

Research Article

Proximate, Mineral and Amino acid Composition of Dried Laver (*Porphyra* spp.) Seaweed

Habtamu Admassu^{1,3}, Tilahun Abera⁴, Bereket Abraha², Ruijin Yang^{1,2} and Wei Zhao^{1,2*}

¹State Key Laboratory of Food Science and Technology; ²School of Food Science and Technology, Jiangnan University, 1800 Lihu Avenue, Wuxi 214122, Jiangsu, China; ³Dept. of Food Process Engineering, Addis Ababa Science and Technology University, P. O. Box 16417, 1000 Addis Ababa, Ethiopia; ⁴Dept. of postharvest management, College of Agriculture and veterinary medicine, Jimma University, P.O. Box 307, Jimma, Ethiopia
zhaow@jiangnan.edu.cn*; +86-139-52466350

Abstract

Major nutritional compositions of dried laver (*Porphyra* spp.) were evaluated in this study. Findings showed that dried laver contains: moisture (9.34-9.46%), crude protein (42.939-43.041%), dietary fibres (31.598-31.662%), total ash (10.267-10.333%), and crude fat (0.45-0.53%), and total carbohydrate (36.64-37.00%). The total energy value was estimated to be 8,467.69 KJ.kg⁻¹. Among the mineral elements (Ca, Mg, K, Na, Cu, Zn, Fe and Mn) analyzed, potassium was the most abundant (1390.76 -1399.24 mg/100 g), while copper was present in the lowest concentration (1.36-1.40 mg/100 g DW). The total and free essential amino acids were 14412.69 mg/100 g and 56.06 mg/100 g respectively. Glutamic, alanine and aspartic amino acids were high in the total amino acids, while, arginine was high in the free amino acids. The dried laver showed appreciable nutritional composition and energy value thus, laver could be an alternative ingredient in the food products.

Keywords: Edible seaweed, dried laver, proximate analysis, amino acids, mineral element, energy value.

Introduction

Aquaculture is the fastest growing food production sector that can play a role in solving the challenges of increasing global food demand (FAO, 2014). In the year 2014, total aquaculture production in the world was increasing to more than 100 million tonnes. Among this, 27 million tonnes were aquatic plants, which are commonly seaweeds that contributed 5.6 billion US\$ in the world's economy (Stévant *et al.*, 2017). Asian countries are the most seaweed producers and consumers since dates back to the ancient times. China is one of the leading global producers, which is more than 13 million tonnes per year (Admassu *et al.*, 2015; Cian *et al.*, 2015; Stévant *et al.*, 2017). At present, more than 10,000 different species of seaweeds are well-known and classified as red (Rhodophyta), brown (Phaeophyta) or green (Chlorophyta) seaweeds based on their pigmentation (Benjama and Masniyom, 2011; Collins *et al.*, 2016).

Laver (*Porphyra* spp.) is a red seaweed, popular side dishes of Asian countries where rice is the stable food (Hwang and Thi, 2014). Traditionally, laver is known as Kim in Korea, nori in Japan, and zicai in China (Rao *et al.*, 2007; Hwang *et al.*, 2013). Laver contains various nutritional compositions: high in essential amino acids, essential fatty acids, minerals and vitamins, and bioactive compounds and therefore, it is recognized as a health food (Thi and Hwang, 2014). Lavers are mostly consumed in dried form to improve palatability.

Most previous studies have focused on fresh seaweeds. Some studies have reported that thermal treatments can alter the chemical composition or their chemical forms. Studies on chemical components such as proximate composition, amino acids and mineral contents have a direct role on the characteristics and nutritional quality of food products (Wong and Cheung, 2000; Kaur and Singh, 2005; Kumar *et al.*, 2014; Yaich *et al.*, 2011). As far as the authors knowledge, limited literature are available on nutritional composition of commercial dried laver (*Porphyra* spp.) cultivated in China. Therefore, the objective of the present study was to evaluate major nutritional composition (macro and micro nutrients) of dried laver cultivated in China.

Materials and methods

Materials: The commercial dried laver (*Porphyra* spp.) was obtained from Rudong Laver farming and processing Industry (Nantong, Jiangsu, China). It was ground in an IKA grinder model A11BS25 (IKA werk, Staufen, Germany). The powder was then stored in airtight plastic bags at temperature (-20°C) prior to analysis. All chemical reagents used in the analysis were of analytical grade.

Proximate analysis: Total nitrogen content was determined using a standard micro-Kjeldahl method (Ragab *et al.*, 2004) and converted to total protein (N% X 6.25).

*Corresponding author

Residual moisture, total fibre, lipids and total ash contents were determined using the official methods (AOAC, 1995). Total carbohydrates (TC) were calculated by difference as follows:

$$TC = 100 - (m_p + m_L + m_W + m_A) \quad (1)$$

Where m_P , m_L , m_W and m_A is content of crude protein, crude lipids, water and ash, respectively.

Energy: Food energy value of dried laver was determined using the Atwater conversion factor as:

$$\text{Energy} = [37 \text{ kJ.g}^{-1} \times m_L + 17 \text{ kJ.g}^{-1} \times m_P + 17 \text{ kJ.g}^{-1} \times m_C] \quad (2)$$

Where, m_P , m_L , and m_C is content of crude lipids, crude protein and available carbohydrate, respectively (expressed in kilojoule per kilogram of food).

Determination of mineral contents: Total Na, K, Mg, Ca, Zn, Fe, Cu, and Mn concentration in dried laver sample were determined using a modified method (Jung et al., 2015). Dried laver sample (1 g) was weighed in porcelain crucible and dry-ashed in muffle furnace at 550°C. The ash was dissolved in 5 mL of HNO₃/HCl/H₂O₂ (1:2:3) and heated gently on a hot plate until brown fumes disappeared. Double distilled water (5 mL) was added into the acid digest and heated until colorless. The solution in each crucible was transferred in to a 50 mL volumetric flask and filtered through whatman No. 42 filter paper. Finally, the volume was made up-to mark with deionized water and the minerals were analyzed by Atomic Absorption Spectroscopy (Varian Spectra AA-220 FS, Varian Inc., Australia). The values were expressed in mg/100 g of the sample on dry basis.

Amino acid analysis: Amino acids (total and free) were determined using acid digestion following the procedure of Cian et al. (2014) with slight modification. Samples (100 mg) in triplicate were hydrolyzed with 8 mL of 6 mol·L⁻¹ HCl under nitrogen and incubated in an oven at 120°C for 22 h. Hydrolyzed samples were injected in to analytical HPLC column of 4.6 × 250 mm I.D, 5 µm particle size (Agilent Technologies, Palo Alto, California, USA) system with ophthaldialdehyde (OPA) precolumn derivation. The determination was made by reverse-phase HPLC (RP-HPLC) (HP-Agilent 1100 model, Agilent Technologies) assembly system at 338 nm detection, 1.0 mL·min⁻¹ flow rate and 40°C column temperature. Mobile phase A was (7.35 mmol·L⁻¹) sodium acetate/trimethylamine/tetrahydrofuran (500: 0.12: 2.5, v/v/v), adjusted to pH 7.2 with acetic acid, while mobile phase B (pH 7.2) was (7.35 mmol·L⁻¹) sodium acetate/methanol/acetonitrile (1: 2: 2, v: v: v). The amino acid composition was expressed as milligram per 100 gram of samples.

Statistical analysis: The data were calculated using SPSS software package (Version 17.0) (SPSS, Chicago, Illinois, USA). All experiments were conducted in triplicate and the values represent the average mean of three independent determination and standard deviation.

Results and discussion

Proximate compositions: The proximate compositions of dried laver are shown in Table 1. The moisture content of dried laver (9.34-9.46%) recorded in this study was lower than the reported for *P. columbina* (12.80%) (Cian et al., 2014). The lower moisture content could be attributed to the water lost during drying of laver. This lower moisture content can be an indication of quality indices for effective storage of commercial dried laver with promising shelf stability for long term utilization. The crude protein content of dried laver was 42.99±0.051 g/100 g DW). Partially agrees with the reported for red and green seaweed (10~47% DW) (Fleurence, 1999), but higher than the reported for *Palmaria palmata* (35% DW) by the same author and for red seaweed laver *Pyropia dentata* (37.7±1.7%) cultivated in Korea as reported earlier (Jung et al., 2015). However, the protein content of laver in this study was lower than that of *Porphyra tenera* (47% DW) described by Fleurence, (1999). The difference could be ascribed due to species, harvesting season and location (Fleurence, 2004). In general, red seaweeds have protein content comparable with plant food known for their remarkably high protein content like soybean (Cian et al., 2014). The high level of protein in the Laver under study is a plus for the high potential of laver to be used in the formulation of value-added protein-rich food products that can be used in protein supplementation to overcome the protein deficiency.

The ash content (10.30±0.033 g/100 g DW) of dried laver in this study was the highest of all in the reported for *P. columbina* (6.49±0.09 g/100 g), dried laver *P. tenera* (9.07 ±0.29 g/100 g), *P. haitanensis* (8.78±0.12 g/100 g) (Hwang et al., 2013), and dried laver *Porphyra yezoensis* (8.01~8.95%) (Kim et al., 2014). On the other hand, the ash content of dried laver was considerably lower than the result previously reported for some subtropical red and green seaweeds (21.30~22.8% DW) (Wong and Cheung, 2000), in four Brazilian red seaweeds in the range of 22.5±0.3 to 38.4±0.1 g/100 g (Gressler et al., 2010) and *Porphyra tenera* (Nori) (20.59±0.16 g/100 g DW) (Ruperez, 2002). This reduction in ash content might be due to the drying process, species, season of harvest and location (Fleurence, 2004). The crude lipid content of Laver (0.49±0.04 g/100 g DW) was lower than the reported for *Porphyra* species from China (1.0±0.2), and Japan and Korea (2.8±1.0 g/100 g DW) (Dawczynski et al., 2007).

Table 1. Proximate composition and total energy value of commercial dried laver.

Composition	Unit: g/100 g DM
Moisture	9.40±0.056
Crude protein	42.99±0.051
Crude fat	0.49±0.040
Ash	10.30±0.033
Total dietary fibre	31.63±0.032
Total Carbohydrate	36.82±0.180
Available carbohydrate	5.19±0.212
Energy (Unit: KJ.Kg ⁻¹)	
Carbohydrate	978.69±36.04
Protein	7308.30±8.67
Lipid	181.30±6.80
Total Energy	8,467.69±51.54

Table 2. Mineral content of commercial dried laver (*Porphyra* spp.) (mg/100 g DW).

Macro minerals	Contents (mg/100g)	Micro minerals	Contents (mg/100g)
Na	348.75±1.06*	Fe	12.28±0.32
K	1395.00±4.24	Zn	2.79±0.1
Ca	525.00±1.41	Mn	2.26±0.04
Mg	261.75±1.06	Cu	1.38±0.02

*Values are mean ± SD (n=3).

Generally, seaweeds are reported to be a poor sources of lipids (<4.00 g/100 g DW) (Ortiz *et al.*, 2006). The low lipid content is of a great advantage, especially in regards to producing healthy food products that may help to improve the health status of obese people with hypocholesterolemic cases. The total dietary fibre of dried laver was 31.63±0.032 g/100 g DW (Table 1). The total dietary fibre content of dried laver is within the range reported for many algal species by different authors (Escrig and Muniz, 2000; Gómez-Ordóñez *et al.*, 2010). Seaweeds contain quite large amount of dietary fibres (25-75 g/100 g DW) of which the majority is soluble fractions (50-85 g/100 g DW) (Gómez-Ordóñez *et al.*, 2010), and the high dietary fibre content of seaweeds makes it nutritionally very important (Escrig and Muniz, 2000; Wong and Cheung, 2000). The total and available carbohydrate content of the laver was 36.82±0.18 and 5.19±0.212 g/100 g DW respectively. Thus, the level of dietary fibres obtained in this study is in accordance with the previously reported level of carbohydrates, indicating that fibres make up the majority of the carbohydrate part of the commercial dried Laver. This could be considered as a useful nutritional characteristic of Laver to use it as an ingredient of functional food that improves bowel function and provide fecal bulk. The energy value of dried laver sample (8467.69±51.54 kJ.kg⁻¹) was quite larger which might have been contributed by the high crude protein content (Table 1). This indicates that dried Laver could be used as a great source of daily energy requirement in diet, especially among resource-poor rural households.

Mineral element compositions: The mineral element compositions of the dried laver are given in Table 2. The result showed that the mineral content was: Ca (523.59-526.41 mg/100 g), Mg (260.69-262.81 mg/100 g), K (1390.76 - 1399.24 mg/100 g), Na (347.69-349.81 mg/100 g), and trace minerals with nutritional interest such as: Fe (11.96-12.60 mg/100 g), Zn (2.69-2.89 mg/100 g), Cu (1.36-1.40 mg/100 g), and Mn (2.22-2.30 mg/100 g). The most abundant mineral element was potassium (K) (1390.76-1399.24 mg/100 g), which is recognized as a healthy mineral, while copper (Cu) was present in lowest concentration (1.36-1.40 mg/100 g DW). However, total potassium content of the dried laver in this study was lower than the previously reported value for laver *P. tenera* (2801.286-2802.714) and *P. haitanensis* (2733.255 – 2734.745 mg/100 g DW) from Korea and china, respectively and *P. yezeensis* (1555.00-1862.00 mg/100 g DW) in Korea harvested from four different regional locations (Kim *et al.*, 2014). Calcium (525.00 mg/100 g) contents were higher than the previously reported values for *P. tenera* (Ca, 154.4 mg/100 g), *P. haitanensis* (Ca, 460.6 mg/100 g) and *P. yezeensis* (Ca, 252.28-417.00 and Cu, 0.52-0.88 mg/100 g) (Hwang *et al.*, 2013; Kim *et al.*, 2014). On the other hand, the sodium and magnesium contents were lower than the results reported previously for *P. tenera* (Na, 781, Mg, 420.3) mg/100 g, *P. haitanensis* (Mg, 612.00 mg/100 g) and *P. yezeensis* (Na, 444-593, Mg, 330-409 mg/100 g) (Hwang *et al.*, 2013; Kim *et al.*, 2014).

Table 3. Total and free amino acid contents in commercial dried lavers (Units: mg/100g protein).

Amino acids	Total amino acid	Free amino acid	FAO/WHO/HNU pattern ^a	Whole egg protein ^b
Phenyl alanine	1561.00 ± 4.58 ⁽¹⁾	1.11 ± 0.01 ⁽¹⁾	1900.0	5700.0
Threonine	1772.62 ± 2.52	1.52 ± 0.02	900.0	5100.0
Methionine	633.00 ± 2.65	4.66 ± 0.06	2500.0	3400.0
Isoleucine	1616.57 ± 0.58	0.39 ± 0.11	1300.0	6300.0
Arginine	2099.00 ± 3.00	41.19 ± 0.21	460.0	6100.0
Leucine	2643.01 ± 3.00	1.11 ± 0.15	1900.0	8800.0
Lysine	1682.49 ± 2.31	1.22 ± 0.34	1600.0	6960.0
valine	2405.00 ± 2.65	4.86 ± 0.31	1800.0	6900.0
Tryptophan	**nd	**nd	500.0	1700.0
EAA ⁽²⁾	14412.69 ± 13.68	56.06 ± 0.55	12,860.0	50,960.0
Aspartic acid	4213.33 ± 1.53	19.32 ± 0.02	880.0	9600.0
Glutamic acid	5527.31 ± 2.08	11.31 ± 0.03	1750.0	12702.0
Alanine	4539.27 ± 2.52	11.12 ± 0.61	260.0	5900.0
Glycine	2351.41 ± 0.58	2.55 ± 0.07	200.0	3300.0
Proline	1434.71 ± 1.53	0.13 ± 0.02	610.0	4200.0
Serine	1202.31 ± 2.00	0.13 ± 0.02	530.0	7600.0
Tyrosine	781.63 ± 1.53	4.87 ± 0.33	460.0	4200.0
*Histidine	485.58 ± 2.52	1.24 ± 0.09	1600.0	2426.0
Cysteine	28.43 ± 2.08	0.45 ± 0.01	1700.0	2426.0
Total AA ⁽³⁾	34976.67 ± 37.63	107.2 ± 2.40	20,850.0	103,314.0

*Histidine: Essential amino acid for children, **nd: not determined, ⁽¹⁾ Values are mean ± SD (n=3), ⁽²⁾ EAA: Essential amino acid, ⁽³⁾ Total AA: Total amino acid; ^aAmino acids requirement pattern for adults (WHO/FAO/UNU, 1985), ^bWhole egg protein (FAO, 1970).

Many factors including the analytical and processing methods employed, geographical location of harvest, seaweed species, oceanic residence time, season, annual environment, and so forth could affect the mineral contents of seaweed and cause variation (Rao et al., 2007; Hwang et al., 2013). In a nutshell, the results of this study shows that laver is a good source of dietary mineral elements. Thus, laver could be considered as a viable strategy for counteracting mineral deficiencies among the vulnerable population groups, where laver harvesting is large and laver-based foods are highly consumed. Evaluation of mineral contents in any edible seaweed is important to address their potential contribution to human nutrition and their adverse toxic effects (Rao et al., 2007). The low content of sodium compared to potassium in the dried Laver implies Na/K ratio of dried laver to be less than 1, suggesting suitability of Laver as healthy food for people that have high risk of blood pressure. Foods with Na: K ratio (a suitable index of body electrolyte balance) of less than one is suggested for prevention of high blood pressure. Unlike potassium, the high content of sodium in food risk factor cardiovascular and other non-communicable diseases (Campbell et al., 2011).

Amino acid composition: The amino acid (total and free) composition of dried laver (*Porphyra* spp.) is presented in Table 3. A total of seventeen (17) different amino acids were determined in this study. Except Tryptophan (which was not determined), all essential amino acids were found in dried laver in different quantities.

The dried Laver had remarkably a high level of glutamic acid (5527.33±2.08 mg/100 g), alanine (4539.33±2.52 mg/100 g) and aspartic acid (4213.33±1.53 mg/100 g) in its total amino acids, which are responsible for the special flavor and taste of laver. Similar observation was previously reported in red and green seaweed from Hong Kong (Wong and Cheung, 2000), and in four Brazilian red algae species (Gressler et al., 2010). However, arginine was present in higher concentration in its free amino acids (41.19±0.21), followed by aspartic acid (19.32±0.020 mg/100 g), glutamic acid (11.31±0.08 mg/100 g) and alanine (11.12±0.61 mg/100 g). Cysteine was present in the lowest concentration in total amino acid whereas proline and serine were lowest in free amino acids. The total and free amino acid content of essential amino acids was 14412.69±13.68 and 56.06±0.55 respectively. From the obtained results, it appeared that dried laver had reasonable concentrations of essential amino acids (except tryptophan) that are very important to human nutrition. These are methionine, leucine, isoleucine, lysine, phenylalanine, arginine, threonine and valine. The levels of different essential amino acids ranged from 633.00 to 2643.00 mg/100 g protein DW. Dried laver was rich in arginine (2099.00±3.00), leucine (2643.01±3.00), valine (2405.00±2.65) and threonine (1772.62±2.52) for total amino acids (Table 3). This result is in agreement with previously reported for two red seaweed species (*Gracillaria fisheri* and *G. tenuistipitata*) (Benjama and Masniyom, 2012). The non-EAA, namely histidine, aspartic acid, glutamic acid, serine, proline, glycine, alanine, tyrosine, and cysteine were analyzed.

Fleurence (1999) reported that a large part of amino acid fractions for most seaweeds are constituted by aspartic and glutamic acids. This, same author has also reported, the level of these amino acids might be lower in red seaweed species than the other species, example, *Palmaria palmate* (14,000 mg/100 g) and *P. tenera* (19,000 mg/100 g) of the total amino acid. The sum of aspartic (5527.33 mg/100 g) and glutamic acid (4213.33 mg/100 g) in this study was 9740.66 mg/100 g of proteins for the total amino acid. In the free amino acid fraction, the sum total of aspartic (19.32 mg/100 g) and glutamic acid (11.31 mg/100 g) was estimated to be 30.63 mg/100 g. The EAA was found to be 14412.69 mg/100 g and 56.06 mg/100 g for total and free amino acids with a ratio of 0.74: 1 and 0.52: 1 (EAA: non-EAA), respectively. This result was favorably compared with the value reported for *Porphyra* species from Korea and Japan, however, lower than *Porphyra* species in china which was determined by Wong and Cheung (2000). Dried laver contained small concentrations of free amino acids. This indicates that most amino acids and small peptides are encrypted with the original protein and needs *in vivo* or *in vitro* digestion to release them so that can perform their specific biofunctionality in the body. In general, dried laver had significantly higher concentration of both essential and non-essential amino acid content, which compared and found to be greater than FAO/WHO recommended pattern.

Conclusion

In conclusion, the commercial dried laver analyzed in this study has a great potential as food product or as an ingredient in other food products due to its quite unique nutrient composition with high protein contents, moderate ash and dietary fibre contents. Dried laver (*Porphyra* spp.) showed higher gross energy value and thus could be used as potential source of dietary calorie. Commercial dried laver was furthermore found to have mineral contents including important trace elements Zn and Fe which may provide adequate quantity of minerals to meet the mineral requirements of human body. Dried laver also contains various essential and non-essential amino acids important in body synthesis. With further investigation of more nutritional quality parameters and functional components, dried laver could be used in different food applications.

Acknowledgements

Authors gratefully acknowledge the support by “the National Natural Science Foundation of China (Project No. 31522044)” and “the Fundamental Research Funds for the Central Universities (JUSRP51406A)”.

References

1. Admassu, H., Zhao, W., Yang, R., Gasmalla, M.A.A. and Alsir, E. 2015. Development of Functional Foods: Sea Weeds (algae) Untouched Potential and alternative

- resource. *Int. J. Sci. Technol. Res.* 4(09): 108-115.
2. AOAC. 1995. Official methods of analysis of AOAC International. Total, Soluble, and Insoluble Dietary Fibre in Foods. AOAC International, In: Cunniff, Patricia, (Ed.), 16th edition. Arlington, 5.
3. Benjama, O. and Masniyom, P. 2012. Biochemical composition and physicochemical properties of two red seaweeds (*Gracilaria fisheri* and *G. tenuistipitata*) from the Pattani Bay in Southern Thailand. *Songklanakarin J. Sci. Technol.* 34(2): 223-230.
4. Benjama, O. and Masniyom, P. 2011. Nutritional composition and physicochemical properties of two green seaweeds (*Ulva pertusa* and *U. intestinalis*) from the Pattani Bay in Southern Thailand. *Songklanakarin J. Sci. Technol.* 33(5): 575-583.
5. Campbell, N., Correa-Rotter, R., Neal, B., and Cappuccio, F. P. 2011. New evidence relating to the health impact of reducing salt intake. *Nutr. Metab. Cardiovasc. Dis.* 21(9): 617-619.
6. Cian, R.E., Drago, S.R., deMedina, F.S. and Martínez-Augustin, O. 2015. Proteins and carbohydrates from red seaweeds: Evidence for beneficial effects on gut function and microbiota. *Mar. Drugs.* 13(8): 5358-5383.
7. Cian, R.E., Fajardo, M.A., Alaiz, M., Vioque, J., Gonzalez, R. J. and Drago, S.R. 2014. Chemical composition, nutritional and antioxidant properties of the red edible seaweed *Porphyra columbina*. *Int. J. Food Sci. Nutr.* 65(3): 299-305.
8. Collins, K.G., Fitzgerald, G.F., Stanton, C. and Ross, R.P. 2016. Looking Beyond the Terrestrial: The Potential of seaweed derived bioactives to treat non-communicable diseases. *Mar. Drugs.* 14.
9. National Research Council. 1989. Recommended dietary allowances : 10th ed., pp. 58-68. Washington, DC: National Academy of Sciences.
10. Dawczynski, C., Schubert, R. and Jahreis, G. 2007. Amino acids, fatty acids, and dietary fibre in edible seaweed products. *Food Chem.* 103(3): 891-899.
11. FAO. 1970. Amino-acid content of foods and biological data on proteins. *Food and Agricultural Organization of United Nations, Rome, pp.295.*
12. FAO. 2014. The State of World Fisheries and Aquaculture: Opportunities and challenges. Retrieved from <http://www.fao.org/3/a-i3720e/i3720e01.pdf>.
13. Fleurence, J. 1999. Seaweed Protein: Biochemical, nutritional aspects and potential uses. *Trend. Food Sci. Technol.* 10: 25-28.
14. Fleurence, J. 2004. Seaweed proteins. In: Yada RY (ed) *Proteins in food processing*. Woodhead Publishing Limited, Cambridge, 197-213.
15. Ordóñez, E.G., Jiménez-Escrig, A., and Rupérez, P. 2010. Dietary fibre and physicochemical properties of several edible seaweeds from the northwestern Spanish coast. *Food Res. Int.* 43(9): 2289-2294.

16. Gressler, V., Yokoy, N.S., Fujii, M.T., Colepicolo, P., Filho, J. M., Torres, R.P. and Pinto, E. 2010. Lipid, fatty acid, protein, amino acid and ash contents in four Brazilian red algae species. *Food Chem.* 120: 585-590.
17. Hwang, E.S., Ki, K.N. and Chung, H.Y. 2013. Proximate composition, amino acid, mineral, and heavy metal content of dried laver. *Prev. Nutr. Food Sci.* 18(2): 139-144.
18. Hwang, E.S. and Thi, N.D. 2014. Effects of Extraction and processing methods on antioxidant compound contents and radical scavenging activities of laver (*Porphyra tenera*). *Prev. Nutr. Food Sci.* 19(1): 40-48.
19. Escrig, A.J. and Muniz, F.J.S. 2000. Dietary fibre from edible seaweeds Chemical structure physicochemical properties and effects on cholesterol metabolism. *Nutrit. Res.* 20(4): 585-598.
20. Jung, S.-M., Kang, S.-G., Kim, K.-T., Lee, H.-J., Kim, A. R., and Shin, H.-W. 2015. The Analysis of proximate composition, minerals and amino acid content of red Alga *Pyropia dentata* by Cultivation Sites. *Kor. J. Environ. Ecol.* 29(1): 1-6.
21. Kaur, M. and Singh, N. 2005. Studies on functional, thermal and pasting properties of flours from different chickpea (*Cicer arietinum* L.) cultivars. *Food Chem.* 91(3): 403-411.
22. Kim, K.W., Hwang, J.H., Oh, M.J., Kim, M.Y., Choi, M.R. and Park, W.M. 2014. Studies on the major nutritional components of commercial dried lavers (*Porphyra yezoensis*) cultivated in Korea. *Kor. J. Food Preserv.* 21(5): 702-709.
23. Ortiz, J., Romero, N., Robert, P., Araya, J., Lopez-Hernández, J., Bozzo, C. and Rios, A. 2006. Dietary fiber, amino acid, fatty acid and tocopherol contents of the edible seaweeds *Ulva lactuca* and *Durvillaea antarctica*. *Food Chem.* 99(1): 98-104.
24. Ragab, D.M., Babiker, E.E. and Eltinay, A.H. 2004. Fractionation, solubility and functional properties of cowpea (*Vigna unguiculata*) proteins as affected by pH and/or salt concentration. *Food Chem.* 84(2): 207-212.
25. Rao, P.V.S., Mantri, V.A. and Ganesan, K. 2007. Mineral composition of edible seaweed *Porphyra vietnamensis*. *Food Chem.* 102: 215-218.
26. Ruperez, P. 2002. Mineral content of edible marine seaweeds. *Food Chem.* 79: 23-26.
27. Stévant, P., Chapman, A. and Rebours, C. 2017. Seaweed aquaculture in Norway: recent industrial developments and future perspectives. *Aquacult. Int.* 25(4): 1373-1390.
28. Suresh Kumar, K., Ganesan, K., Selvaraj, K. and Subba Rao, P.V. 2014. Studies on the functional properties of protein concentrate of *Kappaphycus alvarezii* (Doty) Doty-an edible seaweed. *Food Chem.* 153: 353-360.
29. Thi, N.D. and Hwang, E.S. 2014. Effects of laver extracts on adhesion, invasion, and migration in SK-Hep1 human hepatoma cancer cells. *Biosci. Biotechnol. Biochem.* 78(6): 1044-1051.
30. WHO/FAO/UNU. 1985. Food and Agriculture Organization of the United States/World Health Organization/United Nations University, Energy and Protein Requirements. Report of a joint FAO/WHO/UNU meeting. World Health, Organization, Geneva. *Food and Agriculture Organization (FAO)*.
31. Wong, K.H. and Cheung, C.K. 2000. Nutritional evaluation of some subtropical red and green seaweeds, Part I-Proximate composition, Amino acid profile and some physicochemical properties. *Food Chem.* 71: 475-482.
32. Yaich, H., Garna, H., Besbes, S., Paquot, M., Blecker, C. and Attia, H. 2011. Chemical composition and functional properties of *Ulva lactuca* seaweed collected in Tunisia. *Food Chem.* 128(4): 895-901.