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Research Article
Bioactive Compounds of *Sargassum polycystum* as Potential Osmo Protectants for Mitigating Drought Stress in Vegetable Production

[1]Fahrurrozi Fahrurrozi, [1]Wuri Prameswari, [2]Zainal Muktamar and [3]Dia Novita Sari

[1]Department of Crop Production, Faculty of Agriculture, University of Bengkulu, Bengkulu 38121, Indonesia
[2]Department of Soil Science, Faculty of Agriculture, University of Bengkulu, Bengkulu 38121, Indonesia
[3]Faculty of Agriculture, University of Ratu Samban, Arga Makmur, Bengkulu 38618, Indonesia

Abstract

Background and Objective: *Sargassum polycystum* is a brown seaweed species that contains organic biostimulants and might serve as an exogenous osmoprotectant. The application of exogenous osmoprotectants is expected to increase the production of indigenous osmoprotectants in plant cells to alleviate the detrimental effects of vegetable crops experiencing drought stress. This research aimed to identify the content of bioactive compounds and pigments of *S. polycystum* seaweed. **Materials and Methods:** Samples of brown seaweed were harvested from Teluk Sepang Beach, Bengkulu City, Indonesia. Determination of biochemical compositions of *S. polycystum* was addressed in terms of amino acids, ash content, water content, carbohydrates, total fat, protein and total phenol as well as its pigment properties (total chlorophyll, chlorophyll a, chlorophyll b and carotenoids). **Results:** Results indicated that *Sargassum polycystum* had the highest proximate composition, namely carbohydrate content of 57.75% and the lowest proximate content, namely total fat content of 0.06%. Additionally, *Sargassum polycystum* has other proximate content, such as water content of 14.80%, ash content of 18.43% and protein content of 8.96%. The research results showed that 15 types of amino acids were detected in *Sargassum polycystum*. The L-glutamic acid content in *Sargassum polycystum* had the highest content, namely 5.09%, while the L-methionine content had the lowest content at 0.19%. **Conclusion:** It is concluded that 15 amino acids were detected, of which 7 were essential amino acids (L-histidine, L-threonine, L-arginine+tyrosine, L-methionine, L-valine, L-phenylalanine and L-isoleucine) and 8 of them are non-essential amino acids (L-aspartic acid, L-glutamic acid, L-serine, L-glutamine, L-glycine, L-alanine, L-leucine and L-lysine).

Key words: Amino acids, bioactive compounds, osmoprotectants, *sargassum polycystum*, seaweed

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Corresponding Author: Wuri Prameswari, Department of Crop Production, Faculty of Agriculture, University of Bengkulu, Bengkulu 38121, Indonesia

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Vegetable production worldwide is increasingly subjected to the impact of global climate change. Global climate change has a significant impact on vegetable production activities because increasing temperatures can change the pattern of the growing season, change the physiological responses of plants (flowering, fruiting, tuber filling), change the behavior of pathogens and even increase the area of land susceptible to drought in coastal areas[1]. According to Salinger[2], there are three main impacts of global climate change on the agricultural sector, including changes in rain patterns, increasing incidence of floods and droughts and increasing air temperatures and sea levels. Drought stress on coastal land can interact with salinity stress because groundwater evaporation leaves salt ions in the soil and causes double stress on plants[3]. It is, therefore, essential to develop innovative agronomical inputs to increase the ability of plants to adapt to drought stress by exploiting the local potential in coastal areas and applying it as exogenous osmoprotectants during crop growth and development.

There are four essential physiological responses for plants to survive under drought stress conditions, including osmotic adjustment to maintain cellular turgor by accumulating compatible solutes (osmoprotectants); partial closure of stomata to reduce water loss through transpiration; synthesis of protective proteins such as dehydrins and activation of antioxidant systems to counteract oxidative stress[4]. According to Hammad and Ali[5], for plants to withstand drought stress, free amino acids are crucial osmotic molecules. Producing an abundance of various kinds of suitable osmolytes in plants is one of the most prevalent stress tolerance mechanisms. These osmolytes, which include proline, glycine betaine, mannitol, sorbitol and others, are typically non-toxic, tiny, non-reactive molecules that shield plants from stress by aiding in osmotic adjustment, detoxifying reactive oxygen species, stabilizing membranes and preserving the natural structures of proteins and enzymes[6].

Osmoprotectants are bioactive compounds produced by plant cells under stress conditions in the form of highly soluble, non-toxic and compatible solutes with low molecular weight or amino acid compounds (proline), amines, sugars and alcohols[7]. Increasing osmoprotectants in plant cells will increase the plant's ability to overcome abiotic stress caused by drought. Providing exogenous osmoprotectants based on natural sources is expected to increase the production of indigenous osmoprotectants in plant cells to mitigate drought stress during crop growth and development. Seaweed is one of the flora resources in coastal ecosystems that can be used as a source of exogenous osmoprotectants because it is a biostimulant for plant growth[8]. Seaweed extracts contain various biostimulating compounds in the form of carbohydrates, amino acids, phytohormones, osmoprotectants and proteins[9]. Recently, there are four reasons to use seaweed extracts as biostimulants: Including work at very low concentrations, increase abiotic stress resilience in many crops, enhance protein production in protein-rich crops and offshore seaweed cultivation does not compete with land use for food production[10]. In addition, seaweeds are classified into three major classes: The brown Phaeophyta, the red Rhodophyta and the green Chlorophyta. Brown seaweed of *Sargassum polycystum* has the potential as an organic biostimulant and serves as an exogenous osmoprotectant in crop production due to its bioactive compounds. These substances include protein, carbohydrate, lipid, fiber and ash[11]. In addition, this species also contains chlorophyll a, chlorophyll c, β carotene, fucoxanthin, pheophytin and xanthophyll[12]. The primary chemical composition of secondary metabolites of *S. polycystum* is reactive saponins, alkaloids, flavonoids and phenol hydroquinone[13]. The use of seaweed extracts from *Sargassum* sp. as biofertilizers has been practiced, increasing crop growth and yield[14-16]. Nevertheless, using *S. polycystum* extracts as an osmoprotectant has been less evaluated. This study aimed to determine the biochemical compositions of *S. polycystum* in terms of amino acids, ash content, water content, carbohydrates, total fat, protein and total phenol, as well as its pigment properties (total chlorophyll, chlorophyll a, chlorophyll b and carotenoids).

MATERIALS AND METHODS

Study area: This research was carried out in the laboratory Agronomy of the Faculty of Agriculture, University of Bengkulu, Indonesia and the Laboratory Integrated Research and Testing at Gadjah Mada University Indonesia, from August to October, 2024.

Sample collection: Samples of fresh brown seaweed of *S. polycystum* were collected in July, 2024 from Teluk Sepang Beach, Kampung Melayu (3°56'23.6"S and 102°16'43.2"E) Bengkulu City, Indonesia. Hand-picking collection was conducted while the sea water was receding. Fresh seaweed was placed into a cooling box filled with ice and transported to the laboratory immediately.

Water and ash content analysis: Both water and ash contents of *S. polycystum* were determined by using the gravimetric method[17]. The steps are as follows: A weighing the empty

crucible (A), weighing the homogeneous sample, put it in a porcelain crucible (B), heat in the oven at 105°C for 3 hrs until constant weight, add the desiccator, weight (C), close the porcelain crucible, put it in the furnace, then heat it at 600°C for 8 hrs (turns to ash) until the weight is constant, Add the desiccator, weight (D), Calculate water content using the formula (F)[18]:

$$\frac{\left[(A+B)-C\right]}{B}\times 100\%$$

and calculating the ash content using the formula (g)[19]:

$$\frac{(D-A)}{B}\times 100\%$$

Protein content analysis: The total protein content of *S. polycystum* was determined using the automatic Kjeldahl method[20]. The first step was the destruction of the sample, starting with inserting 1 g of the sample into the Kjeldahl's tube, then adding 3.5 g of K_2SO_4, 0.1 g $CuSO_4.5H_2O$ and 12 mL of H_2SO_4(c). Heat this mixture in the acid storage cabinet using the Automatic Digestion Unit's instrument. Once destruction is finished, distillation and automatic titration steps are continued. The result of destruction was removed to the Automatic Distillation and Titration System. Before conducting distillation and titration analysis, ensure all reagents H_3BO_3 4%, NaOH 35%, HCl 0.2 N and distilled water are available.

Calculate the N (%) using formula:

$$\text{Liquid sample} = \frac{14.007\times(T-B)\times N\times 100}{1000\times mL}$$

The sample calculates % protein (total) by multiplying the conversion factor with %N[21].

Fat content analysis: The total fat content of *S. polycystum* was determined using the gravimetric method. The sample was homogeneously crushed and a 5 g sample was added with 10 mL of concentrated HCl. The hydrolysis was done in a water bath at 80°C for 90 min while shaking. After cooling the samples, the extraction using 25 mL diethyl ether, vortex it for 1 min 25 mL petroleum benzene and then vortex it for another minute. Dry the extract, then oven at 100°C until constant weight (1-2 hrs). Calculation of total fat was determined by using the formula[22]:

$$\text{Tota fat (\%)} = \frac{(\text{Beaker weight} + \text{fat}) - \text{empty beaker weight}}{\text{Sample weight}}\times 100$$

Carbohydrate content analysis: The carbohydrate content of *S. polycystum* was determined based on the difference in the calculation[23]:

Carbohydrate (%) = 100-(moisture+ash+crude fiber+crude protein+fat (%))

Determination for total phenol content (TPC): The phenolic content of *S. polycystum* is estimated using the Folin–Ciocalteu method with modifications[24]. Folin-Ciocalteu solution consisting of 160 mL of purified water, 10 mL of Folin-Ciocalteu reagent (10%) and 20 mL of Na_2CO_3 (10%) was mixed with *S. polycystum* extract and incubated for 30 min. The absorbance of the sample was measured at a wavelength of 750 nm using a microplate reader. The TPC was defined as mg gallic acid equivalent per gram of extract (mg GAE/g).

Determination for amino acid contents: Amino acid contents of *S. polycystum* were determined using the high-performance liquid chromatography (HPLC) method. Sample preparations included weighing the sample carefully, adding 2 mL of HCl 6N, vortexing and hydrolysis at 110°C for 12 hrs. Cool the sample at room temperature, then neutralize it with 6 N NaOH. Clear this sample with 5 mL Pb-Acetate, 40% and 2-mL oxalic acid, 15% and correct 10 mL using aqua bidest. Take the sample as much as ±3 mL and filter it with Millex 0.45 µm. Setting the autosampler program with a mix ratio of 10% sample size in OPA, react it for 3 min and inject 20 µL sample into the HPLC. Standards of amino acids, including L-asparagine (Asn), L-glutamic acid (Glu), L-alanine (Ala), L-leucine (Leu), L-serine (Ser), L-isoleucine (Ile), L-aspartic acid (Asp), L-arginine (Arg), Glycine (Gly), L-valine (Val), L-methionine (Met), L-cystine (CyS-SC), L-cysteine (Cys), L-phenylalanine (Phe), L-threonine (Thr), L-glutamine (Gln), L-proline (Pro), L-histidine (His), L-tyrosine (Tyr), L-lysine (Lys) obtained from Sigma (Sigma-Aldrich, St. Louis, MO, USA), were of analytical grade (> 99% purity)[25,26].

Identification and calculation of content of amino acid: The identification of amino acids was performed according to their hold-up time (using standards as a reference). The quantitative content of amino acids is calculated from the value of the peak area of the amino acids. The content of bound amino acids was determined by subtracting the content of free amino acids from their total content[27-29].

Pigment analysis: Pigment contents (Chlorophyll a, b and total chlorophyll) and carotenoid. A sample of *S. polycystum* (0.5 g of fresh samples) was extracted using 80% acetone[30]. Using a UV/Visible Spectrophotometer, the absorbances of

this extract were measured at 480 nm (A480), 645 nm (A645) and 663 nm (A663). As advised by Vijay *et al.*[31] the concentrations (µmoL/L) of chlorophyll a, chlorophyll b and total carotenoid were calculated using the following equations:

$$\text{Total carotenoid} = (A480+0.114*A663-0.638*A645)*1*1000/112.5*0.3$$

$$\text{Chlorophyll a (Ca)} = (12.72*A663-2.59*A645)$$

$$\text{Chlorophyll b (Cb)} = (22.9*A645-4.67*A663)$$

where, Ca + Cb calculated the total chlorophyll in plant tissues.

Data analysis: Proximate analysis of bioactive compounds was descriptively presented, meanwhile pigment analysis was conducted in triplicate and the results are presented as Mean±Standard Deviation.

RESULTS AND DISCUSSION

***Sargassum polycystum* proximate composition:** The research showed that *Sargassum polycystum* had the highest proximate composition, namely carbohydrate content of 57.75% and the lowest proximate content, namely total fat content of 0.06%. Additionally, *Sargassum polycystum* has other proximate content, such as water content of 14.80%, ash content of 18.43% and protein content of 8.96% (Fig.1).

The most significant proximate composition in *Sargassum polycystum* is carbohydrates, namely around 57.75%. The carbohydrate content in *Sargassum polycystum* is a source of hydrocolloids that play a role in the food and non-food industries[32]. In *Sargassum polycystum*, carbohydrates are generally fucoidan, laminarin, cellulose and alginate[33]. The water content of *Sargassum polycystum* is 14.8%, indicating that it has a relatively high amount of water content. The high-water content can cause damage, making the shelf life short. Therefore, one way to maintain quality and extend shelf life is by carrying out the drying process.

Ash is an important component in food that influences mineral levels. *Sargassum polycystum* has a relatively high ash content, approximately 18.43%. This high ash content is linked to the way mineral nutrients are absorbed and serves as an adaptation to the environmental conditions in marine waters, which contain various minerals in high concentrations. Unlike many plants that absorb nutrients through their roots, *S. polycystum* absorbs mineral nutrients through the entire surface of its thallus, making the absorption process more effective. The quantity of mineral nutrients absorbed directly impacts the ash content in the seaweed's tissue, resulting in a high ash content for this species. Additionally, the ash content of *S. polycystum* reflects the mineral content it contains. Therefore, *S. polycystum* can be considered an alternative source of minerals[34,35].

This study obtained total fat content at 0.06% (Fig. 1). *Sargassum polycystum* contains very little fat. The fat content in *S. polycystum* is relatively low, ranging between 1-5%[26]. Seaweed and plants generally store their food reserves in carbohydrates, especially polysaccharides. Meanwhile, animals store their food reserves as fat in adipose tissue[36]. This difference in the form of storage of food reserves causes vegetable fats to have a low percentage generally, while animal fats have a high percentage. Meanwhile, the protein content obtained by *S. polycystum* was 8.96%. This was in line with the opinion of Dawczynski *et al.*[32] that *S. polycystum* contains protein levels in the range of 3-9% wet weight, while red seaweed and green seaweed contain 6-20% protein levels. Even though the fat and protein content is low, *S. polycystum* has a relatively complete essential amino acid content and is rich in good unsaturated fatty acids[37]. It was also added that *S. polycystum* contains alanine, glycine and glutamic acid[38].

Amino acid content profile of *Sargassum polycystum*: The amino acid profiles of *Sargassum polycystum* were determined using the high-performance liquid chromatography (HPLC) method. Injection of a mixture of standard amino acids produces a chromatogram, where each peak indicates a particular type of amino acid. Amino acid chromatogram of the sample. The type of amino acid in the sample is obtained by comparing the peaks of the sample and the amino acid standard. Calculation of the concentration of each amino acid is based on the area of each peak. The Glycine type amino acid showed the highest peak value with an area of 3364.9878 at a retention time (RT) of 14.700 min. Meanwhile, Histidine-type amino acids showed the lowest peak value, with an area of 702.9330 and a retention time of 10.775 min, as per the standard HPLC chromatogram results of amino acids (Fig. 2). The HPLC chromatogram of amino acids of *Sargassum polycystum* shows that the highest peak value is for the amino acid type Glutamic Acid with an area of 1050.9751 at a retention time of around 5,466 min. Meanwhile, Tryptophan amino acids showed the lowest peak value with an area of 1.8830 at a retention time of around 24.570 min (Fig. 3).

The types of amino acids found in *Sargassum polycystum* were obtained by comparing the retention time (RT) of standard amino acids with the retention time (RT) of the samples tested. Retention time is the time the sample requires from the time of injection until the sample

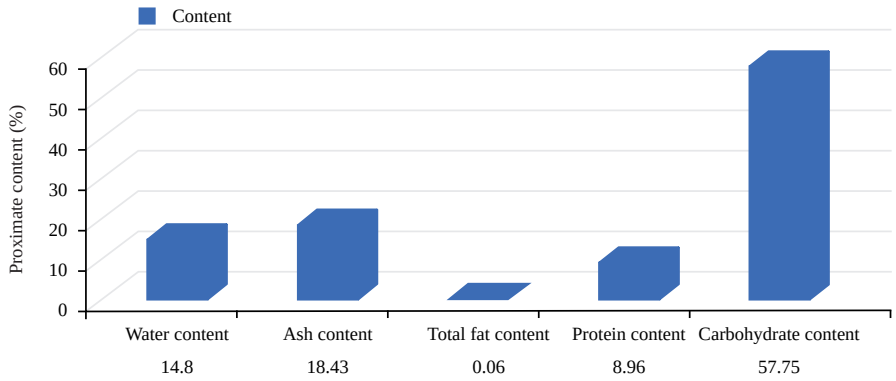

Fig. 1: *Sargassum polycystum* nutritional composition

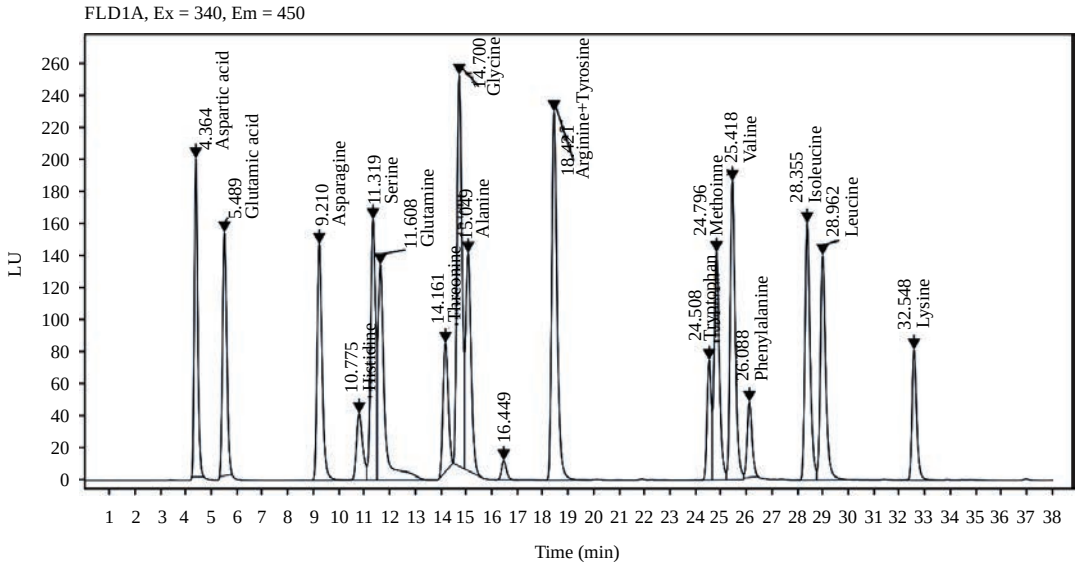

Fig. 2: HPLC chromatogram of amino acids standard

reaches its maximum peak[39]. The amino acid peaks tested will have the same retention time value as the standard retention time value (Table 1). Testing for amino acids in *Sargassum polycystum* produces almost all essential and non-essential amino acids except tryptophan, cysteine, proline and asparagine. This occurs due to damage to the amino acid tryptophan during amino acid hydrolysis. The non-identification of other amino acids is thought to be due to damage at the protein hydrolysis, drying and derivatization stages.

The results of the chromatogram of amino acids in *Sargassum polycystum* based on retention time show that nine peaks are close to the retention time of standard amino acids (Fig. 2, Table 1), including aspartic acid, glutamic acid, threonine, glycine, alanine, arginine+tyrosine, tryptophan, valine and phenylalanine namely 4,179; 5,46; 14,126; 14.55; 18.052; 24.570; 25.288; and 26.060 min, respectively. Meanwhile, the amino acid L-alanine showed the highest retention factor (RF) value of 265.44644 and L-tryptophan showed the lowest retention factor value of -45.53599. The retention factor (RF) value for L-asparagine showed no results at all or could be said to be undetectable.

Amino acids are divided into essential amino acids and non-essential amino acids. Essential amino acids are amino acids that cannot be formed by the human body (nutritive food) and non-essential amino acids are amino acids that the human body can form[40]. The research results showed that 15 types of amino acids were detected in *Sargassum polycystum*. The detected amino acids consisted of 7 and 8 non-essential amino acids. The essential amino acids in *Sargassum polycystum* are histidine, threonine, arginine+tyrosine, methionine, valine, phenylalanine and

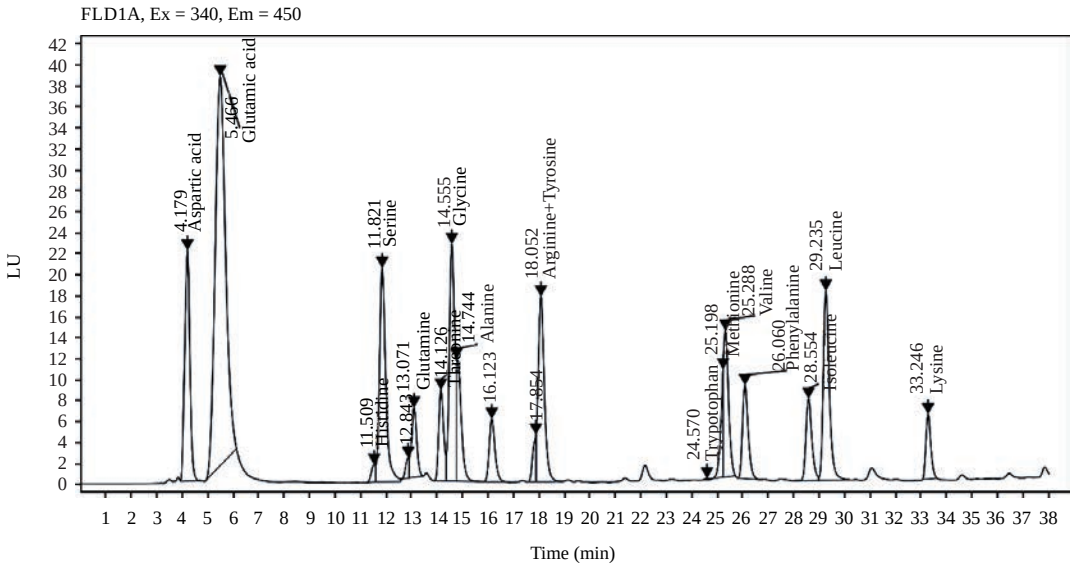

Fig. 3: HPLC chromatogram of amino acids of *Sargassum polycystum*

Table 1: Retention time and retention factor value of amino acids from *Sargassum polycystum*

	Retention time (min)		Retention factor	
Type of amino acid	Standard*	Results**	Standard*	Results**
L-aspartic acid	4.364	4.179	118.16547	123.08752
L-glutamic acid	5.489	5.466	109.18034	108.71372
L-asparagine	9.210	-	126.79339	-
L-histidine	10.775	11.509	44.11243	54.06209
L-serine	11.319	11.821	139.46216	150.95817
L-glutamine	11.608	13.071	152.54290	162.62506
L-threonine	14.161	14.126	72.62967	163.19070
L-glycine	14.700	14.555	208.32837	99.69808
L-alanine	15.049	14.744	130.34252	265.44644
L-arginine+L-tyrosine	18.421	18.052	106.22463	112.58561
L-tryptophan	25.508	24.570	53.54256	-45.53599
L-methionine	24.796	25.198	128.42957	156.17192
L-valine	25.418	25.288	163.37864	199.62026
L-phenylalanine	26.088	26.060	80.67932	81.35079
L-Isoleucine	28.355	28.554	142.68971	156.97584
L-leucine	28.962	29.235	129.90158	133.27392
L-lysine	32.548	33.246	63.12580	59.23136

*Amino standard reference and **Sample test result value

isoleucine. Meanwhile, the non-essential amino acids found in *Sargassum polycystum* are aspartic acid, glutamic acid, serine, glutamine, glycine, alanine, tryptophan, leucine and lysine.

Validation analysis procedure of the amino acid content: The validation method and analysis procedure for the amino acid content followed the validation guidelines set forth by EURACHEM for analytical methods. To assess the sensitivity and linearity of the signal about concentration, linear calibrations were established for each amino acid. Five different concentrations of standards were used to determine the linearity, specifically 0.1, 0.3, 0.6, 1.3 and 3.3 mg/100 g. The correlation coefficients (R^2) varied from 0.98599 to 0.9981, as presented in Table 2. L-histidine showed the highest correlation coefficient (R^2) value of 0.99981 with an area of around 18.3959 and content of 0.23% in *Sargassum polycystum*. Meanwhile, L-threonine showed the highest correlation coefficient (R^2) value of 0.98599 with an area of around 148.1907 and a content of 0.57% in *Sargassum polycystum*. The amino acid content of L-asparagine and L-tryptophan was not detected in *Sargassum polycystum*. The highest amino acid content is L-glutamic acid at 5.03% and the lowest is L-methionine at 0.19%, which is found in *Sargassum polycystum*.

Table 2: Performance parameters of the method for determining amino acids and area

Type of amino acid	Area		Correlation coefficient R^2	Content (%)
	Standard	Results		
L-aspartic acid	1833.9484	312.0727	0.99917	1.28
L-glutamic acid	1762.2497	1050.9751	0.99733	5.09
L-asparagine	2011.6701	-	-	not detection
L-histidine	702.9330	18.3959	0.99981	0.23
L-serine	2197.0300	346.7892	0.99937	1.13
L-glutamine	2434.0014	95.6021	0.99967	0.29
L-threonine	1136.5817	148.1907	0.98599	0.57
L-glycine	3364.9878	117.0001	0.99832	0.61
L-alanine	2050.0018	336.3342	0.99834	1.31
L-arginine+L-tyrosine	3371.1225	296.4565	0.99969	0.45
L-tryptophan	849.4649	1.8830	0.99976	not detection
L-methionine	2034.8555	64.0042	0.99866	0.19
L-valine	2593.8433	189.5508	0.99887	0.77
L-phenylalanine	627.1704	138.6887	0.99871	0.86
L-isoleucine	2262.7583	126.6243	0.99967	0.40
L-leucine	2058.0263	297.9581	0.99971	1.12
L-lysine	1031.1630	82.8405	0.99953	0.69

L- asparagine and L-tryptophan were not detected, Detection limits of L-asparagine (4.48 ppm) and L-tryptophan (0.1 ppm)

Table 3: Total content chlorophyll and carotenoid *Sargassum polycystum*

Sample	Chlorophyll a µg/100 g DW	Chlorophyll bµ g/100 g DW	Total chlorophyll µg/100 g DW	Carotenoid µg/100 g DW
Sargassum polycystum	10.39	2.48	12.87	6.37

The resulting peak area data is then used in concentration measurements by multiplying the resulting peak area by the standard amino acid concentration. The resulting concentration is then converted into a percent by multiplying the molecular weight of each amino acid divided by the sample weight[41]. The research results showed that the L-glutamic acid content in *Sargassum polycystum* had the highest content, namely 5.09%, while the L-methionine content had the lowest content at 0.19%. L-glutamic acid is important in most metabolic reactions and influences metabolic processes in the brain. L-glutamic acid is a source of glucose and can maintain normal blood levels[42,43]. The high content of glutamic acid in the meat and innards of feather clams is due to the analysis process using acid hydrolysis, which has a higher degree of analysis. The L-aspartic acid content in *Sargassum polycystum* is relatively high, 1.28%. L-aspartic acid is the main component of antibodies, immunoglobulin and the immune system. With this type of amino acid, carbohydrates are converted into energy, which helps the body to reduce ammonia levels. It has hepatoprotective properties and is involved in reanimation reactions and synthesizing methionine, threonine and lysine[44,45].

The L-glycine is classified as a non-essential amino acid, a substrate for synthesizing several biologically important compounds and biomolecules. This amino acid plays a crucial role in detoxification reactions and synthesizing the tripeptide glutathione and proteins. The L-glycine content in *S. polycystum* is 0.61%. Additionally, L-glycine possesses a broad spectrum of immunomodulatory, anti-inflammatory and cytoprotective properties[46]. In *S. polycystum*, two types of amino acids are present: Essential and non-essential. Among the essential amino acids, L-phenylalanine has the highest content at 0.86%, while L-methionine has the lowest at 0.19%. L-alanine plays a key role as an intermediary between protein catabolism and carbohydrate synthesis. It is central to muscle protein metabolism and is a significant factor in nitrogen metabolism, enabling muscles to utilize the energy produced by other amino acids. L-alanine is commonly used as an ingredient in infusion solutions, food additives and as a precursor for pharmaceutical and chemical products[47].

Contents of total chlorophylls: Results for the major photosynthetic pigments studied in *Sargassum polycystum* are usually presented as the content of total carotenoids, chlorophylls a and b and expressed as µg/100 g dry weight (DW). The values for total carotenoids, chlorophyll a and chlorophyll b content determined in the *S. polycystum* were shown in Table 3. From the table, it may be observed that the concentration of total carotenoids measured 6.37 µg/100 g DW, whereas chlorophyll a, chlorophyll b and total chlorophyll contents measured 10.39, 2.48 and 12.87 µg/100 g DW, respectively.

CONCLUSION

Using the HPLC method, amino acids were identified in *S. polycystum* and their quantitative levels were determined. The results of this study found that 15 amino acids were detected, of which 7 were essential amino acids (L-histidine, L-threonine, L-arginine+tyrosine, L-methionine, L-valine, L-phenylalanine and L-isoleucine) and 8 of them are non-essential amino acids (L-aspartic acid, L-glutamic acid, L-serine, L-glutamine, L-glycine, L-alanine, L-leucine and L-lysine). The amino acids L-asparagine and L-tryptophan could not be detected in *S. polycystum*. Meanwhile, L-glutamic content has the highest content, 5.09% and L-methionine has the lowest amino acid content at 0.19%. Future suggestions would involve more research on the precise functions of essential and non-essential amino acids in *Sargassum polycystum* crop physiological processes. From an agronomical point of view, it is very important to investigate their possible uses as osmoprotectant substances for stress elimination of crops grown under stressful conditions, such as drought and salinity stresses.

SIGNIFICANCE STATEMENT

This study discovered the biochemical compounds in brown seaweed (*Sargassum polycystum*) from the City of Bengkulu, Indonesia, that can be beneficial for enhancing vegetable crop tolerance to environmental stressors such as drought and salinity. These compounds serve as effective exogenous osmoprotectants, offering a sustainable approach to improving agricultural resilience in climate-vulnerable regions. The application of *S. polycystum* extracts could revolutionize stress mitigation strategies, ensuring higher crop yields and food security. This study will help researchers uncover the critical areas of agricultural biotechnology and stress physiology that many researchers were not able to explore. Thus, a new theory on seaweed-based osmoprotection in crop production may be arrived at.

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REFERENCES

1. Hirpo, F.H. and M.N. Gebeyehu, 2019. Review on the effects of climate change variability on horticultural productivity. Int. J. Environ. Sci. Nat. Res., 17: 130-134.
2. Salinger, M.J., 2005. Climate variability and change: Past, present and future-An overview. Clim. Change, 70: 9-29.
3. Hailu, B. and H. Mehari, 2021. Impacts of soil salinity/sodicity on soil-water relations and plant growth in dry land areas: A review. J. Nat. Sci. Res., 12: 1-10.
4. Haghpanah, M., S. Hashemipetroudi, A. Arzani and F. Araniti, 2024. Drought tolerance in plants: Physiological and molecular responses. Plants, Vol. 13. 10.3390/plants13212962.
5. Hammad, S.A.R. and O.A.M. Ali, 2014. Physiological and biochemical studies on drought tolerance of wheat plants by application of amino acids and yeast extract. Ann. Agric. Sci., 59: 133-145.
6. Zia, R., M.S. Nawaz, M.J. Siddique, S. Hakim and A. Imran, 2021. Plant survival under drought stress: Implications, adaptive responses, and integrated rhizosphere management strategy for stress mitigation. Microbiol. Res., Vol. 242. 10.1016/j.micres.2020.126626.
7. Pattnaik, D., D. Dash, A. Mishra, A.K. Padhiary, P. Dey and G.K. Dash, 2021. Emerging Roles of Osmoprotectants in Alleviating Abiotic Stress Response Under Changing Climatic Conditions. In: Climate Impacts on Sustainable Natural Resource Management, Kumar, P., R.K. Singh, M. Kumar, M. Rani and P. Sharma (Eds.), John Wiley & Sons Ltd., Hoboken, New Jersey, ISBN: 9781119793403, pp: 302-324.
8. Ali, O., A. Ramsubhag and J. Jayaraman, 2021. Biostimulant properties of seaweed extracts in plants: Implications towards sustainable crop production. Plants, Vol. 10. 10.3390/plants10030531.
9. du Jardin, P., 2015. Plant biostimulants: Definition, concept, main categories and regulation. Sci. Hortic., 196: 3-14.
10. Deolu-Ajayi, A.O., I.M. van der Meer, A. van der Werf and R. Karlova, 2022. The power of seaweeds as plant biostimulants to boost crop production under abiotic stress. Plant Cell Environ., 45: 2537-2553.
11. Al Azad, S. and M.T.B.M. Lal, 2022. Effects of inoculum size of *Afifella marina* in the bioprocessing of *Sargassum* spp. meal. Adv. Biol. Chem., 12: 185-195.
12. Kusmita, L., H.D. Pratiwi and I.K. Bagiana, 2023. Identification, isolation and antioxidant activity of pigments from *Sargassum polycystum* from Sumbawa, Indonesia. Egypt. J. Aquat. Biol. Fish., 27: 433-443.
13. Widyaswari, S.G., Metusalach, Kasmiati and N. Amir, 2024. Bioactive compounds and DPPH antioxidant activity of underutilized macroalgae (*Sargassum* spp.) from coastal water of Makassar, Indonesia. Biodiversitas J. Biol. Diversity, 25: 162-168.

14. Vijayanand, N., S.S. Ramya and S. Rathinavel, 2014. Potential of liquid extracts of *Sargassum wightii* on growth, biochemical and yield parameters of cluster bean plant. Asian Pac. J. Reprod., 3: 150-155.
15. Fatimah, S., H. Alimon and N. Daud, 2018. The effect of seaweed extract (*Sargassum* sp) used as fertilizer on plant growth of *Capsicum annum* (chilli) and *Lycopersicon esculentum* (tomato). Indones. J. Sci. Technol., 3: 115-123.
16. Mohammed, S., M.M. El-Sheekh, S.H. Aly, M. Al-Harbi, A. Elkelish and A. Nagah, 2023. Inductive role of the brown alga *Sargassum polycystum* on growth and biosynthesis of imperative metabolites and antioxidants of two crop plants. Front. Plant Sci., Vol. 14. 10.3389/fpls.2023.1136325.
17. Campos, B.M., E. Ramalho, I. Marmelo, J.P. Noronha, M. Malfeito-Ferreira, P. Mata and M.S. Diniz, 2022. Proximate composition, physicochemical and microbiological characterization of edible seaweeds available in the Portuguese Market. Front. Biosci. Elite, Vol. 14. 10.31083/j.fbe1404026.
18. da Silva, V.M., L.A. Silva, J.B. de Andrade, M.C. da Cunha Veloso and G.V. Santos, 2008. Determination of moisture content and water activity in algae and fish by thermoanalytical techniques. Quim. Nova, 31: 901-905.
19. Mokoginta, M.K., N. Indriati, N. Dharmayanti and S.Z. Nurbani, 2019. Extraction and characterization of sodium alginates from *Sargassum polycystum* for manufacturing of tuna (*Thunnus* sp.) meatballs. IOP Conf. Ser.: Earth Environ. Sci., Vol. 278. 10.1088/1755-1315/278/1/012047.
20. Hayes, M., 2020. Measuring protein content in food: An overview of methods. Foods, Vol. 9. 10.3390/foods9101340.
21. Reyes-Tisnado, R., G. Hernández-Carmona, Y.E.R. Montesinos, D.L.A. Higuera and F.L. Gutiérrez, 2005. Food grade alginates extracted from the giant kelp *Macrocystis pyrifera* at pilot-plant scale. Rev. Investigaciones Marinas, 26: 185-192.
22. Slobodianiuk, L., L. Budniak, H. Feshchenko, A. Sverstiuk and Y. Palaniza, 2022. Quantitative analysis of fatty acids and monosaccharides composition in *Chamerion angustifolium* L. by GC/MS method. PHARMACIA, 69: 167-174.
23. Rorong, J.H., M.M.F. Rampengan, V.I.Y. Roring and N.L.I.M. Ogi, 2024. Nutritional content of green algae *Caulerpa racemosa* and brown algae *Sargassum polycystum* at Ranowangko II Beach, Kombi District, Minahasa Regency. Rumphius Pattimura Biol. J., 6: 40-47.
24. Calvindi, J., M. Syukur and W. Nurcholis, 2020. Investigation of biochemical characters and antioxidant properties of different winged bean (*Psophocarpus tetragonolobus*) genotypes grown in Indonesia. Biodiversitas J. Biol. Diversity, 21: 2420-2424.
25. Slobodianiuk, L., L. Budniak, S. Marchyshyn, L. Kostyshyn and M. Ezhned, 2021. Determination of amino acids content of the *Tagetes lucida* Cav. by GC/MS. PHARMACIA, 68: 859-867.
26. Slobodianiuk, L., L. Budniak, S. Marchyshyn, A. Sinichenko and O. Demydiak, 2021. Determination of amino acids of cultivated species of the *Genus primula* L. Biointerface Res. Appl. Chem., 11: 8969-8977.
27. Jámbor, A. and I. Molnár-Perl, 2009. Amino acid analysis by high-performance liquid chromatography after derivatization with 9-fluorenylmethyloxycarbonyl chloride: Literature overview and further study. J. Chromatogr. A, 1216: 3064-3077.
28. Chen, W.P., X.Y. Yang, A.D. Hegeman, W.M. Gray and J.D. Cohen, 2010. Microscale analysis of amino acids using gas chromatography-mass spectrometry after methyl chloroformate derivatization. J. Chromatogr. B, 878: 2199-2208.
29. Feshchenko, H., O. Oleshchuk, L. Slobodianiuk and I. Milian, 2021. Study of *Epilobium angustifolium* L. amino acids content by HPLC method. ScienceRise: Pharm. Sci., 6: 85-90.
30. Wang, Y.T., C.H. Yang, K.S. Huang and J.F. Shaw, 2021. Chlorophyllides: Preparation, purification, and application. Biomolecules, Vol. 11. 10.3390/biom11081115.
31. Vijay, K., S. Balasundari, R. Jeyashakila, P. Velayathum, K. Masilan and R. Reshma, 2017. Proximate and mineral composition of brown seaweed from Gulf of Mannar. Int. J. Fish. Aquat. Stud., 5: 106-112.
32. Dawczynski, C., R. Schubert and G. Jahreis, 2007. Amino acids, fatty acids, and dietary fibre in edible seaweed products. Food Chem., 103: 891-899.
33. Rachmawati, N. and S. Anliza, 2022. Community empowerment in knowing sources of natural antioxidants through hydroponic systems. Kaibon Abhinaya: J. Pengabdian Masyarakat, 4: 156-162.
34. Polat, S. and Y. Ozogul, 2008. Biochemical composition of some red and brown macro algae from the Northeastern Mediterranean Sea. Int. J. Food Sci. Nutr., 59: 566-572.
35. Millena, C.G., J.A.B. Binaday, C.B. Bulawan, E.G.D. Nipas, S.S. Ruivivar and A.L. Rosales, 2024. Nutritional composition and mineral bioavailability of selected root and tuber crops in the Bicol Region, Philippines. Food Res., 8: 382-396.
36. Makkar, H.P., G. Tran, V. Heuze, S. Giger-Reverdin, M. Lessire, F. Lebas and P. Ankers, 2016. Seaweeds for livestock diets: A review. Anim. Feed Sci. Technol., 212: 1-17.
37. Alisha, R.P. Dubey and A. Haider, 2019. Seaweed: Nutritional and health benefits. Pharma Innovation J., 8: 80-83.
38. Jajic, I., S. Krstovic, D. Glamocic, S. Jaksic and B. Abramovic, 2013. Validation of an HPLC method for the determination of amino acids in feed. J. Serb. Chem. Soc., 78: 839-850.
39. Nazarudin, M.F., N.H. Alias, S. Balakrishnan, W.N.I.W. Hasnan and N.A.I.N. Mazli *et al*., 2021. Chemical, nutrient and physicochemical properties of brown seaweed, *Sargassum polycystum* C. Agardh (phaeophyceae) collected from Port Dickson, Peninsular Malaysia. Molecules, Vol. 26. 10.3390/molecules26175216.

40. Romano, C., G. Corsetti, V. Flati, E. Pasini and A. Picca *et al*., 2019. Influence of diets with varying essential/nonessential amino acid ratios on mouse lifespan. Nutrients, Vol. 11. 10.3390/nu11061367.
41. Zhao, R., B. Huang, G. Lu, S. Fu, J. Ying and Y. Zhao, 2023. A practical method for amino acid analysis by LC-MS using precolumn derivatization with urea. Int. J. Mol. Sci., Vol. 24. 10.3390/ijms24087332.
42. Duan, Y., F. Li, Y. Li, Y. Tang and X. Kong *et al*., 2016. The role of leucine and its metabolites in protein and energy metabolism. Amino Acids, 48: 41-51.
43. Campbell, I.H. and H. Campbell, 2024. The metabolic overdrive hypothesis: Hyperglycolysis and glutaminolysis in bipolar mania. Mol. Psychiatry, 29: 1521-1527.
44. Hatazawa, Y., K. Qian, D.W. Gong and Y. Kamei, 2018. PGC-1α regulates alanine metabolism in muscle cells. PLoS ONE, Vol. 13. 10.1371/journal.pone.0190904.
45. Pérez-Torres, I., A.M. Zuniga-Munoz and V. Guarner-Lans, 2017. Beneficial effects of the amino acid glycine. Mini-Rev. Med. Chem., 17: 15-32.
46. Tomé, D., 2018. Protein: What's on in research on clinical nutrition. Eur. J. Clin. Nutr., 72: 1215-1220.
47. Han, X., Y. Shen, Y. Wang, J. Shen and H. Wang *et al*., 2023. Transcriptome revealed the effect of shading on the photosynthetic pigment and photosynthesis of overwintering tea leaves. Agronomy, Vol. 13. 10.3390/agronomy13071701.