Reprint:
JURNAL ILMU-ILMU PERAIRAN DAN PERIKANAN INDONESIA

ISSN 0854-3194
Juni 2004, Jilid 11, Nomor 1
Halaman 45 – 51

Mineral, Fatty Acid and Dietary Fiber Compositions in Several Indonesian Seaweeds

(Komposisi Mineral, Asam Lemak dan Serat pada Beberapa Jenis Rumput Laut Indonesia)

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Berdasarkan Keputusan Direktur Jenderal Pendidikan Tinggi, Departemen Pendidikan Nasional No. 22/DIKTI/Kep /2002 tanggal 8 Mei 2002 tentang *Hasil Akreditasi Jurnal Ilmiah Direktorat Jenderal Pendidikan Tinggi Tahun 2002*, Jurnal Ilmu-ilmu Perairan dan Perikanan Indonesia (JIPPI) diakui sebagai **jurnal nasional terakreditasi**.

MINERAL, FATTY ACID AND DIETARY FIBER COMPOSITIONS IN SEVERAL INDONESIAN SEAWEEDS

(Komposisi Mineral, Asam Lemak dan Serat pada Beberapa Jenis Rumput Laut Indonesia)

Joko Santoso[1], Yumiko Yoshie[2] and Takeshi Suzuki[2]

ABSTRACT

The aim of the research was to study the distribution and profile of nutrient and non-nutrient compounds (*i.e.* mineral, fatty acid and dietary fiber) in nine species of Indonesian seaweeds (green, brown and red algae). The mineral contents were dominated by calcium, potassium, and sodium. Palmitic acid was the main fatty acid found in all of Indonesian seaweed samples, followed by stearic, oleic, and linolenic acids. The highest concentration of eicosapentaenoic acid was found in red alga *Kappaphycus alvarezii* (8.09 %), while the brown alga *Sargassum polycystum* contained the highest percentage of arachidonic acid (14.43 %). The contents of total, insoluble and soluble dietary fibers of the algae were 14.7 - 69.3, 14.3 - 64.1, and 0.4 - 10.7 (*g/100 g* dry weight), respectively. Red alga *K. alvarezii* had the highest content of total and soluble dietary fibers, whereas the highest content of insoluble dietary fiber was found in green alga *Ulva reticulata*.

Key words: dietary fiber, fatty acid, Indonesia, mineral, seaweed.

ABSTRAK

Tujuan penelitian ini adalah untuk mengetahui distribusi dan profil kandungan nutrient dan non-nutrien (mineral, asam lemak dan serat) pada sembilan jenis rumput laut dan beberapa kelas (alga hijau, coklat dan merah). Kandungan mineral didominasi oleh kalsium, potassium, dan sodium. Asam palmitic adalah asam lemak utama yang ditemukan pada semua contoh rumput laut, diikuti oleh asam stearic, asamoleic, dan asam linolenic. Konsentrasi asam eicosapentaenoic tertinggi ditemukan pada jenis alga merah *Kappaphycus alvarezii* (8,09%), sedangkan alga merah *Sargassum polycystum* mengandung asam arachidonic tertinggi (14,43%). Kisaran kandungan serat total, serat terlarut dan serat tidak terlarut pada contoh alga yang dianalisa berturut-turut adalah 14.7 - 69.3, 14.3 - 64.1 dan 0.4 - 10.7 (*g/100 g* berat kering). Alga merah jenis *K. alvarezii* memiliki kandungan serat total dan serat terlarut tertinggi, sedangkan alga yang mengandung serat tidak terlarut tertinggi adalah jenis alga hijau *Ulva reticulate*.

Kata kunci: serat, asam lemak, Indonesia, mineral, rumput laut.

INTRODUCTION

From the viewpoint of food and nutritional sciences, seaweeds provide high nutritional compounds of minerals, fatty acids and free amino acids (Yoshie *et al.*, 1994; Yoshie *et al.*, 1995; Norziah and Ching, 2000), and also provide non-nutrient compound like dietary fibers (Suzuki *et al.*, 1993; Suzuki *et al.*, 1996, Wong and Cheung, 2000).

Seafood including seaweeds is known to be one of the richest sources of minerals. The most common minerals found in seafood are iodine, magnesium, calcium, phosphorus, iron, potassium, copper and fluoride (Ensminger *et al.*, 1995). Minerals are very important for the biochemical reaction in the body as a cofactor of enzyme and defects in mineral nutrition are capable of producing severe impairment of health.

As a source of fatty acids, seaweeds provide different characteristics compared with land plants. Fatty acids compositions of seaweeds are rich in polyunsaturated fatty acids, especially eicosapentaenoic acids (EPA, C20: 5n3) (Yoshie *et al.*, 1994; Yoshie *et al.*, 1993; Resources Council, Science and Technology Agency, 2001). This fatty acid is considered to be essential because it cannot be synthesized by human and must be acquired through the diet, and the fatty acid plays an important role in human health and nutrition.

Although dietary fiber belongs to the non-nutritional compounds, it has been recog-

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nized as an important dietary constituent, which possesses a wide range of positive properties (Rim *et al.*, 1996; Leontowicz *et al.*, 2002). Dietary fiber has been reported to have several physiological effects, depending upon the individual sources (Dreher, 1987). High fiber diets are an important factor in the low prevalence of colon cancer, ischemic heart disease, diabetes mellitus, gallstones, hemorrhoids and hiatus hernia, and also improving large bowel function, increasing fecal bulk, etc (Eastwood, 1989; Schneeman, 1987). Different with dietary fiber from vegetables and fruits, dietary fibers in seaweeds contain some acidic group such as sulfuric group; therefore they have different characteristics in physicochemical and physiological effects, such as water and oil holding capacity (Suzuki *et al.*, 1996; Wong and Cheung, 2000), swelling capacity (Wong and Cheung, 2000), binding of vitamins and minerals (Yoshie *et al.*, 2000), binding of bile salts (Wang *et al.*, 2001), and lipid metabolism effect (Wang *et al.*, 2002).

Indonesia is an archipelago country has a large number of seaweeds. Early marine research in Indonesia started when Ambonia was a headquarter for the Dutch East Indies Company. However, modern marine research stemmed from the Siboga expedition (1899 - 1900), which focused on the marine flora and fauna and their biogeography. This expedition succeeded to collect 555 species of seaweeds from Indonesian territorial waters, and among them, around 20 - 30 species have been utilized locally as foodstuff and/or traditional (folk) medicine by local people (Tydeman, 1903 *cited by* Soegiarto and Sulustijo, 1990; Mubarak *et al.*, 1991).

Although Indonesia has plentiful source of seaweeds, but the utilization level up to present was limited. Certain species were used as a raw material for industry and exported only in dried form. Few species have been used as a foodstuff or traditional (folk) medicine by local people. The consumption level of seaweed is still low, because there is not enough information and no database about their nutritional and non-nutritional compounds. Research activity about them is rare. It has not been systematically studied, and it is still fertile area. Therefore we studied this research to obtain database about the distribution and profile of nutrient and non-nutrient compounds in several Indonesian seaweeds. The database is very useful, especially for reference of strategic policy of Indonesian government in fisheries sector, and also this information may be able to elevate the consumption level of seaweeds.

MATERIALS AND METHODS

Materials

Nine species of Indonesian seaweeds were used in this experiment. Five green algae (*Caulerpa racemosa*, *Caulerpa sertularoides*, *Cladophoropsis vauchaeriaeformis*, *Halimeda macroloba* and *Ulva reticulata*), three brown algae (*Padina australis*, *Sargassum polycystum* and *Turbinaria conoides*), and one red alga (*Kappaphycus alvarezii*) were collected from Seribu Islands, Jakarta Prefecture.

Samples Preparation

After removing sand, the seaweed samples were washed with clean seawater and transported to the laboratory under refrigeration. After washing with tap water and wiping with paper towel, seaweed samples were minced by a food cutter (MK-K75; Matsushita Electric Corp., Osaka, Japan), and stored at -20^{o}C until used.

Total Minerals

To each sample was weighed 2 *g* (wet sample) in a Kjeldahl flask, added with 20 *ml* of concentrated nitric acid and the flask was left overnight. Five milliliters of concentrated perchloric acid and 0.5 *ml* of concentrated sulfuric acid were added, and then the flasks were heated until no white smoke remained. Samples were transferred into volumetric flasks using 2% of hydrochloric acid, and then analyzed by an atomic absorption spectrophotometer (Model AA-600, Shimadzu Co., Kyoto, Japan) with acetylene flame, single-slot head, and Pt-Rh corrosion resistant nebulizer. Mineral standards were prepared from Wako Certified Atomic Absorption Reference Solution (Wako Pure Chemical Industries, Ltd., Osaka, Japan).

Fatty Acids

After total lipid extraction following to the method of Bligh and Dryer (1959) and saponification by 0.88% KCl, the fatty acids methyl esters (FAME) were derived by methyllation with HCl-methanol. Qualitative analysis of the FAME was carried out by gas-liquid chromatography (GLC) (GC-14A Shimadzu Co., Ltd., Kyoto, Japan) equipped with a Supelcowax-10 fused silica capillary column (0.25 *mm* i.d. x 30 *m*, 0.25 *mm* in film thickness) and a flame ionization detector. Injector port and a flame ionization detector were held at 250 and 270°C, respectively. The column temperature was initially held at 170°C for 5 *min* and then programmed to 225°C at 1°C/*min*. Helium was used as a carrier gas at the constant column inlet pressure of 0.5 kg/cm^2. Peak assignments were carried out by comparison of retention time of authentic standard (FAME Qualitative Mixture, GL Sciences, Inc., Tokyo, Japan).

Dietary Fiber

Soluble and insoluble dietary fibers were determined according to an enzymatic-gravimetric method (Porsky *et al*., 1988) which has been approved as the legal or recommended procedure for food analysis. However this method was modified here by using pancreatin (Suzuki *et al*., 1996; Plaami *et al*., 1989) because almost all seaweeds contain little protein and no starch. The procedure consists of following steps: (1) Boiling 2 *g* of wet sample with 30 *ml* of water for 5 *min*. (2) Incubation with 20 *ml* of 2% pancreatin and 30 *ml* of phosphate buffer at pH 6.8 in the presence of NaCl (10 *mM*) for 24 h at 37°C. (3) Water insoluble dietary fiber was filtered off by a glass fiber filter (GA-100, Advantec Toyo Inc., Tokyo, Japan), washed three times with 20 *ml* of 78% ethanol, twice with 20 *ml* of 95% ethanol and once with 10 mL of acetone, and dried at 105°C. Water soluble dietary fiber was precipitated from the filtrate us-ing 4 volumes of ethanol (at 60°C) and recovered by filtration in the same way as for insoluble fiber. (5) All samples analyzed were assayed in duplicate and one of the duplicate was used to determine protein content by Kjeldahl method, while the other was used to determine ash content in the fiber precipitate. (6) The final corrected values or the amounts of dietary fiber were calculated by subtracting the weights of ash and protein from the dietary fiber precipitate.

Statistical Analysis

Results are expressed as mean value ± standard deviation. Comparison of means of three measurements, using a significant level of $p<0.05$, was performed by analysis of variance and means separated by *F-test* and *Student's t-test* (Steell and Torrie, 1980).

RESULTS AND DISCUSSION

Mineral Composition

Table 1 shows the profiles and contents of macrominerals in some Indonesian seaweed samples. The high concentration of Na was found in *Ulva reticulata* (26.4 *mg/g* dry weight), *Caulerpa sertularoides* (25.7 *mg/g* dry weight), and *Cladophoropsis vauchaeriaeformis* (23.9 *mg/g* dry weight), whereas K as major

Table 1. The Contents of Macrominerals in Some Indonesian Seaweed Samples.

(mean ±SD *mg/g* dry weight)

Seaweed Samples	Mg	Ca	K	Na
Green algae:				
Caulerpa racemosa	3.8 ± 0.3^{a}	18.5 ± 5.3^{c}	3.2 ± 0.2^{b}	25.7 ± 1.2^{d}
Caulerpa sertularoides	3.7 ± 1.0^{a}	12.0 ± 4.4^{b}	0.3 ± 0.0^{a}	0.7 ± 0.4^{a}
Cladophoropsis vauchaeriaeformiss	7.1 ± 0.6^{b}	22.3 ± 3.3^{d}	9.9 ± 0.4^{c}	23.9 ± 1.2^{d}
Halimeda macroloba	2.4 ± 0.5^{a}	16.9 ± 0.8^{c}	0.7 ± 0.2^{a}	4.9 ± 0.8^{b}
Ulva reticulata	21.5 ± 2.8^{c}	17.9 ± 5.3^{c}	12.6 ± 0.3^{c}	26.4 ± 0.8^{d}
Brown algae				
Padina australis	4.0 ± 1.6^{ab}	28.3 ± 4.3^{e}	0.5 ± 0.2^{a}	1.0 ± 0.9^{a}
Sargassum polycystum	5.7 ± 0.7^{ab}	18.7 ± 1.4^{c}	17.5 ± 1.4^{d}	9.7 ± 1.4^{c}
Turbinaria conoides	5.7 ± 0.3^{ab}	14.8 ± 2.2^{b}	27.9 ± 1.1^{e}	11.5 ± 0.5^{c}
Red alga				
Kappaphycus alvarezii	2.9 ± 0.3^{a}	2.8 ± 0.3^{a}	87.1 ± 5.8^{f}	11.9 ± 2.5^{c}

Values within columns followed by different superscript letters are significantly different *($p<0.05$)*.

mineral was found in *Kappaphycus alvarezii* (87.1 *mg/g* dry weight), *Turbinaria conoides* (27.9 *mg/g* dry weight), and *Sargassum polycystum* (17.5 *mg/g* dry weight). The range contents of Ca and Mg were 2.8 to 28.3 *mg/g* dry weight and 2.4 to 21.5 *mg/g* dry weight, respectively. The highest and smallest concentrations of Ca were found in *Padina australis* and *Kappaphycus alvarezii*, whereas *Ulva reticulata* and *Halimeda macroloba* contained the highest and smallest of Mg, respectively.

The profiles and contents of macrominerals in Indonesian seaweed samples were almost same to Japanese and Spanish seaweeds, and Na, Ca, Mg and K also became major minerals. In raw Japanese brown alga *Laminaria japonica* (ma-kombu in Japanese) the contents of Na, Ca, Mg and K were 590, 75, 120 and 42 *mg/100g* edible portion (Resources Council, Science and Technology Agency, 1991). In another brown algae (*Fucus vesiculosus*, *Laminaria digitata*, and *Undaria pinnatifida*) and red algae (*Chondrus cryspus* and *Porphyra tennera*) grown in Spain, the concentration range of Na, Ca, Mg and K were 36.3 - 70.6, 3.9 - 10.1, 5.7 - 11.8, and 31.8 - 115.8 *mg/g* dry weight, respectively (Ruperez, 2002). Furthermore, the content of Ca in *Gracillaria changii* grown in Malaysia was 651 *mg/100g* wet weight (Norziah and Ching, 2000).

The wide range in mineral content, not found in edible land plants, is related to the factors such as seaweed phylum, geographical origin, seasonal, environmental and physiological variations (Mabeau and Fluerence, 1993). The mineral content also depends on the type of seaweed processing (Nisizawa *et al*., 1987; Yoshie *et al*., 1994) and on the mineralization methods used (Fleurence and Le Coeur, 1993).

Fatty Acid Composition

The composition of fatty acids in seaweed samples are presented in Table 2. Palmitic acid was the main fatty acid found in all of seaweed samples, with percentage from 39.1 to 59.0. The lowest and highest content of palmitic acid were found in *Padina australis* and *Ulva reticulata*, respectively. The result was same with Japanese seaweeds *Laminaria japonica* (ma-kombu in Japanese), *Hizikia fusiformis* (hijiki in Japanese) and *Undaria pinnatifida* (wakame in Japanese) (Resources Council, Science and Technology Agency, 2001).

All of seaweeds contained myristic, stearic, oleic, linoleic, linolenic, arachidonic and eicosapentaenoic acids in various percentages, except that *Cladophoropsis vaucha-eriaeformis* and *Ulva reticulata* did not contain arachidonic and eicosapentaenoic acids. *Cladophoropsis vauchaeriaeformis* also did not contain linolenic acid. Green algae had higher percentage of linolenic acid than brown and red algae, except *Cladophoropsis vauchaeriaeformis* and *Ulva reticulata*, with percentages range from 9.0 to 13.7. Furthermore, all of brown algae contained higher percentage of omega-6 (*i.e*. linoleic and arachidonic acids) than another groups, except *Padina australis*.

The highest concentration of eicosapentaenoic acid was found in red alga *Kappaphycus alvarezii* (8.1%), followed by green alga *Caulerpa sertularoides* (5.4%), and brown algae *Sargassum polycystum* (3.8%) and *Turbinaria conoides* (3.7%). Two green algae *Cladophoropsis vauchaeriaeformis* and *Ulva reticulata* did not contain eicosapentaenoic acid. The concentration of eicosapentaenoic acid was almost same to Japanese seaweed *Laminaria japonica* (ma-kombu in Japanese) and *Hizikia fusiformis* (hijiki in Japanese). However, in other Japanese red seaweed *Porphyra yezoensis* (susabinori in Japanese), eicosapentaenoic acid was found more than 50% and became a major fatty acid (Yoshie *et al*., 1993[a]; Resources Council, Science and Technology Agency, 2001).

Dietary Fiber Composition

The soluble, insoluble and total dietary fiber contents of nine Indonesian green, brown and red algae are shown in Table 3. The soluble dietary fiber levels in *Kappaphycus alvarezii* were igher than other seaweeds, and the value was 10.7 *g/100g* dry weight, whereas *Cladophoropsis vauchaeriaeformis* and *Padina australis* contained moderate amount, and the values were 4.2 and 4.9 *g/100g* dry weight, respectively. *Caulerpa sertularoides*, *Sargassum polycystum* and *Turbinaria conoides* were found to contain relatively small amount of soluble dietary fiber, and values were 1.8, 2.3 and 2.6 *g/100g* dry weight, respectively. The lowest level of soluble dietary fiber was found in

Table 2. Fatty Acids Composition of Seaweeds Samples.

(mean ± SD percentages)

Fatty acids	Green algae					Brown algae			Red alga
	CR	CS	CV	HM	UR	PA	SP	TC	KA
Caproic (C6:0)	0	0	0	0	0	0	0	0	0
Caprylic (C8:0)	0	0	0	0	0	0.2 ± 0.2	0	0	0
Nonaoic (C9:0)	0	0	0	0	0	0	0	0	0
Capric (C10:0)	0	0	0	0	0	0	0	0	0
Undecanoic (C11:0)	0.7 ± 0.0	0.5 ± 0.3	0	0	0	0	0	0	0
Lauric (C12:0)	0	0.2 ± 0.0	0	0	0	0	0	0	0
Tridecanoic (C13:0)	1.3 ± 0.2	0.9 ± 0.2	0	2.2 ± 0.2	0	0.8 ± 0.2	0	0	0
Myristic (C14:0)	4.5 ± 0.4	6.0 ± 0.1	12.8 ± 1.8	10.5 ± 1.3	4.8 ± 1.3	6.4 ± 0.5	6.7 ± 1.3	4.8 ± 0.6	6.6 ± 2.4
Pentadecanoic (C15:0)	0	0	0	0	0	0.5 ± 0.0	0	0	0
Palmitic (C16:0)	48.4 ± 3.5	45.3 ± 1.1	48.6 ± 1.2	43.6 ± 4.0	59.0 ± 1.1	39.1 ± 1.5	41.3 ± 0.3	41.5 ± 1.2	42.4 ± 6.5
Heptadecanoic (C17:0)	3.1 ± 0.5	7.9 ± 0.1	10.8 ± 1.1	3.0 ± 0.1	0	0.5 ± 0.1	0	0	0
Stearic (C18:0)	3.9 ± 1.5	1.9 ± 0.2	8.5 ± 1.8	5.6 ± 1.3	5.8 ± 0.4	21.5 ± 0.7	13.0 ± 0.1	15.1 ± 0.5	10.6 ± 0.6
Oleic (C18:1)	6.3 ± 0.5	7.1 ± 0.2	3.9 ± 0.6	6.0 ± 2.7	14.0 ± 2.9	3.3 ± 0.2	4.7 ± 0.8	5.5 ± 0.4	3.7 ± 1.6
Linoleic (C18:2)	1.2 ± 0.2	1.0 ± 0.0	9.3 ± 0.8	5.6 ± 0.1	6.8 ± 1.6	2.8 ± 0.2	5.5 ± 0.4	8.6 ± 0.3	2.9 ± 0.2
Linolenic (C18:3)	9.6 ± 1.1	13.7 ± 0.2	0	9.0 ± 0.1	2.6 ± 1.2	4.3 ± 0.2	3.8 ± 0.1	3.7 ± 0.1	1.4 ± 1.3
Nonadecanoic (C19:0)	1.9 ± 1.1	2.2 ± 0.1	0	0	0	0	0	0	0
Arachidic (C20:0)	0	0	0	0	0	1.2 ± 0.0	0	0	0
Eicosenoic (C20:1)	0	0	0	0	0	0	0	0	0
Arachidonic (C20:4)	7.3 ± 0.4	1.6 ± 0.2	0	4.3 ± 0.4	0	5.5 ± 0.3	14.4 ± 0.8	12.8 ± 0.9	9.9 ± 2.6
Eicosapentaenoic (C20:5)	2.8 ± 0.4	5.4 ± 0.3	0	3.4 ± 0.4	0	1.3 ± 0.1	3.8 ± 0.3	3.7 ± 0.7	8.1 ± 1.8
Docosanoic (C22:0)	0	0	0	0	0	0	0	0	0
Erucic (C22:1)	1.7 ± 2.4	0	0	0	0	0.3 ± 0.3	0	0	0
Docosahexaenoic C22:6)	0	0	0	0	0	0	0	0	0
Lignoceric (C24:0)	1.9 ± 0.5	1.3 ± 0.3	0	0	0	0	0	0	0
Nervonic (C24:1)	0	0	0	0	0	0	0	0	0
Others	5.4 ± 0.6	5.1 ± 0.2	6.1 ± 0.8	6.8 ± 0.4	7.0 ± 2.5	12.5 ± 2.4	6.9 ± 0.6	4.4 ± 0.5	14.5 ± 4.1

Notes: CR, *Caulerpa racemosa*; CS, *Caulerpa* sertularoides; CV, *Cladophoropsis vauchaeriaeformis*; HM, *Halimeda macroloba*; UR, *Ulva reticulata*; PA, *Padina australis*; SP, *Sargassum polycystum*; TC, *Turbinaria conoides*; KA, *Kappaphycus alvarezii.*

Table 3. Dietary fiber contents of Indonesian seaweed samples

(mean ± SD g/100 g dry weight)

Seaweed Samples	Total Dietary Fiber (TDF)	Insoluble Dietary Fiber (IDF)	Soluble Dietary Fiber (SDF)	SDF/TDF (%)
Green algae				
Caulerpa racemosa	64.9 ± 4.9^{de}	64.1 ± 3.8^{e}	0.9 ± 0.1^{ab}	1.4 ± 0.1^{a}
Caulerpa sertularoides	61.8 ± 1.1^{cd}	60.1 ± 0.7^{de}	1.8 ± 0.9^{ab}	2.9 ± 1.5^{a}
Cladophoropsis vauchaeriaeformis	47.0 ± 4.8^{b}	42.8 ± 4.8^{b}	4.2 ± 1.1^{cd}	9.0 ± 2.4^{b}
Halimeda macroloba	14.7 ± 1.6^{a}	14.3 ± 1.8^{a}	0.4 ± 0.3^{a}	2.5 ± 2.1^{a}
Ulva reticulata	65.7 ± 0.9^{de}	64.8 ± 1.8^{e}	0.9 ± 0.8^{ab}	1.4 ± 1.2^{a}
Brown algae				
Padina australis	56.6 ± 3.8^{c}	51.7 ± 1.6^{c}	4.9 ± 2.1^{d}	8.4 ± 2.8^{b}
Sargassum polycystum	65.7 ± 0.6^{de}	63.5 ± 0.9^{de}	2.3 ± 0.3^{abc}	3.5 ± 0.6^{a}
Turbinaria conoides	63.7 ± 3.6^{d}	61.0 ± 4.5^{de}	2.6 ± 1.0^{bc}	4.2 ± 1.7^{a}
Red algae				
Kappaphycus alvarezii	69.3 ± 1.8^{e}	58.6 ± 2.7^{d}	10.7 ± 1.9^{e}	15.4 ± 2.7^{c}

Values within columns followed by different superscript letters are significantly different *($p<0.05$).*

Halimeda macroloba (0.4 *g/100g* dry weight), followed by *Caulerpa racemosa* and *Ulva reticulata*, and each value was 0.9 *g/100g* dry weight. On the other hands, *Kappaphycus alvarezii* also contained the highest amount of total dietary fiber (69.3 *g/100g* dry weight); however, the content of insoluble dietary fiber was not the highest in all of the samples. Green alga *Ulva reticulata* had the highest content of insoluble dietary fiber (64.8 *g/100g* dry weight), followed by *Caulerpa racemosa, Sargassum polycystum, Turbinaria conoides, Caulerpa sertularoides* and *Cladophoropsis vauchaeriaeformis.* The smallest content of insoluble dietary fiber was found in *Halimeda macroloba* containing 14.3 *g/100g* dry weight; this seaweed also had the smallest content of total dietary fiber, and the value was 14.7 *g/100g* dry weight.

As for the percent soluble dietary fiber against total dietary fiber, *Kappaphycus alvarezii* was the highest (15.4%), followed by *Cladophoropsis vaucheriaeformis* (9.0%) and *Padina australis* (8.4%). The moderate value was found in *Halimeda macroloba*, *Caulerpa sertularoides*, *Sargassum polycystum* and *Turbinaria conoides*, and values were 2.5, 2.9, 3.5 and 4.2%, respectively. The lowest values were found in *Caulerpa racemosa* (1.4%) and *Ulva reticulata* (1.4%).

Compared to Japanese edible seaweeds, the soluble dietary fiber content in Japanese seaweeds was higher than that in Indonesian seaweeds, and range values were 7.2 - 25.6 *g/100g* dry weight (Suzuki *et al*, 1996), 7.1 - 25.1 *g/100g* dry weight (Yoshie *et al.*, 2000) for Japanese seaweeds and 0.4 - 10.7 *g/100g* dry weight for Indonesian seaweeds. On the contrary, Indonesian seaweed had the insoluble dietary fiber content (51.7 - 64.8 *g/100g* dry weight) higher than Japanese seaweeds (15.6 - 58.6 *g/100g* dry weight) (Suzuki *et al.*, 1996), (11.3 - 71.3 *g/100g* dry weight) (Yoshie *et al.*, 2000), except *Halimeda macroloba*. As a consequence, Japanese seaweeds also had higher value of soluble dietary fiber to total dietary fiber in percent than Indonesian seaweeds.

From the results it could be concluded that Indonesian seaweed samples contained high nutritional and non-nutritional components (*i.e.* mineral, fatty acid, dietary fiber) which were almost same to Japanese edible seaweeds. Collecting or harvesting time may influence to the composition of nutrient and non-nutrient compounds, and in this experiment sample collection was carried out only in dry season (July); therefore the composition of nutrients and non-nutrients in Indonesian seaweeds have to be analyzed in different collecting or harvesting time (*i.e.* rainy season).

ACKNOWLEDGMENT

The authors gratefully acknowledge the efforts of Dr. H. Oba from Laboratory of Aquaculture, Department of Aquatic Biosciences, Tokyo University of Marine Science and Technology, Japan for his help to identify seaweeds samples.

REFERENCES

Bligh, E. G. and W. J. Dyer. 1959. **A rapid method of total lipid extraction and purification**. Can. J. Biochem. Physiol., 37: 911-917.

Dreher, M. L. 1987. **Handbook of Dietary Fiber**. Marcel Dekker Inc., New York.

Eastwood, M. 1989. **Dietary fibres in human nutrition**. J. Soc. Dairy Technol., 42: 33-34.

Ensminger, A. H., M. E. Ensminger, J. E. Konlande and J. R. K. Robson. 1995. **The Concise Encyclopedia of Foods and Nutrition**. CRC Press, Boca Raton Florida.

Fleurence, J. and C. Le Coeur. 1993. **Influence of mineralization methods on the determi-nation of the mineral content of brown seaweed *Undaria pinnatifida* by atomic absorption spectrophotometry**. *Hydrobiologia,* 260/261: 531-534.

Leontowicz, M., S. Gorinstein, E. Bartnikowska, H. Leontowicz, G. Kulasek, and S. Trakhtenberg. 2001. **Sugar beet pulp and apple pomace dietary fibers improve lipid metabolism in rats fed cholesterol**. *Food Chem*., 72: 73-78.

Mabeau, S. and J. Fleurence. 1993. **Seaweed in food products: Biochemical and nutrition aspects**. *Trends in Food Sci. Technol.*, 4: 103-107.

Mubarak, H, Sulistyo, W. S. Atmadja, and Y. Soselisa. 1991. **Distribution and potency resources of seaweeds**. In: Martosubroto, P, N. Naamin, B. B. A. Malik (eds). **Distribution and potency of fish resources in Indonesian water**. Direktorat Jenderal Perikanan, Puslitbang Perikanan, Puslitbang Oseanologi LIPI. 1991: 95-105. (in Indonesian).

Nisizawa, K., H. Noda, R. Kikuchi, and T. Watanabe. 1987. **The main seaweeds in Japan**. *Hydro-biologia,* 151/152: 5-29.

Norziah, M. H. and C. Y. Ching. 2000. **Nutritional composition of edible seaweed *Gracilaria changgi.*** *Food Chem*., 68: 69-76.

Plaami, S, M. Saastamoinen, and J. Kumpulainen. 1989. **Effect of variety of environment on dietary fiber content of winter rye in Finland**. *J. Cereal Sci.*, 10: 209-215.

Prosky, L., N. G. Asp, T. F. Schweizer, J. W. DeVries, and I. Furda. 1988. **Determination of insoluble and total dietary fiber in foods and food product: Inter-collaborative study**. *J. Assoc. Off. Anal. Chem.*, 71: 1017-1023.

Resources Council, Science and Technology Agency. 2001. **Standard Tables of Food Composition in Japan 5th Revised Edition**. Daiichi-Shuppan Publishing Co., Tokyo.

Resources Council, Science and Technology Agency. 1991. **Standard Tables of Food Composition in Japan, Minerals (Magnesium, Zinc and Copper)**. Resources Council, Science and Technology Agency. Japan.

Rimm, E. B., A. Ascherio, E. Giovannucci, D. Spiegalman M. Stampfer, and W. Willet. 1996. **Vegetables, fruits, and cereal fiber intake and risk of coronary heart disease among men**. *J. Am. Med. Assoc.*, 275: 447-451.

Ruperez, P. 2000. **Mineral content of edible marine seaweeds**. *Food Chem.*, 79: 23-26.

Schneeman, B. O. 1987. **Soluble vs insoluble fiber different physiological responses.** *Food Technol.*, 41: 81-82.

Soegijarto, A. and Sulustijo. 1990. **Utilization and farming of seaweeds in Indonesia**. In: Dogma Jr, U. J., G. C. Trono Jr, and R. A. Tabbada (eds). **Culture and use of algae in Southeast Asia**. Proceeding of the symposium on culture and utilization of algae in Southeast Asia. p9-19.

Steel, R. G. D. and J. H. Torrie. 1980. **Principles and Procedure of Statistic. A Biometrical Approach.** McGraw-Hill Company, Inc. New York.

Suzuki, T., K. Nakai, T. Yoshie, T. Shirai, and T. Hirano. 1993. **Digestability of dietary fiber in brown algae, kombu by rats**. *Nippon Suisan Gakkaishi.*, 59: 879-884.

Suzuki, T., Y. Ohsugi, T. Yoshie, T. Shirai, and T. Hirano. 1996. **Dietary fiber content, water-holding capacity and binding capacity of seaweeds**. *Fish. Sci.*, 62: 454-461.

Wang, W., M. Onnagawa, T. Yoshie, and T. Suzuki. 2001. **Binding of bile salts to soluble and insoluble dietary fibers of seaweeds**. *Fish. Sci.*, 67: 1169-1173.

Wang, W., Y. Yoshie, and T. Suzuki. 2002. **Effect of small particle size on digestibility and lipid in rats**. *Nippon Suisan Gakkaishi*, 68: 172-179.

Wong, K. H. and C. H. Cheung. 2000. **Nutritional evaluation of some subtropical red and green seaweeds. Part I – proximate composition, amino acid profiles and some physico-chemical properties**. *Food Chem.*, 71: 475-482.

Yoshie, Y, T. Suzuki, T. Shirai and T. Hirano. 1993. **Free amino acids and fatty acids composition in dried nori of various culture locations and prices**. *Nippon Suisan Gakkaishi*, 59: 1769-1775.

Yoshie, Y., T. Suzuki, T. Shirai, and T. Hirano. 1994. **Changes in the contents of dietary fibers, minerals, free amino acids and fatty acids during processing of dried nori**. *Nippon Suisan Gakkaishi*, 60: 117-123.

Yoshie, Y, T. Suzuki, T. Shirai, and T. Hirano. 1995. **Effect of sodium alginate on fat content and digestive organs of rats with fat free diet**. *Fish. Sci.*, 61: 668-671.

Yoshie, Y., W. Wang, and T. Suzuki. 2000. **Dietary fiber from seaweed: Distribution and their binding capacities**. *In*: O. Carman, Sulistiono, A. Purbayanto, T. Suzuki, S. Watanabe, and T. Arimoto (eds). **The proceeding of the JSPS-DGHE international symposium on fisheries science in tropical area**. 569-573.