MedCrave
Step into the World of Research
Journal of Nutritional Health & Food Engineering

Research Article

Open Access

# Advancing sustainable aqua-feed policy in Africa: the role of *sargassum* derived polysaccharides

## Abstract

The rapid expansion of global aquaculture necessitates sustainable, cost-effective, and functional feed ingredients that support both production efficiency and fish health. This study investigates *Sargassum spp*., a widely distributed brown seaweed, as a viable alternative feed resource through the sequential extraction of laminarin, fucoidan and alginate. Proximate analysis revealed high carbohydrate (36.8%) and mineral content (13.5%), moderate protein (14.7%), and low lipid (2.1%), confirming the nutritional potential of the biomass. Sequential extraction yielded a total of 21.6% polysaccharides. Functional characterization demonstrated that alginate exhibits superior water holding and oil absorption capacities, while fucoidan displays potent antioxidant activity, and laminarin provides moderate immune-supportive properties. These findings provide empirical evidence aligning with policy priorities on sustainable feed development, circular bioeconomy, and reduction of antibiotic use. Incorporation of Sargassum-derived polysaccharides into aqua-feeds supports local resource valorisation, enhances pellet stability, and improves fish health, thereby addressing FAO recommendations for marine biomass utilization. This study further underscores the importance of regulatory frameworks, standardized extraction protocols, and safety assessments for large-scale implementation. By bridging experimental outcomes with policy imperatives, this research offers actionable insights for stakeholders seeking resilient, environmentally sustainable, and health-promoting aquaculture systems.

**Keywords:** Policy, Sustainable Aqua-feed, Polysaccharides, Circular-Bioeconomy

Volume 14 Issue 2 - 2026

Edah Bernard, Ukenye Esther A, Olagunju Goodness E, Ayokhai Oshio J, Odeniyi Omotayo A
Nigerian Institute for Oceanography and Marine Research (N.I.O.M.R), Nigeria

**Correspondence:** Edah Bernard, Nigerian Institute for Oceanography and Marine Research (N.I.O.M.R), 12729, 3-Wilmot Point Road, Victoria Island, Lagos, Nigeria

**Received:** April 01, 2026 | **Published:** May 07, 2026

## Introduction

The rapid growth of global aquaculture has intensified the demand for sustainable, nutritionally efficient, and cost-effective feed ingredients capable of supporting production while minimizing environmental impacts. Conventional feed resources such as fishmeal and soybean meal are increasingly limited by rising costs, ecological pressures, and competition with human food systems.[1,2] These constraints have stimulated both scientific research and policy interest in alternative feed resources that can enhance sustainability and resilience within aquaculture systems.[3]

Marine macroalgae have emerged as promising candidates due to their abundance, rapid growth rates, and rich biochemical composition. Among them, *Sargassum spp*., a dominant brown seaweed widely distributed in tropical and subtropical regions, has attracted considerable attention for its potential in aqua-feed development.[4,5] In recent years, large-scale *Sargassum* blooms in the Atlantic have created significant ecological and economic challenges, particularly along coastal regions of Africa and the Caribbean, prompting increased interest in its valorisation.[6] Converting this excess biomass into functional feed ingredients aligns with both research innovation and policy goals related to waste utilization and blue economy development. Nutritionally, *Sargassum* biomass is characterized by high carbohydrate content, moderate protein levels, and substantial mineral composition.[7–10] More importantly, its carbohydrate fraction contains structurally and biologically significant polysaccharides, including alginate, fucoidan, and laminarin, which exhibit diverse functional properties relevant to aquaculture.[11,12] Alginate is widely recognized for its gel-forming and water-binding properties, contributing to improved feed pellet stability and reduced nutrient leaching.[13] Fucoidan, a sulphated polysaccharide, demonstrates antioxidant, antimicrobial, and immunomodulatory activities that can enhance fish health and disease resistance.[12] Similarly, laminarin, a β-glucan, has been reported to exert prebiotic and immune-stimulating effects in aquaculture species.[14]

Despite Therefore, this study aims to sequentially extract laminarin, fucoidan and alginate from *Sargassum spp*. (*Sargassum natans*) and evaluate their yields and functional properties. By integrating experimental evidence with emerging sustainability considerations, the study contributes to both these promising attributes, the efficient extraction and utilization of *Sargassum*-derived polysaccharides remain a critical challenge. Conventional extraction techniques often focus on single compounds, limiting overall biomass utilization and economic feasibility. In contrast, integrated biorefinery approaches enables the sequential recovery of multiple valuable components, improving resource efficiency and supporting scalable applications.[15,16] While such approaches are gaining traction globally, there is still limited research on their optimization and functional outcomes for aqua-feed applications, particularly within West African contexts where *Sargassum* biomass is increasingly abundant.

Therefore, this study aims to sequentially extract laminarin, fucoidan and alginate from *Sargassum spp*. (*Sargassum natans*) and evaluate their yields and functional properties. By integrating experimental evidence with emerging sustainability considerations, the study contributes to both scientific understanding and the development of practical policy strategies for sustainable aqua-feed innovation.

## Materials and methods

### Study area

Samples were collected from the Commodore Channel (6°24’N, 3°23’E), Lagos, Nigeria. The channel forms the primary navigational route linking Lagos Harbour with the Atlantic Ocean and supports significant macroalgal growth due to tidal mixing and nutrient inflow.

## Sample collection and extraction of polysaccharides

Fresh drift of *Sargassum spp.* (Figure 1) were collected manually along the shoreline during low tide between February and July 2025. The collected biomass was thoroughly washed with seawater to remove sediments, epiphytes, and associated fauna, followed by rinsing with distilled water. The samples were oven-dried at 60 °C using a laboratory dryer (FP 240, Binder, Germany) until a constant weight was achieved. The dried *Sargassum spp.* were milled using a Wiley laboratory mill (Model 4, Thomas Scientific, USA). The powdered biomass was sieved through a 250 µm mesh to ensure uniform particle size and enhance solvent penetration during extraction. Initial analysis was conducted at the Central Laboratory of the Nigerian Institute for Oceanography and Marine Research (NIOMR), Lagos, after which the prepared samples were transported to BolTech Chemical Laboratory, Abuja, for further analysis. Sequential extraction of polysaccharides from Sargassum was carried out following a biorefinery approach as described by Birgersson[17] and Ummat[18] with slight modifications. Extraction was performed in the order of laminarin, fucoidan, and alginate to ensure selective recovery of water-soluble and sulphated polysaccharides prior to alkaline treatment.

**Figure 1** Fresh *Sargassum spp.* (*Sargassum natans*).

## Laminarin extraction and quantification

The pre-treated biomass was extracted with distilled water at a solid–liquid ratio of 1:20 (w/v) and heated at 80 °C for 2 h with continuous stirring. The mixture was filtered and centrifuged at 5,000–8,000 × g for 10–15 min to remove insoluble residues. The supernatant was concentrated and laminarin was precipitated by the addition of three volumes of ethanol, followed by incubation at 4 °C for 12–24 h. The precipitate was collected by centrifugation, washed with ethanol, and dried at 40–60 °C to constant weight.

## Fucoidan extraction and quantification

The residue obtained after laminarin extraction was subjected to mild acid extraction using 0.05 M HCl at a solid–liquid ratio of 1:15 (w/v) and heated at 65 °C for 2 h with continuous stirring. The mixture was filtered and centrifuged at 8,000 × g for 15 min to remove insoluble materials. The supernatant was treated with $CaCl_2$ to a final concentration of 1% (w/v) and allowed to stand for 1 h to precipitate co-extracted alginate, followed by centrifugation. Fucoidan was precipitated from the clarified extract by the addition of two volumes of ethanol and incubation at 4 °C for 12–24 h. The precipitate was collected by centrifugation, washed with ethanol, and dried at 40–60 °C to constant weight.

## Alginate extraction

The residual biomass obtained after fucoidan extraction was washed thoroughly with distilled water to neutral pH and treated with 0.2 M hydrochloric acid (HCl) for 1 h to convert insoluble alginate salts into alginic acid. The acid-treated residue was washed again with distilled water until a neutral pH was achieved and subjected to alkaline extraction using 2% (w/v) sodium carbonate ($Na_2CO_3$) at a solid–liquid ratio of 1:10 (w/v). The mixture was heated at 85 °C for 2 h with continuous stirring to solubilize the alginate. The resulting slurry was filtered through a filter paper to remove insoluble residues and obtain a clear extract. Alginate present in the filtrate was subsequently precipitated by the addition of two volumes of ethanol. The precipitated alginate was collected and dried in an oven at 60 °C until a constant weight was achieved.

## Determination of extraction yield

The extraction yield of each polysaccharide fraction (laminarin, fucoidan, and alginate) was calculated based on the dry weight of the initial seaweed biomass.

$$\text{Yield}(\%)=\frac{\text{Weight of dried polysaccharide extract}(\text{g})}{\text{Weight of dried seaweed sample}(\text{g})}\times 100$$

Where:

- Weight of dried polysaccharide extract = final dried mass after precipitation
- Weight of dried seaweed sample = initial oven-dried biomass used for extraction

All extractions were conducted in triplicate, and results were expressed as mean ± standard deviation**.**

## Analysis of proximate

The proximate composition of the dried *Sargassum spp*. samples, including moisture, crude protein, crude fibre, lipid, ash, and carbohydrate was determined using standardized methods of the Association of Official Analytical Chemists.[19] All analyses were conducted in triplicate, and results were expressed as percentages on a dry weight basis.

## Functional properties

Water holding capacity and oil absorption capacity were determined using standard gravimetric methods. Antioxidant activity was measured using the DPPH radical scavenging assay.

## Statistical analysis

All analyses were performed in triplicate and results expressed as mean ± standard deviation. Data were analyzed using one-way analysis of variance (ANOVA) followed by Duncan multiple range comparison test. Statistical significance was considered at $p < 0.05$.

# Results

## Proximate composition

The proximate composition of dried *Sargassum spp.* revealed that carbohydrates constituted the largest fraction, accounting for 36.8% of the dry weight (Table 1). This high carbohydrate content reflects the abundance of structural and storage polysaccharides typical of brown macroalgae. The ash content was also considerable (13.5%), indicating the mineral-rich nature of the biomass. Protein content was moderate (14.7%), while lipid levels were low (2.1%), consistent with the general compositional profile of marine seaweeds. The relatively low moisture content (9.4%) suggests effective drying and enhanced storage stability, while the fibre content (19.8%) indicates the presence of significant structural polysaccharides.

**Table 1** Proximate composition of dried *sargassum spp*.

| Parameter | Value (%) |
|---|---|
| Moisture | 9.4 ± 0.5 |
| Protein | 14.7 ± 0.2 |
| Lipid | 2.1 ± 0.6 |
| Ash | 13.5 ± 0.1 |
| Carbohydrate | 36.8 ± 0.5 |
| Fibre | 19.8 ± 0.1 |

Note:Values are means + SD.

## Sequential extraction of polysaccharides

Sequential extraction of *Sargassum* biomass yielded three major polysaccharide fractions: laminarin, fucoidan and alginate (Figure 2). Among these, alginate was the predominant component, with a yield of 14.8% (dry weight), reflecting its role as the principal structural polysaccharide in the brown seaweeds. In contrast, fucoidan and laminarin were obtained in lower yields of 3.2% and 3.6%, respectively. The total polysaccharide recovery was 21.6%, indicating the effectiveness of the sequential extraction process in maximizing biomass utilization.

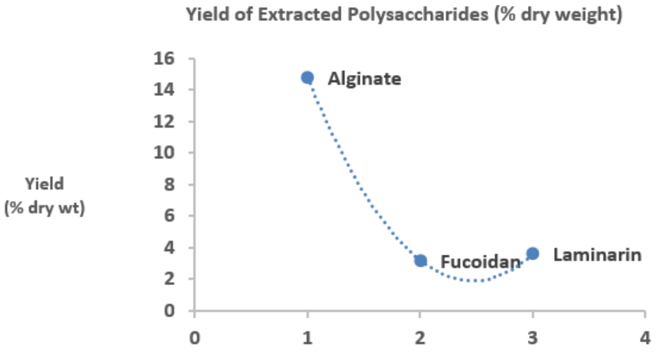

**Figure 2** Polynomial plot showing the yield of extracted polysaccharides (alginate, fucoidan, and laminarin) from *sargassum spp*., expressed as percentage of dry weight. Each point represents the mean yield (n = 3). Alginate exhibited the highest yield, followed by laminarin and fucoidan. The dotted line connects the data points to show the trend in extraction efficiency across the polysaccharides.

## Functional property

The functional properties of the extracted polysaccharides are presented in (Figure 3). Alginate exhibited the highest water holding capacity (4.6 ± 0.7 g/g), indicating strong hydration and gel-forming properties suitable for feed binding and pellet stabilization. It also showed the highest oil absorption capacity (2.4 ± 0.2 g/g), suggesting its ability to retain lipids within feed matrices. Fucoidan demonstrated the highest antioxidant activity (47.1 ± 0.2%), as indicated by DPPH radical scavenging, highlighting its potential as a bioactive component in aqua-feeds. Laminarin showed comparatively lower values across all parameters, although it maintained moderate functional properties.

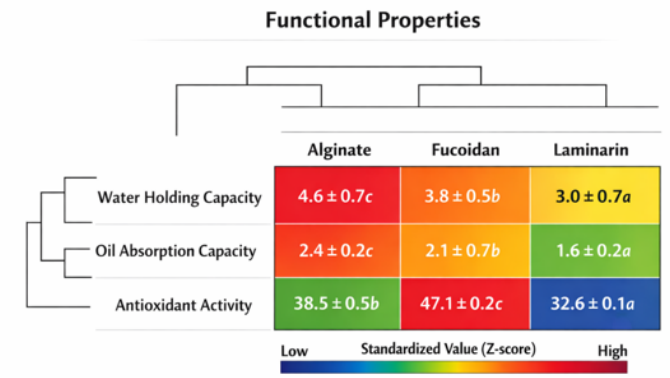

**Figure 3** Clustered heatmap showing the functional properties of polysaccharides (alginate, fucoidan, and laminarin) extracted from *sargassum spp*. Hierarchical clustering was performed using ward's method based on euclidean distance. Color intensity represents relative magnitude of each property, with red indicating higher values and blue indicating lower values. Values are expressed as mean ± standard deviation (n = 3), and different superscript letters (a–c) denote significant differences ($p < 0.05$) among samples within each property.

## Discussion

The proximate composition obtained in this study highlights the nutritional potential of *Sargassum spp*. and its relevance for aqua-feed applications. The low moisture content observed indicates effective drying and suggests enhanced storage stability, as reduced moisture limits microbial growth and prolongs shelf life. Similar moisture levels were reported by Bamidele[20] for *Sargassum* from the Badagry coast, confirming that properly dried seaweed biomass remains stable under tropical conditions. The protein content, although moderate compared to conventional plant protein sources, is significant for marine biomass and suggests that *Sargassum* can contribute to dietary protein in aqua-feeds. However, supplementation may be required in high-protein formulations. This observation agrees with Ismail[21] who reported comparable protein values in Red Sea brown seaweeds and concluded that seaweed-derived proteins enhance immune responses in fish. Similarly, Bauta[22] reported protein levels of 12–16% in Caribbean *Sargassum*, supporting its role as a supplementary protein source.

The lipid content was low, which is characteristic of brown seaweeds. This is attributed to their limited accumulation of neutral lipids, although they contain essential fatty acids of nutritional importance. Ismail[21] further noted that despite low lipid levels, seaweed lipids are rich in omega-3 fatty acids, which contribute to improved fish health. The ash content was relatively high, reflecting the rich mineral composition of marine algae due to continuous absorption of dissolved salts from seawater. This finding aligns with Delphonso,[23] who reported similar ash values in Nigerian *Sargassum* and emphasized its contribution to mineral balance in aqua-feeds. The carbohydrate fraction was predominant, indicating the abundance of structural and storage polysaccharides such as laminarin, fucoidan and alginate. This high carbohydrate content suggests that *Sargassum* can serve both as an energy source and as a functional ingredient in aqua-feed formulations. Ahmad and Turkistani[24] similarly emphasized the importance of *Sargassum* species as valuable carbohydrate resources for sustainable aquaculture. The fibre content was also substantial, reflecting the presence of structural polysaccharides and insoluble dietary components. While high fibre supports gut health and feed stability, excessive levels may reduce digestibility if not properly processed. Adharini[25] reported comparable fibre values and concluded that controlled inclusion enhances intestinal function and supports sustainable feed development.

Beyond the nutritional composition, the extraction yield of polysaccharides provides further insight into the resource potential of *Sargassum spp*. The results of this study showed that alginate had the highest yield, which is expected as it is the principal structural polysaccharide in brown seaweeds. Its localization within the cell wall matrix and its strong association with divalent cations (e.g., $Ca^{2+}$) enhance its abundance and facilitate recovery during alkaline extraction. In addition, its uronic acid-rich composition, consisting of β-D-mannuronic and α-L-guluronic acid residues, contributes to its solubility and extractability. The high yield obtained therefore suggests that alginate can serve as the bulk functional component in aqua-feeds, particularly in improving pellet cohesion and water stability. This finding is in line with Hu,[26] who reported alginate yields above 12% in *Laminaria japonica* and concluded that its structural predominance makes it the most extractable polysaccharide. Similarly, Rahman[27] emphasized that alginate consistently represents the largest fraction of brown seaweed polysaccharides which agrees with the findings of this study.

In contrast, fucoidan and laminarin were obtained in lower yields, which is attributed to their lower natural abundance and specific cellular localization. Fucoidan is primarily associated with the outer cell wall and exists as a sulphated, heterogeneous polysaccharide that may be partially lost during pre-treatment and purification processes. Despite its low yield, fucoidan remains highly valuable due to its strong bioactive properties. The findings of this study agree with Khanzadeh[28] who reported fucoidan yields of 2–4% in *Sargassum ilicifolium* and concluded that its biological activity compensates for its limited abundance. Ummat[29] also reported comparable yields and highlighted its potential in functional aqua-feeds. Similarly, Laminarin, a storage polysaccharide located in vacuoles, also exhibited a relatively low yield. Its content is known to vary depending on environmental conditions such as season, light intensity, and nutrient availability. The slightly higher yield of laminarin compared to fucoidan observed in this study may therefore reflect biological variability and extraction efficiency. Although present in modest quantities, laminarin plays an important physiological role. This observation agrees with Wu,[30] who reported laminarin yields of 3–6% and concluded that its prebiotic and immune-stimulatory functions outweigh its lower physicochemical contribution. Krishnan[31] similarly noted that laminarin yields are consistently moderate but biologically significant which agrees with the findings of this study. The total polysaccharide yield obtained in this study demonstrates the effectiveness of the sequential extraction approach in maximizing biomass utilization. This integrated recovery strategy enhances both economic value and sustainability by producing multiple functional compounds from a single raw material. A similar conclusion was reached by Otero[32] who emphasized that comprehensive extraction approaches significantly improve the overall value of seaweed biorefineries.

In addition to yield, the functional properties of the extracted polysaccharides further demonstrate their suitability for aqua feed applications. Alginate exhibited the highest water holding and oil absorption capacities, which can be attributed to its linear copolymeric structure and the presence of hydrophilic carboxyl groups. These structural features enhance water binding, swelling, and gel formation, thereby improving pellet integrity and reducing nutrient leaching in aquatic environments. This observation is consistent with Anjana and Arunkumar,[33] who reported that alginate significantly enhances feed texture and water stability. In a similar vein, Hu reported improved pellet durability with alginate inclusion, which aligns with the findings of this study. Fucoidan showed moderate water holding and oil absorption capacities but the highest antioxidant activity. This is attributed to its sulphated structure, where sulphate ester groups enhance electron-donating ability and free radical scavenging activity. The relatively lower binding capacity compared to alginate is due to its branched structure and limited gel-forming ability. The high antioxidant activity observed suggests that fucoidan can play a protective role in aqua-feeds by reducing oxidative stress and enhancing immune responses in fish. This finding agrees with Lan[35] who attributed fucoidan antioxidant properties to its sulphate content. Furthermore, Liu[36] reported improved intestinal health and antioxidant status in fish fed fucoidan-supplemented diets, while Li[37] demonstrated enhanced disease resistance, supporting the present results. Laminarin exhibited comparatively lower water holding capacity, oil absorption capacity, and antioxidant activity. This is observed by its low molecular weight and relatively simple β-(1→3)-glucan structure, which limits its ability to form viscous gels or interact strongly with water and lipids. However, despite these lower physicochemical properties, laminarin remains biologically important due to its prebiotic and immune-modulatory effects. Its lower viscosity may be advantageous, as it allows incorporation into feeds without compromising pellet quality. This observation agrees with Wu[38] who reported moderate antioxidant activity but significant immune-enhancing effects of laminarin. Similarly, Cui[39] noted that laminarin exhibits lower functional properties compared to other brown seaweed polysaccharides due to its simpler molecular structure. Although structural characterization was not performed in this study due to equipment limitations, the extraction procedures employed were based on established and validated protocols. The observed differences among the polysaccharides can therefore be attributed to their distinct molecular architecture and functional groups. Alginate primarily enhances feed physical quality, fucoidan provides antioxidant and health-promoting benefits, and laminarin supports immune modulation and gut health. These complementary functionalities suggest that their combined application could provide both structural and physiological advantages in aqua-feed formulations. This integrated potential has been emphasized by Ummat[18] and Dhakal[40] who highlighted the importance of sequentially extracted seaweed polysaccharides as multifunctional ingredients for sustainable aquaculture systems.

Furthermore, the outcome of this study is consistent with global policy directions which emphasizes the transition toward sustainable and locally sourced feed resources. The FAO[41] policy report on aquaculture transformation highlighted that alternative feed ingredients derived from marine biomass are essential for reducing dependence on fishmeal and improving sector resilience. This aligns with the present findings, where *Sargassum* biomass yielded a high total polysaccharides, confirming its practical potential as a feed resource. Similarly, Edu[42] reported in a global seaweed policy framework that macroalgae utilisation can significantly enhance feed sustainability while supporting coastal economies, which directly supports the valorisation approach demonstrated in this study. The dominance of alginate in the extracted fractions further supports policy recommendations advocating the use of natural binders in feed production. Hecht[43] emphasized in their policy-oriented review that improving feed physical quality through sustainable binders is critical for reducing feed waste and enhancing efficiency. The high water holding capacity observed for alginate in this study therefore provides empirical backing to this policy recommendation. In a similar vein, Vargas-Cárdenas[44] reported that alginate-rich seaweed extracts can improve pellet durability and reduce nutrient leaching, which is consistent with the functional outcomes recorded in this study. In terms of health-promoting properties, the high antioxidant activity exhibited by fucoidan aligns with policy frameworks addressing antimicrobial resistance in aquaculture. Lulijwa[45] reported that global aquaculture policies are increasingly encouraging the use of natural immune-stimulants as alternatives to antibiotics. The findings of this study are in line with this policy direction, as fucoidan demonstrated strong antioxidant capacity, suggesting its suitability as a natural health-promoting additive. Likewise, Dhakal[40] emphasized that marine-derived polysaccharides such as fucoidan and laminarin play critical roles in enhancing fish immunity and stress tolerance, which supports the observed functional relevance of these compounds in this study.

Additionally, the utilization of *Sargassum* biomass in this study reflects circular bioeconomy policy principles. UNEP[46] reported that converting marine biomass waste into valuable products is a key strategy for achieving sustainable ocean economies. The present findings, which demonstrate the successful conversion of *Sargassum* into functional feed ingredients, are directly in line with this policy recommendation. Fagundo-Mollineda[47] also noted that *Sargassum* blooms, often considered an environmental nuisance, can be transformed into economically viable resources, reinforcing the environmental and economic relevance of this research. However, policy literature also highlights important implementation challenges. Ciaramella[48] emphasized the need for standardization, safety assessment, and regulatory frameworks for seaweed-derived products in aquaculture. The absence of advanced structural characterization in this study reflects these broader policy gaps, indicating the need for further research and institutional support. Dhakal[40] also noted that while seaweed polysaccharides show strong potential, their large-scale adoption depends on improved processing technologies and regulatory clarity. The findings of this study not only align with existing aquaculture policy frameworks but also provide experimental validation for policy recommendations on sustainable feed development, circular bioeconomy, and reduced antibiotic use. The functional and economic potential of *Sargassum*-derived polysaccharides in this study also contributes to bridging the gap between policy intentions and practical implementation in sustainable aquaculture systems.

## Conclusion

This study provides empirical evidence supporting the integration of *Sargassum spp.* into sustainable aqua-feed systems, with direct implications for policy development in aquaculture, blue economy, and circular bioresource utilization. The favourable proximate composition and the successful recovery of alginate, fucoidan, and laminarin demonstrate that *Sargassum* biomass can serve as a viable, locally available alternative to conventional feed ingredients. This aligns with global aquaculture policy priorities that advocate reducing dependence on imported fishmeal and promoting indigenous, resource-efficient feed inputs, as emphasized in FAO,[1] and Tacon and Turchini.[49] The dominance of alginate and its strong functional properties further reinforce policy recommendations encouraging the use of natural binders to improve feed efficiency and reduce nutrient losses. From a broader policy perspective, this study reinforces circular bioeconomy and blue economy frameworks by demonstrating the conversion of *Sargassum* which is often regarded as an environmental nuisance into high-value functional products. This aligns with global sustainability mandates that emphasize transforming marine biomass waste into economically viable resources. The findings therefore provide actionable evidence to support policies that integrate coastal biomass management with aquaculture development and industrial innovation. Furthermore, consistent with prevailing policy frameworks, the study highlights critical gaps that must be addressed to enable large-scale adoption, including the need for standardized extraction protocols, robust quality control systems, and clear regulatory approval pathways for seaweed-derived feed ingredients. Finally. this study not only advances scientific understanding but also offers strong policy-relevant evidence for the development of sustainable, health-promoting, and locally adaptable aqua-feed systems. By bridging experimental results with policy priorities, it provides a solid foundation for informed decision-making, strategic investment, and regulatory development aimed at achieving resilient and environmentally sustainable aquaculture.

## Author contribution

Edah Bernard: Conceptualization, sampling, formal analysis, project administration. Ukenye Esther A: Sampling, biochemical, proximate analysis, first original draft and data curation. Olagunju Goodness. E: Sample preparation, laboratory experimentation, data interpretation. Ayokhai Oshio J: Project administration, data curation, writing original draft, review and editing. Odeniyi Omotayo. A: Sampling, first original draft and data curation, data interpretation. Edah Bernard and Olagunju Goodness. E: Second original draft, editing and review. All Authors: Writing, review, and approval of final manuscript.

## Acknowledgement

The authors gratefully acknowledge Dada Kehinde Olutola, Jubril Lawal Ibrahim, Ayetan Barnabas, and Whesu Maria, technologists in the Department of Biotechnology and Fish Nutrition at the Nigerian Institute for Oceanography and Marine Research (NIOMR), for their invaluable technical support throughout this study. Their assistance during the collection, handling, and processing of *Sargassum spp*. samples, as well as their commitment and professionalism, greatly contributed to the successful execution of this research.

## Funding

This research received no external funding.

## Conflict of interest statement

The authors declare that they have no competing interests that could have influenced the work reported in this study.

## Data availability statement

The datasets produced and examined during this study are presented within the manuscript. Any further supporting data may be requested from the corresponding author, without undue reservation.

## References

1. Food and Agriculture Organization of the United Nations. *The State of World Fisheries and Aquaculture 2024*. FAO; 2024.
2. Naylor RL, Hardy RW, Buschmann AH, et al. A 20-year retrospective review of global aquaculture. *Nature*. 2021;591(7851):551–563.
3. Tacon AGJ, Metian M. Feed matters: satisfying the feed demand of aquaculture. *Rev Fish Sci Aquac*. 2015;23(1):1–10.
4. Corrigan S, Cottier-Cook EJ, Lim PE, et al. *The State of the World's Seaweeds*. Natural History Museum; 2025.
5. Silva A, Cassani L, Carpena M, et al. Exploring the potential of invasive species *Sargassum muticum*: microwave-assisted extraction optimization and bioactivity profiling. *Mar Drugs*. 2024;22(8):352.

**Citation:** Bernard E, Esther UA, Goodness OE, et al. Advancing sustainable aqua-feed policy in Africa: the role of *sargassum* derived polysaccharides. *J Nutr Health Food Eng*. 2026;14(2):55‒61. DOI: 10.15406/jnhfe.2026.14.00388

6. Podlejski W, Berline L, Jouanno J, et al. Drivers of growth and decay of *Sargassum* in the tropical Atlantic: a *Lagrangian* approach. *Prog Oceanogr*. 2024;229:103364.

7. Gullón B, Gagaoua M, Barba FJ, et al. Seaweeds as promising resource of bioactive compounds: overview of novel extraction strategies and design of tailored meat products. *Trends Food Sci Technol*. 2020;100:1–18.

8. Matos J, Cardoso C, Serralheiro ML, et al. Seaweed bioactives potential as nutraceuticals and functional ingredients: a review. *J Food Compos Anal*. 2024;133:106453.

9. Jayapala HPS, Gamage NH, Haryanti D, et al. Seaweed bioactive compounds as functional food for modulating gut microbiota. *Fish Aquat Sci*. 2025;28(12):810–821.

10. Edah B, Goodness OE, Joshua IC, et al. From waste to wealth: nutritional, ecological and economic valorization of drifting brown algae (*Sargassum* spp.). *J Nutr Health Food Eng*. 2026;14(1):41–46.

11. Zhu X, Healy L, Wanigasekara J, et al. Characterisation of laminarin extracted from *Laminaria digitata* using optimized ultrasound- and ultrafiltration-assisted extraction method. *Algal Res*. 2023;75:103277.

12. Hudiyati M, Sunarintyas S, Ardhani R, et al. Therapeutic potential of fucoidan in dentistry: a review. *J Herbmed Pharmacol*. 2024;13(2):188–198.

13. Chen X, Wu T, Bu Y, et al. Fabrication and biomedical application of alginate composite hydrogels in bone tissue engineering: a review. *Int J Mol Sci*. 2024;25(14):7810.

14. Li Z, Sun C, Wang F, et al. Structural and gelation characteristics of alkali-soluble β-glucan from *Poria cocos*. *Gels*. 2025;11(6):387.

15. Dutta S, Kataki S, Jaiswal KK, et al. Microalgal biorefineries in sustainable biofuel production and other high-value products. *New Biotechnol*. 2025;87:39–59.

16. McElroy R, Kopanitsa L, Helmes R, et al. Integrated biorefinery approach to valorise Saccharina latissima biomass: combined sustainable processing to produce biologically active fucoxanthin, mannitol, fucoidans and alginates. *Environ Technol Innov*. 2023;29:103014.

17. Birgersson M, Oftebro M, Hreggviðsson GÓ. Seaweed biorefinery approaches for sustainable biomass utilization. *Bioresour Technol Rep*. 2023;21:101351.

18. Ummat V, Tiwari BK, Jaiswal AK, O'Donnell CP. Sequential extraction of fucoidan, laminarin, and alginate from brown macroalgae. *Int J Biol Macromol*. 2024;256:128195.

19. AOAC International. *Official Methods of Analysis*. 21st ed. AOAC International; 2019.

20. Bamidele TD, Delphonso TV, Kayode-Isola TM, et al. Proximate and mineral composition of *Sargassum* spp. *World J Biol Pharm Health Sci*. 2025;21(2):94–102.

21. Ismail MM, El Zokm GM, Lopez JMM. Nutritional and bioactive compounds of brown seaweeds from the Red Sea. *Front Nutr*. 2023;10:1210934.

22. Bauta J, Calbrix E, Capblancq S, et al. Global chemical characterization of *Sargassum* spp. seaweeds from different locations on caribbean islands: a screening of organic compounds and heavy metals contents. *Phycology*. 2024;4(2):190–212.

23. Delphonso TV, Bamidele TD, Kayode-Isola TM, et al. Proximate and mineral composition of Sargassum spp from Badagry coast, Lagos state. *World J Biol Pharm Health Sci*. 2025;21(2):94–102.

24. Ahmad I, Turkistani A. Sustainable aquaculture feeds: the potential of *Sargassum* brown seaweeds as carbohydrate sources. In: *Sustainable Feed Ingredients and Additives for Aquaculture Farming*. Springer; 2024:291–308.

25. Adharini RI, Budhiyanti SA, Hia PA, et al. Exploring Chemical Compounds Diversity and Potential Applications of Four Sargassum Species from the South Coast of Yogyakarta, Indonesia: Implications for Blue Economy and Sustainability. *Thalassas*. 2025;41:154.

26. Hu X, Zhang Y, Li J, Chen H. Extraction and characterization of alginate from *Laminaria japonica* for aquafeed applications. *J Appl Phycol*. 2025;37(2):455-466.

27. Rahman MM, Shahid MA, Hossain MT, et al. Sources, extractions, and applications of alginate: a review. *Discover Appl Sci*. 2024;6:443.

28. Khanzadeh M, Hoseinifar SH, Zargari AZ, et al. Fucoidan derived from *Sargassum ilicifolium* affects growth and hemato-immunological parameters and antioxidant defense in Oscar (*Astronotus ocellatus*). *Front Mar Sci*. 2024;11:1370871.

29. Ummat V, Tiwari R, Dhakal R. Extraction and functional evaluation of fucoidan from *Fucus vesiculosus*. *Mar Biotechnol*. 2023;25(4):567-578.

30. Wu Y, Cheng Y, Qian S, et al. An Evaluation of Laminarin Additive in the Diets of Juvenile Largemouth Bass (*Micropterus salmoides*): Growth, Antioxidant Capacity, Immune Response and Intestinal Microbiota. *Animals*. 2023;13(3):459.

31. Krishnan L, Ravi N, Mondal AK, et al. Seaweed-based polysaccharides: extraction, characterization, and bioplastic application. *Green Chem*. 2024;26(10):5790–5823.

32. Otero P, Carpena M, Garcia-Oliveira P, et al. Seaweed polysaccharides: emerging extraction technologies and bioactive properties. *Crit Rev Food Sci Nutr*. 2023;63(13):1901–1929.

33. Anjana K, Arunkumar R. Brown algae biomass for fucoxanthin, fucoidan and alginate; update review on structure, biosynthesis, biological activities and extraction valorisation. *Int J Biol Macromol*. 2024;280:135632.

34. Doan HV, Prakash P, Hoseinifar SH, et al. Marine-derived products as functional feed additives in aquaculture. *Aquac Rep*. 2023;31:101679.

35. Lan Y, Qin K, Wu S. The physiological activities of fucoidan and its application in animal breeding. *Fish Shellfish Immunol*. 2024;147:109458.

36. Liu Q, Li G, Zhu S, et al. The effects of kelp powder and fucoidan on the intestinal digestive capacity, immune response, and bacterial community structure composition of large yellow croakers (Larimichthys crocea). *Fish Shellfish Immunol*. 2024;153:109810.

37. Li H, Liu Y, Teng Y, et al. Enhancement of seaweed polysaccharides on immune responses in fish. *Front Mar Sci*. 2023;10:1124880.

38. Wu Z, Zhao J, An H, et al. Effects of laminarin on growth performance and disease resistance in fish. *Fish Shellfish Immunol*. 2024;144:109271.

39. Cui Z, Jiang F, Li L, et al. Advances in biomedical applications of hydrogels from seaweed-derived sulphated polysaccharides. *J Ocean Univ China*. 2024;23:1329–1346.

40. Dhakal S, Naghdi M, Saeed M. Seaweed polysaccharides for aquafeed: processing challenges and regulatory considerations. *Rev Aquac*. 2024;16:175-194.

41. Food and Agriculture Organization of the United Nations. *The State of Global Aquaculture 2023*. FAO; 2023.

42. Edu WW, Cottier E, Nagabhatla N, et al. Ensuring the sustainable future of the rapidly expanding global seaweed aquaculture industry: a vision. 2021.

43. Hecht T. Review of feeds and fertilizers for sustainable aquaculture development in sub-Saharan Africa. In: Hasan MR, Hecht T, De Silva SS, Tacon AGJ, eds. *FAO Fisheries Technical Paper No. 497*. FAO; 2007:77–109.

44. Vargas-Cárdenas J, Brito LO, Silva SMBC, et al. Effect of green seaweed meal blend on shrimp performance. *Span J Agric Res*. 2023;21(3):e0605.

45. Lulijwa R, Rupia EJ, Alfaro AC. Antibiotic use in aquaculture, policies and regulation, health and environmental risks: a review of the top 15 major producers. *Rev Aquac*. 2020;12(2):640–663.

46. United Nations Environment Programme. Turning off the tap: how the world can end plastic pollution and create a circular economy. UNEP; 2023.

47. Mollineda-Fagundo A, Freile-Pelegrín Y, Vásquez-Elizondo RM, et al. *Sargassum*: turning coastal challenge into a valuable resource. *Biomass*. 2026;6(1):9.

48. Ciaramella M, Perry J, Shore A, et al. *Seaweed Food Safety Guidance*. New York Sea Grant; 2025.

49. Tacon AGJ, Turchini G. Healthy diets and global aquatic food production. *Rev Aquac*. 2024;16:1461–1462.

**Citation:** Bernard E, Esther UA, Goodness OE, et al. Advancing sustainable aqua-feed policy in Africa: the role of *sargassum* derived polysaccharides. *J Nutr Health Food Eng*. 2026;14(2):55–61. DOI: 10.15406/jnhfe.2026.14.00388