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RESEARCH ARTICLE

Proximate Composition, Trace and Macro Element, and Heavy Metal Content of Edible Seaweed *Solieria robusta* in Tawi-Tawi, Philippines

Kingpu O. Ajik[1] • Albaris B. Tahiluddin[1,2]✉

[1]Mindanao State University-Tawi-Tawi College of Technology and Oceanography, College of Fisheries, Sanga-Sanga, Bongao, Tawi-Tawi/Philippines
[2]Kastamonu University, Institute of Science, Department of Aquaculture, Kastamonu/Türkiye

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ABSTRACT

Solieria robusta is a red seaweed consumed widely by the local population in the southern Philippines. However, current information regarding its proximate composition, trace and macro element, and heavy metal content is lacking. This study marks the first attempt in the Philippines to ascertain the proximate composition, trace and macro element, and heavy metal content of edible seaweed *S. robusta*. Our findings revealed that *S. robusta* primarily consists of ash content, measuring 44.30 ± 0.4 g/100 g, followed by carbohydrates at 32.96 ± 0.45 g/100 g. The moisture content of dried *S. robusta* was 16.91±0.04 g/100 g. The crude protein content of this edible seaweed was determined to be 5.61 ± 0.05 g/100 g, with total fat noted at 0.22 ± 0.01 g/100 g. The average concentration of trace elements (Zn, Fe, Mg, and Cu), macro element (K), and heavy metals (Pb and Cd) followed the order of Zn > Fe > K > Mg > Pb > Cu > Cd. Notably, three essential minerals -Zn, Fe, and K- were present in significant quantities in *S. robusta*, with concentrations of 219±8.70, 209±5.75, and 9.83±0.22 mg/kg, respectively. However, one trace element, Zn, and one heavy metal, Pb, exceeded the permissible values, and the rest were within the safe limits. This study constitutes a significant contribution to the comprehension of the nutritional profile and mineral composition of *S. robusta*, emphasizing its potential as a valuable dietary resource.

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1. Introduction

Seaweeds, commonly consumed in various cultures, offer a plethora of health benefits due to their rich nutritional profile. Packed with essential vitamins, minerals, and antioxidants, seaweeds contribute to overall well-being and can potentially support various bodily functions (Michalak & Chojnacka, 2018). They are particularly renowned for their high iodine content, which is crucial for thyroid function and the prevention of iodine deficiency disorders. Seaweeds also contain bioactive compounds such as fucoidans, which exhibit anti-inflammatory and anti-cancer properties (Sakthivel & Devi, 2019; Amlani & Yetgin, 2022). Additionally, the fiber content in seaweeds may aid digestion and promote a healthy gut microbiome (Praveen et al., 2019). Research suggests that the consumption of seaweeds may contribute to cardiovascular health by helping to regulate blood pressure and cholesterol levels (Cardoso et al., 2015). Furthermore, their potential anti-diabetic properties and role in weight management make them a valuable addition to a

✉Correspondence
E-mail address: albarist20@gmail.com

balanced diet (Chin et al., 2015). Incorporating seaweeds into one's regular nutritional intake could thus offer a range of health advantages, supporting both preventive and therapeutic aspects of overall wellness (Brown et al., 2014).

Solieria spp., a member of the Solieriaceae family within the Gigartinales order of Rhodophyta, exhibits a diverse habitat range spanning from marine environments to low-salinity estuarine settings. These red macroalgae, rich in carrageenans - linear sulfated galactans- hold considerable significance in various industries such as food, cosmetics, and pharmaceuticals, owing to their valuable properties as gelling, thickening, and stabilizing agents (Burlot et al., 2023). *Solieria robusta*, a seaweed that varies in color from yellowish brown to reddish, is typically found thriving in intertidal reef flats. It grows in rocky-sandy substrates and coral rubble and can even anchor itself to other marine animals, such as sponges (Ganzon-Fortes et al., 2006). As an edible seaweed popularly consumed by the Tausug and Sama/Badjao natives of Mindanao, Philippines, this seaweed is usually harvested from the wild and sold in local markets. It is commonly prepared and enjoyed as fresh salads, garnished with sliced onions, tomatoes, slivers of green mango, and a touch of vinegar (Tito & Liao, 2000). Furthermore, *S. robusta* possesses antifungal properties (Khanzada et al., 2007), which suggest its potential use as an organic fertilizer to address root diseases in crops (Sultana et al., 2011). In Tawi-Tawi, Philippines, the seaweed flora exhibits remarkable diversity, with 81 species cataloged to date (Puig-Shariff, 2015; Tahil & Liao, 2019; Dumilag et al., 2021). One of the edible seaweeds famous among locals is the *S. robusta*. Locally known as 'gulaman', this red seaweed is popularly sold in the local market and is known for its delicacy prepared as a salad (Dumilag, 2019).

Trace and macro elements play vital roles in sustaining health, participating in essential processes that keep the body functioning optimally. Macro elements like calcium, phosphorus, magnesium, sodium, and potassium are required in larger quantities and are pivotal for functions such as maintaining strong bones, supporting nerve function, and facilitating muscle contractions. These elements also contribute to energy metabolism and cellular communication. Conversely, trace elements like iron, zinc, copper, selenium, and iodine are necessary in smaller amounts but are equally indispensable. Iron aids in oxygen transport, zinc supports the immune system, and copper assists in wound healing. Acting as cofactors for enzymes, these elements ensure the smooth progression of critical biochemical reactions. Imbalances or deficiencies in trace and macro elements can lead to health complications, underscoring the importance of a balanced diet rich in these essential nutrients for overall health and disease prevention (Prashanth et al., 2015; Nieder et al., 2018; Skalnaya & Skalny, 2018). Heavy metals, crucial among inorganic pollution parameters, naturally occur in the Earth's crust and are non-degradable. While essential metals like copper and selenium are vital for human metabolism, they can become toxic when they accumulate in organisms beyond a certain concentration. Some heavy metals exhibit strong toxicity even in minute amounts and can be present in water as free ions, organic or inorganic compounds, or absorbed by particulate matter (Merian, 1991; Egemen, 1999).

Studies on the nutritional components, trace and macro element and heavy metal contents of edible seaweeds remain scarce. Therefore, this work determined the nutritional composition, trace and macro elements, and heavy metal content of edible seaweed *S. robusta* obtained from Batu-Batu Public Market in Panglima Sugala, Tawi-Tawi, Philippines. To the best of our knowledge, the present study is the first to report the proximate composition, trace and macro element, and heavy metal content of edible seaweed *S. robusta* in the Philippines.

2. Materials and Methods

2.1. Study Site and Collection

The sampling site is the Batu-Batu Public Market (5°04'12'' N, 119°53'01'' E), one of the major public markets in Tawi-Tawi, Philippines. During the market operation, edible seaweed, *S. robusta*, was purchased in fresh state form from the vendor on August 2023.

2.2. Sample Processing and Drying

An edible seaweed sample, *S. robusta*, was transported to the Fish Processing Laboratory, College of Fisheries, Mindanao State University-Tawi-Tawi College of Technology and Oceanography. These were washed carefully and dried under the sun for 3-4 days and were sent to DOST-Region IX at Zamboanga City, Philippines, for analysis. The drying process was necessary since the analyses of samples were done in a dried form, and the results were expressed as mg per kg dried weight.

2.3. Trace and Macro Element and Heavy Metal Determination

Different trace elements (Fe, Mg, Zn, and Cu), macro element (K), and heavy metals (Cd and Pb) of edible seaweed *S. robusta* (dried form) were determined through the flame atomic absorption spectrophotometric method with dry ashing digestion technique (AOAC, 2016).

2.4. Nutritional Content Analysis

The proximate composition (moisture content, crude protein, total fat, ash, and carbohydrates) of the edible seaweed (*S. robusta*) samples, which were in a dried form, was determined using AOAC (2016). The moisture content of the edible seaweed was determined using the gravimetric method (air-oven drying at 65 °C). Crude protein was investigated using the Kjeldahl method (Block digestion and steam distillation). Total fat was analyzed using the

Randall/Soxtec/Ether extraction-submersion method with acid hydrolysis. Ash content was determined using the gravimetric method (Furnace at 600 °C). Lastly, the carbohydrate determination was done by obtaining the difference of the above compositions from 100.

Figure 1. Wet and dried edible seaweed S. *robusta*.

3. Results

The nutritional composition of the edible seaweed (*S. robusta*) in the present study is depicted in Figure 1. *S. robusta* is mainly composed of ash content of 44.30 ± 0.4 g/100 g, followed by carbohydrates with 32.96 ± 0.45 g/100 g. The moisture content of dried *S. robusta* was 16.91 ± 0.04 g/100 g. The crude protein of this edible seaweed was found to be 5.61 ± 0.05 g/100 g, and the total fat was noted at 0.22 ± 0.01 g/100 g.

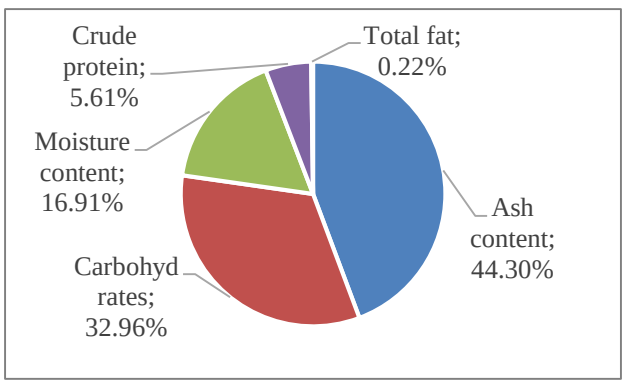

Figure 1. Proximate composition of edible seaweed *Solieria robusta* (dried sample).

The concentrations of determined trace and macro elements and heavy metals in the edible seaweed *S. robusta* are presented in Table 1. On average, the trace and macro elements and heavy metals are ranked in the following order: Zn > Fe > K > Mg > Pb > Cu > Cd. This implies that Zn and Fe are the most abundant trace elements in *S. robusta*. Specifically, the seaweed contains a significant amount of Zn (219±8.70 mg/kg) and Fe (209±5.75 mg/kg). Additionally, the K content was 9.83±0.22 mg/kg, while Mn was recorded at 5.95±0.36 mg/kg. Pb was present at 2.64±0.18 mg/kg, Cu at 1.55±0.02 mg/kg, and Cd was below the method detection limit. While the rest are within the safe limits set by FAO/WHO, one trace element, Zn, and one heavy metal, Pb, exceeded the permissible values.

Table 1. Trace element, macro element, and heavy metal content (mg/kg) of dried edible seaweed *Solieria robusta.*

Trace element				**Macro element**	**Heavy metal**	
Iron (Fe)	Manganese (Mn)	Zinc (Zn)	Copper (Cu)	Potassium (K)	Cadmium (Cd)	Lead (Pb)
209±5.75	5.95±0.36	219±8.70	1.55±0.02	9.83±0.22	<MDL	2.64±0.18

4. Discussion

Solieria spp., like other red seaweeds, are known for their high nutrient content. This makes them valuable in enhancing the nutrition of species like the olive flounder. Gunathilaka et al. (2021) showed positive results in their study on fish performance. Our research in the Philippines focuses on the proximate composition, trace element (Fe, Zn, K, and Cu), macro element (K), and heavy metal content (Cd and Pb) of the edible seaweed S. *robusta*. Since this is the first study on this topic, we could not make a direct comparison with existing research on the same species. Our findings broadly align with reported ranges for red seaweeds worldwide, often surpassing others, as detailed by Ullah et al. (2023). Various factors, including spatial and seasonal variations, geographical distribution, reproductive status, abiotic parameters, and species, influence seaweed's chemical composition, as discussed by Adharini et al. (2020). For instance, *S. filiformis*, a related species, cultivated in integrated multi-trophic aquaculture (IMTA), revealed water-soluble extracts with carbohydrate content ranging from 7.9% to 11.6%, protein levels between 12.3% and 12.8%, and lipids accounting for 0.67% to 0.72%, as documented by Peñuela et al. (2018). In comparison to other tropical edible seaweeds, our study found that *S. robusta* has lower protein content (5.61%), depending on geographical location. This falls within the range of 1.03% to 23.62% for *Kappaphycus alvarezii*. Additionally, it has less protein than edible *Caulerpa* species (which have between 10.41% and 21.52%), as reported by various researchers (Matanjun et al., 2009; Nagappan & Vairappan, 2014; Ahmad et al., 2016; Wahidatul et al., 2019; Zhang et al., 2020; Zuldin et al., 2021). Carbohydrates dominate as the primary constituent, making up nearly 33% of the composition in our study of edible seaweed *S. robusta*. Our results on carbohydrate content exceed those reported for the edible seaweed *K. alvarezii* (5-23%) by Suresh Kumar et al. (2015) and Adharini et al. (2020), yet fall short of the levels reported for edible *Caulerpa* species (37-50%) in prior studies (Matanjun et al., 2009; Nagappan & Vairappan, 2014; Ahmad et al., 2016; Zhang et al., 2020; Zuldin et al., 2021).

Trace elements (Fe, Mn, and Cu), macro element (K), and heavy metal (Cd) were within the safe limits of WHO, the US (EPA and FDA), and EMA. This indicates that the coastal waters of Tawi-Tawi are not heavily polluted by these elements and heavy metals, similar to findings reported by Imlani et al. (2022). However, one trace element, Zn, and one heavy metal, Pb, exceeded the permissible values set by FAO/WHO. As an edible seaweed, the high but safe content of Fe and K, with concentrations of 219±8.70 and 9.83±0.22 mg/kg, respectively, is beneficial for consumers, considering that locals have less access to these minerals from other sources rather than seafood. Regular consumption of seafood (e.g., edible seaweed *S. robusta)* that is rich in essential minerals like Zn, Fe, and K can have significant positive implications for human health. Zinc (Zn), a critical component for a robust immune system, aids in the activation and production of immune cells, bolstering the body's defense against infections. Additionally, it plays a pivotal role in wound healing and tissue repair, showcasing its importance in maintaining overall health (Prasad, 2008). However, precautions are necessary as the edible seaweed *S. robusta* contains an excessive amount of Zn that may be harmful with regular consumption. Elevated levels of zinc in the human body can lead to adverse health effects, including but not limited to gastrointestinal disturbances, such as nausea and vomiting, and interference with the absorption of other essential minerals like copper and iron. Prolonged exposure to high zinc intake may also compromise immune function and result in chronic conditions (Prasad, 2008; Plum et al., 2010; Wani et al., 2017). Therefore, it is imperative to monitor and regulate the intake of *S. robusta* to mitigate the potential negative impacts on human health. Iron (Fe), on the other hand, is indispensable for preventing anemia, as it is vital for the production of hemoglobin, the protein responsible for oxygen transport in red blood cells. Furthermore, iron is a key player in energy production, ensuring optimal metabolic function. For cognitive development, particularly in children, maintaining adequate iron levels is crucial (WHO, 2001). Potassium (K), another essential mineral abundant in seafood, plays a dual role in regulating blood pressure and supporting heart health. By counteracting the effects of sodium, potassium helps maintain healthy blood pressure levels, reducing the risk of hypertension-related complications. Moreover, it aids in normal muscle and nerve function, contributing to overall bodily well-being (Whelton et al., 1997). Embracing a diet that includes seafood rich in these minerals, such as edible seaweed *S. robusta*, can offer a multifaceted approach to achieving and sustaining optimal health. However, it is important to exercise moderation, as excessive intake of certain minerals can lead to adverse effects.

Furthermore, it is surprising that edible seaweed *S. robusta*, collected from the sampling site in August, contained a higher Pb content exceeding the permissible value. Pb is deemed the most significant toxic heavy element in the environment. When consumed above the limit, it has deleterious effects on humans,

such as respiratory issues, reproductive problems, neurological disorders, birth defects, cancer, and other adverse effects (Ara & Usmani, 2015). Generalizing the findings is still challenging because there are numerous sources of this edible seaweed supplying the market, and some consumers directly collecting from the wild may bring it immediately to their tables.

5. Conclusion

The consumption of *Solieria robusta* by local communities in the southern Philippines holds significant implications. As revealed by the present study, this edible seaweed offers a nutrient-rich addition to their diet, potentially addressing nutritional gaps. Essential minerals like Fe and K provide potential health benefits, supporting immune function and overall well-being. However, it contains higher values of Zn and Pb above the recommended limits. Additionally, recognizing the nutritional value of *S. robusta* may lead to economic opportunities through its cultivation. Sustainable harvesting practices can be implemented, ensuring long-term viability. Culturally, *S. robusta*, known as 'gulaman', carries important traditions and strengthens cultural ties within the community. In sum, this study's findings have broad-reaching impacts on the health, economy, and cultural heritage of the local population. Therefore, further studies need to be investigated as other consumers depend on different locations, and the month of the collection might also influence the overall nutritional and elemental contents of this edible seaweed.

Conflict of Interest

The authors declare no conflict of interest.

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