**Review Article**



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# Phytochemical Profile and Pharmacological Potentials of *Ulva lactuca*: A Marine Green Alga for Biomedical Applications

**Ni Luh Linda Sukrawati, Putu Oka Samirana, Anak Agung Gede Rai Yadnya Putra**

Pharmacy Students, Faculty of Mathematics and Natural Sciences, Udayana University

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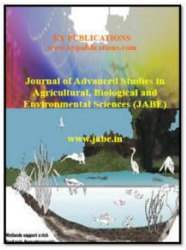


**ABSTRACT**

*Ulva lactuca* is a marine alga belonging to the genus *Ulva* and the family Ulvaceae. *Ulva lactuca* contains a high-value chemical composition that offers potential applications in cosmetics, pharmaceuticals, chemistry, food, and energy industries. This review article aims to examine the phytochemical profile and pharmacological activities of *Ulva lactuca*. Data were collected from national and international journals through scientific databases such as PubMed and Google Scholar. Based on the literature search, seven articles met the inclusion criteria. The results revealed that *Ulva lactuca* contains various secondary metabolites, including alkaloids, terpenoids, steroids, saponins, and flavonoids. Several compounds such as sinapic acid, naringin, rutin, and quercetin have been isolated from this seaweed. The pharmacological activities most frequently reported in the literature include antioxidant, antibacterial, antifungal, anticancer, and antidiabetic properties. Although this marine alga presents a promising source in pharmacology and phytochemistry, further research is needed to explore the potential of *Ulva lactuca* as a natural product beneficial for human health. Given that current studies on its phytochemical constituents and pharmacological activities remain limited, more in-depth investigations are warranted.

**Keywords** – Pharmacology, Phytochemical, Secondary Metabolite, *Ulva lactuca*.

## 1. Introduction

The exploration of marine resources as raw materials for pharmaceuticals has developed significantly in recent decades. The richness of marine biota, particularly macroalgae, has become a major focus in the search for new bioactive compounds. Algae are known to produce a wide variety of compounds with promising biological activities, including antioxidant, antimicrobial (antibacterial, antiviral, antifungal), anticancer, anti-inflammatory, antiproliferative, and antihyperlipidemic effects. These biological activities provide opportunities for the advancement of pharmaceutical sciences in Indonesia, a maritime country with vast coastal and marine resources. This geographical condition

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places Indonesia in a strategic position to develop research and production of seaweed-based pharmaceuticals (da Costa et al., 2018).

One macroalga of pharmacological importance is *Ulva lactuca* (Pappou et al., 2022). Commonly referred to as sea lettuce, *U. lactuca* belongs to the genus *Ulva* and family Ulvaceae, first described by Linnaeus in 1753 (Ktari, 2017). *U. lactuca* exhibits wide geographic distribution and strong adaptability. It can be found across different intertidal zones, from shallow waters to depths of up to 10 meters, particularly in sheltered harbor areas within temperate to cold regions. Its natural habitats include rocky and sandy coastal areas, open-sea shores, and estuarine zones. Scientific studies and literature on *U. lactuca* remain relatively limited. This narrative review provides comprehensive information on the phytochemical constituents and pharmacological activities of *U. lactuca*, and discusses its prospects as a potential source of bioactive molecules for drug discovery (Windyaswari et al., 2019).

Several studies have demonstrated that *U. lactuca* is rich in nutrients, including carbohydrates, proteins, lipids, fibers, minerals, chlorophyll b, and carotenoids in significant amounts. It has a high-value chemical composition that offers opportunities in cosmetics, pharmaceuticals, chemistry, food, and energy applications. Reports indicate that carbohydrates make up as much as 60% of its dry weight, while protein content varies between 10% and 47%. Lipids are relatively low, ranging from 1% to 3%. Mineral content, measured as ash, ranges from 7% to 38% (Domínguez & Loret, 2019). Bioactive compounds with antibacterial potential in green algae include saponins, flavonoids, and triterpenoids. Phenolic compounds present in *U. lactuca* also exhibit antioxidant activity. Furthermore, ethanol extracts of this seaweed containing alkaloids, steroids, and tannins have been reported to possess antifungal activity (Emelda et al., 2021).

Although research on *U. lactuca* remains limited, this alga shows strong potential as a source of novel bioactive compounds or drug precursors. This potential is supported by emerging scientific findings on its pharmacological properties. This review outlines the pharmacological activities reported from *U. lactuca* and provides updated scientific information. It is expected that this article will encourage researchers and the scientific community to further explore the pharmacological potential of this alga, ultimately leading to new discoveries that enrich our understanding of its health and medicinal benefits.

## 2. Methods

A systematic search was conducted to retrieve all publications (national and international journals, in English and Indonesian) from 2015 to January 2024. Data sources included scientific databases such as Google Scholar and PubMed. Inclusion criteria were articles reporting on phytochemical constituents and pharmacological activities of *U. lactuca*, as summarized in Table 1. Articles were excluded if they were review papers, conference proceedings, theses, dissertations, or if they lacked sufficient extractable data. The following keywords were used during the search: "*Ulva lactuca, Pharmacology, Phytochemical*" or "*Ulva lactuca, Pharmacology, Secondary Metabolite.*"

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Table 1: Pharmacological Activities of *Ulva lactuca* Extracts

| No. | Extract Type | Test Method | Pharmacological Activity | Activity Category | Reference |
|---|---|---|---|---|---|
| 1 | Ethyl acetate, methanol, and aqueous extracts of *Ulva lactuca* | DPPH free radical scavenging assay | Antioxidant | Strong | (Ouahabi et al., 2024) |
| 2 | Methanol extract of *Ulva lactuca* | Agar well diffusion | Antibacterial | Strong | (El-Sayed et al., 2023) |
| 3 | Methanol extract of *Ulva lactuca* | Disc diffusion method | Antibacterial | Strong | (Sujina M. G. et al., 2016) |
| 4 | Protein extract of *Ulva lactuca* | Disc diffusion | Antifungal | Strong | (Krishnamoorthi & Sivakumar, 2019) |
| 5 | Ethyl acetate extract of *Ulva lactuca* | Disc diffusion | Antifungal | Strong | (Sujina M. G. et al., 2016) |
| 6 | Methanol extract of *Ulva lactuca* | Agar diffusion | Antifungal | Strong | (Kolanjinathan & Stella, 2011; Ouahabi et al., 2024) |
| 7 | Ethyl acetate, methanol, and aqueous extracts of *Ulva lactuca* | Molecular docking analysis | Antidiabetic | Strong | (Ouahabi et al., 2024) |
| 8 | Ethanol extract of *Ulva lactuca* | MTT assay | Anticancer | Strong | (Chidambararajan et al., 2019) |
| 9 | Ethanol extract of *Ulva lactuca* | MTT assay, Flow cytometry, FITC staining, Comet assay | Anticancer | Strong | (Mohamed et al., 2023) |

**3. Results and discussion**

A total of seven studies met the inclusion criteria and were included in this review. Most of the selected articles were dominated by *in vitro* studies using assays such as DPPH (2,2-diphenyl-1-

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picrylhydrazyl), diffusion methods, calorimetry, as well as *in silico* approaches including molecular docking. Additional supporting literature was used to provide relevant background information in line with the primary articles reviewed.

### 3.1 Botanical Aspects of *Ulva lactuca*

*Ulva lactuca* is a green macroalga classified under the genus *Ulva*, class Ulvophyceae, order Ulvales, and family Ulvaceae. It is one of the most common seaweeds found along global coastlines. Morphologically, it has a flattened, sword-like thallus composed of two cell layers without tissue differentiation, with most cells being identical except basal cells that form rhizoid attachments. Each cell contains a cup-shaped nucleus and a pyrenoid-bearing chloroplast. The thallus is flat, broad, reaching up to 10 cm, anchored by a small disc-shaped holdfast. The bilayered thallus is composed of rectangular cells (20–23 µm × 20–21 µm) containing a single parietal chloroplast. Although it can grow at depths of up to 10 meters, *U. lactuca* thrives best in shallow waters around 1 meter below the surface, due to its high demand for sunlight. Its two-layered thallus structure provides a large surface-to-volume ratio, enabling efficient nutrient absorption—up to 4–6 times more than other algal species under favorable conditions (Ouahabi et al., 2024; Ulaan et al., 2019).

### 3.2 Phytochemical Constituents of *Ulva lactuca*

Phytochemical screening is an essential step in understanding the therapeutic potential of natural resources such as *U. lactuca*. Qualitative phytochemical analyses of aqueous and methanolic extracts of *U. lactuca* revealed the presence of various secondary metabolites, including flavonoids, terpenoids, alkaloids, saponins, and steroids, which collectively contribute to its pharmacological activities (Anjali et al., 2019).

Several bioactive compounds isolated from *U. lactuca* have been associated with specific biological activities. These include sinapic acid, naringin, and quercetin. Sinapic acid, a phenolic acid, exhibits strong antioxidant properties and protects cells from oxidative stress while reducing inflammation. Extracts of *U. lactuca* rich in sinapic acid demonstrated inhibitory activity against α-amylase and α-glucosidase enzymes, suggesting antidiabetic potential. Naringin, a flavonoid identified in *U. lactuca*, is known for its antioxidant properties and its role in glycemic regulation. Quercetin, another flavonoid detected in *U. lactuca*, is widely recognized for its antioxidant and anti-inflammatory properties, as well as potential antidiabetic benefits (Ouahabi et al., 2024). The chemical structures of naringin and quercetin are illustrated in Figures 1 and 2

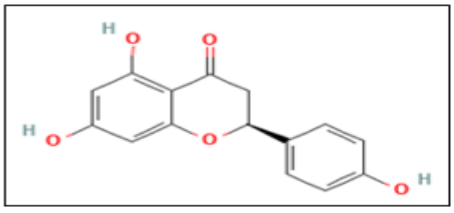

Figure 1. Chemical Structure of Naringin

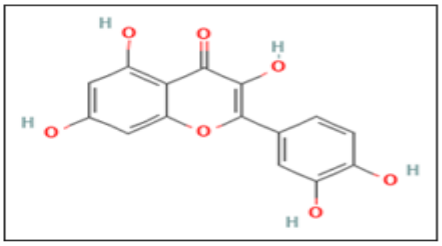

Figure 2. Chemical Structure of Quercetin

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### 3.3. Antioxidant Activity of *Ulva lactuca*

Antioxidants are secondary metabolites that play a crucial role in neutralizing free radicals within the body. Uncontrolled free radicals can potentially initiate damage to lipids, lipoproteins, and DNA. A study by Ouahabi et al. (2024) evaluated the antioxidant potential of ethyl acetate, methanol, and aqueous extracts of *Ulva lactuca* using the DPPH free radical scavenging assay and β-carotene bleaching assay. Based on these methods, the aqueous extract exhibited an $IC_{50}$ value of 0.09 mg/mL, compared with ascorbic acid ($IC_{50}$ = 0.06 mg/mL), demonstrating the strongest antioxidant effect among the tested extracts.

In contrast, the antioxidant activity of ethyl acetate and methanol extracts showed similar results, with $IC_{50}$ values ranging from 0.55 to 0.65 mg/mL, indicating that organic solvents are less effective compared to water for extracting antioxidant compounds from *Ulva lactuca*. A more detailed analysis revealed that the high antioxidant activity of the aqueous extract is associated with abundant polyphenols and flavonoids, including quercetin, kaempferol, and apigenin, which are well-known for their potent antioxidant capabilities.

Overall, the antioxidant activity of *Ulva lactuca* highlights its potential as a natural source of bioactive compounds with strong antioxidant properties, which may provide broad health benefits, including roles in diabetes management and protection against oxidative stress–related diseases.

### 3.4. Antibacterial Activity of *Ulva lactuca*

Antibacterial agents are compounds capable of inhibiting or killing pathogenic bacteria. A study by EL-Sayed et al. (2023) investigated the antibacterial activity of *Ulva lactuca* extracts against *Klebsiella pneumoniae* using the agar well diffusion method. Methanolic extracts of *Ulva lactuca* produced an inhibition zone of 14.04 mm ± 0.376, indicating significant antibacterial activity. In comparison, gentamicin (positive control) showed a larger inhibition zone of 20.91 mm ± 0.522.

The study also determined the minimum inhibitory concentration (MIC) of the methanol extract using the microdilution method, which was 1.25 mg/mL, confirming its significant inhibitory effect against *K. pneumoniae*.

Similarly, Sujina M. G. et al. (2016) reported that extracts of *Ulva lactuca* prepared with methanol, ethyl acetate, chloroform, and other solvents exhibited antibacterial activity when tested via the disc diffusion method. Methanol extracts showed the highest activity, producing inhibition zones of 12 mm against *Bacillus subtilis* and 20 mm against *Clostridium perfringens* and *Staphylococcus epidermidis*. These findings suggest that *Ulva lactuca* has strong antibacterial potential against diverse pathogenic bacteria.

### 3.5. Antifungal Activity of *Ulva lactuca*

Antifungal activity refers to the ability of a compound to inhibit the growth of pathogenic fungi that affect plants, animals, and humans. Krishnamoorthi & Sivakumar (2019) demonstrated that protein extracts from *Ulva lactuca*, prepared using ethanol, methanol, and ammonium persulfate, exhibited

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antifungal activity against several fungal pathogens, including *Aspergillus clavatus*, *Fusarium oxysporum*, *Alternaria solani*, *Aspergillus niger*, and *Aspergillus flavus*. The disc diffusion method revealed inhibition zones, with the strongest activity observed against *A. clavatus* and *A. flavus*, while *F. oxysporum* showed weaker inhibition.

Sujina et al. (2016) further confirmed that ethyl acetate extracts of *Ulva lactuca* exhibited the highest antifungal activity, producing inhibition zones up to 20 mm against *Candida tropicalis* and *A. niger*. Similarly, Kolanjinathan & Stella (2011) reported that methanol extracts of *Ulva lactuca* produced significant inhibition zones against *Candida albicans* and *Candida glabrata* (up to 16 ± 0.3 mm). MIC values ranged from 4 to 32 mg/mL, with the lowest concentration (4 mg/mL) effectively inhibiting fungal growth. These findings confirm the strong antifungal potential of *Ulva lactuca*, making it a promising candidate for developing natural antifungal agents.

### 3.6. Antidiabetic Activity of *Ulva lactuca*

Diabetes is a chronic disease characterized by elevated blood glucose levels in patients. Prolonged hyperglycemia may trigger severe complications and eventually lead to fatal damage to multiple organ systems. A study conducted by Ouahabi et al. (2024) demonstrated that *Ulva lactuca* exhibits potential in inhibiting digestive enzymes associated with glucose regulation. The two key enzymes involved in carbohydrate digestion—α-amylase and α-glucosidase—are critical therapeutic targets for diabetes management, as they break down complex carbohydrates into simple sugars that can be absorbed by the body.

In vitro experiments revealed that extracts of *Ulva lactuca* were able to inhibit the activity of both enzymes effectively. Among the extraction methods tested, methanolic extracts prepared using the Soxhlet method exhibited the highest inhibitory potential. This suggests that bioactive metabolites present in *Ulva lactuca*—particularly polyphenols and flavonoids—play a significant role in regulating glucose metabolism.

Furthermore, the findings are supported by previous research highlighting that increased reactive oxygen species (ROS) production can trigger apoptosis in cancer cells, suggesting that *Ulva lactuca* may also possess anticancer activity (Chidambararajan, 2019). Thus, *Ulva lactuca* demonstrates promising dual pharmacological potential as both an antidiabetic and anticancer natural agent.

## 4. Conclusion

The data presented in this article demonstrate that *Ulva lactuca* is a green algal species with broad pharmacological potential. Based on available studies, *Ulva lactuca* contains various important phytochemical compounds, including steroids, terpenes, flavonoids, saponins, and alkaloids. These bioactive compounds have been shown to contribute to diverse and significant pharmacological activities, such as antioxidant, antibacterial, antifungal, antidiabetic, and anticancer effects.

Although current research on *Ulva lactuca* remains limited, the available findings provide a strong scientific foundation for its further development in the fields of health and medicine. Therefore,

*Ulva lactuca* has the potential to serve as a natural source of bioactive compounds that could be utilized as candidates for drugs or health supplements in the future.

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