

# From Waste to Wealth: Nutritional, Ecological and Economic Valorization of the Drifting Brown Algae (*Sargassum spp.*)

## Abstract

The seasonal influx of the drifting brown algae (*Sargassum spp.*) along the Lagos Commodore Channel creates significant ecological and economic challenges, while also offering an underexplored opportunity for sustainable utilization. This study examines the nutritional profile, mineral content, bioactive properties, and environmental safety of dried *Sargassum spp.* with the aim of evaluating its suitability for value-added economic use and environmentally responsible applications. Drifting samples of *Sargassum spp.* were harvested from the offshore regions of Lagos Commodore Channel, Nigeria. Samples were rinsed with clean water, oven-dried at a temperature of 45°C for a period of 48 hours, milled and prepared for analysis. Proximate analysis revealed higher nitrogen-free extract ( $48 \pm 1.03\%$ ), crude protein ( $15.2 \pm 0.51\%$ ), and ash ( $13.5 \pm 0.11\%$ ) contents, making it ideal for use in feed and fertilizer production. Mineral analysis was found to be rich in potassium ( $4,100 \pm 2.52$  mg/100g), sodium ( $2,400 \pm 0.61$  mg/100g), calcium ( $1,451 \pm 4.11$  mg/100g), and iodine ( $35 \pm 1.06$  mg/100g), making it ideal for utilization in production of nutraceuticals and agricultural pest control products. The presence of bioactive compounds, flavonoids, saponins, and tannins, reflects its invaluable properties in treatment and prevention of diseases and antioxidant properties. Anti-nutrients present include phytic acid and oxalates, both of which are present in safe levels and suitable for use as feed. The detection levels of heavy metals in *Sargassum spp.* show low presence of cadmium (0.098 mg/kg), and arsenic (0.52 mg/kg), both of which are below regulatory standards, while lead and mercury could not be detected in analysis. These findings demonstrate that dried *Sargassum spp.* from the Lagos Commodore Channel is nutritionally rich, environmentally safe, and suitable for value-added applications. Its favorable biochemical composition and low contaminant levels support sustainable integration into agro-industrial, nutraceutical, and environmental remediation sectors, offering a practical pathway for transforming marine waste into a valuable resource.

**Keywords:** *Sargassum spp.*, commodore channel, valorization, circular economy, nutritional composition

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## Introduction

Increasing proliferation of drifting brown algae, especially *Sargassum spp.*, at tropical shorelines has developed as a serious ecological and economic concern. During the last few years, immense blooms hit shores in the Caribbean, West Africa, and the Gulf of Mexico, causing severe disturbances to marine ecosystems and tourism fisheries.<sup>1,2</sup> The Lagos Commodore Channel of Nigeria also presents a case of seasonal surges of *Sargassum* biomass, which is subsequently discarded in landfills with most of the drift biomass considered waste.<sup>3</sup> This small-sized marine macroalga also provides a unique opportunity for its sustainable valorization, complementary to global attempts toward the transition to circular bioeconomies and blue growth strategies. *Sargassum spp.* presents a high concentration of bioactive compounds, essential minerals, and organic matter that makes it a very promising feedstock for various applications in agriculture, pharmaceuticals, biofuels, and environmental remediation.<sup>4</sup>

Formerly considered a nuisance to the shoreline, *Sargassum spp.* is progressively being identified as a valuable resource for the blue economy.<sup>5,6</sup> Recent technologies have shown its adaptability as a material for biodegradable films, biostimulants, as well as carbon-reducing technologies.<sup>7,8</sup> In Nigeria, the utilization of *Sargassum spp.* as an abundant material also shows promise for employment

generation, shoreline clean-up, as well as improved methods for enhanced climate resilience activities.<sup>9,10</sup> Yet, its safe use as an agro-industrial and biotechnological material for environmental applications needs integral biochemical analysis, especially with regards to its suspected heavy metal concentration as well as its levels of anti-nutritional factors.<sup>11,12</sup>

Through the integration of worldwide knowledge with domestically generated information, this research seeks to shift the perspective on *Sargassum spp.* from being viewed as marine litter to being considered as a precious biological resource which can provide solutions on how *Sargassum spp.* can be utilized as a sustainable resource in agriculture, medicine, and ecological restoration for increased food security in Africa.<sup>13-16</sup> This study therefore undertakes a comprehensive biochemical and nutritional assessment of desiccated *Sargassum spp.* harvested from the Commodore Channel along the Lagos coastline, Nigeria. The investigation integrates analyses of proximate composition, mineral profile, bioactive compounds, anti-nutritional factors, and heavy metal concentrations to evaluate both nutritional potential and safety implications. By contextualizing the findings within established global research and applying them to local environmental conditions, this work seeks to reposition *Sargassum spp.* from a persistent coastal pollutant to a valuable marine bio-resource.

## Materials and methods

### Study area and sample collection

Drifting samples of *Sargassum spp.* were harvested from the offshore areas of the Lagos Commodore Channel, Nigeria (6°25'25"N, 3°24'26"E) between February and July 2025. The Lagos Commodore Channel is a dynamic estuarine environment that receives the periodic exchange of tidal seawater and freshwater. Such high nutrient environments favour the biannual blooms of the macrophyta. Harvesting *Sargassum spp.* was performed with a sterile hand net in the period of heaviest accumulations. The samples were packaged immediately in insulated containers and kept cold (4°C) to retain biochemical fractions.

### Sample preparation

The *Sargassum* biomass (Figure 1) was washed in the laboratory with ambient seawater to get rid of sand, epiphytes, and macro-debris. It was then rinsed with distilled water. Clean samples were oven-dried at 45°C for 48 hours using a laboratory dryer (Germany: FP 240 model) until a constant weight was attained (Figure 2). Dried Biomass samples were pulverized into a fine homogenous powder using a Wiley laboratory mill (Model 4, Thomas Scientific, USA). Powdered samples were sealed in an airtight container and stored at room temperature before transportation to the Biochemistry Laboratory of the College of Medicine, Lagos State University Teaching Hospital for analyses.



Figure 1 Fresh *Sargassum spp.*



Figure 2 Oven-dried *Sargassum spp.*

### Analysis of proximate and mineral composition

Proximate composition of the dried *Sargassum* samples for moisture, crude protein, crude fibre, lipid content, ash, and nitrogen-free extract (NFE) was determined using standardized procedures described by the Association of Official Analytical Chemists.<sup>17</sup> All the analyses were performed in triplicate and the results presented as per cent of dry weight.

In mineral profiling, the quantitative measurement of macrominerals such as calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), and phosphorus (P) as well as micronutrients such as iron (Fe), zinc (Zn), manganese (Mn), and copper (Cu) was done by atomic absorption spectrophotometry (AAS; Perkin Elmer AAnalyst 400). The iodine(I) values were determined by the Sandell–Kolthoff spectrophotometric method to ensure accuracy and sensitivity for marine-derived samples.

### Concentrations of bioactive compounds

Alkaloids, Flavonoids, Saponins, Tannins, and Phenolics were measured with colorimetry and gravimetry as explained by Balamurugan, 2019. Results were presented as mg of bioactive compounds per 100g of dried material.

### Analysis of antinutritional factors

Anti-nutritional factors like phytic acid, oxalates, saponins, tannins, and total polyphenols were estimated using standard spectrophotometric and titration techniques. Phytic acid estimation was carried out using the Wade reagent assay method, while the estimation of oxalates and total polyphenols was carried out using permanganate titration and the Folin–Ciocalteu method, respectively. Data were expressed in mg/g dry weight.

### Heavy metal determination

The levels of heavy elements such as cadmium (Cd), nickel (Ni), arsenic (As), lead (Pb), chromium (Cr), and mercury (Hg) were determined by the method of flame atomic absorption spectrophotometry after acid digestion by mixtures of nitric and perchloric acids. The levels of lead and mercury were given as below detection limit (BDL) if applicable. All values were within the safety levels set by the WHO/FAO for edible marine biomass.<sup>18</sup>

### Statistical analysis

The quantitative results obtained from the biochemical, mineral, phytochemical, anti-nutritional, and heavy metal composition of the samples were analyzed for descriptive purposes. Replicates were computed for accuracy in analytical measurements, and results were presented as means and their standard deviations. The results were assessed for authenticity and modes of distribution by inferential statistics available in SPSS 21.0 software.

## Results and discussion

### Analysis of proximate composition

Table 1 shows the proximate composition of dried *Sargassum spp.* The dried samples recorded relatively high nitrogen-free extract (48 ± 1.03%), crude protein (15.2 ± 0.51%), moderate fibre (10 ± 1.12%), and ash (13.5 ± 0.11%) contents. Meanwhile, its moisture and lipid were relatively low (9 ± 0.22%) and (1.8 ± 0.06%) respectively.

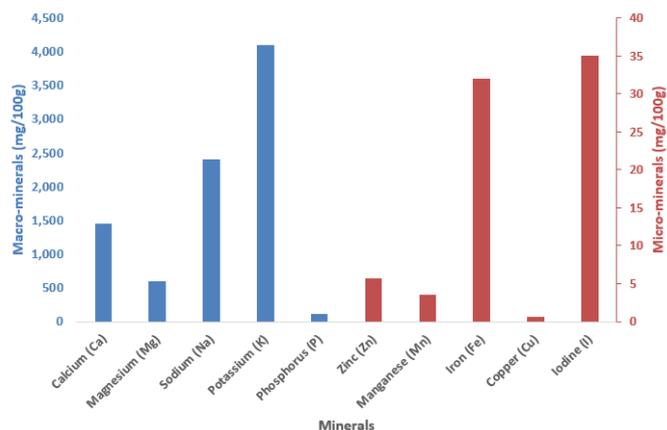
Table 1 Proximate composition of dried *Sargassum spp.*

Content	Percentage
Moisture	9.0 ± 0.22
Crude protein	15.2 ± 0.51
Crude fibre	10 ± 1.12
Fat/lipid	1.8 ± 0.06
Ash	13.5 ± 0.11
Nitrogen free extract	48 ± 1.03

Note: Value is means ± standard deviation

### Analysis of mineral composition

Macro- and micro-mineral profiles (Figure 3) reveal high concentrations of potassium ( $4,100 \pm 2.52$  mg/100g), sodium ( $2,400 \pm 0.61$  mg/100g), and calcium ( $1,451 \pm 4.11$  mg/100g). Iodine ( $35 \pm 1.06$  mg/100g) content were also notably high.



**Figure 3** Dual-axis comparative plot of macro- and micro-mineral composition (mg/100g) of dried *Sargassum spp.*

### Bioactive compounds

Table 2 details the bioactive profile. Flavonoids ( $765 \pm 3.1$  mg/100g) and saponins ( $488 \pm 1.4$  mg/100g) were highest, followed by tannins ( $116 \pm 2.1$  mg/100g), phenolics ( $73 \pm 0.3$  mg/100g), and alkaloids ( $42.5 \pm 0.5$  mg/100g).

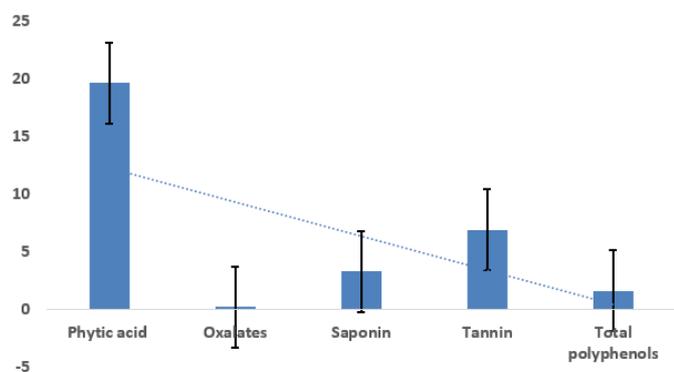
**Table 2** Bioactive compounds in dried *Sargassum spp.*

Compound	Value (mg/100g)
Flavonoids	$765 \pm 3.1$
Saponins	$488 \pm 1.4$
Tannins	$116 \pm 2.1$
Phenolics	$73 \pm 0.3$
Alkaloids	$42.5 \pm 0.5$

Note: Value is means  $\pm$  standard deviation

### Anti-nutritional factors

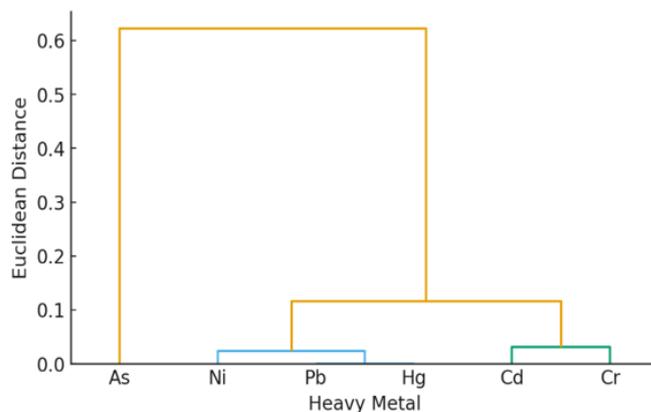
Anti-nutritional factors (Figure 4) were within acceptable limits. Phytic acid was highest ( $19.67$  mg/g), with tannins at  $6.9$  mg/g, saponins at  $3.31$  mg/g, total polyphenols at  $1.6$  mg/g, and oxalates at  $0.22$  mg/g.



**Figure 4** Anti-nutritional factors of *Sargassum spp.* (mg g<sup>-1</sup>).

### Heavy metal analysis

Heavy metal concentrations (Figure 5) were below toxic thresholds. Cadmium ( $0.098 \pm 0.98$  mg/kg), nickel ( $0.021 \pm 0.05$  mg/kg), and arsenic ( $0.52 \pm 0.09$  mg/kg) were detected, while lead and mercury were below detection limits (BDL).



**Figure 5** Dendrogram of hierarchical cluster analysis among heavy metals based on Euclidean distance.

Compositional analysis of *Sargassum spp.* from the Lagos Commodore Channel revealed great potential as a multi-use bio-resource. The low nitrogen-free extract and crude protein recorded in this study indicate that this algae is rich in carbohydrates and amino acids and can be used as bio-energy and protein additives in animal feed. These results agree with Tonon<sup>19</sup> who gave similar results for nutrients in *Sargassum species* collected from the Mexican Caribbean. Also, Sarker<sup>20</sup> reported that tropical species of *Sargassum* have been shown to have adequate energy density suitable for the production of biofuel and thus reported that the algae has bio-energy potential. The low lipid content recorded in this study is desirable for its resistance to oxidation and thus is ideal for storage and processing. This is in line with the report of Martínez-Molina<sup>7</sup> who showed that low lipid content in *Sargassum* algae makes it ideal and non-damaging due to rancidity and thus ideal for production of bioplastics. In addition, the ash content indicates the high mineral content, thus its suitability for use in making fertilizers. Holdt and Kraan<sup>21</sup> reported that, brown algae are rich in minerals and are used for improving soil fertility which agrees with the findings of this study.

Mineral profiling of this study indicated high levels of potassium, sodium, calcium, and magnesium. These levels exceeded the levels found in terrestrial crop plants and agree with the study carried out by Liu<sup>22</sup> who studied pharmaceutical and nutraceutical potential applications of *Sargassum fulvellum*. The iodine level of  $35$  mg/100g is significant, which has potential applications as an iodine supplement for iodine-deficient people. This agrees with the study carried out by Cotas<sup>23</sup> who emphasized the importance of iodine from seaweed used as a supplement for micronutrient deficiencies.

The existence of bioactive compounds like flavonoids, saponins, tannins, phenolic, and alkaloids in *Sargassum spp.* shows the medical potentiality of these algae. The results obtained are in agreement with those of Corbin<sup>10</sup> which found the same phyto-constituents in Caribbean *Sargassum*, showing antioxidant and antibacterial properties. In addition, the findings of this study are consistent with those of Swetha<sup>9</sup> who demonstrated through phytochemical profiling that *Sargassum polycystum* possesses significant antimicrobial and antioxidant activities thus, underscoring the therapeutic relevance of

this algae. This therapeutic potential is further supported by Milledge and Harvey<sup>12</sup> who highlighted the roles of bioactive constituents from brown algae in wound healing processes and metabolic regulation.

Anti-nutrient factors were within safe levels. The presence of phytic acid and oxalates was also reported to be non-interfering with mineral bioavailability. These results were consistent with the findings reported by Siddik<sup>24</sup> which assessed the safety of seaweed addition to aqua-feeds and found similar levels of anti-nutrients. The levels of saponins, tannins, and polyphenols measured in the study were also comparable to those found by Abu<sup>25</sup> which assessed the nutritional safety of *Sargassum spp.* found in the Red Sea. The results are consistent with the addition of *Sargassum spp.* to feeds and foods without any negative effects as proposed by Balamurugan<sup>26</sup>.

The heavy metals' concentration was depicted through a dendrogram, showing the clustering of heavy metals in *Sargassum spp.*, using the Euclidean distance measure. The clustering analysis showed clear demarcations based on the similarity of concentration. Cadmium (Cd) and Chromium (Cr) showed a high degree of similarity in clustering, which shows a high degree of similarity between them. Mercury (Hg) and Lead (Pb) also showed a high degree of similarity in clustering, but they were not detectable in the samples used in this study.<sup>18</sup> Nickel (Ni) showed moderate similarity to the other metals. Arsenic (As) showed the highest degree of dissimilarity, which was only evident in extreme Euclidean distance, implying that it had a high degree of uniqueness in concentration amongst all other metals. This study supports the report of Corbin<sup>10</sup> which documented low heavy metal accumulation in *Sargassum spp.* biomass collected from Caribbean beaches. The cluster analysis indicates that it was environmentally safe for controlled uses in agriculture.<sup>27,28</sup>

Economically, the use of *Sargassum spp.* from the Lagos Commodore Channel offers enormous benefits for coastal and national development. Commonly viewed as an aquatic waste, the periodic influx of these biomass materials has affected fishing, tourism, and maritime movements. But its biochemically rich nature seen in this study, namely the nitrogen-free extract value, crude protein, iodine, potassium, and importantly the value of bioactive components, clearly shows that this sea biomass is not a waste. The composition makes it ideal for application in bio-fertilizer, animal feed, and bio-stimulants.<sup>29</sup> The potentials were equally noted by Martínez-Molina<sup>7</sup> with a focus on *Sargassum* being a potential resource for biodegradable films and carbon capture techniques. Further, Martínez-Martínez<sup>30</sup> established the economic and agricultural significance of *Sargassum*, with its significant role in lowering farming expenses related to feed processing. This study supports the significance of *Sargassum spp.* in industrial aspects with a focus on sustainable resource management.

In addition, the establishment of businesses using seaweed can provide opportunities for creating jobs, particularly in harvesting, processing, and product development.<sup>31-33</sup> This is consistent with the findings of Kee<sup>34</sup>, Mohan<sup>35</sup>, and Rosas-Medellín<sup>36</sup>, who collectively reported that *Sargassum* contributes to advancing blue economy initiatives through innovative solutions that support sustainability, resource utilization, and coastal community development. Likewise, Khan<sup>8</sup> reported that the use of *Sargassum* in tropical regions supports the bio-economy paradigm, further reinforcing its role in sustainable development and commercialization prospects.

The levels of the heavy metals and anti-nutritional compounds reported in this study are further seen to be non-toxic and safe for commercialization purposes. This aligns with the findings of Corbin<sup>10</sup> where the Caribbean *Sargassum* biomass presented non-toxicity in its

biomass form, making its agricultural agri-scrape for food productive use safe for application. This is also similar to another study conducted by UNCTAD<sup>37</sup> which emphasized the role of seaweed in promoting economic growth and empowering people living near the coasts, especially women.

## Conclusion

This study shows that the brown drifting algae *Sargassum spp.* in the Lagos Commodore Channel, which was considered to be a nuisance alga, has immense potential for sustainable utilization. From proximate analysis, it was seen to contain substantial amounts of carbohydrates, proteins, and minerals, making it an excellent feedstock for animal feed, fertilizers, and fuel conversion. The mineral content, specifically the prevalence of high levels of potassium, sodium, calcium, and iodine, clearly indicates potential for applications in nutraceutical formulation, agricultural soil conditioners, and agricultural pesticides. In addition, it clearly exemplifies potential in pharmaceutical formulation, including antioxidant, antimicrobial, and disease-preventing attributes, with the prevalence of bioactive secondary compounds in it such as flavonoids, saponins, and tannins. Significantly, it has Anti-Nutritional Factor content and Heavy Metal values that were below safety standards, clearly indicating that it does not pose pollution threats to the ecosystem or to users, hence suitable for marketing. In addition to biochemical potential, other advantages of this algae utilization contribute to enhanced sustainability. These advantages include shoreline cleaning, reducing landfill pressures, relieving carbon emissions, among others. Economically, the rise of industries based on the procurement, processing, and development of products can create jobs, promote inventions, and enhance the blue economy in Nigeria. By converting marine waste to wealth, the study is in line with the global bio-economy approach in the circular economy because it intends to create wealth from waste materials in the marine environment. This study also shows the importance of incorporating *Sargassum species* in agro-industrial, pharmaceutical, and environmental applications.

## Author contributions

The research was conceptualized and implemented by Edah Bernard. Sampling for the research was conducted by Edah Bernard and Olagunju Goodness E. The biochemical and mineral analysis part of the research was done by Edah Bernard and Olagunju Goodness E. Joshua C. Igwe collaborated with other authors in sample preparation for laboratory analysis, laboratory experimentation and interpretation of data. The final composition of this research and other aspects of it were developed by Olaiya Olukayode E. The data curation for this research was handled by Olaiya Olukayode E and Edah Bernard. The contribution of this research to discussing the global perspective of the findings was developed by Edah Bernard and Olaiya Olukayode E. All the authors contributed to the manuscript from the point of conceptualization, analysis, and writing. All authors have read and approved the manuscript. Authors also agree to be responsible for all the content of the manuscript.

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None

## Conflict of interest

The authors declare that they have no known competing financial or personal interests that could have appeared to influence the work reported in this paper.

## Data availability

All data generated and analysed during this study are included in the manuscript. Additional datasets or raw data are available from the corresponding author upon reasonable request.

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