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Standing stock, nutritional composition, agar yield and physical properties of agar in red seaweed *Gracilaria salicornia* (C. Agardh) Dawson along the coast of Iligan Bay

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Abstract

Gracilaria is a red alga notable for its economic importance as a major source of agar world-wide. Considering its importance and the very limited data available in the locality, this study was conducted to determine the abundance, standing stock, nutritional composition, agar yield and some of the agar properties of *G. salicornia* along the coast of Iligan Bay. Using the transect-quadrat method, the abundance and biomass was determined in the intertidal flat of Barangay Minaulon, Bacolod, Lanao del Norte, while the analysis of nutritional composition and agar extraction was done using the standard methods. Results showed that the cover value of *G. salicornia* was 67.53±51.43% and its mean biomass was 218.35±74.20 g/m^2. The nutritional composition represented by protein, fat, carbohydrate, ash and moisture content was within the values specified for seaweeds. The agar yield was 2.18±0.22% and the average gel strength was 70.87±14.07 g cm^{-2}. It was concluded that the wild populations of *G. salicornia* in Iligan Bay were high based on its cover and standing stock, hence sustainable for commercial exploitation for agar production. Lastly, its nutritional composition was in considerable quantities and within the values specified for seaweeds.

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Introduction

Gracilaria is one of the genera that comprise the greatest number of species in the family Gracilariaceae (Rhodophyta), with the majority of them being reported from warm-water and tropical regions (Santos, 1990). Currently, this genus is the major world-wide agar source (McDermid and Stuercke, 2003; Freile-Pelegrin and Murano, 2005; Baghel *et al*., 2011). Five (5) species of *Gracilaria*: *G. arcuata* Zanardini, *G. salicornia* (C. Agardh) Dawson, *G. canaliculata* Sonder, *G. eucheumoides* Harvey and *G. coronopifolia* J. Agardh have been found in abundance along the coast of Iligan Bay (unpublished studies). However, information on biomass productivity of these red seaweed species is lacking. In addition, only two (2) of these species have been shown to have potential for agar production as well as their nutritional composition. Sumile *et al.* (2015) reported the agar yield of 22.86% (dry weight) for *G. arcuata* while it was 14.32% for *G. coronopifolia*. Moreover, the carbohydrate, protein, lipid, ash and moisture content of *G. coronopifolia* and *G. arcuata* were comparable to those reported for several other species of the genus *Gracilaria*.

Agar has many applications depending on its quality. Properties that determine its quality include the melting and gelling temperatures, gel strength, breaking strength, cohesiveness, breaking energy and rigidity. Agar from *Gracilaria* species is widely used in food preparation. In this study, the standing stock of *Gracilaria salicornia*, which is one of the most abundant *Gracilaria* species along the coast of Iligan Bay, its nutritional composition, agar yield and quality are presented.

Materials and methods

Study area

Collections were made at the intertidal flat of Barangay Minaulon, Bacolod, Lanao del Norte (08° 11’ 50” North Latitude 124° 3’ 2” East Longitude). Barangay Minaulon was chosen as the sampling area because of its high diversity in *G. salicornia*. The intertidal area was covered mostly by seagrass and seaweeds. Landward was a mangrove forest and seaward was a coral reef. The major substratum consists of a mixture of sand and rocks.

Plant collection

The red seaweed *G. salicornia* were collected randomly during low tide in 2016. Sampling for abundance and biomass estimation was carried out according to English *et al.* (1997). In the laboratory, samples were sorted and washed thoroughly with tap water to remove rock debris and epiphytes. Plants for biomass determination were then dried in an oven at 105°C to a constant weight, while plants for biochemical components and agar extraction were rinsed with tap water and dried first in the sun and then oven dried at 60°C to constant weight.

Protein, fat, carbohydrate, ash and moisture analysis

Dried samples of *G. salicornia* were ground into powder and were brought to the Chemical Testing Laboratory of the Department of Science and Technology, Cagayan de Oro City for analysis. Analysis of crude protein was done using Kjeldahl method, total fat by hydrolysis and solvent extraction method, ash content by dry ashing procedure, moisture content by air oven method, and total carbohydrate content by computational method [Carbohydrate = 100% - (% protein + % fat + % ash + % moisture)]. The method used for the analysis of crude protein, total fat, ash content and moisture content was based on OMA AOAC (2008) and the values were expressed as percentage on dry weight basis.

Agar extraction and quality determination

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). Agar gelling and melting temperature and gel strength at 1.5% w/v was tested according to Oyieke (1993). Other physical properties such as breaking strength, deformation or cohesiveness, breaking energy and rigidity were tested following the method of Hurtado-Ponce and Umezaki (1988) with some modifications.

Results and discussion

Abundance and biomass

The abundance of *G. salicornia* represented by percent cover was 67.53±51.43% and its biomass was 218.35±74.20 g/m², respectively. This value was higher than the highest biomass value (~20 g/m²) obtained for the same seaweed species harvested from Negros Islands in the Philippines (Calumpong *et al.*, 1999) and likewise along the Tanzanian coast ([Cover: 20.00±22%; Biomass: 59.80±66.00g/m²] Buriyo and Kivaisi, 2003).

These values seemed high for sustainable commercial exploitation for agar production in this area.

Table 1. Levels of carbohydrate, protein, total fat, ash and moisture content measured in *G. salicornia* (mean ± SD). Values are presented as percent (%) dry weight.

Nutritional Composition	
Carbohydrate	24.94 ± 1.70
Protein	5.12 ± 0.4
Total Fat	0.48 ± 0.02
Ash	4.75 ± 0.75
Moisture	64.74 ± 1.91

Nutritional composition

In this study, the carbohydrate content of *G. salicornia* was 24.94±1.70. Carbohydrate in seaweeds is of immense importance since it is utilized as a good source of dietary fibers for human nutrition (Baghel *et al.*, 2014). Red seaweeds were reported to have high carbohydrate content compared to other group of seaweeds (Fleurence, 1999; Ahmad *et al.*, 2012). The protein content was 5.12±0.44% and the value was comparable to the sample obtained from Oheshm, Iran ([9.58±0.15]; Tabarsa *et al.,* 2012).

Seaweed protein is called complete protein with all the essential amino acids at levels close to that recommended by FAO/WHO (Wong and Cheung, 2000; Matanjun *et al.,* 2009) and higher protein content are recorded in green and red seaweeds [(average: 10-30% of dry weight); Wong and Cheung, 2001]. The total fat content in *G. salicornia* was 0.48±0.02%. Generally, seaweeds have very low total fat contents (Dawes, 1998). Moreover, the moisture content was 4.75±0.75% and ash content was 64.74±1.91%; and the value was higher than those specified for terrestrial counterparts with only 5% - 10% dry weight (USDA, 2001). Such higher ash contents were reported to contain microelements important for human and animal nutrition (Mantanjun *et al.,* 2009).

Agar yield and physical properties

The agar yield was 2.18±0.22% and this value was relatively lower when compared to the previous studies done on *Gracilaria salicornia* (Hurtado-Ponce and Umezaki, 1988; Calumpong *et al.,* 1999; Buriyo and Kivaisi, 2003) which might be due to the method used in agar extraction (Buriyo and Kivaisi, 2003). In this study, the seaweed sample was treated with alkali (5% NAOH) and this sometimes results to the degradation of polysaccharides and loss of agar by diffusion during the extraction process, as suggested by authors (Freile-Pelegrin and Murano, 2005). Similar result was observed by Buriyo and Kivaisi (2003) where alkali treated sample of *Gracilaria salicornia* had reduced to 31-56 % in Oyster Bay, Dar es Salaam and 25-35 % in Chwaka Bay, Zanzibar. In contrast, other studies showed higher agar yield when treated with alkali (Hurtado-Ponce and Umezaki, 1998; Arvizu-Higuera *et al.,* 2008). In addition, environmental changes brought about by season would also affect the agar yield of seaweeds even in tropical habitats (Nelson *et al.,* 1983). In this study, collection of *G. salicornia* was done during northeast monsoon or "amihan". This season is characterized by low nutrients, elevated light intensity, temperature and salinity (Buriyo and Kivaisi, 2003). This condition might have affected the agar yield of *G. salicornia* hence the value was low.

Table 2. Yield and physical properties of agar extracted from *G. salicornia*.

	Value
Yield (%)	2.18 ± 0.22
Gel strength (g cm^{-2})	70.87 ± 14.07
Gelling temperature (°C)	32.65 ± 2.29
Melting temperature (°C)	80.13 ± 0.25
Breaking strength (g)	131.38 ± 3.50
Cohesiveness (mm)	5.00 ± 0.93
Breaking energy (g mm)	659.63 ± 138.62
Rigidity (g mm^{-1})	26.99 ± 4.38

The average gel strength of *G. salicornia* was 70.87±14.07 g cm^{-2} and lower than those reported in previous studies for the same species because gel strength of agar would vary depending on season of harvest, location and extraction process (Hoyle, 1978; Kumar and Fotedar, 2009; Villanueva *et al.,* 2010; Muñoz and Fotedar, 2011). According to Yaphe and Duckworth (1972) and Hurtado-Ponce and Umezaki (1998), agars extracted from *Gracilaria* species normally form soft and elastic gels and are mainly used in food industry rather than in bacteriological applications. Moreover, the United States Pharmacoepia standards require that agars have a congealing temperature between 32°C – 39°C and that they do not melt below 85°C. The gelling temperature (32.65±2.29°C) of agar extracted from *Gracilaria salicornia* was within the range specified by United States Pharmacoepia but it had a low melting temperature (80.13±0.25°C). Similar result was observed by Hurtado-Ponce and Umezaki (1988), Oyieke (1993, 1994) and Calumpong *et al.* (1999) on the gelling and melting temperature of *G. salicornia* sampled from different areas. Other physical properties of agar extracted from *G. salicornia* such as the breaking strength (131.38±3.50), cohesiveness (5.00±0.93), breaking energy (659.63±138.62), and rigidity (26.99±4.38) were comparable to the study of Hurtado-Ponce and Umezaki (1988) for the same species.

Conclusion

The abundance and standing stock of wild populations of *Gracilaria salicornia* were high for sustainable commercial exploitation of this red seaweed for agar production in Iligan Bay. Also, its nutritional composition was within the values specified for seaweeds, hence there is a potential for this species to be used as raw material or ingredients in human diet and animal feed. However, similar to other studies using the same species its agar quality is below the standard for commercial bacteriological agar therefore, it can only be used in applications that require soft gels unless its quality is improved.

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References

Ahmad F, Sulaiman MR, Saimon W, Yee CF, Matanjun P. 2012. Proximate compositions and total phenolic contents of selected edible seaweed from Semporna, Sabah, Malaysia. Borneo Science **31,** 74-83.

AOAC 2008. Official Methods of Analysis of AOAC International, 18th Edition, AOAC International Publisher, Gaithersburg.

Arvizu-Higuera DL, Rodríguez-Montesinos YE, Murillo-Álvarez JI, Muñoz-Ochoa M, Hernández-Carmona G. 2008. Effect of alkali treatment time and extraction time on agar from *Gracilaria vermiculophylla.* Journal of Applied Phycology **20(5),** 515-519. https://dx.doi.org/10.1007/sl08lI-007-9258-4

Baghel RS, Kumari P, Bijo AJ, Gupta V, Reddy CRK, Jha B. 2011. Genetic analysis and marker assisted identification of life phases of red alga *Gracilaria corticata* (J. Agardh). Molecular Biology Reports **38(6),** 4211-4218.
https://dx.doi.org/10.1007/s11033-010-0543-y

Baghel RS, Kumari P, Reddy CRK, Jha B. 2014. Growth, pigments, and biochemical composition of marine red alga *Gracilaria crassa*. Journal of Applied Phycology **26(5),** 2143-2150.
https://dx.doi.org/10.1007/s10811-014-0250-5

Buriyo AS, Kivaisi AK. 2003. Standing stock, agar yield and properties of *Gracilaria salicornia* harvested along the Tanzanian Coast. Western Indian Ocean Journal of Marine Science **2(2),** 171-178.
https://dx.doi.org/10.4314/wiojms.v2i2.28433

Calumpong HP, Maypa A, Magbanua M, Suarez P. 1999. Biomass and agar assessment of three species of *Gracilaria* from Negros Island, central Philippines. Hydrobiologia **398/399**, 173-182
https://dx.doi.org/10.1007/978-94-011-4449-0_20

Dawes CJ. 1998. Marine botany. New York: John Wiley & Sons, Incorporated.

English S, Wilkinson C, Baker V. 1997. Survey manual for tropical marine resources (2nd ed.). Australian Institute of Marine Science.

Fleurence J. 1999. Seaweed proteins: biochemical, nutritional aspects and potential uses. Trends in Food Science and Technology 10(1), 25-28.
https://dx.doi.org/10.1016/S0924-2244(99)00015-1

Freile-Pelegrin Y, Murano E. 2005. Agars from three species of *Gracilaria* (Rhodophyta) from Yucatán Peninsula. Bioresource Technology **96(3)**, 295-302.
https://dx.doi.org/10.1016/j.biortech.2004.04.010

Hoyle MD. 1978. Agar studies in two *Gracilaria* species (*Gracilaria bursapastoris* (Gmelin) Silva and *Gracilaria coronopifolia,* C. Agardh.) from Hawaii. II. Seasonal aspects. Botanica Marina, **21(6)**, 347-352.
https://doi.org/10.1515/botm.1978.21.6.347

Hurtado-Ponce AQ, Umezaki I. 1988. Physical properties of agar gel from *Gracilaria* (Rhodophyta) of the Philippines. Botanica Marina **31(2)**, 171-174.
https://doi.org/10.1515/botm.1988.31.2.171

Kumar V, Fotedar R. 2009. Agar extraction process for *Gracilaria cliftonii*, Carbohydrate Polymers **78(4),** 813-819.
https://dx.doi.org/10.1016/j.carbpol.2009.07.001

Matanjun P, Mohamed S, Mustapha NM, Muhammad K. 2009. Nutrient content of tropical edible seaweeds, *Eucheuma cottonii, Caulerpa lentillifera* and *Sargassum polycystum*. Journal of Applied Phycology **21(1)**, 75-80.
https://dx.doi.org/10.1007/s10811-008-9326-4

McDermid KJ, Stuercke B. 2003. Nutritional composition of edible Hawaiian seaweeds. Journal of Applied Phycology, **15(6)**, 513-524.
https://dx.doi.org/10.1023/B:JAPH.0000004345.31686.7f

Munoz J, Fotedar R. 2011. Seasonal variations of agar extracted from different life stages of *Gracilaria cliftonii* (Gracilariales, Rhodophyta) from Western Australia. African Journal of Marine Science **33(1),** 59-65.
https://dx.doi.org/10.2989/1814232X.2011.572337

Nelson SG, Yang SS, Chiang YM. 1983. Yield and quality of agar from species of *Gracilaria* (Rhodophyta) collected from Taiwan and Micronesia. Botanica Marina **26(8),** 361-366.
https://dx.doi.org/10.1515/botm.1983.26.8.361

Oyieke HA. 1993. The yield, physical and chemical properties of agar gel from *Gracilaria* species (Gracilariales, Rhodophyta) of the Kenya Coast. Hydrobiologia, **261**, 613–620.
https://dx.doi.org/10.1007/978-94-011-1998-6

Oyieke HA. 1994. The effect of phenotypic plasticity on agar from *Gracilaria salicornia* (J. Agardh.) Dawson (Gracilariales, Rhodophyta) in Kenya. Bioresource Technology **49(3),** 267-271. https://dx.doi.org/10.1016/0960-8524(94)90051-5

Rath J, Adhikary SP. 2004. Effect of alkali treatment on the yield and quality of agar from red alga *Gracilaria verrucosa* (Rhodophyta, Gracilariales) occurring at different salinity gradient of Chilika lake. Indian Journal of Marine Sciences, **33(2)**, 202-205. http://nopr.niscair.res.in/handle/123456789/1668

Santos GA. 1990. A manual for the processing of agar from *Gracilaria*. ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project. Retrieved from: http://www.fao.org/3/a-ag156e.pdf

Sumile K, Orbita MLS, Mag-aso AV, Orbita RR. 2015. Proximate composition and agar content of selected red seaweeds in Initao, Misamis Oriental, Mindanao, Philippines. Advances in Agriculture & Botanics – International Journal of the Bioflux Society **7(2),** 115-121.

Tabarsa M, Rezaei M, Ramezanpour Z, Waaland JR. 2012. Chemical compositions of the marine algae *Gracilaria salicornia* (Rhodophyta) and *Ulva lactuca* (Chlorophyta) as a potential food source. Journal of the Science of Food and Agriculture **92(12)**, 2500-2506. https://dx.doi.org/10.1002/jsfa.5659

USDA. 2001. Agricultural Research Service. Nutrient Database for Standard Reference, Release 14.

Villanueva RD, Sousa AMM, Gonçalves MP, Nilsson M, Hilliou L. 2010. Production and properties of agar from the invasive marine alga, *Gracilaria vermiculophylla* (Gracilariales, Rhodophyta). Journal of Applied Phycology **22(2),** 211-220. https://dx.doi.org/10.1007/s10811-009-9444-7

Wong KH, Cheung PCK. 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(4),** 475-482. https://dx.doi.org/10.1016/S0308-8146(00)00175-8

Wong KH, Cheung PCK. 2001. Nutritional evaluation of some subtropical red and green seaweeds part II. In vitro protein digestibility and amino acid profiles of protein concentrate. Food Chemistry **72(1),** 11-17. https://dx.doi.org/10.1016/S0308-8146(00)00175-8

Yaphe W, Duckworth M. 1972. The relationship between structures and biological properties of agars. Proceedings of the 7th International Seaweed Symposium, University of Tokyo Press, Tokyo. **7**, 15-22.