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Proximate composition and agar content of selected red seaweeds in Initao, Misamis Oriental, Mindanao, Philippines

[1]Kevin C. Sumile, [1]Maria L. S. Orbita, [1]Angeli V. Mag-aso, [2]Ronaldo R. Orbita

[1] Department of Biological Sciences, College of Science and Mathematics, Mindanao State University – Iligan Institute of Technology, Iligan City, Philippines; [2] Department of Professional Education, College of Education, Mindanao State University – Iligan Institute of Technology, Iligan City, Philippines. Corresponding author: M. L. S. Orbita, mlwsasil@yahoo.com

Abstract. The present study reveals proximate composition and agar content of four commonly occurring seaweeds along the coast of Iligan Bay. Seaweeds such as *Gracilaria arcuata*, *Gracilaria coronopifolia*, *Laurencia papillosa* and *Laurencia thuyoides* were analyzed for carbohydrate, crude protein, total fat, ash, moisture and agar content. *L. papillosa* ranked highest in carbohydrate among other species analyzed. *L. thuyoides* and *G. coronopifolia* were both ranked highest in crude protein. Total fat was highest in *G. coronopifolia* and *G. arcuata* ranked first in ash and agar content. Based from the result, it can be seen that there is a potential for the four red seaweed species to be used as raw material or ingredients to improve nutritive value and functional properties in human diet and animal feed.
Key Words: Biochemical component, phycocolloid, Iligan Bay, *Gracilaria arcuata*, *Gracilaria coronopifolia*, *Laurencia papillosa*, *Laurencia thuyoides*

Introduction. Seaweeds are marine plants that are ecologically and commercially valuable living marine resources which belong to the primitive groups of non-flowering plants. Seaweeds are commonly categorized into three groups such as Chlorophyceae (Green seaweeds), Phaeophyceae (Brown seaweeds) and Rhodophyceae (Red seaweeds) especially on the basis of pigments and the stored food materials (Jagadeesan et al 2010).

Currently, seaweeds are used worldwide for many different purposes. The human consumption of seaweed is common in Asian countries, mainly Japan, China, Korea, Vietnam, Indonesia and Taiwan (Dawes 1998). In Western countries, seaweeds have been used as sources of phycocolloids, thickening and gelling agents for various applications, including food and pharmaceutical industries. Furthermore, they are also used for improving nutrients in animal feed, cosmetics, herbal medicine, fertilizers, etc. (Fleurence 1999; Marinho-Soriano et al 2006). Seaweeds are known as valuable sources of protein, trace elements, dietary fibers, vitamins, essential amino acids and essential fatty acids. Moreover, seaweeds also contain potential bioactive compounds which exhibit antibacterial, antiviral and antifungal properties (Marinho-Soriano et al 2006).

Considering the importance of seaweeds, it is vital that much attention should be given on seaweeds to compensate the food problem to some extent and fulfill the deficiency of nutrition for erecting the economy of several countries.

In Iligan Bay, some red seaweeds, namely *Gracilaria arcuata*, *Gracilaria coronopifolia*, *Laurencia papillosa* and *Laurencia thuyoides* are abundant (Kho 2014). Although these species are common among the red seaweeds occurring all along the coast of Iligan Bay, however, very little is known about their biochemical composition and agar content. The present study aims to analyze the levels of biochemical composition and agar content in the four species of red seaweeds namely: *G. arcuata*, *G. coronopifolia*, *L. papillosa* and *L. thuyoides.*

Material and Method. Samples of *G. arcuata*, *G. coronopifolia*, *L. papillosa* and *L. thuyoides* were collected randomly in the coastal area of Barangay Tubigan, Initao, Misamis Oriental (08° 32.0' North Latitude 124° 18.7' East Longitude) during the month of December 2013 and August 2014. Barangay Tubigan was chosen as the sampling area because of its high diversity in seaweeds especially red seaweeds. Collected samples were placed in an ice bucket and brought to the laboratory where they were sorted and cleaned with water. After sorting and cleaning, the collected samples were oven dried at 100^0C for 24 hours. The dried samples were ground into powder and were brought to the Chemical Testing Laboratory of the Department of Science and Technology, Cagayan de Oro City, Mindanao, Philipppines for analysis. The analysis of crude protein was done using Kjeldahl method, total fat by hydrolysis and solvent extraction method, ash content by gravimetric method, moisture content by air oven method, and carbohydrate content by computational method [Carbohydrate = 100% - (%crude protein + %total fat + %ash + %moisture)]. The method used for the analysis of crude protein, total fat, ash content and moisture content was based on OMA AOAC (2011) and the values were expressed as percentage on dry weight basis. The agar extraction was done following the method of Rath & Adhikary (2004) and the agar yield was calculated based on the formula described by Hurtado-Ponce & Umezaki (1988). The difference in carbohydrate, crude protein, total fat, ash, moisture and agar content among seaweed species was determined by Analysis of Variance (One-Way ANOVA, level of significance, P of 0.05) in SPSS (version 8.0). Tukey's Pairwise Comparison of Means was used to determine which variables were significantly different.

Results and Discussion. Significant variation in the proximate levels of carbohydrate, crude protein, total fat, ash, moisture and agar content among the four red seaweed species was visible (Table 1). The carbohydrate concentrations of the investigated seaweeds varied from 29.56 to 78.95% DW (Figure 1). The maximum concentration was recorded from *L. papillosa* (78.95% DW) followed by *G. coronopifolia* (42.18% DW) and *L. thuyoides* (41.72% DW). The minimum carbohydrate content was observed in *G. arcuata* (29.56% DW). The carbohydrate content of *L. papillosa* was higher than the one reported by Kaliaperumal et al (2002) for the same species from Mandapam coast of India (12.61% DW) and from the Northeastern Mediterranean coast [6.38% (Polat & Ozogul 2013)]. Also, Mohammadi et al (2013) reported a value of 25.0% for the same species in Northern Persian Gulf. On the other hand, the present value was found to be comparable to that reported for several other species of the genus *Laurencia*. Ahmad et al (2012) recorded a carbohydrate content of 66.78% in *Laurencia* sp. (yellow variety) and 66.0% in *Laurencia* sp. (brown variety) from Semporna, Sabah, Malaysia, while Mwalugha (2014) recorded a yield of 55.19% in *L. intermedia* from Mkomani and Kibuyuni, Kenya.

Table 1

Statistical analysis (One-Way ANOVA) on the effects of species on carbohydrate, crude protein, total fat, ash, moisture and agar content

Dependent variable	*Independent variable*	*d.f.*	*F-statistics*	*p*	*Analysis*
Carbohydrate	Species	3	177.33	0.000	Significant
Crude protein	Species	3	227.57	0.000	Significant
Total fat	Species	3	461.96	0.000	Significant
Ash	Species	3	191.05	0.000	Significant
Moisture	Species	3	17.26	0.001	Significant
Agar	Species	3	17.42	0.000	Significant

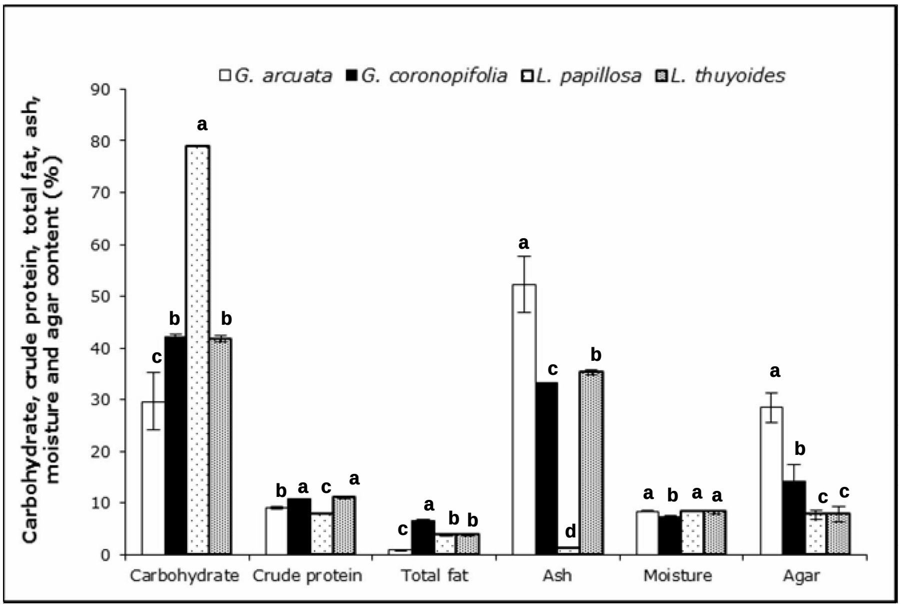

Figure 1. Levels of carbohydrate, crude protein, total fat, ash, moisture and agar content in *Gracilaria arcuata*, *Gracilaria coronopifolia*, *Laurencia papillosa* and *Laurencia thuyoides* (mean ± SD). Letters represent differences in group means as determined by Tukey's multiple comparison test.

Carbohydrates in seaweeds are of immense importance since they are in different forms like floridean starch in red seaweed, laminarin in brown seaweed and starch in green seaweed as food reserves and source of energy (Dawes 1998). Seaweeds contain carbohydrates different from those in higher land plants (Arasaki & Arasaki 1983). They are often termed as "super food" due to high concentration of carbohydrates in them. Likewise, red seaweed was reported to have high carbohydrate content compared to other group of seaweeds (Ahmad et al 2012; Fleurence 1999). The present study revealed considerably high quantities of carbohydrates in the studied seaweed species from Iligan Bay. Range of carbohydrate concentration in the four species was from 29.65-78.95% DW and was higher than the range specified for seaweeds [50-60% DW (Sekine et al 1965)]. Marked individual carbohydrate content difference was also evident from the result. This variation might be due to different season and growth stage experienced per individual (Fleurence 1999).

The protein content in all four species was significantly different ($p<0.05$) from each other. The values ranged from 7.91% to 10.94% DW in *L. thuyoides* (10.94%) followed by *G. coronopifolia* (10.66%), *G. arcuata* (9.05%) and *L. papillosa* (7. 91%). The protein content of *L. thuyoides* in this study was higher than the one reported by Mwalugha (2014) (7.76%) in *L. intermedia* from Mkomani and Kibuyuni, Kenya. Seaweed protein is called complete protein with all the essential amino acids at levels close to that recommended by FAO/WHO (Matanjun et al 2009; Wong & Cheung 2000). According to Kolb et al (1999), red seaweeds have the highest amount of protein compared to brown and green seaweeds. The protein content of *G. coronopifolia* (10.66%) is in agreement with the protein content in most *Gracilaria* spp. which is in between 7-13% DW (Briggs & Funge-Smith 1993).

Lipids have been recognized as essential components in human and animal nutrition and are used as feed additives in aquaculture. The data presented in the literature show that the lipid content in seaweed is <5% dry weight (Taboada et al 2011, 2013). In contrast, the present results showed that *G. coronopifolia* has about 6.68% DW which is higher than the specified value for red algae (Herbetreau et al 1997; Benjama & Payap 2011; Nor Salmi et al 2012) and higher when compared to other species of *Gracilaria* – *G. changgi* 3.30% (Norziah & Ching 2000), *G. manilaensis* 4.32% (Nor Salmi et al 2012), *G. cervicornis* 0.43% (Marinho-Soriano et al 2006), *G. verrucosa* 2.6% (Chakraborty & Bhattacharya 2012) and *G. salicornia* 1.48% (Mwalugha 2014). There was a significantly lower percentage of lipid in other seaweed species (0.78-3.74%) and this was attributed to the state of nutrition in algal cells (Chakraborty & Bhattacharya 2012).

The ash content in all four species varied from 1.12 to 52.24% DW. These results were comparatively higher than those of terrestrial counterparts with only 5-10% DW (USDA 2001). The high ash content is a general feature of seaweeds, and these values are generally much higher than those of terrestrial vegetables other than spinach (Ruperez 2002). The highest ash value (52.24%) was recorded in *G. arcuata* followed by *L. thuyoides* (35.24%) and *G. coronopifolia* (33.22%). The lipid content of *G. arcuata*, *L. thuyoides* and *G. coronopifolia* was higher compared to the other species of *Gracilaria* (Norziah & Ching 2000; Nor Salmi et al 2012; Marinho-Soriano et al 2006; Chakraborty & Bhattacharya 2012; Mwalugha 2014) and *Laurencia* (Ahmad et al 2012). High ash content invariably indicates the presence of appreciable amounts of diverse mineral components (Mantanjun et al 2008). Seenivasan et al (2012) reported that seaweeds contain higher concentration of more than sixty trace elements.

The moisture content of the dried seaweed samples ranged between 8.36–7.26% and the values varied significantly ($p<0.05$) among species. Moisture content is an important criterion in determining the shelf- life and quality of processed seaweed meals as high moisture may hasten the growth of microorganisms (Rohani-Ghadikolaei et al 2012). The moisture content must be preferably not more than 40% (McHugh 2006) however the recommended value is not more than 35% (Pelinggon & Tito 2009). The moisture content of *G. arcuata* (8.36%), *G. coronopifolia* (7.26%), *L. papillosa* (8.28%) and *L. thuyoides* (8.24%) are within the recommended level of not more than 35% (Pelinggon & Tito 2009).

The agar content varied significantly among species. The values ranged from 7.72% to 22.86%. The highest agar content was observed in *G. arcuata* (22.86%) followed by *G. coronopifolia* (14.32%) while the lowest value was recorded in the two species of *Laurencia*. The present value was found to be comparable to that reported for several other species of the genus *Gracilaria.* Chennubhotla et al (1977) reported agar yield of 23% from *G. verrucosa,* while Rao et al (1977) recorded a yield of 25% in *G. foliifera.* Kim & Henriquez (1978) obtained agar yields of 17% and 22% from Chilean *G. verrucosa.* Bird & Hinson (1992) reported agar contents of 20.9-22.2% in *G. tikvahiae* and 24.2-25.7% in *G. blodgettii.* Falshaw et al (1999) recorded agar contents of 21% in *G. arcuata* and 23% in *G. maramae* from Fiji. Arano et al (2000) reported agar yield of 23.5% in *G. firma* from Philippines. Freile-Pelegrín & Murano (2005) reported agar content of 25% in *G. cervicornis* and 24% in *G. blodgettii* in Yucatán Peninsula. Freile-Pelegrín & Murano (2005) also recorded lower value in *G. crassissima* (15.0%), while Whyte & Englar (1980) also recorded lower values in *G. chorda* (15.7%), *G. verrucosa* (13.5%), *G. pseudoverrucosa* (11.3%) and *G. pseudoverrucosa variant* (16.8%) from British Columbia.

Conclusions. Based on the present study, it can be seen that there is a potential for the four red seaweed species (*G. arcuata*, *G. coronopifolia*, *L. papillosa* and *L. thuyoides*) to be used as raw material or ingredients to improve nutritive value and functional properties in human diet and animal feed. With respect to the higher level of carbohydrate, *L. papillosa* appeared to be an interesting potential source of plant carbohydrates for human consumption. Likewise, *G. coronopifolia* showed a good potential source for lipid content. Moreover, there is a potential for *G. arcuata* to be used as source for agar production since their agar yield where within the commercial requirement needed for commercial crops.

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Authors:
Kevin Cabili Sumile, Mindanao State University - Iligan Institute of Technology, College of Science and Mathematics, Department of Biological Sciences, Philippines, Iligan City 9200, e-mail: kevin_sumile@yahoo.com
Maria Luisa Sasil Orbita, Mindanao State University - Iligan Institute of Technology, College of Science and Mathematics, Department of Biological Sciences, Philippines, Iligan City 9200, e-mail: mlwsasil@yahoo.com
Angeli Valera Mag-aso, Mindanao State University - Iligan Institute of Technology, College of Science and Mathematics, Department of Biological Sciences, Philippines, Iligan City 9200, e-mail: angeli.valera@g.msuiit.edu.ph
Ronaldo Rosario Orbita, Mindanao State University - Iligan Institute of Technology, College of Education, Department of Professional Education, Philippines, Iligan City 9200, e-mail: r_r_o2003@yahoo.com

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