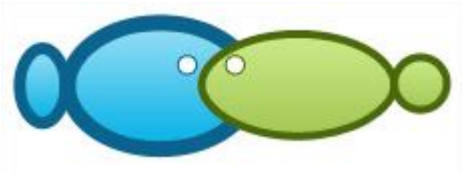

Evaluation of the biochemical composition of tropical red seaweeds *Galaxaura rugosa* and *Gelidiella acerosa* from Ujung Genteng waters, Indonesia

Abdullah Rasyid, Tri Handayani

Research Center for Oceanography, Indonesian Institute of Sciences, Jakarta, Indonesia.
Corresponding author: A. Rasiyd, a.rasyid.qf@gmail.com

Abstract. *Galaxaura rugosa* and *Gelidiella acerosa,* two selected Indonesian red seaweeds were analyzed to determine their proximate composition, amino acid and fatty acid contents. The objective of this study was to evaluate the various nutritional parameters of *G. rugosa* and *G. acerosa* for utilization in human nutrition Proximate composition, including moisture, ash, protein, fat and carbohydrate were determined according to AOAC standard methods. Amino acid was determined by Ultra Performance Liquid Chromatography (UPLC) and fatty acid by gas chromatography. Ash and carbohydrate contents were the two most abundant components in these seaweeds. The ash content of *G. rugosa* and *G. acerosa* were 72.97% and 13.42%, while carbohydrate content were 16.91% and 68.67% based on dry weight, respectively. Both seaweeds contained significantly higher amounts of protein where *G. rugosa* and *G. acerosa* were found to be 5.34% and 8.66% based on dry weight, respectively. While moisture and fat contents were relatively low. The moisture content of *G. rugosa* and *G. acerosa* were 4.25% and 8.71%, while fat content were 0.53% and 0.54% based on dry weight, respectively. Total 14 amino acids were identified where glutamic acid was the major constituent in both species. In the case of fatty acids, 8 components were identified in *G. rugosa* and 7 components identified in *G. acerosa.* Lauric acid was the major constituent in the both species followed by palmitic acid. *G. rugosa* and *G. acerosa* contained 0.21%, 0.20% lauric acid and 0.10%, 0.14% palmitic acid respectively. Based on the above, this present study results showed that *G. rugosa* and *G. acerosa* from Ujung Genteng waters could be utilized as functional ingredient for the valuable nutritional properties for food supplement industries in the future.
Key Words: marine red algae, *Galaxaura rugosa, Gelidiella acerosa*.

Introduction. The ocean is an enormous pool of biodiversity resources that covers about 70% of the earth surface and it is the natural habitat of many plants, animals and microorganisms. Marine algae comprising few thousands of species represent a considerable part of the littoral biomass and they are classified as red (Rhodophyta), brown (Phaeophyta) or green algae (Chlorophyta) (Dawczynski et al 2007).

Seaweed, or marine macroalgae are rich in a large variety of natural compounds used in nutritional and pharmaceutical areas (Belattmania et al 2016). Seaweeds are known to be a good source of healthy food due to a natural richness in minerals and vitamins as well as bioactive molecules content (Tiwari & Troy 2015).

Seaweeds have been used as food, animal feeds, fertilizer and as sources of traditional medicine in many Asian civilizations since ancient times. Seaweeds are excellent dietary sources of vitamins, proteins, carbohydrates, trace minerals and other bioactive compounds (Kumar et al 2008).

Seaweed as a food in Indonesia is not as common as in countries like Japan and China. About 25% of all food consumed in Japan consists of seaweed prepared and served in many forms and has become the main source of income for the fishermen there (Norziah & Ching 2000).

For several centuries there has been a traditional use of seaweeds as food in China, Japan and the Republic of Korea. As people from these countries have migrated around the world, this custom has moved with them, so that today there are many more countries where the consumption of seaweed is not unusual. Coastal dwellers in tropical

climates such as Indonesia and Malaysia have also eaten fresh seaweeds, especially as salad components (McHugh 2003; Abowei & Ezekiel 2013; Ferdouse et al 2018).

Some studies have been conducted on the proximate composition of seaweeds (Mwalugha et al 2015; Norziah & Ching 2000; Rameshkumar et al 2012; Rohani-Ghadikolaei et al 2012), fatty acid analysis and amino acid composition (Ortiz et al 2006; Dawczynski et al 2007; Gressler et al 2010; Silva et al 2013). One of the most important nutritional qualities of protein is amino acid composition (FAO/WHO 1990). While fatty acids are used as a marker to confirm and trace food resources and trophic relationships in different aquatic habitats (Penha-Lopes et al 2009). It is believed that the fatty acids content varies among the seaweeds species (Rohani-Ghadikolaei et al 2012). In addition, fatty acids are essential for life because of their role as a source of energy and membrane constituents (Santos et al 2015).

The biochemical composition of marine seaweeds is generally known to be highly influenced by geographical location and local environmental conditions (Rohani-Ghadikolael et al 2012). To the best of our knowledge, the biochemical composition of seaweeds from Ujung Genteng waters Indonesia is not yet available. Thus, in this present study, the proximate composition, fatty acid and amino acid profile of the red algae *Galaxuara rugosa* and *Gelidiella acerosa* were determined.

Material and Method

Sample collection and preparation. The two selected red seaweed namely *G. rugosa* and *G. acerosa* were collected from Ujung Genteng coastal waters Indonesia at the time of low-tide in May 2017. The seaweed samples were picked by hand and immediately cleaned and washed with seawater to remove sand, debris, epiphytes and other unnecessary matter attached to the thalli and transported to the laboratory. In the laboratory, the samples were sorted and then thoroughly cleaned by rinsing with distilled water to remove the surface salty materials. It was air dried with sun directly for 4 days and later ground in a blender. The powdered samples were subsequently kept in dark container and stored in the room temperature for further analysis. All chemicals were obtained commercially.

Proximate analysis. Proximate composition including moisture, ash, protein, fat and carbohydrate were determined according to AOAC (1990) standard method. The moisture content (% dry weight) was determined by drying 2 g sample. The sample was put into an oven at 105^{o}C and heated for 3 hours. The dried sample was put into desiccator, allowed to cool and reweighed. Ash content (% dry weight) was determined by heating sample for 4 hours in a muffle furnace at 550^{o}C until it turned white and free of carbon. The sample was then removed from the furnace, cooled in a desiccator to a room temperature and reweighed immediately.

Total fat content (% dry weight) was determined by loosely wrapping 2 g sample with a filter paper and put into the thimble which was fitted to a clean round bottom flask, which has been cleaned, dried and weighed. The flask contained 120 mL of petroleum ether. The sample was heated with a heating mantle and allowed to reflux for 5 hours. The heating then stopped and the thimbles with the spent samples kept and later weighed (AOAC 2000). Total protein (%) was calculated from the elemental N determination using the nitrogen-protein conversion factor of 6.25 according to the standard AOAC method (2000). The carbohydrate content (% dry weight) was estimated by difference: 100 – (moisture + ash + protein + fat) %.

Amino acid analysis. Determination of amino acid by Ultra Performance Liquid Chromatography (UPLC) was done based on the literature methods (Waters 2012). The chromatography condition: column (AccQ.Tag Ultra C18 1.7 µm (2.1 x 100 mm); temperature (49^{o}C); mobile phase (mobile phase A = eluent A concentrate AccQ Taq Ultra (Part No. 186003838), mobile phase B = 10% mobile phase D, mobile phase C = aquabidest and mobile phase D = eluent B AccQ Taq Ultra (Part No. 186003839); Flow

rate (0.5 mL per minute); detector (PDA, wave length 260 nm) and injection volume (1 µL).

Sample preparation (Waters 2012): accurately 0.1 g sample was weighted, added 5 mL HCl 6N and then vortexed. The mixture was hydrolysed for 22 hours at temperature 110°C. The hydrolysed mixture was subsequently cooled down and transferred into volumetric flask 50 mL and diluted to volume with aquadest. The solution was filtered with 0.45 µm filter. The 500 µL of filtrate was added 40 µL AABA and 460 µL aquabidest. The 10 µL of solution was added 70 µL AccQ Fluor Borate and 20 µL reagent fluor A and then vortexed during 1 minute. The solution was incubated during 10 minutes at 55°C and then injected into UPLC system.

Standard solution preparation: the 40 µL of standard solution was mixed of amino acid. The 40 µL internal standard AABA and 920 µL aquabidest were added and then homogenized. The 10 µL of standard solution was pipetted and 70 µL AccQ Fluor Borate was added and then vortexed. The 20 µL of reagent fluor A was added and vortexed. It was allowed for 1 minute. The solution was incubated for 10 minutes at 55^{o}C and injected into UPLC system.

Fatty acid analysis. Fatty acid profile analysis with gas chromatography (Perkin Elmer Clarus 580 GC) was done using apparatus condition: column (Supelco SPTM 2560 100 m 0.25 mm 0.2 µm); flow rate (18.0 cm sec^{-1} with column length 100 m); carrier gas (N_2) detector FID (240ºC); injector temperature (225ºC) and split (1:100).

Sample preparation for fat extraction (AOAC 2000): accurately 5 g of sample was weighted and added 4 mL of isopropanol and then was shaken for 1 minute. Into the solution, 6 mL of n-hexane was added then vortexed for 1 minute. The solution was subsequently centrifuged for 3 minutes at 9000 RPM. The clear upper solution was moved into a Hach tube and was dried in a water bath. Approximately 0.03-0.04 g of the fat extract was weighted and added 1.5 mL KOH methanol 0.5 M. The solution was heated in a water bath at 100^{o}C for 20 minutes and then cooled. Subsequently, 1.5 mL of BF_3 20% in methanol was added. The solution was heated in a water bath at 100^{o}C for 20 minutes. The solution was cooled down to 30^{o}C while shaken. Accurately 3 mL of saturated NaCl was added into the solution and was vortexed for 2 minutes. Subsequently, 0.2 mL of n-hexane was added into the mixture and was vortexed for 2 minutes. It was allowed to stand at room temperature for 10 minutes. The resulting n-hexane methyl ester layer was transferred into 10 mL volumetric flask, diluted with n-hexane and injected to Gas Chromatography.

Results. The tropical red seaweed *G. rugosa* and *G. acerosa* from Ujung Genteng waters was studied for proximate, amino acids and fatty acids analysis. Moisture content of *G. rugosa* (4.25%) and *G. acerosa* (8.71%), ash content of *G. rugosa* (72.97%) and *G. acerosa* (13.42%), fat content of *G. rugosa* (0.53%) and *G. acerosa* (0.54%), protein content of *G. rugosa* (5.34%) and *G. acerosa* (8.66%), and carbohydrate content of *G. rugosa* (16.91%) and *G. acerosa* (68.67%) (Figure 1). Ash and carbohydrate contents were the two most abundant components in these seaweeds.

Total 14 amino acids identified where glutamic acid was the major constituent in the both species (Figure 2). In the case of fatty acids, 8 components were identified in *G. rugosa* and 7 components identified in *G. acerosa.* Lauric acid was the major constituent in the both species followed by palmitic acid (Figure 3). *G. rugosa* and *G. acerosa* contained 0.21%, 0.20% lauric acid and 0.10%, 0.14% palmitic acid respectively. Omega-6 and omega-9 were also identified in both samples examined in this study.

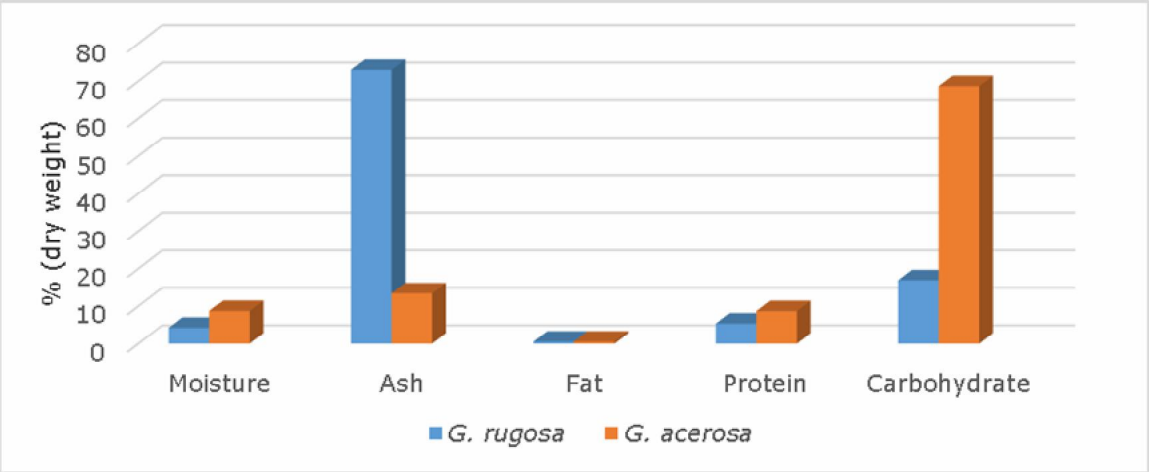

Figure 1. Proximate composition of dried sea weed *Galaxaura rugosa* and *Gelidiella acerosa*.

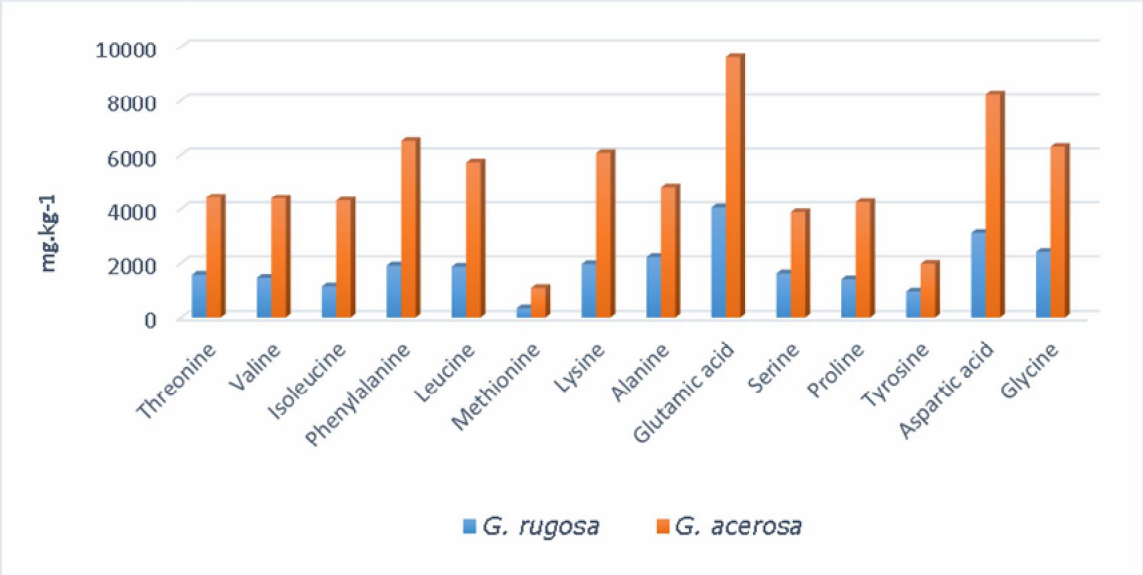

Figure 2. Amino acid composition of dried seaweed *Galaxaura rugosa* and *Gelidiella acerosa*.

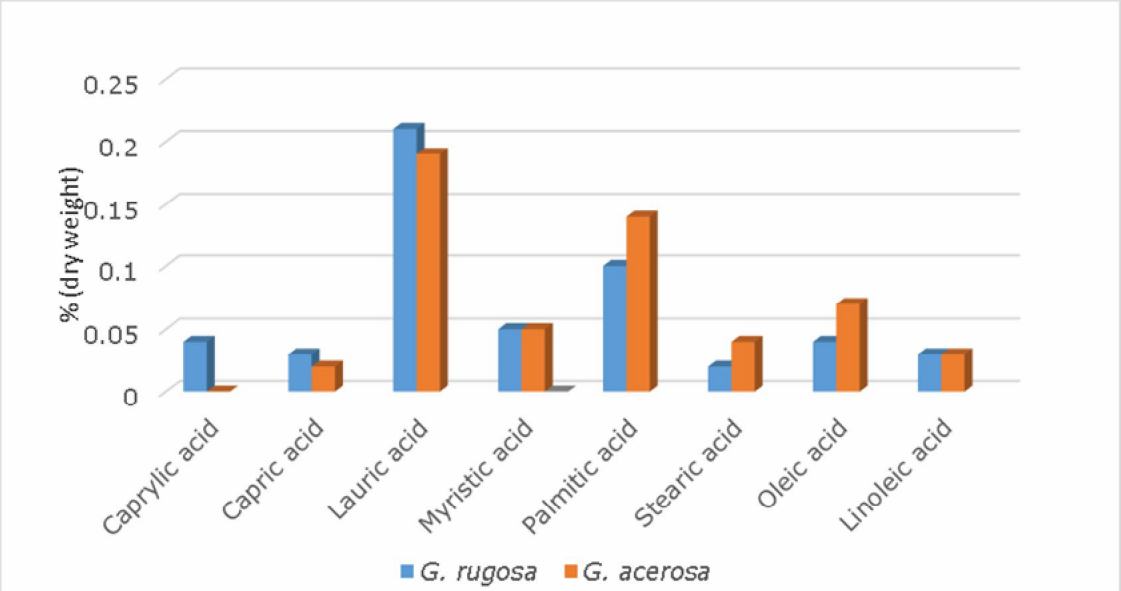

Figure 3. Fatty acid composition of dried seaweed *Galaxaura rugosa* and *Gelidiella acerosa*.

Discussion. The proximate composition based on dry weight of *Galaxaura rugosa* and *Gelidiella acerosa* were shown in Figure 1. It was found that the moisture contents of *G. rugosa* and *G. acerosa* were 4.25% and 8.71% respectively. These results are similar to previous study reported by Rohani-Ghadikolaei et al (2012) for green seaweeds (*Ulva lactuca* and *Enteromorpha intestinalis* were 0.2% and 8.5% respectively), brown seaweeds (*Sargassum ilicifolium* and *Colpomenia sinuosa* were 8% and 5.3% respectively) and red seaweeds (*Hypnea valentiae* and *G. corticata* were 6.5% and 2.1% respectively), but lower than reported by Ratana-Arporn & Chirapart (2006) for green seaweeds *Caulerpa lentilifera* (25.31%) and *U. reticulata* (25.51%).

Water is biologically significant as an essential metabolite. It participates in the chemical reaction of metabolism. In particular it is used as a source of hydrogen ion in photosynthesis and is used in hydrolysis reactions (Shanmugan & Palpandi 2008). Moisture content is an important criterion in determining the shelf-life and quality of processed seaweed meals as, where high moisture may hasten the growth of microorganisms (Rohani-Ghadikolaei et al 2012). Moisture content is a quality factor in the preservation of some products and affects stability of food materials and often it is specified in compositional standard (Nielsen 2010). The moisture contents examined in this study were also lower than quality standard of several commercial seaweeds in Indonesia (The National Standardization Agency of Indonesia 2015), namely *Eucheuma* sp. (20%), *Gracilaria* sp. (25%), *Turbinaria* sp. (20%) and *Sargassum* sp. (20%) based on dry weight.

The ash content in *G. rugosa* and *G. acerosa* were examined in this study, 72.97% and 13.42% respectively. The ash content in *G. rugosa* was the major proximate component. If compared to other species in previous studies, it is showed that the ash content of seaweeds was varied in different species. Ratana-Arporn & Chirapart (2006) reported that ash content of *C. lentilifera and U. reticulata* were 22.1% and 17.58% respectively. Rohani-Ghadikolaei et al (2012) reported that ash content in *U. lactuca, E. intestinalis, S. ilicifolium, C. sinuosa, H. valentiae* and *G. corticata* were 12.4%, 22.4%, 29.9%, 28.1%, 21.8% and 23.1% respectively. Gressler et al (2010) reported that ash content in *Laurencia filiformis, L. intricata, Gracilaria domingensis* and *G. birdiae* were 38.4%, 33.5%, 23.8% and 22.5% respectively. Mwalugha et al (2015) reported that ash content of several green seaweeds from Kenya coast namely *C. racemosa, C. scapelliformis, C. crassa, C. dwarkense, C. geopiorum, E. kylinii, E. muscoides, H. macroloba, U. fasciata, U. lactuca, U. pulchra, U. reticulata* were 53.50%, 19.41%, 20,18%, 69.94%, 37.96%, 42.73%, 30.02%, 66.07%, 29.28%, 23.67%, 22.04% and 18.60% respectively. In the brown seaweeds namely *C. myrica, C. trinodis, D. bartaynesiana, D. cervicormis, Dictyota* sp., *Dictyota* sp., *H. cuneiformis, H. clathrus, P. tetrastromatica, S. cristaefolium, S. oligocystum, Sargassum* sp., *S. asperum* were 41.39%, 33.64%, 30.09%, 36.54%, 22.70%, 19.49%, 33.19%, 33.58%, 41.24%, 24.64%, 26.38%, 25.64%, and 18.01 % respectively. While in the red seaweeds namely *A. spicifera, C. papillosus, E. denticulatum, G. arcuata, G. salicornia, H. musciformis, Hypnea* sp., *L. intermedia* and *S. robusta* were 36.01%, 31.52%, 36.21%, 16.51%, 29.10%, 20.77%, 26.85%, 30.32% and 24.51% respectively. Smith et al (2010) also reported that the ash content of edible seaweeds in New Zealand namely *E. radiata, U. stenophylla, D. antarctica, H. banksii*, *Porphyra* spp. and *Undaria pinnatifida* were 22.1%, 22.7%, 22.12%, 28.43%, 19.80% and 26.58% respectively.

According to Davis et al (2003), seaweeds generally have high ash content because of their cell wall polysaccharides and protein contain ammonic carboxyl, sulfate and phosphate group that are excellent binding sites for metal retention. It indicates the presence of appreciable amounts of diverse mineral components.

The fat content of both seaweeds examined in this study was similar, 0.53% and 0.54% respectively. These results were lower than other species reported by Ratana-Arporn & Chirapart (2006) for *C. lentilifera* (0.86%) and *U. reticulata* (0.75%), Rohani-Ghadikolaei et al (2012) for *U. lactuca* (3.6%), *E. intestinalis* (2.9%), *S. ilicifolium* (2%), *C. sinuosa* (1.5%), *H. valentiae* (2.8%) and *G. corticata* (1.8%), Gressler et al (2010) for *Laurencia filiformis, L. intricata, Gracilaria domingensis* and *G. birdiae*) were 0.8%, 0.7%, 0.8% and 1% respectively. Mwalugha et al (2015) reported that ash content of several

green seaweeds from Kenya coast namely *C. racemosa, C. scapelliformis, C. crassa, C. dwarkense, C. geopiorum, E. kylinii, E. muscoides, H. macroloba, U. fasciata, U. lactuca, U. pulchra, U. reticulata* were 1.91%, 2.49%, 2.20%, 1.54%, 1.91%, 1.42%, 1.83%, 1.95%, 1.63%, 1.65%, 1.31% and 1.34%, respectively. In the brown seaweeds namely *C. myrica, C. trinodis, D. bartaynesiana, D. cervicormis, Dictyota* sp., *Dictyota* sp., *H. cuneiformis, H. clathrus, P. tetrastromatica, S. cristaefolium, S. oligocystum, Sargassum* sp., *S. asperum* were 1.58%, 2.08%, 3.10%, 3.65%, 4.04%, 4.21%, 1.82%, 1.62%, 1.91%, 2.76%, 2.56%, 2.19% and 1.76% respectively. While in the red seaweeds namely *A. spicifera, C. papillosus, E. denticulatum, G. arcuata, G. salicornia, H. musciformis, Hypnea* sp., *L. intermedia* and *S. robusta* were 1.39%, 1.52%, 1.82%, 1.07%, 1.47%, 1.38%, 1.44%, 1.51% and 1.57 respectively. Smith et al (2010) also reported that the fat content of edible seaweeds in New Zealand namely *E. radiata, U. stenophylla, D. antarctica, H. banksii Porphyra* spp. and *U. pinnatifida* were 1.8%, 1.24%, 2.03%, 2.63%, 2% and 3.30% respectively.

The protein contents of seaweed species examined in this study were 5.34% (*G. rugosa*) and 8.66% (*G. acerosa*). If compared to other species in previous studies, the protein content of seaweeds was varied in different species. Ratana-Arporn & Chirapart (2006) reported that the protein content in *C. lentilifera* was 12.49% and 21.06% in *U. reticulate*. Rohani-Ghadikolaei et al (2012) reported that the protein content of several seaweeds from Persian Gulf of Iran, namely *U. lactuca, E. intestinalis, S. ilicifolium*, *C. sinuosa, H. valentiae* and *G. corticata* were 17.1%, 10.5%, 8.9%, 9.2%, 16.5% and 19.3% respectively. Gressler et al (2010) reported that the protein content of four Brazilian red seaweeds, namely *L. filiformis, L. intricata, G. domingensis* and *G. birdiae* were 18.3%, 4.6%, 6.2% and 7.1% respectively. Mwalugha et al (2015) reported that ash content of several green seaweeds from Kenya coast namely *C. racemosa, C. scapelliformis, C. crassa, C. dwarkense, C. geopiorum, E. kylinii, E. muscoides, H. macroloba, U. fasciata, U. lactuca, U. pulchra, U. reticulata* were 1.91%, 2.49%, 2.20%, 1.54%, 1.91%, 1.42%, 1.83%, 1.95%, 1.63%, 1.65%, 1.31% and 1.34%, respectively. In brown seaweeds namely *C. myrica, C. trinodis, D. bartaynesiana, D. cervicormis, Dictyota* sp., *Dictyota* sp., *H. cuneiformis, H. clathrus, P. tetrastromatica, S. cristaefolium, S. oligocystum, Sargassum* sp. *S. asperum* 8.16%, 6.94%, 14.21%, 10.83%, 6.74%, 1.71%, 6.94%, 7.73%, 7.62%, 9.41%, 7.56%, 5.63% and 17.17% respectively. While in red seaweeds namely *A. spicifera, C. papillosus, E. denticulatum, G. arcuata, G. salicornia, H. musciformis, Hypnea* sp., *L. intermedia* and *S. robusta* were 13.73%, 9.61%, 5.07%, 13.79%, 9.55%, 19.79%, 21.39%, 12.40% and 10.84% respectively. Smith et al (2010) reported that the protein content of edible seaweeds in New Zealand, namely *E. radiata, U. stenophylla, D. antarctica, H. banksii Porphyra* spp. and *U. pinnatifida* were 9.6%, 20.43%, 7.26%, 6.07%,32.71% and 19.66% respectively. Rameshkumar et al (2012) also reported that protein content of some slected seaweeds from Palk Bay and Gulf of Mannar India, namely *C. racemosa, U. faciata, Chnoospora minima, P. gymnospora* and *A. spicifera* were 18.3%, 14.7%, 11.3%, 10.5% and 18.9% respectively.

Carbohydrate is the most important component for metabolism and it supplies the energy needed for respiration and other metabolic processes (Shanmugan & Palpandi 2008). The carbohydrate content of seaweeds species examined in this study were 16.91% (*G. rugosa)* and 68.67% (*G. acerosa)*. These result showed that the carbohydrate content of *G. rugosa* was lower than *G. acerosa* and other species reported in previous studies. Different with *G. rugosa,* the carbohydrate content of *G. acerosa* was higher than other species reported in previous studies. Ratana-Arporn & Chirapart (2006) reported that the carbohydrate content of *C. lentilifera* and *U. reticulata* were 59.27% and 55.77% respectively. Rohani-Ghadikolaei et al (2012) reported for several seaweeds from Persian Gulf of Iran, namely *U. lactuca, E. intestinalis, S. ilicifolium, C. sinuosa, H. valentiae* and *G. corticata* were 59.1%, 35.5%, 32.9%, 32.1%, 31.8% and 43% respectively. Smith et al (2010) reported that the carbohydrate content of edible seaweeds in New Zealand namely *E. radiata, U. stenophylla, D. antarctica, H. banksii Porphyra* spp. and *U. pinnatifida* were 66.9%, 55.6%, 58.82%, 62.9%, 45.4% and 50.4% respectively. Rameshkumar et al (2012) also reported that the carbohydrate was

the major component in the some selected seaweeds from Palk Bay and Gulf of Mannar India, namely *C. racemosa, U. fasciata, Chnoospora minima, P. gymnospora* and *A. spicifera* were 83.2%, 70.1%, 28.5%, 38.3% and 34.7% respectively.

Total 14 amino acids were identified, where glutamic acid was the major constituent in both species. Lysine (1957.33 mg kg^{-1}) was the major component of essential amino acid in *G. rugosa*, followed by phenylalanine, leucine, threonine, valine, isoleucine and methionine were 1910.16, 1866.48, 1578.07, 1471.36, 1162.13 and 337.76 mg kg^{-1} respectively. Glutamic acid (4049.68 mg kg^{-1}) was the major component of non-essential amino acid in *G. rugosa* followed by aspartic acid, glycine, alanine, serine, proline and tyrosine were 3116.6, 2398.7, 2211.34, 1625.78, 1418.25 and 977.43 mg kg^{-1} respectively.

Phenylalanine (6538.56 mg kg^{-1}) was the major component of essential amino acid in *G. acerosa,* followed by lysine, leucine, threonine, valine, isoleucine and methionine were 6068.34, 5721.42, 4429.93, 4398.25, 4311.83 and 1105.07 mg kg^{-1} respectively. Glutamic acid (9603.27 mg kg^{-1}) was the major component of non-essential amino acid in *G. acerosa,* followed by aspartic acid, glycine, alanine, proline, serine and tyrosine were 8235.11, 6329.35, 4811.14, 4247.50, 3882.51 and 1970.62 mg kg^{-1} respectively. Similar to other species, some previous studies reported that glutamic acid was the major component of amino acids in *C. lentilifera* and *U. reticulata* (Ratana-Arporn & Chirapart 2006), *Laminaria* sp., *U. pinnatifida*, *H. fusiforme* and *Porphyra* sp. (Dawczynski et al 2007), *C. racemosa, U. faciata, Chnoospora minima, P. gymnospora* and *A. spicifera* (Rameshkumar et al 2012). Similar to Ortiz et al (2006) for *Kappaphycus alvarezii* and *Hypnea musciformis.* Whereas, the major component of amino acid in *Laurencia filiformis, L. intricata, G. domingensis* and *G. birdiae* was aspartic acid followed by glutamic acid (Gressler et al 2010). Aspartic acid was the major component of amino acid in *S. wightii, U. lactuca, A. spicifera and G. corticata* (Ortiz et al 2006).

The composition of fatty acids was given in Figure 3. The composition was dominated by saturated fatty acids followed by polyunsaturated fatty acids and monounsaturated fatty acids. Compared with previous studies, the saturated fatty acid was the dominant one in seaweeds such as *U. lactuca, E. intestinalis, S. ilicifolium*, *C. sinuosa, H. valentiae* and *G. corticata* (Rohani-Ghadikolaei et al 2012), *Laminaria* sp., *U. pinnatifida*, *H. fusiforme* and *Porphyra* sp. (Dawczynski et al 2007).

In the analyzed seaweeds species, the major saturated fatty acid in *G. rugosa* was lauric acid (0.21%) followed by palmitic acid, myristic acid, caprylic acid, capric acid and stearic acid were found to be 0.10%, 0.05%, 0.04%, 0.03% and 0.02% respectively. Whereas major saturated fatty acid in *G. acerosa* was lauric acid (0.19%) followed by palmitic acid, myristic, stearic and capric acid were found to be 0.14%, 0.05%, 0.04% and 0.02% respectively. Caprylic acid was not identified in *G. acerosa.*

The content of lauric acid was higher in *G. rugosa* than *G. acerosa.* Whereas the content of palmitic acid was higher in *G. acerosa* than *G. rugosa.* Compared to other species in the previous studies reported that palmitic acid was the major component of fatty acid, namely *U. lactuca, E. intestinalis, S. ilicifolium, C. sinuosa, H. valentiae* and *G. corticata* (Rohani-Ghadikolaei et al 2012), *Laminaria* sp. and *Porphyra* sp. (Dawczynski et al 2007), *L. filiformis, L. intricata, G. domingensis* and *G. birdiae* (Gressler et al 2010), *D. antarctica* and *U. lactuca* (Ortiz et al 2006). Interestingly, lauric acid was not detected in several species, namely *U. pinnatifida* and *H. fusiforme* (Dawczynski et al 2007) and *L. intricata* (Gressler et al 2010).

Omega 6 and omega 9 were identified in both samples examined in this study. The omega 9 content was higher than omega 6 in both species. Interestingly, omega 3 was not identified in both species. This result was similar to the previous study reported by Rohani-Ghadikolaei et al (2012) for *U. lactuca* and *G. corticata* from Persian Gulf of Iran. Silva et al (2013) reported that omega 3 was not identified in *P. pavonica.* Gressler et al (2010) also reported omega 3 was not identified in *G. domingensis* and *G. birdiae* species.

Conclusions. It can be concluded that, particularly, red seaweeds *Galaxaura rugosa* and *Gelidiella acerosa* from Ujung Genteng waters of Indonesia represent an important source of carbohydrate and protein which contains almost all essential amino acids. Lauric acid

was the major constituent in both species, followed by palmitic acid. The nutritional value of both seaweeds appears to be an interesting potential source of food ingredient for human food supplement industries in the future.

References

Abowei J. F. N., Ezekiel E. N., 2013 The potentials and utilization of seaweeds. Scientia Agriculturae 4(2):58-66.

AOAC, 1990 Official Methods of Analysis of the Association of Official Analytical Chemists, 15th ed., Washington D.C., 771 pp.

AOAC, 2000 Official Methods of Analysis of the Association of Official Analysis Chemists, 17th ed., Washington, D.C., 2200 pp.

Belattmania Z., Engelen A. H., Pereira H., Serrao E. A., Barakate M., Elatouani S., Zrid R., Bentiss F., Chahboun N., Reani A., Sabour B., 2016 Potential uses of the brown seaweed *Cystoseira humilis* biomass: 2-fatty acid composition, antioxidant and antibacterial activities. Journal of Materials and Environmental Science 7(6):2074-2081.

Davis T. A., Volesky B., Mucci A., 2003 A review of biochemistry of heavy metal biosorption by brown algae. Water Research 37(18):4311-4330.

Dawczynski C., Schubert R., Jahreis G., 2007 Amino acids, fatty acids, and dietary fibre in edible seaweed products. Food Chemistry 103(3):891-899.

FAO/WHO, 1990 Protein quality evaluation: report of the joint FAO/WHO expert consultation of protein quality evaluation. Bethesda, MD, 66 pp.

Ferdouse F., Holdt S. L., Smith R., Murua P., Yang Z., 2018 The global status of seaweed production, trade and utilization. FAO of the United Nations, Rome, Italy, volume 124, 114 pp.

Gressler V., Yokoya N. S., Fujii M. T., Colepicolo P., Filho J. M., Torres R. P., Pinto E., 2010 Lipid, fatty acid, protein, amino acid and ash contents in four Brazilian red algae species. Food Chemistry 120(2):585-590.

Kumar C. S., Ganesan P., Suresh P. V., Bhaskar N., 2008 Seaweeds as a source of nutritionally beneficial compounds - a review. Journal of Food Sciences and Technology 45:1-13.

McHugh D. J., 2003 A guide to the seaweed industry. FAO Fisheries Technical Paper, No. 441, FAO, Rome, 105 pp.

Mwalugha H. M., Wakibia J. G., Kenji G. M., Mwasaru M. A., 2015 Chemical composition of common seaweeds from the Kenya coast. Journal of Food Research 4(6):28-38.

Nielsen S. S., 2010 Food analysis laboratory manual. 2nd edition, Springer, 171 pp.

Norziah M. H., Ching C. Y., 2000 Nutritional composition of edible seaweed *Gracilaria changgi*. Food Chemistry 68(1):69-76.

Ortiz J., Romero N., Robert P., Araya J., Lopez-Hernández J., Bozzo C., Navarrete E., Osorio A., Rios A., 2006 Dietary fiber, amino acid, fatty acid and tocopherol contents of the edible seaweeds *Ulva lactuca* and *Durvillaea antarctica*. Food Chemistry 99:98-104.

Penha-Lopes G., Torres P., Narciso L., Cannicci S., Paula J., 2009 Comparison of fecundity, embryo loss and fatty acid composition of mangrove crab species in sewage contaminated and pristine mangrove habitats in Mozambique. Journal of Experimental Marine Biology and Ecology 381:25-32.

Rameshkumar S., Ramakritinan C. M., Yokeshbabu M., 2012 Proximate composition of some selected seaweeds from Palk Bay and Gulf of Mannar, Tamilnadu, India. Asian Journal of Biomedical and Pharmaceutical Sciences 3(16):1-5.

Ratana-Arporn P., Chirapart A., 2006 Nutritional evaluation of tropical green seaweeds *Caulerpa lentillifera* and *Ulva reticulata.* Kasetsart Journal - Natural Science 40:75-83.

Rohani-Ghadikolaei K., Abdulalian E., Ng W. K., 2012 Evaluation of the proximate, fatty acid and mineral composition of representative green, brown and red seaweeds from the Persian Gulf of Iran as potential food and feed resources. Journal of Food Science and Technology 49(6):774-780.

Santos R., Dias S., Pinteus S., Silva J., Alves C., Tecelao C., Pombo A., Pedrosa R., 2015 The biotechnological and seafood potential of *Stichopus regalis*. Advances in Bioscience and Biotechnology 6(3):194-204.
Shanmugan A., Palpandi C., 2008 Biochemical composition and fatty acid profile of the green alga *Ulva reticulata*. Asian Journal of Biochemistry 3:26-31.
Silva G., Pereira R. B., Valentão P., Andrade P. B., Sousa C., 2013 Distinct fatty acid profile of ten brown macroalgae. Brazilian Journal of Pharmacognosy 23(4):608-613.
Smith J. L., Summers G., Wong R., 2010 Nutrient and heavy metal content of edible seaweeds in New Zealand. New Zealand Journal of Crop and Horticultural Sciences 38(1):19-28.
The National Standardization Agency of Indonesia, 2015 Dried seaweed (SNI-2890-2015), 12 pp.
Tiwari B. K., Troy D. J. (eds), 2015 Seaweed sustainability food and non-food applications. Elsevier-Academic Press, 438 pp.
Waters, 2012 Acquity UPLC H-Class an H-Class Bio Amino Acid Analysis System Guide. Waters Cooperation, USA, 170 pp.

Received: 11 November 2018. Accepted: 23 February 2019. Published online: 28 April 2019.
Authors:
Abdullah Rasyid, Research Center for Oceanography, Indonesian Institute of Sciences, Jl. Pasir Putih No.1 Ancol Timur, Jakarta 14430, Indonesia, e-mail: a.rasyid.qf@gmail.com
Tri Handayani, Reseach Center for Oceanography, Indonesian Institute of Sciences, Jl. Pasir Putih No.1 Ancol Timur, Jakarta 14430, Indonesia, e-mail: umuamel@gmail.com

How to cite this article:
Rasyid A., Handayani T., 2019 Evaluation of the biochemical composition of tropical red seaweeds *Galaxaura rugosa* and *Gelidiella acerosa* from Ujung Genteng waters, Indonesia. AACL Bioflux 12(2):601-609.