



# Seaweed and Its Applications in Biotechnology: From Pharmaceuticals to Bioplastics

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## Introduction

Seaweed, a form of marine algae, has long been valued for its use in food, cosmetics, and agriculture. In recent years, seaweed has gained significant attention in the field of biotechnology due to its unique properties and wide range of applications. As a renewable resource, seaweed offers sustainable solutions across industries, from pharmaceuticals to bioplastics, with the potential to revolutionize modern technology. In this article, we'll explore the diverse applications of seaweed in biotechnology and how it is transforming various sectors.

## The Unique Composition of Seaweed

Seaweed is a rich source of bioactive compounds, including polysaccharides, proteins, lipids, vitamins, minerals, and antioxidants. This diverse biochemical makeup makes it highly versatile and useful in biotechnology. Depending on the species—whether brown, red, or green seaweed—different components can be extracted and applied in various industrial processes.

## 1. Seaweed in Pharmaceuticals

One of the most exciting areas of seaweed biotechnology is its role in pharmaceuticals. Seaweed contains numerous bioactive compounds with medicinal properties, which have been explored for the treatment of various diseases.

### Antiviral, Antibacterial, and Anticancer Agents

Seaweed polysaccharides such as fucoidan, carrageenan, and alginate exhibit strong antiviral, antibacterial, and anticancer properties. For instance, **fucoidan**, found in brown seaweed, has shown promise in inhibiting the growth of cancer cells and boosting the immune system. It is currently being researched for potential use in cancer therapies and immune-boosting supplements.

Similarly, **carrageenan**, extracted from red seaweed, is widely used in antiviral drugs and is even used as a key ingredient in certain nasal sprays that can prevent viral infections, including the common cold and influenza.



### **Anti-Inflammatory and Wound Healing Properties**

Seaweed extracts are also known for their anti-inflammatory and wound healing properties. **Alginate**, another compound derived from brown seaweed, has been used in wound dressings and medical devices due to its ability to form gels that promote healing and provide moisture to wounds. Seaweed-based wound care products are commonly used in hospitals to treat burns, chronic ulcers, and other serious skin injuries.

### **Drug Delivery Systems**

In drug delivery, seaweed polysaccharides like alginate and carrageenan are being used to develop controlled-release systems. These polymers can encapsulate drugs, protecting them from degradation while delivering them slowly over time. Such systems are particularly useful for oral or topical drug delivery, where precision and timing are critical.

## **2. Seaweed in Food Biotechnology**

Beyond its traditional use as a food source, seaweed is increasingly being utilized in food biotechnology to enhance the nutritional value of food products and develop functional foods.

### **Nutraceuticals and Dietary Supplements**

Seaweed is packed with essential nutrients such as iodine, calcium, magnesium, and vitamins A, C, and K. Extracts from seaweed are commonly used in nutraceuticals—foods or supplements

that provide health benefits beyond basic nutrition. For example, **spirulina**, a type of blue-green algae, is widely used as a supplement due to its high protein content and antioxidant properties. It is also being studied for its potential to combat malnutrition and improve immune function.

### **Food Additives and Gelling Agents**

Seaweed-derived substances like carrageenan and agar are widely used as gelling, thickening, and stabilizing agents in the food industry. These compounds are essential in a variety of products, including dairy alternatives, processed meats, and plant-based desserts. Their ability to form gels and maintain consistency makes them valuable in creating textures that replicate those of traditional animal-based products.

## **3. Seaweed in Cosmetics and Skincare**

The natural compounds found in seaweed also have valuable applications in cosmetics and skincare. Seaweed extracts are rich in antioxidants, vitamins, and minerals that help protect the skin from oxidative stress, hydrate, and rejuvenate it.

### **Anti-Aging and Hydrating Properties**

Seaweed is a popular ingredient in anti-aging products due to its ability to fight free radicals, which contribute to aging. The antioxidants in seaweed, particularly **phlorotannins** from brown seaweed, help reduce the appearance of wrinkles and improve skin elasticity. Additionally, seaweed's hydrating properties



make it an excellent ingredient in moisturizers, serums, and face masks, promoting healthy, glowing skin.

#### **Sustainable Cosmetics**

As the demand for natural and sustainable beauty products grows, seaweed is becoming a key ingredient in eco-friendly skincare. Seaweed-based formulations are not only effective but also biodegradable, offering a more sustainable alternative to synthetic chemicals and microplastics commonly found in cosmetic products.

#### **4. Seaweed in Agriculture**

Seaweed has long been used as a natural fertilizer in coastal communities, but its role in agriculture has expanded thanks to advances in biotechnology. Seaweed extracts are used to develop biofertilizers, biostimulants, and soil conditioners, improving plant health and crop yields.

##### **Bio stimulants and Fertilizers**

Seaweed-based biostimulants contain natural growth hormones like **cytokinins** and **auxins**, which promote root development, enhance nutrient uptake, and increase plant resistance to environmental stress. These biostimulants are used to boost the growth of crops, particularly in organic and sustainable farming, where synthetic fertilizers and pesticides are avoided (Kaur, 2020).

Seaweed also helps improve soil structure by adding organic matter, enhancing moisture retention, and promoting the growth of beneficial microbes. This makes it an ideal natural fertilizer for improving soil health and reducing reliance on chemical inputs.

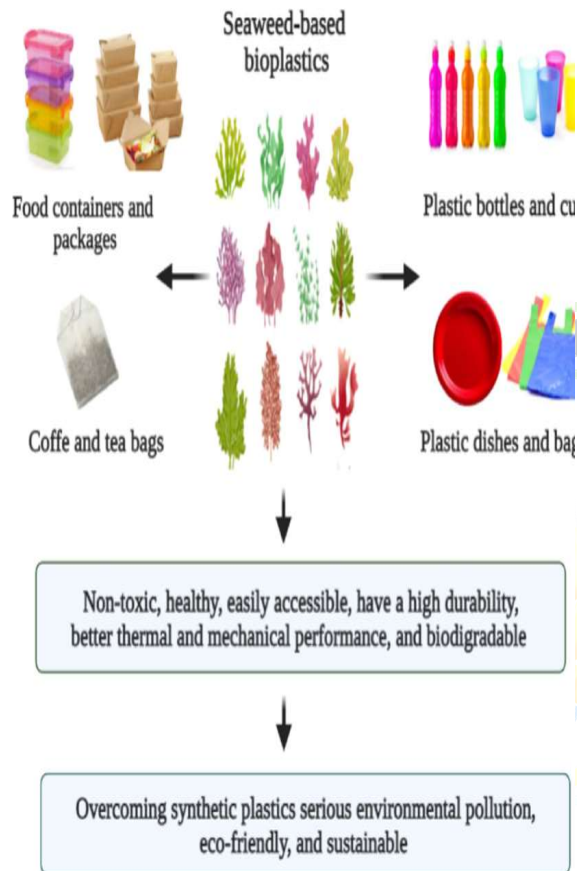
#### **5. Seaweed in Bioplastics**

One of the most exciting applications of seaweed in biotechnology is the development of bioplastics, a sustainable alternative to conventional petroleum-based plastics. With plastic pollution becoming a global crisis, seaweed offers a promising solution for creating biodegradable, eco-friendly materials.

##### **Biodegradable Packaging**

Seaweed-based bioplastics are made by extracting the polysaccharides (such as alginate and agar) from seaweed and processing them into materials that resemble conventional plastic. These bioplastics are fully biodegradable, breaking down naturally in the environment without leaving harmful microplastics behind.

Startups like **Notpla** are already using seaweed to develop innovative packaging solutions, such as edible water pods and biodegradable food containers. As technology advances, seaweed-based bioplastics could replace single-use plastics in packaging, reducing the environmental impact of plastic waste.



### Sustainable Alternatives

Unlike other bio-based plastics, which are often derived from food crops like corn or sugarcane, seaweed bioplastics do not compete with food production and do not require land, freshwater, or fertilizers. This makes them a truly sustainable alternative for packaging and other industrial applications.

### 6. Environmental Benefits of Seaweed Biotechnology

Beyond its industrial applications, seaweed cultivation offers significant environmental benefits. Seaweed farms absorb carbon dioxide from the atmosphere, helping to mitigate climate change by acting as carbon sinks. They also absorb excess nutrients like nitrogen and

phosphorus from the water, preventing harmful algal blooms and improving water quality in coastal areas.

Additionally, seaweed farming has a low environmental impact, requiring no land or freshwater, and can be cultivated on a large scale in oceans without disrupting ecosystems. As a result, seaweed biotechnology aligns with the growing demand for sustainable solutions in industries that are seeking to reduce their carbon footprint and environmental impact (Kim et al.,2017).

### Conclusion

Seaweed's role in biotechnology is expanding rapidly, with applications spanning pharmaceuticals, food, agriculture, cosmetics, and bioplastics. Its unique chemical composition and sustainable nature make it a valuable resource in the development of innovative, eco-friendly products. As research and technology continue to advance, seaweed is poised to play a significant role in addressing global challenges such as plastic pollution, food security, and climate change. The future of biotechnology is increasingly turning to the ocean, and seaweed is at the forefront of this revolution.

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