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SEAWEED: A Complete Medical Overview

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Abstract

Objective of current work is to make everyone aware about the medical potentials of seaweed and to know various species of seaweed. The NOAA is an American scientific and regulatory agency which gives information about valuable health benefits of seaweed and its varieties. According to CDC report Approximately 190 million preschool-aged children worldwide suffer from vitamin A insufficiency. This article will put a retrospect on future scope of seaweed, as we can formulate many clinically useful formulations from isolated extract of the same using various chromatographic analytical methods like HPLC and spectroscopy.

Keywords: (NOAA) National Oceanic and Atmospheric Administration; (CDC) Centres for Disease Control and Prevention; (HPLC) High Performance Liquid Chromatography.

1. Introduction

The term "seaweed" refers to a wide range of marine plant and algae species that grow in the ocean, rivers, lakes, and other bodies of water. They are good source of vitamins, minerals and fibres. Seaweeds are also high in polysaccharides; a type of carbohydrate utilised in the food industry to thicken and emulsify. These polysaccharides also act as dietary fibres, promoting gut health by providing a prebiotic food supply for healthy gut bacteria. Figure 1. [1]

Seaweed has been classified as a functional food or nutraceutical due to its disease-fighting properties, which include polyphenols, carotenoids, and omega-3 fatty acids. As a result, seaweed or its components are sometimes added to dishes to boost their nutritional and antioxidant content. For example, you may add seaweed polysaccharides to noodles, flour, or biscuits. However, evidence from human research supporting health claims of seaweed, particularly as a nutraceutical supplement, is currently limited. Antioxidants and healthy nutrients like iodine, tyrosine, vitamins, and minerals can be found in seaweed. It might enhance blood sugar balance and promote gastrointestinal and heart health.[2]

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Figure 1 Seaweed

1.1. Governing Bodies

According to WHO over 2 billion people worldwide are currently lacking in important vitamins and minerals, especially iron, zinc, iodine, and vitamin A. Most of these individuals reside in low-income nations and usually have several micronutrient deficiencies. Figure 2.

Because they are typically too costly to purchase or unavailable locally, persons who lack access to micronutrient-rich foods such as fruits, vegetables, animal products, and fortified foods develop deficiencies. Micronutrient deficiencies raise the overall risk of contracting an infectious disease and of passing away from pneumonia, measles, malaria, and diarrhoea. These illnesses rank in the top ten causes of disease worldwide. [3-4]

Figure 2 Governing Bodies

1.2. Deficiency crisis and mortality rate

The World Health Organization (WHO) report says that not less than 250 million children develop blindness due to vitamin A deficiency, and half of them die within 12 months. A 2019 Global Burden of Disease (GBD) analysis found that a low-fiber diet was linked to 348,850 deaths worldwide. Figure 3 and 4

Figure 3 Mortality and Morbidity

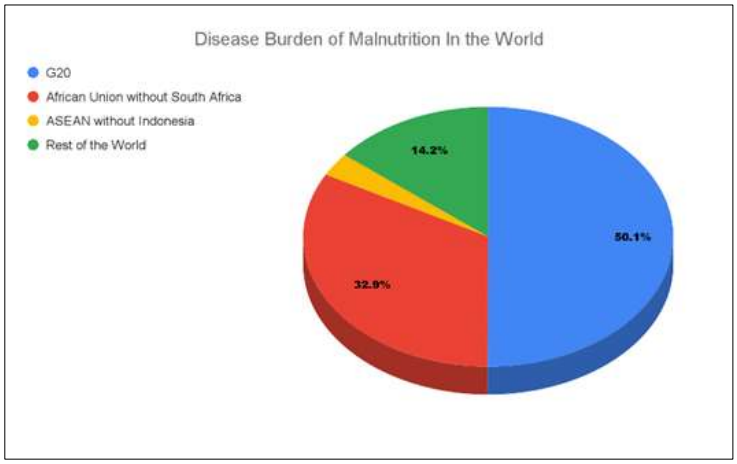

Figure 4 Malnutrition in the World

1.3. Varieties of seaweed

Seaweed, often known as macroalgae, is a term used to describe thousands of macroscopic, multicellular marine algae species. The name refers to macroalgae classified as Rhodophyta (red), Phaeophyta (brown), and Chlorophyta (green). Figure 5.

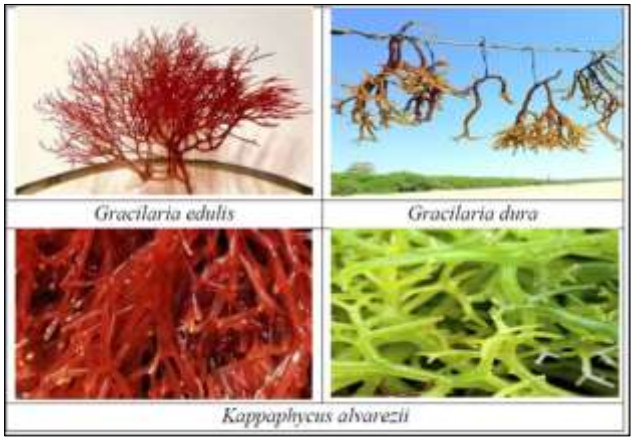

Figure 5 Species of Seaweed

Some of the seaweed species are as given below:

- Fucus vesiculosus: Also known as Bladder wrack. It has antibacterial properties and, when taken internally, helps decrease blood sugar and cholesterol.
- Laminaria: It contains desirable amounts of proteins, carbs, fibre, minerals, and vitamins, as well as biological substances that help to combat disease. Laminarin is a glucan and linear polysaccharide found in the fronds of Laminaria/Saccharina, Ascophyllum, Fucus, and Undaria. It has been demonstrated to be a safe surgical dusting powder, a tumour suppressing agent, and an anti-coagulant in the form of sulphate ester (Miao et al., 1999). It decreases total cholesterol, free cholesterol, triglycerides, and phospholipids in the liver. [5-6]
- Brown algae: Brown algae have a vast group of multicellular algae that belong to the class Phaeophyceae. They include several seaweeds found in the cooler waters of the Northern Hemisphere. Brown algae are the dominant seaweeds in temperate and polar climates.
- Codium bursa: Codium bursa is a green, medium-sized sea algae. It is made up of loosely packed filaments that at the surface create a cortex of utricles, which are single-celled bladder-like or club-shaped structures.
- Macrocystis: Also known as Macrocystis pyrifera. It is also known as enormous kelp or bladder kelp. This genus contains the largest Phaeophyceae (brown algae). It is high in potassium, iodine, and other minerals. It can be used in cooking in many of the same ways as other sea vegetables, and it is especially useful for flavouring bean meals.[7]
- Ulva intestinalis: Ulva intestinalis is a green alga from the Ulvaceae family, often known as sea lettuce, green bait weed, gutweed, and grass kelp.
- Chrysophyceae: Chrysophytes, also known as chrysomonads, golden-brown algae, or golden algae, are a vast species of algae that live primarily in freshwater. Golden algae is also widely used to describe a single species, Prymnesium parvum, which causes fish fatalities.
- Laminaria digitata: It is known to harbour the pathogenic fungus Phycomelaina laminariae. Laminaria digitata is harvested offshore of France and Morocco to produce alginic acid. It is an ingredient in various cosmetics. It was originally used as a fertiliser
- and spread over the ground. In the 18th century, it was burned to extract the potash contained within it for use in the glass industry. In the nineteenth century, it was employed for iodine extraction. Historically, dried stalks of L digitata, known as sea-tangle tents, were used in traditional medicine as an abortifacient and to mechanically induce labour.
- Caulerpa bartoniae: Caulerpa is a seaweed genus belonging to the Caulerpaceae family (green algae). They are unique because they are made up of only one cell with several nuclei, making them among the largest single cells in the world.
- Gracilaria: Often known as Irish Moss or Ogonori is a genus of red algae in the Gracilariaceae family. It is significant for its economic value as an agarophyte, which means it is used to manufacture agar, as well as its use as food for humans and several types of shellfish. [8]
- Pelvetia canaliculate: sometimes known as channelled wrack, is a common brown alga (Phaeophyceae) found on the rocks of Europe's upper coastlines. It is the sole species left in the monotypic genus Pelvetia.
- Sargassum: Sargassum is a genus of brown macroalgae in the Fucales order of the Phaeophyceae family. Sargassum is a significant seaweed that is widely spread in tropical and subtropical climates. Different Sargassum species are used in traditional human diet and are high in vitamins, carotenoids, proteins, and minerals. Many beneficial chemical substances known as terpenoids, sterols, sulfated polysaccharides, polyphenols, sargaquinoic acids, sargachromanol, and pheophytin have been identified from various Sargassum species. These isolated compounds and/or extracts display numerous biological actions, such as analgesic, anti-inflammatory, antioxidant, neuroprotective, anti-microbial, anti-tumor, fibrinolytic, immune-modulatory, anticoagulant, hepatoprotective, and antiviral activities. Porphyra: Porphyra is a genus of coldwater seaweeds that thrive in cold, shallow waters. It is more accurately classified as a red algae phylum comprising laver species. It produces marine vegetable products.
- Codium bursa: Codium bursa is a marine alga that can grow up to 30 cm broad. It is made up of loosely packed filaments that at the surface create a cortex of utricles, which are single-celled bladder-like or club-shaped structures. [9-10]
- Saccharina latissimi: Saccharina latissima is a brown alga from the family Laminariaceae. It is known by the common names sugar kelp, sea belt and Devil's apron.
- Chlorophyta: Chlorophyta is a group of green algae also known as chlorophytes. Chlorophytes are eukaryotic creatures made of cells with a variety of coverings or walls, and typically a single green chloroplast in each cell.

1.4. Clinical uses of Seaweed

- Weight control: Alginate, a fiber in brown seaweed, may suppress hunger and reduce calorie intake.
- Blood sugar regulation: Alginate and beta glucan in seaweed may prevent blood sugar surges and control appetite by slowing digestion.
- Prebiotic properties: Seaweed can act as a prebiotic.
- Anticancer potential: Some research suggests seaweed may have anticancer properties.
- Antioxidant benefits: Seaweed contains vitamins and antioxidants. [11-13]

1.5. Chemistry of Seaweeds

1.5.1. Carbohydrates

Carbohydrates are vital macronutrients that provide energy for biological functions and physical activity. Seaweed is a good source of carbs. According to the most recent SR Legacy data given by the United States Department of Agriculture, edible seaweeds have a carbohydrate content of around 81% on a dry weight basis.

Red, green, and brown seaweeds have carbohydrate levels ranging from 8.3-68.2%, 4-79.9%, and 12.8-81% of their dry weight, respectively. Carbohydrates are categorised into four types based on their complexity and length: monosaccharides, disaccharides, oligosaccharides, and polysaccharides. Monosaccharides found in seaweed hydrolysates include mannose, glucose, fructose, galactose, fucose, xylose, and arabinose.

1.5.2. Protein

Proteins are huge macromolecules made up of one or more long chains of amino acid residues. Proteins serve an essential part in the human body. In general, proteins can aid in the formation and repair of human body tissues, the facilitation of metabolic events, and the coordination of a variety of bodily functions. Green, brown, and red seaweeds have protein levels ranging from 0.4 to 32.1%, 3.1-42.1%, and 3.5 to 47% of their dry weight, respectively.[14-16]. Seaweed proteins contain all the amino acids required by the human body. The standard amino acids found in proteins isolated from diverse seaweed species are alanine, arginine, glycine, aspartic, and glutamic acid, with less cystine, lysine, and tryptophan. Significantly, the total essential amino acid content of seaweeds is sufficient for the dietary requirements according to FAO and WHO guidelines.

1.5.3. Lipid

Brown, red, and green seaweeds have lipid levels ranging from 0.1 to 11.5%, 0.4 to 12%, and 0.2-15% of their dry weight, respectively. Meanwhile, many of these lipid contents are composed of polyunsaturated fatty acids (PUFAs), which typically take the form of omega-6 (n-6) and omega-3 (n-3) lipids. Recent investigations found that seaweed lipids contain 20:4 n-6 arachidonic acid (ARA), 18:2 n-6 linoleic acid (LNA), 22:6 n-3 docosahexaenoic acid (DHA), 20:5 n-3 eicosapentaenoic acid (EPA), and 18:3 n-3 α-linolenic acid (ALA). Omega-6 (*n-6*) and omega-3 (*n-3*) fatty acids are essential for the human diet. [17]

1.5.4. Vitamins

Vitamins are micronutrients that organisms require to live and function properly. Vitamins are categorised into two classes based on their solubility: water-soluble vitamins and fat-soluble vitamins. Seaweeds include both water-soluble vitamins (vitamin B complex and vitamin C) and fat-soluble vitamins (vitamins A, D, E, and K). Even though numerous vitamins have been detected in seaweeds. Seaweeds are not a good source of vitamin B5, B6, B8, B9, or E. Notably, many species, including Pylaiella littoralis, Fucus vesiculosus, and Ulva lactuca, were shown to have high levels of vitamin B12.

1.5.5. Minerals

Minerals are critical micronutrients required by the living body to support cell function and metabolism. Seaweeds are a rich supply of minerals due to their marine habitat, which allows them to absorb a wide range of minerals. Seaweeds' mineral content can account for up to 30% of their dry weight. Previous investigations have discovered seaweed minerals such as sodium (Na), potassium (K), phosphorus (P), magnesium (Mg), calcium (Ca), zinc (Zn), iron (Fe), copper (Cu), manganese (Mn), and iodine (I). Among these elements, it was discovered that the Na, Ca, K, Mg, and Cu levels in seaweeds were higher than in terrestrial diets. [18]

1.5.6. Cultivation of Seaweeds

The Food and Agriculture Organization (FAO) reported that world production in 2019 was over 35 million tonnes. North America produced some 23,000 tonnes of wet seaweed. The largest seaweed-producing countries as of 2022 are China (58.62%) and Indonesia (28.6%); followed by South Korea (5.09%) and the Philippines (4.19%). Seaweed cultivation is the practice of cultivating and harvesting seaweed. The Central Marine Fisheries Research Institute (CMFRI) at Mandapam in Tamil Nadu developed technology for the commercial cultivation of Gracilaria edulis by using a floating raft and rope net/spore method. Figure 6

Figure 6 Cultivation of Seaweed

Single rope floating raft (SRFR) method developed by the Central Salt and Marine Chemical Research Institute (CSMCRI). It is suited for culturing seaweeds in an extensive area and greater depth. Fixed bottom long thread method, in which seaweed is made synthetically.

Long-lines which are suspended below the water (often in grids) and fixed in place by a system of buoys and anchors. Cultivation will generally take place in coastal areas which provide sufficient nutrients and appropriate depth, salinity, and temperature. [19]

Commercial seaweed cultivation can be done in 4 ways i.e.

- Floating raft method
- Semi-floatingraft method
- Half-bottom method
- Bottom planting method.

2. Methods of separation for seaweeds

Following methods, we can use for the separation and purification of seaweed after cultivation**.**

2.1. Techniques of analytical separation are

- Spectrophotometric method - UV
- Chromatographic methods - HPLC, HPTLC
- Other methods - LC-MS, GC-MS

2.2. Types of chromatography

- Column chromatography.
- Ion-exchange chromatography.
- Gel-permeation (molecular sieve) chromatography.

- Affinity chromatography.
- Paper chromatography.
- Thin-layer chromatography.
- Gas chromatography.

Chromatography: It is a technique for separating the components, or solutes, of a mixture on the basis of the relative amounts of each solute distributed between a mobile phase and stationary phase. The mobile phase may be either a liquid or a gas, while the stationary phase is either a solid or a liquid.

2.3. HPTLC: High Performance Thin Layer Chromatography

An extension of TLC is high-performance thin layer chromatography (HPTLC) is robust, simplest, rapid, and efficient tool in quantitative analysis of compounds. The HPTLC works on the same principles as TLC, mobile phase solvent flows through because of capillary action and the principle of separation is adsorption, but with enhancements intended to increase the resolution of the compounds to be separated and to allow quantitative analysis of the compounds. Figure 7.

Figure 7 HPTLC instrumentation

Extraction: It is a separation process consisting of the separation of a substance from a matrix. The distribution of a solute between two phases is an equilibrium condition described by partition theory. [20]

2.4. Uses of Seaweeds

Seaweed Polysaccharides are employed in several industries for their physical qualities, including gelation, viscosity, and stabilisation. Phycocolloids are used in various industries, including food as a thickener and stabiliser, biotechnology and pharmaceuticals.

2.4.1. Nutritive Value

Seaweeds have been a traditional staple in Japan and China for centuries. Seaweeds include a variety of nutrients, including fibre, protein, lipids, vitamins (A, B, C, D and E), minerals (Ca, P, Na, K and I), polyunsaturated fatty acids (PUFA), and bioactive compounds like carotenoids, polyphenols, and pigments. They contain structural (cellulose, hemicellulose, and xylose) and storage polysaccharides (carrageenan, laminarin, fucoidan, alginic acid, alginate, and agar) that act as prebiotics, promoting the growth of beneficial bacteria in the gut. Applications include food (as a thickener and stabiliser), biotechnology (agar), and pharmaceuticals.

2.4.2. Source of Phycocolloids

Seaweed cell walls contain phycocolloids such agar, alginate, ulvan, and carrageenan, which have commercial significance globally. Seaweed polysaccharides have numerous applications due to their physical qualities, including gelation, viscosity, and stabilisation. Phycocolloids are used in various industries, including food (as a thickener and stabiliser), biotechnology (agar), and pharmaceuticals.

2.4.3. Source of animal feed

Seaweed additives in animal feed can improve animal health by providing antimicrobial, anti-inflammatory, anti-cancer, antioxidant, and antimethanogenic properties. India has the potential to become a major supplier of these additives. Seaweed supplements and products have been proved to benefit animal health and wellbeing. Seaweeds have numerous functional qualities, making them an ideal feed supplement for animals. Seaweeds have been extensively examined as a feed supplement for monogastric species such as pigs and poultry, as well as ruminants.

Seaweeds can operate as soil conditioners, bioremediators, and biological pest control agents. Brown seaweeds are mostly utilised for fertiliser manufacture. Seaweed fertiliser can be applied to soil as mulch or compost, or as a fermented liquid fertiliser. Sagarika, a seaweed-based organic fertiliser made from red and brown algae, serves as a bio-stimulant.

2.4.4. As nutraceutical

Seaweeds are often consumed for their health advantages. Seaweeds are rich in fibre, protein, PUFAs, vitamins, and minerals. Seaweed polysaccharides can lower serum cholesterol and lessen the risk of coronary heart disease. Seaweed polysaccharides have been shown to have a hypolipidemic/hypocholesterolemic impact by inhibiting lipid absorption in the gastrointestinal tract, as shown by numerous research. Seaweeds are high in omega-3 fatty acids (DHA and EPA), which promote cognitive development. Seaweeds include bioactive chemicals with antibacterial, antiviral, anti-inflammatory, and immune-modulatory properties. [21-22]

3. Recent Searches and formulations of Seaweed

3.1. Progress and future directions for seaweed holobiont research

Seaweeds, which include red, green, and brown macroalgae, are photosynthetic multicellular organisms that thrive in a variety of settings ranging from intertidal zones to deep oceans and are critical to the functioning of marine ecosystems. They create oxygen and organic materials that maintain the marine food web, as well as providing habitat, shelter, and food for a vast range of marine species, including finfish, shellfish, crabs, and invertebrates

3.2. Environmental Impact

Some seaweeds have the ability to extract heavy metals from water and may be employed in biomonitoring and bioremediation of these contaminants. Seaweeds also have good survival strategies for dealing with the various environmental challenges to which they are exposed. For all these reasons, as well as their distinct life cycle and biochemistry, seaweeds are fascinating research subjects.

3.3. Evaluating the Effect of Seaweed Formulations on the Quality and Yield of Sugarcane

Seaweed extracts have a considerable favorable impact on cane yield and biometric measures. The treatments showed the greatest increase in cane production. Seaweed extracts have a considerable favorable impact on cane yield and biometric measures. The treatments showed the greatest improvement in cane output. They create oxygen and organic materials that maintain the marine food web while also providing habitat, shelter, and food for a varied range of marine species, including finfish, shellfish, crabs, and invertebrates.

3.4. Sustainable bioplastics from seaweed polysaccharides

Bioplastics is an umbrella term for a wide variety of polymers that can be either biobased or biodegradable, or both. Macroalgal polysaccharides and their inherent film-forming capacity are exploited in the bioplastics industry and macroalgal polysaccharide-based biofilms are extensively used in food packaging due to their compatibility and ease of production [23-24]

3.5. Formulations of seaweed

3.5.1. Seaweed Extract Powder

Content: Seaweed Extract Powder Seaweed extract promotes healthy tissue growth. It gives the crops more strength. Additionally, it gives plant cells more nourishment and vigor. It regulates the pre-harvest drop of fruits and flowers. It offers all the necessary nutrients and components for crops to thrive in a balanced manner. It promotes crop blossoming and general growth. It promotes the production of new tissue and chlorophyll. It supplies energy to improve yield. Figure 8

Figure 8 Seaweed powder

3.5.2. Seaweed Extract Liquid Formulation

The Seaweed Extract Liquid Formulation stimulates root, shoot, and overall plant vigor, acting as a natural plant growth stimulator. Rich in growth-promoting hormones, trace minerals, and vital nutrients, the formulation improves plant nutrient uptake and utilization. Seaweed extract makes crops healthier and more resilient by assisting plants in withstanding environmental challenges like heat, drought, and disease. It increases fruit quality and productivity, encourages floral initiation, and improves fruit setting. Consistent application of the Seaweed Extract Liquid Formulation enhances microbial activity, fertility, and soil structure, promoting long-term agricultural sustainability. Figure 9

Figure 9 Seawed Extract

3.5.3. Seaweed Extract Colostrum Magnesium Sulphate Tablet

Contents: The tablets contain the following ingredients: 90% kelp seaweed extract (600 mg), 100 mg colostrum, 100 mg magnesium sulfate, and 12 mg zinc.

Bioactive substances such as proteins, vitamins, minerals, and dietary fiber are abundant in seaweeds. Inflammation, cancer, oxidative stress, allergies, diabetes, thrombosis, obesity, hypertension, lipidemia, and several degenerative disorders can all be treated with these substances. Low magnesium levels, some kinds of seizures, a childhood kidney disease, and an uncontrollable muscle spasm are all treated with magnesium sulfate. Seaweed extract colostrum magnesium sulphate is used to treat several ailments, such as: Anemia, immunological response, infections, wound healing, weak bones, neuropathy, and thyroid function. Figure 10

Figure 10 Seaweed Extract Colostrum Magnesium Sulphate Tablet

CadalminTM Ade

Contents: Per capsule 400 mg active principle enriched with 100% natural antidiabetic ingredients. Hydroxypropyl MethylCellulose was used as polymer.

An anti-diabetic nutraceutical called CadalminTM ADe works well to treat type-2 diabetes. It is made entirely of natural marine bioactive compounds that have been isolated from specific seaweeds. Tyrosine phosphatase 1B and dipeptidyl peptidase-IV are competitively inhibited by the bioactive components in CadalminTM ADe. The product's active components inhibit the release of simple sugars from the stomach, which lowers postprandial hyperglycemia and prevents type-2 diabetes from developing. They also suppress the development of several mediators that cause type-2 diabetes. Long-term toxicity tests have demonstrated that CadalminTM ADe has no adverse effects. To satisfy the dietary requirements of vegetarians, the product's 350 mg of concentrated and purified active components are included in plant-based capsules made of cellulose-based hypermelose.[25]

3.6. Current Scenario

There is an enormous biorefinery potential in marine macroalgae. Contributed by their nutritional and biochemical values, seaweeds have been subjected to diverse applications among a broad range of industries. Most seaweeds are used in food (43.77%), hydrocolloid (18.10%), plant and soil nutrition (11.57%), personal care (7.86%), bioplastics (5.34%), feed (3.86%) and nutraceutical (1.93%) industries

3.7. Future Prospective

The global demand for seaweed has been gradually increasing, with the commercial seaweed industry predicted to exceed (US) $95 billion by 2027. While India's seaweed industry is limited, it has the capacity to produce approximately 9.7 million tonnes per year. According to the Central Marine Fisheries Research Institute (CMFRI), which is linked with the Indian Council of Agricultural Research (ICAR), India has the potential to contribute significantly to world seaweed production.

The future of seaweed appears hopeful, with a growing market, the potential to replace fossil fuels, and the opportunity to provide revenue for coastal communities. [26-28]

- Market growth: The global seaweed market is predicted to increase from $7 billion in 2023 to $16.1 billion in 2033. The commercial seaweed market is expected to increase from $17.14 billion in 2023 to $34.56 billion in 2032.
- Carbon sequestration: Seaweed can help to sequester carbon.
- Income for coastal communities: Seaweed can provide income to vulnerable coastal communities.
- India's potential: India has the capacity to produce around 9.7 million tonnes of seaweed per year. The government wants to invest approximately $86.6 million to raise seaweed production to one million tonnes per year by 2025.
- Algal hydrogels and hydrocolloids have medical applications such as wound healing, medication delivery, in vitro cell culture, and tissue engineering.

Other applications: Seaweed possesses antioxidant, anti-hyperglycemic, anti-cancer, antiviral, antifungal, anti-diabetic, antihypertensive, anti-inflammatory, UV-protective, and neuroprotective properties.

4. Conclusion

Considering the potential health benefits of seaweed, it can be a topic of interest in the field of pharmaceutical industry as the process of isolation and purification of raw seaweed and converting it into a suitable dosage form will increase market turnover, it can give job to many jobless people as well as it can help to fight with malnutrition as the raw seaweed can be converted to various nutritional supplements, vitamin supplements and probiotics. This will help to improve business margin in the market as well.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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