Nutritional Value of Green Seaweeds *Ulvarigida* and *Ulvaintestinalis*

Nopparat Mahae[1*], Wanninee Chankaew[2] and Vatcharee Seechamnanturakit[3]

ABSTRACT

Seaweeds are traditionally used as human food, because they provide nutritional value and a specific taste. This study illustrated some nutritional value of two marine algaes (*U. rigida* and *U. intestinalis*) which belong to the division chlorophyta. The composition and content of sterol, unsaturated fatty acid, amino acid and mineral in *U. rigida* and *U. intestinalis* were analyzed. For sterol study, the result showed that fucosterol (29,961µg /100g DW) was found in *U. rigida*, while beta-sitosterol (2,126 µg /100g DW) and desmosterol (923.50 µg /100g DW) were found in *U. intestinalis*. Unsaturated fatty acids content in *U. rigida* and *U.intestinalis* were 885.75 and 20.06 mg /100g fatty acid, respectively. Eicosapentaenoic acid (EPA), omega-3 fatty acid, was detected only in *U. rigida*. Total amino acid content in *U. rigida* and *U. intestinalis* were 11.06 and 4.65 g/100g DW, respectively. Aspartic acid was dominant in *U. rigida*, whereas cyteine was dominant in *U. intestinalis*. Calcium, iron and magnesium were similar in both types of algae, with the exception of magnesium that was high in *U. rigida*. Both green algaes from this study were a good source of nutritional food for human and animal. However, *U. rigida* seem to show the better nutritional value.

Keywords: *U. rigida*, *U. intestinalis*, nutritional value

INTRODUCTION

Seaweeds (or called as sea vegetables) have become a valuable vegetable (both fresh and dried) and an important food ingredient in the human diet because of their high nutritional value and a peculiar taste. The nutritional value of seaweeds are very interesting as they are low calorie foods but rich in vitamins, minerals and dietary fiber (Jensen, 1993; Noda, 1993; Oohusa, 1993). Seaweeds belonging to the Rhodophyta (e.g. *Porphyra*) and Chlorophyta (e.g. *Ulva*) contain substantial amount of proteins (10-47% DW) with potential for human and animal nutrition (e.g. as functional food and

[1] Department of Food Industry and Fishery Product, Faculty of Science and Fisheries Technology, Rajamangala University of Technology Srivijaya, Trang 92150,Thailand
[2] Department of Fisheries, Faculty of Agriculture, Rajamangala University of Technology Srivijaya, Nakhon Si Thammarat Campus, Tungyai, Nakhon Si Thammarat 80240
[3] Nutraceuticals and Functional Foods Research and Development Center, Faculty of Agro-Industry, Prince of Songkla University, HatYai, Songkhla 90112, Thailand
* Corresponding author, e-mail: klnongnu@kmitl.ac.th

fish feed) (Fleurence *et al*., 1999). In some green seaweeds, such as the species belonging to the genus Ulva, the protein content is between 10 and 26% (DW) of the plant. For instance, the species *Ulvapertusa* has a high protein content, between 20 and 26% (DW) (Fujiwara-Arasaki *et al*., 1984).

Green algaes are distributed worldwide and are very common in coastal areas. *U.rigida* and *U.intestinalis* are one kind of green seaweed Ulvales (Chlorophyta) and ulvan is a complex acidic sulfated polysaccharide extracted from the cell-walls of the green sea weed Ulvales. In general, ulvan represents about 8–29% of the algae dry weight. It is composed of different repeating chemical sequences mostly based on disaccharides made of rhamnose, glucuronic acid, iduronic acid, xylose and sulphate (Percival and Wold, 1963; Quemener *et al*., 1997). This polysaccharide has shown several physicochemical and biological properties (Lahayeand Robic, 2007) that could have a potential impact in many applications. Some green seaweed Ulvales (*U.rigida*) has been found to contain high amounts of good -quality protein, carbohydrates, vitamins and minerals (Taboada *et al*., 2010). *U. rigida* acid polysaccharide can be used as an experimental immunostimulant for analysing inflammatory responses related to macrophage functions and this polysaccharide may also be of clinical interest for modifying certain macrophage activities in diseases where macrophage (Leiro *et al*., 2007). For *U.intestinalis*, it is previously called *Enteromorpha intestinalis* (Björk *et al*., 2004). In the past, it was used as edible and medical algae by residents of the coastal districts in China.

The chemical composition of seaweeds varies with species, habitats, maturity and environmental conditions (Ito and Hori, 1989). Compared to land plants, the chemical composition of seaweeds in Thailand has been poorly investigated and most of the available information only deals with seaweeds in other country. Therefore, the objective of this study was to evaluate some nutritional value of *U. rigida* and *U. intestinalis* in order to evaluate their potential use as food ingredients.

MATERIALS AND METHODS

Collection and preparation of seaweeds

U. rigida (dried sample) was purchased from Trat Coastal Fisheries Research and Development Centre, Trat, Thailand and *U. intestinalis* (fresh sample) was collected from shrimp culture ponds in Nakhon Si Thamarat province, south of Thailand. The fresh sample was washed thoroughly using tap water to remove the salt on the surface of the sample. Then the seaweeds were air-dried. Both dried algaes were stored in glass bottle at -18°C for further analysis.

Sterol analysis

The sterol isolation method was described as modified method of AOAC (2005). In brief, the dried samples were saponified with 50% KOH in 95 % Ethanol and extracted with hexane. Sterols were derivatized to form trimethylsilyl (TMS) ether which were determined quantitatively by gas chromatography (Agilent Model

6890, Agilent Technologies, USA) with flame ion detector, using 5α-cholestane as internal standard. Retention times were compared with those of authentic sterols.

Unsaturated fatty acid analysis

Unsaturated fatty acids were obtained by modified method of AOAC (2005) and Compendium of Methods for Food Analysis of DMSc (2003). Fatty acid composition was determined by gas chromatography (Agilent Model 6890, Agilent Technologies, USA) with flame ion detector. Identification of fatty acids in the samples was performed by comparison with chromatograms of fatty acids standard (C4-C24 fatty acids). Fatty acids composition was calculated from the total identified fatty acids area and the average values were computed from the data collected from at least two injections of each duplicate extracts.

Amino acid analysis

Amino acid composition were performed according to Sarwar *et al*. (1988). Samples were analyzed using an Agilent 1100 Series high performance liquid chromatography system Agilent Technologies, USA) coupled with mass spectrometer (Agilent model SL G1956 B, Agilent Technologies, USA).

Mineral analysis

Calcium, iron and magnesium were estimated by modified method of AOAC (2005). The microwave digestion procedure obtained from the United States Environmental Protection Agency (USEPA method 3052) (US Environmental Protection Agency, 1996). The concentration of calcium, iron and magnesium were determined by ICP–MS (Agilent model 7500C, Agilent Technologies, USA).

RESULTS

U. rigida and *U. intestinalis* were analyzed for sterol content. β-sitosterol, stigmasterol, campesterol, fucosterol, desmosterol and ergocalcalciferol were used as standard. The result found that fucosterol (29,961 µg /100g DW) was found in *U. rigida* Furthermore, β-sitosterol (2126 µg /100g DW) and desmosterol (923.50 µg /100g DW) were found in *U. intestinalis*, as shown in Table 1.

Table 1. Sterol from *U. rigida* and *U.intestinalis.*

Sterol Type	Sterol content (µg /100g DW)	
	U. rigida	*U. intestinalis*
β-sitosterol	-	2,126.00 ± 8.49
Stigmasterol	-	-
Campesterol	-	-
Fucosterol	29,961.00 ± 82.73	-
Desmosterol	-	923.50 ± 4.95
Ergocalciferol	-	-

The profile and contents of unsaturated fatty acid from *U. rigida* and *U. intestinalis* are shown in Table 2. Unsaturated fatty acids of *U. rigida* were ranged from 0.49 – 153.40 mg/100 g fatty acid and 0.09 – 12.19 mg/100 g fatty acid for *U. intestinalis*. Total contents of unsaturated fatty acid for *U. rigida* and *U. intestinalis* were 885.75 and 20.06 mg/100 g fatty acid respectively. The dominant type of unsaturated fatty acid in *U. rigida* was oleic acid. While the dominant type of unsaturated fatty acid in *U. intestinalis* was elaidic acid.

Table 2. Unsaturated fatty acid (UFA) from *U. rigida* and *U.intestinalis*.

Type of unsaturated fatty acid	UFA content (mg /100 g fatty acid)	
	U. rigida	*U. intestinalis*
Myristoleic acid/Tetradecenenoic (C14 : 1)	-	0.09 ± 0.12
cis-10-Pentadecenoic acid (C15 : 1)	1.66 ± 0.01	0.12 ± 0.17
Palmitoleic acid/ Hexadecenoic (C16 : 1)	91.60 ± 0.24	0.95 ± 0.17
cis-10-Heptadecenoic acid/Margaroleic (C17 : 1)	13.22 ± 0.03	-
Elaidic acid (C18 : 1n9t)	27.20 ± 0.25	12.19 ± 0.06
Oleic acid (C18 : 1n9c)	153.40 ± 0.57	3.70 ± 0.14
Linolelaidic acid (C18 : 2n6t)	-	-
Linoleic acid/Octadecdieoic (C18 : 2n6c)	38.79 ± 0.00	1.86 ± 0.16
g-Linolenic acid (C18 : 3n6)	6.01 ± 0.09	-
Linolenic acid (ALA) (C18 : 3n3)	88.31 ± 0.24	-
cis-11-Eicosenoic acid/Ecosenic (C20 : 1)	-	0.68 ± 0.09
cis-11,14-Eicosadienoic acid (C20 : 2)	-	-
cis-8,11,14-Eicosatrienoic acid (C20 : 3n6)	1.53 ± 0.16	-
Arachidonic acid (C20 : 4n6)	5.15 ± 0.10	-
cis-11,14,17-Eicosatrienoic acid (C20 : 3n3)	0.49 ± 0.07	-
cis-5,8,11,14,17-Eicosapentaenoic acid (EPA) (C20 : 5n3)	8.41 ± 0.03	-
Erucic acid/Docosaenoic (C22 : 1n9)	-	0.48 ± 0.05
cis-13,16-Docosadienoic acid (C22 : 2)	-	-
Nervonic acid (C24 : 1)	-	-
cis-4,7,10,13,16,19-Docosahexaenoic acid (DHA) (C22 : 6n3)	-	-
Total	885.75 ± 0.00	20.06 ± 0.38

Amino acid profile and contents of *U. rigida* and *U. intestinalis* were evaluated, data as shown in Table 3. Amino acid content of *U. rigida* was 11.06 g/100g DW which was higher than *U. intestinalis*. The dominant amino acidtype of *U. rigida* was aspartic acid. Though, the dominant amino acid type of *U. intestinalis* was cyteine.

Table 3. Amino acid profile and contents from *U. rigida* and *U.intestinalis*.

Amino acid		Amino acid content (g/100g DW)	
		U. rigida	*U. intestinalis*
Essential amino acid			
	Valine	0.56	0.12
	Methionine	0.23	0.05
	Lysine	0.56	0.32
	Isoleucine	0.44	0.20
	Leucine	0.68	0.22
	Phenylalanine	0.63	0.18
	Threonine	0.64	0.36
	Cystine	0.04	0.00
	Cysteine	1.01	0.84
	Thyptophan	0.18	0.00
	Histidine	0.22	0.02
	Arginine	0.60	0.42
	Total	5.79	2.73
Non-essential amino acid			
	Aspartic acid	1.15	0.39
	Serine	0.43	0.17
	Glutamic acid	0.91	0.51
	Glycine	0.74	0.34
	Alanine	0.70	0.25
	Proline	0.68	0.06
	Tyrosine	0.66	0.20
	Total	5.27	1.92
Total amino acid		11.06	4.65

Mineral content of *U. rigida* for calcium, iron and magnesium were 0.499, 0.010 and 2.758 g/100 g DW, respectively. While the content of calcium, iron and magnesium for *U. intestinalis* were 0.393, 0.061 and 0.291 g/100 g DW, respectively (Table 4).

Table 4. Mineral from *U. rigida* and *U.intestinalis*.

Mineral type	Mineral content (g/100g DW)	
	U. rigida	*U. intestinalis*
Calcium	0.499 ± 0.000	0.393 ± 0.035
Iron	0.010 ± 0.000	0.061 ± 0.001
Magnesium	2.758 ± 0.192	0.291 ± 0.009

DISCUSSION

It is noted that the sterols in algae vary during the life cycle of algae and because of that seasonal variations have been studied (Patterson, 1991; Culioli *et al*., 2002). Generally, in green algae (Chlorophyceae) there is no single major sterol, the dominant sterol seems to vary within the order or for the same order, within a family (Govundan *et al*., 1993). However, in the algae of the family Ulvaceae, the main sterol is almost always isofucosterol (Siddhanta *et al*., 2002; Iatrides *et al*., 1983). The result from some report differ from the literature data, the specific ecological conditions may be the reason. *U. rigida* from the Black Sea had a sterol composition completely different from other Ulvaceae, the main sterol being fucosterol (63 %), with lower concentrations of isofucosterol and cholesterol (Popov *et al*., 1985). For this study, fucosterol was found in *U. rigida* while β-sitosterol and desmosterol were found in *U. intestinalis*. The different of geographical location may be the reason and only 6 sterols were evaluated in this study.

Fatty acids (FAs) in marine algae have aroused considerable interest among researchers. This is because marine plants can produce C18 and C20 polyunsaturated fatty acids (PUFAs; Kayama *et al*., 1989). These fatty acids are essential for nutrition of many animals, including humans (Uki *et al*., 1986), and are of interest in biotechnology, in food chain studies and in cosmetics (Servel *et al*., 1994). In this study, unsaturated fatty acid content of *U. rigida* (885.75 mg /100 g DW) was higher than unsaturated fatty acid content of *U. intestinalis* (20.06 mg /100 g DW). Furthermore, omega-3 fatty acid, eicosapentaenoic acid (EPA) was detected only in *U. rigida*. Among the isolated compounds of unsaturated fatty acid, oleic acid was the main compound in *U. rigida*. Oleic acid is a monounsaturated fatty acid that elicits a cholesterol-lowering effect among other healthful attributes including a reduced risk of stroke and a significant decrease in both systolic and diastolic blood pressure in susceptible populations (Kris-Etherton, 1999). In addition, oleic acid may have protective effects against cardiovascular complications of diabetes since glutathione (GSH), total lipid, and triacylglycerol (TAG) levels are beneficially affected. The decreased tissue factor (TF) activity in diabetic-hyperlipidemic persons may protect these tissues from the risk of thrombosis (Emekli-Alturfan *et al*., 2010).

The dividing of amino acid as essential amino acid and nonessential amino acid in this study was divided according to deMan (1999). Total amino acid content in *U. rigida* and *U. intestinalis* were 11.06 and 4.65 g/100g DW, respectively. Compare with total amino acid in *G. domingensis*, *G. birdiae*, *L. filiformis* and *L. intricate* which were 7.6, 9.1, 11.3 and 6.7 mg/100 mg of dry weight, respectively (Gressler, *et al*., 2010). Aspartic acid was dominant in *U. rigida*, whereas cyteine was dominant in *U. intestinalis*. Furthermore, *U. rigida* contained a high level of amino acids, both essential amino acids (5.79 g/100g DW) and non-essential amino acid (5.27 g/100g DW). For non-essential amino acids such as aspartic and glutamic acids were responsible for the special flavour and taste of the seaweeds (Mabeau *et al*., 1992)

Seaweeds are not a main source of energy although they are reported to be of nutritional value regarding vitamin, protein and mineral contents. (Chan *et al*., 1997; Norziah and Ching, 2000). For this study, the mineral content (calcium, iron and magnesium) of *U. rigida* and *U. intestinalis* were similar, with the exception of magnesium that was high in *U. rigida*. Murakami *et al*. (2011) reported that seasonal changes in calcium and magnesium contents in *S. horneri* did not vary significantly throughout the season. Calcium contents were 10.3–14.7mg/g on dry weight basis and magnesium contents were 12.1–19.8 mg/g on dry weight basis.

In addition to terrestrial organisms, the marine environment has proven to be a rich source of potent compounds with diverse therapeutic properties (Newman and Cragg, 2004; Montaser and Luesch, 2011). Reports on seaweed showed that certain edible seaweed contain significant quantities of protein, lipids, minerals and vitamins (Norziah and Ching 2000; Wong and Cheung, 2000), although nutrient contents vary with species, geographical location, season and temperature (Dawes *et al*., 1993; Kaehlerand Kennish, 1996). Then the difference of nutritional value of marine algae in this study may as described in previous report.

CONCLUSION

This study has revealed that *U. rigida* and *U. intestinalis* are a good source of many important nutrients. *U. rigida* could be considered as a better source of nutritional food compared to *U. intestinalis*. Then *U. rigida* is more potent alternative plant nutrient sources for human and animal nutrition than the *U. intestinalis*

ACKNOWLEDGEMENT

The financial support of research from Rajamangala University of technology Srivijaya is gratefully acknowledged.

LITERATURE CITED

AOAC. 2005. **Official methods of analysis of AOAC (Association of Official Analytical Chemists) international (18th ed.).** AOAC International, Gaithersburg, MD.

Björk, M., L. Axelsson and S. Sven Beer. 2004. Why is *Ulva intestinalis* the only macroalga inhabiting isolated rockpools along the Swedish Atlantic coast?. **Marine Ecology Progress Series.** 284: 109–116.

Chan, J. C.-C., P. C.-K. Cheung andP. O. Jr. Ang.1997. Comparative studies on the effect of three drying methods on the nutritional composition of seaweeds *Sargassum hemiphyllum* (Turn) C. Ag. **Journal of Agricultural and Food Chemistry,** 45, 3056–3059.

Culioli G, A. Ortalo-Magné, M. Richou, R. Valls and L. Piovetti. 2002 Seasonal variations in the chemical composition of Bifurcaria bifurcata (Cystoseiraceae). **Biochemical Systematics and Ecology** 30: 61-64.

Dawes C.J., Jr G.C. Trono and A.O. Lluisma. 1993. Clonal propagation of *Eucheuma denticulatum* and *Kappaphycus alvarezii* for Philippine seaweed farms. **Hydrobiologia** 260-261 (1): 379-383.

deMan, J.M. 1999. **Principle of food chemistry, 3rd edition.** Gaithersburg, Aspen Publishers,Inc., Maryland. 520 pp.

DMSc. 2003. **Compendium of methods for food analysis.** Department of Medical sciences (DMSc), National Bureau of Agricultural Commodity and Food Standards (ACFS).

Emekli-Alturfan E, E. Kasikci and A.Yarat. 2010. Effects of oleic acid on the tissue factor activity, blood lipids, antioxidant and oxidant parameters of streptozotocin induced diabetic rats fed a high cholesterol diet. **Medicinal Chemistry Research** 19:1011–1024.

Fleurence, J., E. Chenard and M. Lucon. 1999. Determination of the nutritional value of proteins obtained from *Ulva armoricana*. **Journal of Applied Phycology,** 11, 231-239.

Fujiwara-Arasaki, T., N. Mino and M. Kuroda. 1984. The protein value in human nutrition of edible marine algae in Japan. **Hydrobiologia** 116/117: S13–S16.

Govindan, M., J.D.Hodge, K.A.Brown and M. Nunez–Smith. 1993. Distribution of cholesterol in caribbean marine algae. **Steroids** 58: 178–180.

Gressler, V., N. S.Yokoya, M.T. Fujii, P. Colepicolo, J.M.Filho, R.P. Torres and E. Pinto. 2010. Lipid, fatty acid, protein, amino acid and ash contents in four Brazilian red algae species. **Food Chemistry** 120: 585–590.

Iatrides, M.C., J. Artaud and N. Vicente.1983. Sterol composition of. Mediterranean marine plants. **Oceanologica Acta** 6(1):73-77.

Ito, K. andK. Hori. 1989. Seaweed: chemical composition and potential food uses. **Food Review International** 5: 101 -144.

Jensen, A. 1993. Present and future needs for alga and algal products. **Hydrobiologia** 260/261: 15–23.

Kaehler S, and R. Kennish. 1996. Summer and winter comparisons in the nutritional value of marine macroalgae from Hong Kong. Botanica Marina 39: 11-17.

Kayama, M., S. Araki and S. Sato. 1989. **Lipids of marine plants.** In: Marine Biogenic Lipids, Fats and Oils Vol. 2. (ed. R.G.Ackman), pp. 3-48. CRC Press, Florida.

Kris-Etherton PM. 1999. Monounsaturated fatty acids and risk of cardiovascular disease. **Circulation** 100:1253-1258

Lahaye, M. and A. Robic. 2007. Structure and functional properties of ulvan, a polysaccharide from green seaweeds. **Biomacromolecules** 8:1765–1774.

Leiro, J.M.,R.Castro, J.A. Arranz and J. Lamas. 2007. Immunomodulating activities of acidic sulphated polysaccharides obtained from the seaweed *Ulva rigida* C. Agardh. **International Immunopharmacology** 7: 879–888.

Mabeau, S., E. Cavaloc, J.Fleurence and M. Lahaye.1992. New seaweed based ingredients for the food industry. **International Food Ingredients**, 3: 38-45.

Montaser, R. and H. Luesch. 2011. Marine natural products: a new wave of drugs? **Future Medicinal Chemistry** 3(12): 1475-1489.

Murakami, K., Y. Yamaguchi, K. Noda, T. Fujii, N. Shinohara, T. Ushirokawa, Y. S.- Katayama and M. Katayama. 2011. Seasonal variation in the chemical composition of a marine brown alga, *Sargassum horneri* (Turner) C. Agardh. **Journal of Food Composition and Analysis** 24: 231–236

Noda, H. 1993. Health benefits and nutritional properties of Nori. **Journal of Applied Phycology** 5: 255–258.

Newman, D.J. and G. M. Cragg. 2004. Marine natural products and related compounds in clinical and advanced preclinical trials. **Journal of Natural Product** 67: 1216-1238.

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

Oohusa, T. 1993. Recent trend in Nori products and market in Asia. **Journal of Applied Phycology** 5: 155–159.

Patterson, G.W. 1991. **Sterols of algae**, In: Physiology and biochemistry of sterols (ed.G.w. Patterson, and W.D. Nes), pp. 118-157. American Oil Chemists' Society, Champaign, IL.

Percival, E. and J.K.Wold. 1963. The acid polysaccharide from the green seaweed *Ulva lactuca*. Part I. The site of the ester sulphate. **Journal of the Chemical Society** 1040: 5459–5468.

Popov, S.S., N.L.Marekov, M.I.Konaklieva, M.I. Panayotova and S. Dimitrova-Konaklieva. 1985. Sterols from some Black Sea Ulvaceae. **Phytochemistry** 24: 1987-1990.

Quemener, B.,M. Lahaye and C.Bobin-Dubigeon. 1997. Sugar determination inulvans by a chemical-enzymatic method coupled to high performance anionexchange chromatography. **Journal of Applied Phycology** 9: 179–188.

Sarwar, G., H.G. Botting and R.W. Peace. 1988. Complete amino acid analysis in hydrolysates of foods and feces by liquid chromatography of precolumn phenylisothiocyanate derivatives. **Journal Association of Official Analytical Chemistry** 71 (6): 1172-1175.

Servel, M.-O., C. Claire, A. Derrien, L. Coiffard and Y. De Roeck-Holtzhauer. 1994. Fatty acid composition of some marine microalgae. **Phytochemistry** 36 (3): 691–693.

Siddhanta, A.K., A.M. Goswami, M. Shanmugam, K.H. Mody and B.K. Ramavat. 2002. Sterols from marine green algae of Indian waters. **Journal of Indian Chemical Society** 79: 294 -297.

Taboada, C., R. Millán and I. Míguez. 2010. Composition, nutritional aspects and effect on serum parameters of marine algae *Ulva rigida*. **Journal of the Science of Food and Agriculture** 90: 445–449.

Uki, N., M. Sugiuzaand T. Watanabe. 1986. Requirement of essential fatty acids in the abalone *Haliotis discus hannai*. **Bulletin of the Japanese Society of Scientific Fisheries** 52 (6): 1013 –1023.

US Environmental Protection Agency. 1996. **EPA-Method 3052, Microwave assisted acid digestion of siliceous and organically based matrices.** US Government printing office, Washington, DC.

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