

Review of Marine Algae in The Ulva Genus: *Ulva lactuca*, *Ulva intestinalis* and *Ulva rigida*

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ABSTRACT

This review focuses the comparative analysis of Marine algae of the genus *Ulva*, commonly known as sea lettuce such as *Ulva lactuca*, *Ulva intestinalis*, and *Ulva rigida* in order to evaluate their similarities and differences in terms of morphological features, phytochemical characteristics and potential pharmacological activities. Morphologically, *Ulva* exhibits a simple thallus structure, typically flat, sheet-like, or tubular. It is made up of two cell layers that grow quickly and can adapt to different environmental circumstances. The genus demonstrates considerable variation in size, shape, and cellular organization across species. However, challenges such as seasonal variation in composition and sustainable harvesting practices remain. Phytochemical analysis reveals that *Ulva* species are rich in bioactive compounds, including polysaccharides called ulvan, proteins, vitamins, minerals, phenolic compounds, and pigments like chlorophyll and carotenoids. These constituents contribute to their antioxidant, antimicrobial, anti-inflammatory, anti cancer and antiviral properties. Due to these attributes, *Ulva* has gained attention for applications in food, pharmaceuticals, nutraceuticals, and biofuel production. It concludes that *Ulva* species possess significant potential for the future research and industrial utilization, particularly in the development of natural bioactive products.

KEY WORDS: Marine algae, Ulvan, Morphology, Phytochemistry, Polysaccharide.

I. INTRODUCTION

Marine algae are an important group of photosynthetic organisms that are very essential to coastal ecosystems and possess numerous biological and pharmacological properties. Among marine

macroalgae, green algae belonging to the genus *Ulva* (family Ulvaceae) are widely distributed in marine and estuarine environments around the world. These algae are commonly referred to as sea lettuce due to their bright green colour and leaf-like appearance. Species of *Ulva* are known for their rapid growth, high nutritional value, and diverse bioactive compounds such as polysaccharides, proteins, vitamins, minerals, antioxidants, and phenolic compounds. Because of these properties, they have attracted significant attention in various fields including pharmaceutical research, nutraceutical development, biotechnology, and environmental studies. Among the various species of this genus, *Ulva intestinalis*, *Ulva lactuca*, and *Ulva rigida* are commonly studied due to their abundance, ecological importance, and potential biological activities. *Ulva intestinalis* is characterized by its tubular, hollow thallus structure and is commonly found in intertidal zones and estuaries. In contrast, *Ulva lactuca* possesses a thin, flat, sheet-like thallus resembling lettuce leaves, making it one of the most recognizable green seaweeds. *Ulva rigida*, on the other hand, has a more rigid and thicker blade structure compared to *U. lactuca* enabling it to tolerate varying environmental conditions. Despite belonging to the same genus, these species exhibit differences in morphology, biochemical composition, ecological adaptability, and bioactive potential. Comparative studies of these species are therefore essential to better understand their structural characteristics, phytochemical composition, and possible pharmacological activities.^[1,5,17,29]

Ulva lactuca

TAXONOMICAL CLASSIFICATION ^[1]

KINGDOM : PLANTAE.

SUB KINGDOM : VIRIDIPLANTAE.

INFRA KINGDOM : CHLOROPHYTA.
DIVISION : CHLOROPHYTA.
SUB DIVISION : CHLOROPHYTINA.
CLASS : ULVOPHYCEAE.
ORDER : ULVALES.

FAMILY : ULVACEAE.
GENUS : *Ulva*
SPECIES: *lactuca*
BOTANICAL NAME : *Ulva lactuca* Linn.
COMMON NAME : SEA LETTUCE.



DESCRIPTION

Ulva lactuca is a thin flat green marine alga growing from a discoid holdfast. The margin is somewhat ruffled and often torn. It may reach 18 centimeters (7.1 in) or more in length, though generally much less and upto 30 centimeters (12 in) across. The membrane is two cells thick, soft and translucent and grows attached without a stipe, to rocks or other algae by a small disc-shaped holdfast. Green to dark green in colour, this species in the chlorophyta is formed of two layers of cells irregularly arranged, as seen in cross-section. The chloroplast is cup-shaped in some references but as a parietal late in others with one to three pyrenoids.^[2,3] There are other species of ulva which are similar and not always easy to differentiate. Plants bright yellowish-green, grows are large sheets and attached by small disc, leaf like with undulating wide blade. Blades upto 20 cm tall much broad than long heart or oval shaped and occasionally with some holes, like waxed paper to touch. It is found in moderately exposed situations on rocks, wood works or coarse algae in pool and quiet shallow waters near the low tidemark. It also thrives in brackish water with organic pollution. This species occurs in all months of the year.^[4]

DISTRIBUTION

It is distributed in variety of regions such as Kanyakumari, Tiruchendur, Tuticori, Mandapam and Lakshadweep, Gulf of Kutch, Okha, Dwarka, Porbandar, Diu, Bombay, Goa, Karwar, Alleppey, Quilon, and also worldwide in Europe, North America, Africa, Indian Ocean Islands, South-West Asia, China, Pacific Islands, Australia and New Zealand.^[4]

PHYTOCHEMISTRY

The phytochemical analysis revealed the presence of alkaloids, carbohydrate, flavonoids, phenol, steroids, protein, amino acids, glycosides, polysaccharides, vitamins, minerals, fibers, tannins, catechin, terpenoids, coumarins, saponins, quinine and anthro quinine.^[5,6,7] The green algae extract contain alkaloids, flavonoids and saponins that were 79.58, 2.36 and 0.03mg/100g algae dry weight respectively and the concentration of total phenols was 14.223mg/100g dry algae tissue. Although among this terpenoids and cardiac glycosides are also present.^[2] Marine Green algae *Ulva lactuca* consists of 25.8% protein, 16.0% carbohydrate and 7.4% lipid^[4]. Also Marine algae *Ulva lactuca*

revealed the presence of 17 different phyto compounds viz. 7-Hexadecene, (z) (1.50%), 8-Heptadecene (3.78%), Tetradecanoic acid, ethyl ester (CAS) (2.07%), Phytol 2-Hexadecen-1-ol,3,7,11,15-tetramethyl-,[R-[R*,R*-(E)]- (CAS) (10.51%), Doconexent (2.24), Hexadecanoic acid (CAS) (3.18%), Hexadecanoic acid, ethyl ester(20.24%), Ethyl6,9,12,15-octadecatetraenoate (3.35%), (E)-9-Octadecenoic acid ethyl ester(9.59%), Octadecanoic acid, ethyl ester (1.66%), Hexadecanoic acid, 2,3-dihydroxypropyl ester, (n) (1.77%), 2-(2-mercapto-2-nyl-aminoimino)pentane (2.29%), Hexadecanoic acid, 1,1-dimethyl-1,2-ethanediyl ester (CAS) (1.17%), Heneicosane (CAS) (1.83%), Heptacosane (CAS) (2.02%), Nonacosane (CAS) (3.83%) and Dodecane, 5,8-diethyl (2.07%)^[8]. It is reported that *Ulva lactuca* has Ulvan, it showed the presence of a majority of 4-O-(B-D-glucuronosyluronic acid)-L-rhamnose and small quantities of two other aldobiouronic acids tentatively identified as 3-O- and 4-O-(D-glucuronosyluronic acids)-D-xylose. An acidic tetrasaccharide identified as D-glucuronic acid-(1-4)-L-rhamnosyl (1→3/4)-D-glucuronosyluronic acid-(1-3) D-glucose obtained after partial acid hydrolysis of desulfated and carboxy-reduced Ulvan, demonstrated the association of the three different sugars in the polysaccharide.^[9] Chloroform extract showed the presence of carbohydrates, steroids, protein, terpenoids and phytosterols. Ethanol extract revealed the presence of flavonoids, glycosides, steroids, terpenoids and phytosterols. Acetone extract revealed the presence of flavonoids, glycosides, quinines, coumarins, and alkaloids.^[10]

In *Ulvalactuca*, chemical composition and structural of the glucan in the alkali-insoluble cell-wall polysaccharides from the marine green seaweed are reported. The α -cellulose is composed (in mol%) of glucose (72.9), xylose (9.7), rhamnose (4.6), uronic acid (4.3) and sulfate (8.5). The last three components do not appear to be part of the glucan as they were partially removed by methylmorpholine N-oxide treatment. It was composed of 40.5% protein, 36.1% sugar (neutral sugars and uronic acids), and 9.4% ash including 3.9% sulfate. Glucose was the major sugar (56.9 mol%) followed by xylose (11.0 mol%), rhamnose (8.9 mol%), and uronic acid (6.9 mol%). After extraction of A with 1.0 and 4.0 M KOH, an insoluble fraction B was recovered in 1.3% yield

based on the starting algal wet weight (8.5% dry weight basis). It was composed of 56.6% sugar (neutral sugars and uronic acids), 11.3% protein and although it was extensively washed, 26.3% ash including 2.0% sulfate. The glucose proportion increased from 56.9 in fraction A to 72.9 mol% in fraction B, whereas that of rhamnose and uronic acid decreased. ^[9] Groups with the largest number of species from which sulphated polysaccharides can be prepared include the genera Ulvan (38%). ^[11] It is also reported that Hexadecanoic and octadeca-9-enoic acids were the main lipophilic components detected in *Ulva lactuca* and Cholesterol is the main sterol found in *Ulva lactuca* contain 12.4 mg kg⁻¹ DW. This value is considerably lower than those reported before for this macroalga species from Portuguese coast. The sterol content showed a small increase after alkaline hydrolysis in all macroalgae studied β sitosterol was found in *Ulva lactuca* hydrolyzed extracts contain 28.5 mg kg⁻¹ DW respectively. Several long-chain aliphatic alcohols were also detected in all macroalgae species. And also reported that in *Ulvalactuca* only octadecan-1-ol and octacosan-1-ol were detected and at lower amounts 1.4 and 2.0 mg Kg IDW, respectively. In addition to that other new compounds were identified namely as two diterpenes, phytol and neophytadiene. ^[12]

It is reported that *Ulvalactuca* have the following phytochemicals as carbon content of the samples was in the range of 28.04-34.70% and oxygen content ranged from 58.39% to 64.48% with low heating values of 9.80-14.71 MJ/kg and HHV of 10.90 and 9.80 MJ/kg. In contrast, the nitrogen content in *Ulva lactuca* (4.01%). The crude protein content in *Ulva lactuca* (20.31%) and carbohydrate content of *Ulva lactuca* 43.42%. ^[13]

Ulva intestinalis

TAXONOMICAL CLASSIFICATION ^[14&35]

KINGDOM : PLANTAE.

SUB KINGDOM: VIRIDIPLANTAE.

DIVISION: CHLOROPHYTA

SUB DIVISION: CHLOROPHYTINA

CLASS: ULVOPHYCEAE

ORDER: ULVALES

FAMILY: ULVACEAE

GENUS: *Ulva*

SPECIES: *intestinalis*

BOTANICAL NAME: *Ulva intestinalis* Linn.

COMMON NAME: SEA LETTUCE.



DESCRIPTION

Ulva intestinalis shows the characters of Appearance: Bright green to yellowish-green, tubular, and erect fronds.

Shape: The thallus is unbranched or rarely with few branches at the base, erect, cylindrical, and typically inflated or convoluted and monostromatic [1 cell layer] in nature.

Dimensions: Algae (fronds) can be 10-30 cm in length and 1-2 cm in diameter.

Texture: Soft, smooth, and delicate.

Attachment: Attached to the substrate via a small, disc-shaped holdfast.

Cell Arrangement: Irregular

Habitat: Marine/ Brackish, often euryhaline in nature. [15]

DISTRIBUTION

It is distributed in variety of regions such as Tiruchendur, Mandapam, Ramanathapuram Coastal areas, Kanya kumari, Tuticorin, Gulf of

Kutch, Okha, Dwarka, Porbandar, Diu, Bombay, Goa, Karwar, Alleppey, Quilon, and Lakshadweep [16]

PHYTOCHEMISTRY

The phytochemical analysis of *Ulva intestinalis* revealed the presence of alkaloids, carbohydrate, flavonoids, phenol, steroids, protein, amino acids, glycosides and tannins. [5] The phytochemical screening revealed that 18 phytochemicals were simple carboxylic acids, fatty acids, or their derivatives (palmitic acid, HIP, methylpalmitate, ethylpalmitate, butanoic acid, paullinic acid, doconexent, allyl stearate, ethyllinolelaidate, ethyllinolenate, ethylelaidate, icosapent, MHDTE, BOD4E, BOD3E, BTES, DPPP, and propyllinoleate), seven belonged to terpenoid class (damascene, cyclosativene, dihydroactinolide, 3-DOCH, phytol, CMBA, and oxymesterone), three (6.98%) each were aldehydes and its derivatives (methylglyoxal, furfural, and retinal), alcohols and its derivatives (TAA, 1-heptatriacotanol, and DTD), alkene hydrocarbons

and its derivatives (cetene, 8-heptadecene, and 9-octadecene), and alkane hydrocarbons and its derivatives (myristyl chloride, TMHA, and EEBOD), two were monoglycerides (2-monopalmitin and 1-monolinolein), and one each were an organosulfur compound (DMSO), an aromatic hydrocarbon (azulene), a phenol (2,4-DtBP), and a glycoside (RBGUL). The results indicated that mainly phenols, polyenes, phytosteroids, and aliphatic compounds from the extract, such as 2,4-di-tert-butylphenol (2,4-DtBP), doconexent, 4,8,13-duvatriene-1,3-diol (DTD), retinoyl- β -glucuronide 6',3'-lactone (RBGUL), and retinal, showed better binding affinity to the target. [17 & 20] Phytochemical screening of ethanolic extract of *Ulva* revealed the presence of alkaloids, steroids, flavonoids and coumarins. From the quantitative test of nutrients, it demonstrated that the seaweed contains 15.41% of protein, 51.79% of carbohydrate, 1.21% of fat, 3.74% of fiber, 18.81% ash, and 12.78% moisture. [21,22,23] Additionally, the presence of vitamin B12 was promising (1300 $\mu\text{g}/100\text{ g}$). Interestingly, heavy metals were not detected in *Ulva intestinalis* whereas other micronutrients were present. [18] The phytochemical studies revealed the presence of tannins, phenols, flavonoids and proteins. [19] Green seaweeds reportedly contain proteins, peptides, polysaccharide, carotenoids, phenolic compounds. Among all these active ingredients, polysaccharides are the components most intensively investigated for medical purposes. [11,24]

Ulva rigida

TAXONOMICAL CLASSIFICATION [25&35]

KINGDOM : PLANTAE.

SUB KINGDOM: VIRIDIPLANTAE.

DIVISION: CHLOROPHYTA

SUB DIVISION: CHLOROPHYTINA

CLASS: ULVOPHYCEAE

ORDER : ULVALES

FAMILY : ULVACEAE

GENUS : *Ulva*

SPECIES : *rigida*

BOTANICAL NAME : *Ulva rigida* Linn.,

COMMON NAME : SEA LETTUCE.



DESCRIPTION

U. rigida pale to grass green, up to 30 cm tall, irregularly incised or lobed, consistency firm, especially near the base; thallus margins near the base with minute teeth. Cells in surface view organized in long curved rows, rounded angular, 10-16 μm in diameter. Thickness of lamina from 75 μm in the apical region to 100 μm in the mid-thallus and increasing to 200 μm in the upper basal region. Cell height 25-35 μm , cells 2-4 times higher than broad, cylindrical with rounded angles at the outer periclinal wall. Chloroplast parietal, located against the outer periclinal cell wall or shifted to one of the radial cell walls; pyrenoids 1-3. Rhizoidal cells larger and darker than normal vegetative cells, in older plants forming ribs on the membrane surface. [26]

DISTRIBUTION

Ulva rigida is a widely distributed, opportunistic green macro alga found in intertidal and subtidal zones globally, particularly in temperate and subtropical waters. It thrives in high-nutrient areas, such as rocky shores, tidepools, and places with freshwater input (e.g., European coasts, Atlantic North America, Mediterranean, and Hawaii. [27]

PHYTOCHEMISTRY

Ulva species are known to be a rich source of valuable polysaccharides, including ulvans and oligosaccharides, that can comprise almost 40% of their dry weight (DW). Moreover, similar to other green species, they are a good source of protein (10–25% DW) with an appreciable amount of essential amino acids (48%) and macro and trace elements, particularly iron and manganese. [28-30] Moreover, despite the fact that lipids may only represent from

residual to 3% of the whole algal DM, they display an important nutritional value, being rich in *n*-3 polyunsaturated fatty acids (PUFAs), such as α -linolenic acid, eicosapentaenoic acid and docosahexaenoic acid. The specific chemical composition of *Ulva* spp. is, however, dependent on several factors, including the specific species and the growing conditions (e.g., location, seasonality and cultivation conditions)^[31].

In general, the nutritional values of *U. rigida* were in accordance with those previously reported for wild samples from other regions, including the Azores and Tunisia for which protein and ash contents ranged from 7 to 16% dw and 21 to 26% dw, respectively^[32&33].

Ulva rigida is a green marine macroalga rich in bioactive compounds, primarily including sulfated polysaccharides (notably ulvan), proteins, essential fatty acids, and high ash content. Although low in total lipids (around 1%), *U. rigida* contains high-value unsaturated fatty acids, including palmitoleic (C16:1), oleic (C18:1), and linolenic acids^[33,34].

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