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First assessment of the proximate, amino acid and mineral composition of sargassum from the Atlantic Ocean coast in the Benin Republic for fish feeding purposes

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ABSTRACT:
Objectives: Tropical and subtropical coastal countries experience seaweeds inundations including sargassum, leading to environmental and economic challenges. This study aimed at assessing, for the first time, the nutritive value of sargassum collected from the Atlantic Ocean coast of Benin to analyse its potential to be valorised in fish feeding.
Methodology and Results: *Sargassum fluitans* and *Sargassum natans* mixture, collected along the beach of Cotonou was analysed to assess the proximal composition (moisture, ash, fat, and crude protein), the essential amino acids (EAA) and the minerals content based on standard AOAC International methods. The results revealed that the mixture of *Sargassum* contained all the ten EAA, although it displayed a slightly low protein content (6.1% Dry weight). Moreover, quite low fat content (0.3% Dry weight) was recorded. Furthermore, five minerals, required for fish growth and survival, were found, including three macrominerals (Ca, Mg, and P) and two microminerals (Zn and P).
Conclusions and Application of results : The *Sargassum* mixture, from the coast of Benin, displayed an interesting content made of amino acids and minerals required for fish as well as fat probably including essential polyunsaturated fatty acids. This seaweed can therefore be collected, processed in meal and used as a fish feed ingredient especially to substitute fish meal for significantly lowering fish feeding costs. The quantity of *Sargassum* required to make the fish feed will depend on the requirement of the targeted fish species to feed and the combination of the different ingredients to use for formulating the feed. Here, we just highlight, due to the content in protein and especially the EAA of *Sargassum*, the possibility to replace the common but expensive protein source of fish feed, which is fish meal, to help low fish feeding cost. Hence, this can help

manage the environmental challenges coming from the sargassum strandings, contribute significantly to strengthen food security and increase the blue economy.
Keywords: Seaweeds, Marine resources, Aquaculture, Food security.

INTRODUCTION

Since 2011, huge strandings of sargassum have been noticed on West Africa's beaches from Senegal to Cameroun, in the Carribean and Brazil causing disturbances on the marine resources, fishery, shores, waterways, and tourism (Doyle and Francks, 2015; Milledge and Harvey, 2016 ; Davis *et al.*, 2021). In West Africa, sargassum strandings include pelagic algae belonging to the genus *Sargassum* C. Agardh, 1820 (Schell *et al.*, 2015). This genus belonging to the class of Pheophyceae (brown algae) is spread throughout the world and is known as one of the most diversified genera of the order of Fucales (Mattio, 2008). It includes 352 described species which are for the most benthic. However, *Sargassum fluitans* (Børgessen) Børgesen, 1814 and *S. natans* (Linnaeus) Gaillon 1828, especially holopelagic, are only present in the Atlantic Ocean (Schell *et al.*, 2015) and give their name to the Sargasso Sea located in a West-Atlantic area at the North of the Caribbean Sea (Le Lann, 2009). To date, only the abovementioned floating *Sargassum* species, *S. fluitans* and *S. natans* (Figure 1), are the two species involved in the beach invasion along the coast in West African countries, including Benin (Oyesiku and Egunyomi, 2014). Therefore, like other parts throughout the world, Benin periodically experiences sargassum strandings, leading to huge biomass to manage, fishing and tourism disturbance and resulting in significant socio-economic damages (Milledge and Harvey, 2016 ; Davis *et al.*, 2021 ; Atiglo *et al.*, 2024). On the other hand, seaweeds present some economic advantages since they are widely used for many purposes such as human consumption, animal fodder, fertilizer, biogas, textile, paper, and pharmaceutical industries (Round, 1973; Chennubhotla *et al.*, 1981; Yokoyama *et al.*, 2007; Wang *et al.*, 2009). Therefore, strategies to take advantage of seaweed events could include their reuse in both human and animal feeds (Yangthong, 2017; Nazarudin *et al.*, 2021). In this line, the potential of seaweeds to be used as fish feed ingredient was demonstrated due to their nutritional benefits, able to help enhance growth performance, boost immunity, improve antioxidant status, and increase resistance to ammonia stress in fish (Pratiwy *et al.*, 2018; Nur *et al.*, 2020; Mwendwa *et al.*, 2023; Hu *et al.,* 2024). However, the chemical and nutritive composition of seaweeds often depends on many factors such as species, geographical area, and seasons (Oyesiku and Egunyomi, 2014; Vijay *et al.*, 2017**;** D'Armas *et al.*, 2019). The nutritive content of *Sargassum* species may be significant. In Benin, despite the regular proliferation of *Sargassum* biomass along the Atlantic coast, there has been no study examining their nutritional value. This study aimed at filling this gap by assessing the proximate composition and, the mineral and amino acid content of the mixture of *S. fluitans and S. natans* collected from the Atlantic coast of Benin, especially to assess their potential to be used as fish feed ingredients and consequently help manage seaweed strandings.

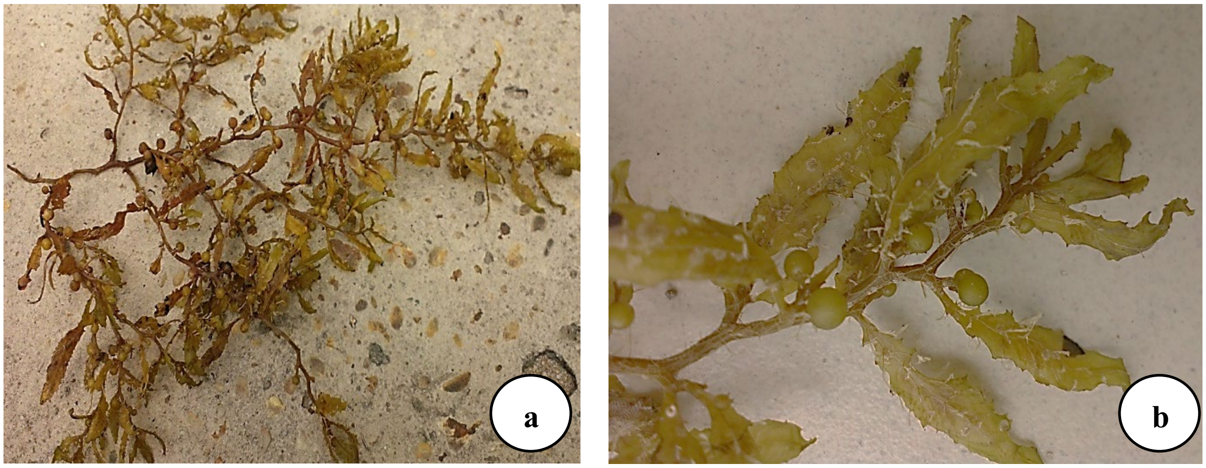

Figure 1 : *Sargassum fluitans* (a) and *S. natans* (b) collected from the Atlantic coast of Benin
Source : This study

MATERIAL AND METHODS

Collection, identification, and processing of *Sargassum* :Sargassum samples were collected from the Atlantic Ocean beach in Cotonou (Benin) (Figure 2). These samples included two species, *Sargassum fluitans* (Borgessen) and *Sargassum natans* (Linnaeus) Gaillon, determined according to Oyesiku and Egunyomi (2014) and Govindarajan *et al.* (2019). The seaweed samples collected were freeze-dried using the lyophilizer EYELA FDU-2110 prior to analysis.

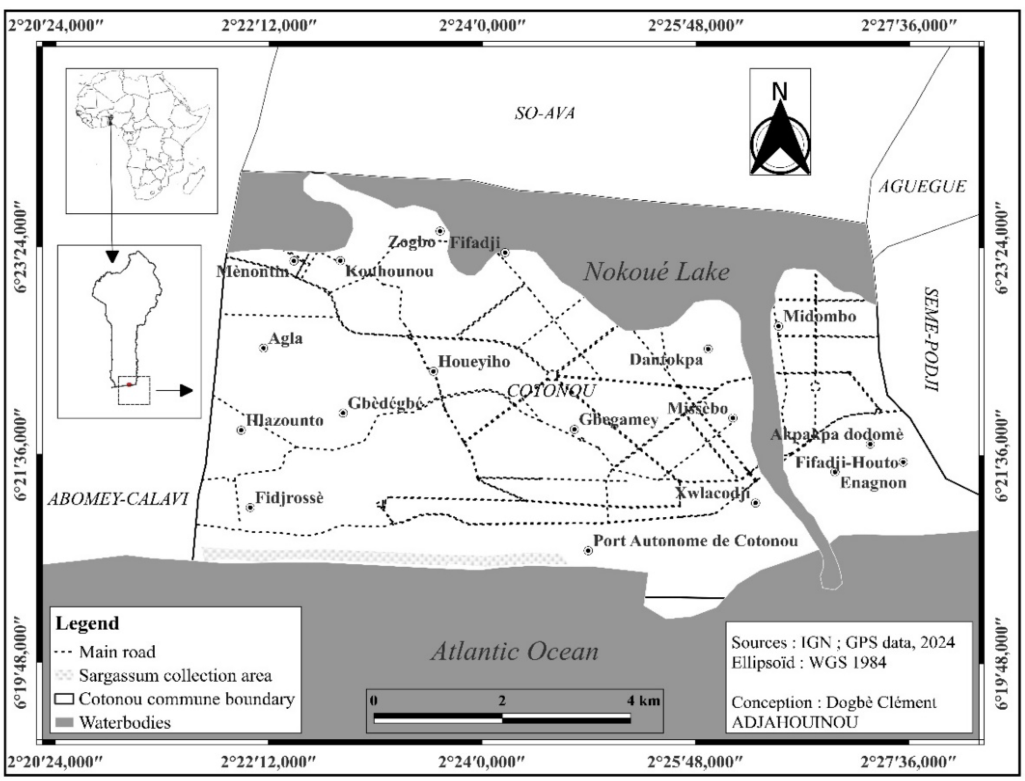

Figure 2: Map of Cotonou showing the *Sargassum* collection area.

Determination of the proximate composition and amino acid content of the *Sargassum* mixture: The moisture content of the *Sargassum* mixture was determined by measuring the weight lost after drying for 24 h in the oven at 105°C. To assess the ash content, the *Sargassum* mixture samples were incinerated for 16 h at 550°C. The seaweed samples were freeze-dried by lyophilizer EYELA FDU-2110 before the analysis of fat, protein, and amino acid content. The fat content was assessed by petroleum ether extraction using a VELP extractor after a chloric acid hydrolysis of the seaweed sample. Crude protein was determined based on the total nitrogen content of *Sargassum* samples by the Kjeldahl method, by multiplying the total nitrogen percentage by 6.25 (FAO/WHO, 1973). The essential amino acids (EAA) (arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine) content of the *Sargassum* mixture was analysed using High-performance liquid chromatography after acid hydrolysis. All these nutritive parameters were assessed according to the Official Methods of Analysis of the Association of Official Analytical Chemists (AOAC) (Latimer, 2023).

Measurement of minerals content of the *Sargassum* mixture: Before the analysis of the mineral contents of the *Sargassum* mixture, the freeze-dried sample was ground and then mineralized by hydrogen peroxide oxidization in a sulfuric medium using a Hach Digesdahl mineralizer. Iron, zinc, and phosphorus contents were assessed by molecular absorption spectrophotometry methods using the spectrophotometer HACH DR 2800. The calcium and magnesium contents were determined by the EDTA complexometric titrimetric method according to Steagall (1966). Sodium and potassium were measured by atomic absorption spectrophotometry methods using the spectrophotometer VARIAN Spectr AA110.

RESULTS

The proximate composition of the studied *Sargassum* mixture is presented in Table 1.

Table 1: Proximate composition of the *Sargassum fluitans and S. natans* mixture collected from the Atlantic Ocean coast in Benin

Parameters	**Composition**
Moisture content (%)*	87.06 ± 2.03
Ash (g/100g DW)	25.62 ± 0.95
Fat (g/100g DW)	0.30 ± 0.07
Protein (g/100g DW)	6. 10 ± 0.28

(DW: Dry weight ; *The moisture content is expressed in percentage of raw wet seaweeds)

As for the essential amino acids profile of the *Sargassum* mixture, it ranged from 0.57% (for Methionine) to 1.42% (for leucine). However, all the 10 EAA were recorded (Figure 3).

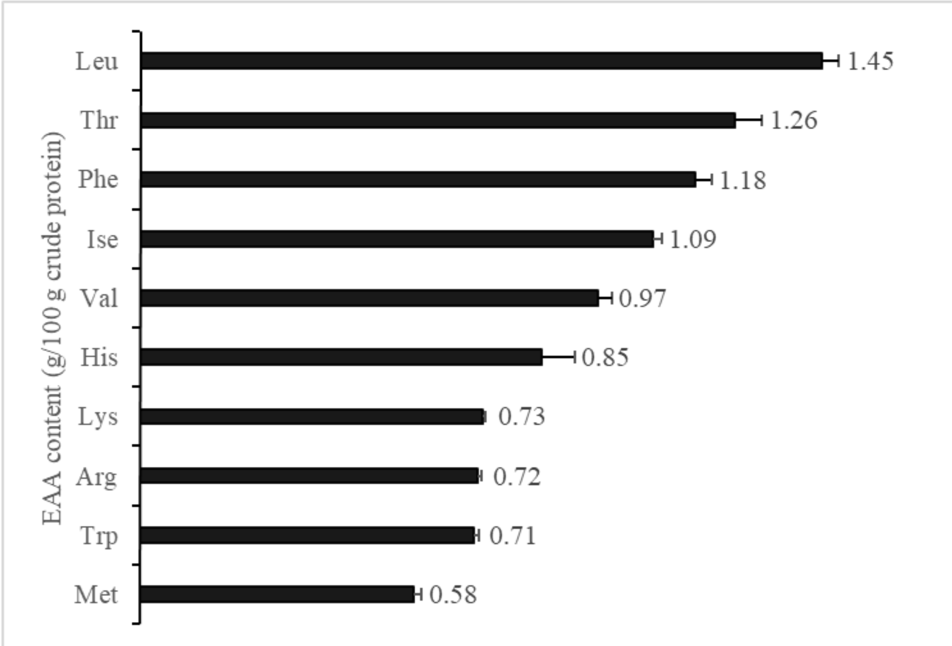

Figure 3 : Essential amino acids (EAA) profile of *Sargassum fluitans and S. natans* mixture collected from the Atlantic Ocean coast in Benin Republic (Arg : arginine ; His : histidine ; Ile : isoleucine, Leu : leucine ; Lys : lysine ; Met : methionine ; Phe : phenylalanine ; Thr : threonine ; Trp : tryptophan ; Val : valine).

Seven minerals were found in the studied *Sargassum* mixture (Table 2). The highest concentration was found for iron, while the least concentrated mineral in the *Sargassum* mixture was zinc.

Tableau 2: Mineral contents of the *Sargassum fluitans and S. natans* mixture collected from the Atlantic Ocean coast in Benin (DW: Dry weight)

Minerals	**Content** (g/100 g DW)
Zn	0.01 ± 0.00
Fe	28.36 ± 1.10
P	0.19 ± 0.02
Ca	1.95 ± 0.06
Mg	1.67 ± 0.03
Na	1.26 ± 0.12
K	1.00 ± 0.09

DISCUSSION

This study found different contents in *Sargassum* seaweed collected from Cotonou Beach in Benin. The proximate composition noticed for the *S. fluitans* and *S. natans* mixture is perfectly within the ranges generally reported for pelagic *Sargassum* (Desrochers *et al.*. 2022). Therefore, the protein content recorded (6.1%) was in line with the range generally noticed for brown seaweeds (5 to 15%) (Burtin, 2003) as well as that found for *S. fluitans* and *S. natans* in the Turks and Caicos islands Bay (5.2 to 12.7%) (Nielsen *et al.*, 2021), and for *S. oligocystum* (5.47%), *S. bindiri* (5.96%) and *S. polycystum* (6.83%) from the Bo Mao Beachin in Thailand (Yangthong, 2017). Likewise, this was also quite close to the protein content previously recorded in the same *Sargassum* mixture in the Arabian Gulf (6.6%) (Kamel. 1981). Nonetheless, it was lower than the protein content noticed in the same seaweed species from China (Wang *et al.*. 2013), Nigeria (Oyesiku and Egunyomi. 2014), and Porto Rico (Diaz-Vazquez *et al.*. 2015) on the one hand and that found in other *Sargassum* species as *S. vulgare* in Brazil (Marinho-Soriano *et al,* 2006), *S. filipendula* in Mexico (Robledo and Freile Pelegrín,1997), *S. pteropleuron* in Florida in USA (Daly and Prince, 1981), *S. wightii* in India (Kumar, 2015), and *S. henslowianum* and *S. patens* in China (Wong and Cheung, 2001; Li, 2012). In return, the protein content in the investigated *Sargassum* mixture was higher than that registered for *S. hemiphyllum* in China (Wong and Cheung, 2001) and *S. cristaefolium* in the Philippines (Borines, 2011). Despite its slightly low protein content, the studied *Sargassum* mixture contains all the 10 EAA required for the growth and maintenance of life in fish (Millamea *et al.*, 2002). The rates of these EAA are in the following order : Leu > Thr > Phe > Ile > Val > His > Lys > Arg > Trp > Met. In total, the EAA profile accounted for 9.32% of the crude protein. Leucine, threonine, phenylalanine, and isoleucine were the most concentrated amino acids in the *Sargassum* mixture with a cumulated rate of 4.86% of the crude protein, while all the remaining amino acids (valine, histidine, lysine, arginine, tryptophan and methionine) displayed a cumulated rate of 4.46% of the crude protein. The total EAA content in the *S. fluitans* and *S. natans* mixture was quite higher than that of *S. cinctum* (5.66%) from Okha in India (Sumara and Vadher, 2020) and *S. zhangii* (5.40%) from Zhanjiang in China (Lin *et al.*, 2022), although both these seaweed species have a higher protein content.

The fat (lipids) content recorded (0.3 %) was very low, as generally recognized for seaweeds (Milledge and Harvey, 2016; Desrochers *et al.*, 2022). However, it was lower than the mean fat content reported for *S. fluitans* and *S. natans from* the Turks and Caicos Islands Bay (10.55% to 13.12% respectively) (Nielsen *et al.*, 2021) as well as for *Sargassum* from the Mexican coast (2.6 to 3.8%) (Saldarriaga-Hernandez *et al.*, 2021) and that from the Gujarat coast in India (0.57 to 2%) (Kumari *et al.*, 2013). Although the lipid content of the studied *Sargassum* mixture was low, it may include interesting polyunsaturated fatty acids profiles as found in other *Sargassum* species (*S. tenerrimum, S. johnstonii, S. sp., S. carpophyllum, S. plagiophyllum, S. cinereum, S. cinctum*) from the Gujarat coast in India (Kumari *et al.*, 2013). Further studyis needed to assess the essential fatty acids content of the studied *Sargassum* mixture, especially for fish. The same trend of difference was noticed for the mineral contents of the *Sargassum* mixture when compared to other reported results (Oyesiku et Egunyomi. 2014; Nava-Jiménez *et al.*, 2022), confirming therefore that the chemical composition of seaweeds depends on many spatial and temporal factors (Desrochers *et al.*. 2022), mainly seasonal and environmental conditions such as but not limited to, pH, salinity, water motion, temperature, light availability, mineral and pollutants content of seawater (Mišurcová *et al.*, 2011; Sumara and Vadher, 2020). The most interesting asset of the studied *Sargassum* mixture pointed out by the present study is its amino acids profile including all the ten essential ones (Leu, Thr, Phe, Ile, Val, His, Lys, Arg, Trp, Met) for fish especially the most common species reared in Africa (Tilapia and catfish) (Robinson and Li, 2015; Furuya *et al.*, 2023). This complete essential amino acids profile of the *Sargassum* mixture shows that it has a high nutritional value for fish without any limiting amino acid since it meets the qualitative requirement (Millamea *et al.*, 2002). The *Sargassum* mixture is thus an important protein/EAA source able to be used as a fish feedstuff. So, it can be used to substitute fish meal, the main dietary protein source used in fish feed (Hardy and Tacon, 2002) but more and more expensive (Indexmundi, 2024). This finding could help significantly reduce fish feeding costs. On the other hand, the *Sargassum* mixture contained some minerals generally required for fish, including three macrominerals (calcium, magnesium, and phosphorus) and two microelements (zinc, iron) (Millamea *et al.*, 2002). In fish and shrimp, iron deficiency could lead to anemia while, that of calcium, magnesium, phosphorus, and zinc could cause poor growth as well as dwarfism and high mortality (Watanabe *et al.*, 1988 cited by Millamea *et al.*, 2002). Among the macrominerals, calcium and phosphorus are commonly supplemented in fish feed, contrary to magnesium, which is generally abundant in plant-origin fish feed ingredients (Millamea *et al.*, 2002). Therefore, based on its contents, the *Sargassum* strandings on the Benin coast represent a useful source of these minerals for fish feeding. Its use to supply minerals in fish feed instead of the high-cost mineral premix may help lower fish farming costs. This could also be a way to prevent excessive mineral supplementation leading to the reduction of the bioavailability of other minerals as well as the increase of breeding water pollution in phosphorus (Millamea *et al.*, 2002).

CONCLUSION AND APPLICATION OF RESULTS

Overall, this study highlights interesting contents for sargassum strandings on the Atlantic Ocean coast in Benin. The mixture of *S. fluitans* and *S. natans* contains protein including all the ten EAA, low concentration in fat with potentially some interesting fatty acids, and seven minerals required for fish growth and survival. Taking advantage from its interesting feeding content, the huge quantity of seaweeds regularly polluting the coast in Benin could be collected, processed in meal and efficiently used as EAA, fat and minerals source in fish feed processing. The *Sargassum* could therefore be used especially in replacement of fish meal and accordingly help reduce fish farming costs and increase fish production. Hence, this cyclical phenomenon to date, considered as an environmental and economic challenge, could be seized as an opportunity to strengthen food security and increase the blue economy.

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