</td>
<td>2.46 ± 0.01$^a$</td>
<td>6.40 ± 0.32$^b$</td>
<td>3.41 ± 0.02$^a$</td>
<td>8.95 ± 0.13$^c$</td>
</tr>
<tr>
<td>C22 : 6n-3</td>
<td>5.79 ± 0.78$^a$</td>
<td>14.64 ± 0.31$^b$</td>
<td>6.28 ± 0.26$^a$</td>
<td>16.43 ± 1.13$^b$</td>
</tr>
<tr>
<td>Total PUFA</td>
<td>10.36 ± 0.78$^a$</td>
<td>33.42 ± 0.30$^b$</td>
<td>12.70 ± 0.18$^a$</td>
<td>40.48 ± 0.75$^c$</td>
</tr>
</tbody>
</table>

$^1$ Values are means ± SE (n = 3 × 3 individual fish muscle samples), and those with the same letters show no significant differences (P > 0.05).

$^2$ dry weight basis.
Table 1 also illustrates contents of linoleic acid (LA), linolenic acid (LNA), eicosapentanoic acid (EPA), docosahexaenoic acid (DHA) and total polyunsaturated fatty acids (PUFA) in wild and cultured fish muscles. Cultured fish demonstrated a significantly eight-fold concentration of LA both dorsal and ventral muscles compared to wild fish. LNA in dorsal and ventral muscles of cultured fish also showed significantly higher composition at 1311 and 1427 ng/g dry sample respectively while wild fish showed lower contents in both muscles. EPA in all muscles of wild fish showed no significant difference, while ventral muscle EPA content in cultured fish showed significantly higher value than that of dorsal muscle. EPA in ventral muscle in cultured fish showed highest content among treatments. Wild fish showed significantly lower DHA content in both dorsal and ventral muscles compared to cultured fish. Results also showed that total polyunsaturated fatty acid (PUFA) content was significantly higher in cultured fish than in wild fish.

**Discussion**

Comparative studies between wild and cultured fishes conducted on seabass (Alasalvar et al. 2002; Orban et al. 2002), gilthead seabream (Grigorakis et al. 2002; Grigorakis et al. 2003), salmon (Sylvia et al. 1995; Farmer et al. 2000; Einen and Thomassen, 1998) and Atlantic halibut (Olsson et al. 2003a) demonstrated that there were significant differences between wild and cultured fish in terms of several attributes like lipid content and texture as were reported in this study. Existence of lipid in fish tissues influences other factors like shelf-life and senso- rial preferences. In terms of shelf-life, changes in k-value, pH and water binding capacity by storage time give high impact to fish quality. The present study demonstrated that cultured fish accumulates more lipids in its muscles especially in ventral area. Gradient degradation of freshness in fish is often associated with lipid content in fish. The present study indicated that critical time for deterioration begins at 6 h after slaughter for both wild and cultured fish, and then became stable from 12 to 36 h. However, deterioration ratio doubled in dorsal and tripled in ventral at 42 h. Concurrently, k-value had similar trends for all respective samples. Cultured ventral and dorsal muscles showed higher elevation of k-values while wild ventral and dorsal ones demonstrated lower and slower elevation rate against time.

Cultured samples also indicated the k-value elevation of more than 300% in both dorsal and ventral muscles at 42 h. The value of cultured ventral muscles at these points exceeded acceptable k-value for sashimi. These eleva- tions of k-value in the cultured samples may be due to rancidity from oxidation (Brody 1999; Bremner 2002), particularly unsaturated “double bonds” sourced from aquafeeds as observed by Raatikainen et al. (2005). This reflects the fact that the actual amounts of unsaturated fatty acids were higher in cultured fish muscles than those in wild ones although compositions of those did not differ so much. High total lipid deposition with inverse amount of DHA in cultured fish muscles suggests possibility of a more rapid oxidation rate in cultured fish muscles than wild ones. Visual observation also showed that samples in cultured fish particularly in ventral muscle changed color from whitish to pinkish starting from 36 h. This could be caused by occurrence of some bacterial spoilage due to oxidation in the samples, which may explain faster rancidity in cultured fish commonly known with more intense lipid deposition in adipose tissues (Suzuki et al. 1986; Richards et al. 2002) than wild fish. Degradation of fish freshness then occurs due to synergism impact between rancidity and autolysis of ATP (Erikson et al. 1997) that resulted undesirable k-value as reported by Aubourg et al. (2007). From freshness point of view, sashimi from cultured fish taken from 42 h is unsuitable for consumption because of exceeded standard k-value (20%).

The pH drop in cultured fish especially in ventral muscle may be due to high production of lactic acid through “ultimate” activities like struggling and force-swimming to escape from being captured as observed by Olsson et al. (2003a) on halibut. In comparison, wild fish that
were exposed to external pressures throughout their life had probably "rested" enough during the acclimatization period. Degradation in fish freshness is often related to low pH which prevents synthesis of ATP (Robb, 2002), resulting in locked rigor mortis, and without ATP, process of rigor and post-rigor becomes more rapid and reduces quality in fish. In relation to this study, deterioration of muscle tissues in cultured fish appeared to be more pronounced as compared to wild fish.

The present study showed that wild fish has better WHC as compared to cultured fish, in which wild fish demonstrated significant lower water loss at 36 h after slaughter while cultured fish illustrated continuously constant high water loss value. Similar observation was also reported by Olsson et al. (2003b) in Atlantic halibut. In general, water loss and pH have an inverse relationship (Olsson et al., 2003b), in which higher pH in wild fish usually contributes to lower water loss. On the other hand, low water content and low postmortem pH (Lavéty et al. 1988) in cultured fish contributed gaping in Atlantic cod (Espe et al. 2004) and rainbow trout (Mørkøre et al. 2002). Low pH is usually associated with degradation of myofibrillar properties in fish muscle. Myofibrils usually occupy a substantial volume of the muscle (Goodband 2002) and control the water holding capacity of the whole muscle as described by Offer and Trinick (1983). In this present study, pH began to degrade after 36 h (dorsal area) and 30 h (ventral area) respectively. The pH values were relatively low at this point of time and may influence the increased water loss in cultured fish. This observation corresponds to Olsson et al. (2003b) that liquid loss (LL) increased with decreasing pH lower than 6.3, whereas at higher pH values, LL was independent on pH.

Fat loss differed significantly in both wild and cultured fish immediately after time of slaughter to 36 h. Melting properties of triglyceride relate to its fatty acid components, in which high proportion of fatty acids with relatively short chain and low melting point melt easily at lower temperature. This corresponds to the study of Rørå et al. (2003) that smoked fillet lost relatively higher quantities of lipid at 22°C. In this study, fats in both wild and cultured fish may consist of low melting fatty acids that promote fat loss at 50°C. High deposition of lipids (Table 1) in adipose tissues may explain the high amount of fat loss especially in cultured fish.

The present study also indicated from the visual observation just after slaughter that cultured fish showed whiter and softer muscles in both dorsal and ventral areas than wild fish, which agreed to the reports by Grigorakis et al. (2003) and Jobling et al. (2002). Hardness force of cultured muscles constantly showed lower values in both dorsal and ventral muscles until 30 hrs after the slaughter in this study. Softer muscles are often associated with accumulation of fats in adipose tissues. Cultured fish accumulates fats easily in its flesh especially in ventral muscles (Suzuki et al. 1986) due to consumption of diets with high total lipid and limited mobility in restricted environment. In comparison, constant mobility (Jutila et al. 2002), prey hunting (Reid et al. 1993) and migration by wild fish develop compositional and textural changes which produce leaner, less-fatty and firmer fish.

Sensory analyses showed that panelists were unable to differentiate between sashimi obtained from dorsal and ventral parts of both wild and cultured fish. High scores of freshness, taste, odor and texture of the sashimi indicated well acceptance by panelists. Our results differed from the study of Grigorakis et al. (2003), in which wild fish was described as 'more juicy' as compared to cultured counterpart. They associated juicy with loosely bound water located in fish flesh and sample preparation by steam-cooking samples for sensory test method may have induced water loss in cultured fish samples. In comparison, our study demonstrated no significant difference of water loss between cultured and wild fish samples within 24 hrs after slaughter, and since water content is still intact in both cultured and wild fish sample, our sensorial taste panelists find no differences in texture and taste in neither cultured nor wild fish. Firmness defines good muscle texture in fish, confirming to Dunajska (1979) and Johnston et al. (2000), in which
firmness in fish texture is influenced by high fiber density. However, texture becomes more tender with storage time (Skjervold et al. 2001) due to reduced content and strength of the connective tissue (Sato et al. 1986). At this point of time, sashimi quality may deteriorate and unsuitable for consumption.

It can be concluded that sashimi of both wild and cultured red sea bream is best consumed at least 24 h after slaughter due to reasonably low k-value, high pH, high WHC and good texture chilled under low designated temperature 0–4°C. Wild and cultured red sea bream also demonstrated similar patterns of quality characteristics within 48 hours after slaughter and these features can be further enhanced through improvement of diet formulation.

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鹿児島産天然及び養殖マダイ可食部の物理化学的成分の比較

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高品質配合飼料の開発に役立てるため、鹿児島産天然及び養殖マダイ可食部の成分比較を行った。可食部を背部と腹部に分けて、殺魚後48時間の変化を6時間ごとに、k値、ペーハー値、弾力性について測定した。また、切身を使った食味テストを行い、殘ったサンプルを一斉分析に供した。可食部の背部、腹部とも、時間が経つにつれてk値が上昇したが、48時間後には、養殖魚の値が有意に高くなったものの、それ以前では有意差が検出されなかった。一方、ペーハー値は、養殖魚が天然魚よりも有意に低い値を示した。背部の水分損失は、養殖魚が高く、脂質損失は、天然魚で高くなった。弾力性は、天然魚で低い傾向があったが、48時間後には天然、養殖個体なく柔らかく変性した。背部サンプルに関するパネルテストでは、新鮮さ、味、香り、弾力性において天然、養殖間に有意差は検出されなかった。

本研究から、物理化学的成分の相違は、蓄積された脂肪分由来であるが、養殖魚の可食部は48時間以内であれば、天然魚とあまり大きな相違が無く、飼料の改良により天然魚に近い品質が得られると示唆される。