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Review Article

SEAWEEDS: A NOVEL BIOMATERIAL

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ABSTRACT

Marine algal seaweed species are often regarded as an underutilized bioresource many have been used as a source of food, industrial raw materials, and in therapeutic and botanical applications for centuries. Seaweeds are best known for the natural polysaccharides. Moreover, seaweed and seaweed-derived products have been widely used as a key ingredient in many pharmaceutical preparations like tablets, as rate retardant in sustained and extended release dosage forms, as stabilizer in liquid orals, cosmetics, implants and as bioplastic in packaging industry. This article provides a comprehensive review of various seaweed species and seaweed products with an emphasis on the use of this renewable bioresource in pharmaceutical industry and medical field.

Keywords: Bioresource, Bioplastic, Implants, Polysaccharide, Seaweed, Underutilized.

INTRODUCTION

Plastics are carbon-based polymers and we make them mostly from petroleum. With the discovery of plastics, life became much more convenient because it is used to make a wide array of useful materials. But these plastics are so durable that it will take many centuries for these plastics to completely degrade while other plastics will last forever. Discarded plastics are also a big cause of pollution and because of that; plastics make our environment a much less attractive place. Getting rid of plastics is extremely difficult. Burning these plastics gives off harmful chemicals such as dioxins that could contribute to Global Warming. Recycling these plastics is also difficult because there are many different kinds of plastics and each has to be recycled by a different process.[1] Though these plastics are considered to be one of the greatest innovations ever, they are also imposing a great havoc to the environment, the wildlife and the general public (Woodford, 2008). For this reason, this study aims to develop a biomass-based plastic from the natural polysaccharides of seaweeds. Biomass-based plastics or bioplastics are a form of plastics derived from renewable biomass resources like vegetable oil or corn starch rather than the conventional plastics which are made from petroleum. Their advantages are innumerable and one is their capability to biodegrade naturally within a short period of time only.

Some of these polysaccharides are Floridian starch, agar and alginate. Since they are renewable biomass resources and are polymers made from sugars which contain carbon, they could be used to create a bioplastic. [2]

Seaweeds are macroscopic algae found attached to the bottom in relatively shallow coastal waters. They grow in the intertidal, shallow and deep sea areas up to 180 meter depth and also in estuaries and back waters on the solid substrate such as rocks, dead corals, pebbles, shells and other plant materials. They form one of the important living resources grouped under three divisions namely, Chlorophyceae (green algae), Phaeophyceae (brown algae) and Rhodophyceae (red algae). They are abundant on hard substrates and commonly extending to depths of 30-40 m. About 624 species have been reported in India with a potential of 77,000 tons (wet weight) per annum.[3-5] The red seaweeds contribute 27.0%, brown 0.2 % and others 72.8 %. About 206 species of algae have been reported from the mangrove environment. Seaweeds are the only source of phytochemicals namely agar-agar, carrageen an and algin, which are extensively used in various industries such as food, confectionary, textiles, pharmaceuticals, dairy and paper industries mostly as gelling, stabilizing and thickening agents. They are also used for human consumption, animal feed and as manure in several countries. The seaweeds found in the mangrove environment are mostly attached to the aerial roots of the trees level makes the mangrove environment unfavorable for the growth of many seaweeds.

Bioplastics are a form of plastics derived from renewable biomass sources, such as vegetable fats and oils, corn starch, pea starch or micro biota. Common plastics, such as fossil-fuel plastics, are derived from petroleum- these plastics rely more on scarce fossil fuels and produce more greenhouse gas. Some, but not all, bioplastics are designed to biodegrade. Biodegradable bioplastics can break down in either anaerobic or aerobic environments, depending on how they are manufactured. There are a variety of materials bioplastics can be composed of, including: starches, cellulose, or other biopolymers.

Bioplastics are characterized by the fact that:

- The petrochemical resin is replaced by a vegetable or animal resin.
- The compounds (glass or carbon fiber or talc) are replaced by natural fiber (wood fibers, hemp, flax, sisal, jute)

Seaweeds- source for bioplastic

Seaweeds are best known for the natural polysaccharides that can be extracted from them which are widely used particularly in the fields of food technology, biotechnology, microbiology and even medicine but not yet in the plastic industry. Some of these polysaccharides are Carrageenan, agar and alginate. Since they are renewable biomass resources and are polymers made from sugars which contain carbon, they could be used to create a bioplastic).

Types of seaweeds[6]

Brown algae

- Alaria esculenta (Dabberlocks, Wing Kelp, Murlins)
- Ascophyllum nodosum (Asco, Sea Whistle, Bladderwrack)
- Asperococcus fistulosus
- Asperococcus bullosus
- Bifurcaria bifurcata (Brown Tuning Fork Weed; Brown Forking Weed)
- Colpomenia peregrina (Oyster Thief)
- Scytosiphon lomentaria

Red algae

- Ahnfeltia plicata (Landlady's Wig; Black Scour Weed)
- Ahnfeltiopsis devoniensis (Devonshire Fan Weed)
- Apoglossum ruscifolium
- Asparagopsis armata (Harpoon weed, an alien species in Europe)
- Bangia fuscopurpurea

Green algae

- Cladophora rupestris
- Codium fragile (Spongeweed)
- Codium tomentosum (Spongeweed)
- Monostroma grevillei
- Prasiola stipitata
- Spongomorpha aeruginosa
- Ulva compressa (A kind of Sea Lettuce; a compressed tube-like green alga)
- Ulva intestinalis (A kind of Sea Lettuce; a tube-like green alga)
- Ulva lactuca (Sea Lettuce)
- Ulva linza
- Ulva rigida (Sea Lettuce)

Carrageenan

The original source of carrageenan was the red seaweed *Chondrus crispus* (common name: Irish moss).

Agar

Primarily from the genera *Gelidium* and *Gracilaria*, or seaweed (*Sphaerococcus euchema*). For commercial purposes, it is derived primarily from *Gelidium amansii.*

Alginate

Alginates are produced from brown sea weeds (*Phaeophyceae*, mainly *laminaria)*

Kunbu (Saccharina and Ecklonia) (Kombu in Japan)

Kunbu produced from a brown algae *Saccharina japonica* and *Ecklonia kurome* (Saccharina- formerly Laminaria) is sometimes called haidai.

Haizao (Sargassum)

Sargassum, brown algae, as the source of haizao. Sargassum is a large genus and several species seem to be in use.

Zicai

(Porphyra) (Nori in Japan) Porphyra, a red algae is the source of zicai.

Brown Algae (BladderWrack) seaweed side effects

1. Bladderwrack consumption is always considered unsafe because of its potential contamination with many heavy metals.
2. High iodine content in bladderwrack may be toxic if taken in large doses. It may lead to abnormal thyroid conditions, acne-type skin lesions, increased salivation, stomach irritation and brassy taste.
3. Bladderwrack may lower blood sugar levels and have blood thinning effects. Thus it should be used with caution for patients with diabetes, hypoglycemia, bleeding disorders, or taking medications for these conditions.
4. Due to high levels of arsenic kidney and liver toxicity have been reported in some individuals.
5. Bladderwrack may not be advisable for children and during pregnancy and lactation due to its high iodine, heavy metal and other contamination.

Red algae seaweed side effects

Being a proper food, there are no side effects with red marine algae and there have been no noted side effects with red marine algae plus consumers.

Green algae side effects

Few side effects have been reported from the ingestion of green algae. However, as green algae can accumulate heavy metals from contaminated water, consuming green algae could increase the body's load of lead, mercury, and cadmium, though noncontaminated green algae have been identified.

Another popular species of green algae, Aphanizomenon flos-aquae, has been found to produce toxins. A few reports also describe allergic reactions to green algae. Animal studies have found spirulina to be safe during pregnancy.

There is one case report of a man who developed liver damage while taking spirulina. As he was also talking three prescription medications, it is not clear whether the spirulina caused or contributed to the liver injury**.**

Methods for extraction of bio plastic from seaweeds

Bioplastics from seaweeds are reported to be more resistant to microwave radiation, less brittle and durable. The component of seaweeds used in the making of bioplastics is polysaccharides. The seaweed is systematically gathered, quickly dried and then baled to maintain its quality and freshness.

Method-1

1. Removal of impurities: The dried seaweed is mechanically ground and sieved to eliminate impurities such as sand and salt which is followed by extensive washing to ensure additional quality

2. Hot extraction process: Seaweeds undergo a hot extraction process to separate the polysaccharides which is a two-step clarification process.

(a) Centrifugation: First the dissolved polysaccharide mixture is centrifuged to eliminate the dense cellulosic particles, filtered to remove the smaller particles and then, the solution is concentrated by evaporation for the removal of water.

(b) Recovery of polysaccharides: The polysaccharides are then recovered by one of the two processing methods.

(i) Potassium chloride solution is added to the concentrated solution of polysaccharides to increase the gelling temperature so that the filtrate will gel immediately. The gel is then frozen and compressed to remove excess water.

(ii) In another method, the concentrated solution is precipitated in isopropyl alcohol and as the polysaccharides are insoluble in alcohol, the filtrate turns into a coagulum of polysaccharides, alcohol and water.

The coagulum is compressed to remove excess of liquids and vacuum dried to completely remove the alcohol. Drying is completed on a belt drier and is blended to meet the finished product of exact specification.

APPLICATIONS[7-9]

Pharmaceutical applications

Carrageenan

- It is used in a variety of nonparenteral dosage forms, including suspensions (wet and reconstitutable), emulsions, gels, creams, lotions, eye drops, suppositories, tablets, and capsules
- It has been shown to mask the chalkiness of antacid suspensions when used as a suspending agent
- Used in hand lotions and Creams to provide slip and improved 'rub out'.
- It has good tablet-binding properties. Furthermore, the inclusion of calcium or potassium salts into the tablet creates a microenvironment for gelation to occur, which further controls drug release
- It has also been used as beads in the preparation of controlled release systems.
- Used as thickening agent in the preparation of tooth pastes especially to treat tooth decay.

Agar

- It is widely used in food applications as a stabilizing agent
- Sustained-release agent in gels, beads, microspheres, and tablets.
- It has been used in a floating controlled-release tablet
- Alginates Used in a variety of oral and topical pharmaceutical formulations. In tablet and capsule formulations, alginates are used as both a binder and disintegrating agent
- As a thickening and suspending agent in a variety of pastes, creams, and gels; and as a stabilizing agent for oil-in-water emulsions.
- Therapeutically, alginates have been used as an antacid.

Surgical applications[10,11]

Prosthetic devices: Alginates are best alternative to prosthetic devices

Joint replacements, fracture fixation plates, bone defect fillers: Furanones have previously been identified as the agents that keep a red alga called Delisea pulchra. Coating artificial hips, heart valves and other medical implants with furanones could prevent patients from contracting life-threatening infections.

Sutures: Alginates derived from crocystis, Laminaria, Sargassum, Ascophyllum used in the preparation of biodegradable sutures.

Dental implants: Spirulina has extremely high chlorophyll content - in fact, it is entirely responsible for its green pigment (phycocyanin is the blue pigment). Taking Spirulina will thus ensure rapid healing of damaged tissue, as well as providing a concentrated source of calcium, necessary to maintain the health of teeth and gums.

Heamorrhage: Fucoidan(brown algae) in the pre-surgical patient diet seems to reduce the intensity of blood loss and vascular bed collapse shock during and after surgery.[12]

Medical applications

Antiviral activity: Fucoidan interferes with every stage of viral attack, cell attachment, cell penetration, and intracellular virion production by stimulating the production of antiviral cytokines in tissue grfting.[13,14]

Cardiovascular: Kombu is one of the top 5 most consumed seaweeds in Japan and USA. The physiological effects of regular kombu consumption can be: resolution of coronary artery disease, healthier liver function, higher metabolic rate, faster food transit time, lower LDL cholesterol,, higher HDL cholesterol blood levels. If the thyroid hormones in Kombu and Sargassum are available from food, this could turn out to be an effective treatment to replace synthetic thyroxines and animal-thyroid medications.[15,16]

Essential fats and vitamins in sea weeds: Most seaweeds are rich in vitamins, especially the B vitamins, including B12. They also have significant amounts (1-3%) of omega-3 fatty acids. Nori, in particular has 3% omega-3 fatty acids and large amounts of vitamins A and C.[17,18]

Weight loss: Those dieting for weight loss release adipose-sequestered PCBs, Dioxins, and PBDEs into their blood and lymph. Ingesting brown seaweeds may mitigate the negative consequences caused by weight loss toxin releases.[19]

Brown sea weed- Enhanced excretion of Dioxins and PCBS: Seaweeds for Dioxin and PCB (polychlorinated biphenyl) excretion demonstrates clearly that the brown seaweeds Hiziki, Wakame, and Kombu speed body clearing of dioxins and PCBs. part of the thyrosupportive action of dietary brown seaweeds probably results from reducing PCB and PBDE uptake from food and their concomitant accelerated fecal excretion.[20]

Carrageenan- An inhibitor of Papilloma virus infection: Pharmaceutical grade carrageenan gels could become a safe perinatal cervicovaginal preventative for JORRP (Juvenile Onset Recurrent Respiratory Papillomatosis) and asymptomatic vertically transmitted HPV by adding the gels to the perinatal birth canal in women known to carry HPV (human papilloma virus) types 6 & 11.[21]

Burns: Alginate dressings meant for the management of partial-thickness (second-degree) burns and wounds that are prone to bleeding, such as wounds that have been mechanically or surgically debrided and donor sites. It can also be used for other indications such as diabetic foot ulcers, leg ulcers (venous stasis ulcers, arterial ulcers and leg ulcers of mixed etiology), pressure ulcers/sores (partial- and full-thickness), surgical wounds left to heal by secondary intention such as dehisced surgical incisions, surgical wounds that heal by primary intention such as dermatological and surgical incisions (e.g., orthopedic and vascular), traumatic wounds, oncology wounds with exudate (e.g. fungoides-cutaneous, tumors, fungating carcinoma, cutaneous metastasis, Kaposi's sarcoma, and angiosarcoma), infected or painful wounds. E.g: AQUACEL® Ag BURN Hydrofiber®

Wound dressings: Composed of calcium alginate (a seaweed component). When in contact with wound, calcium in the dressing is exchanged with sodium from wound fluid and this turns dressing into a gel that maintains a moist wound environment. Good for exudating wounds and helps in debridement of sloughing wounds. Do not use on low exudating wounds as this will cause dryness and scabbing. Dressing should be changed daily.E.g. Kaltostat®, Sorbsan® [22]

Rhumatoid artheritis: Fucus mushes used as best folk medicine for the treatment of rhumatoid artheritis.Brown algal phycopolymers are algin and fucoidan have great therapeutic value as a heavy metal detoxifying agent.[23]

Postmeno pasual changes (PMS): Women patients eating seaweeds to reduce PMS symptom severity report a distinct cyclical waxing and waning of seaweed cravings.[24]

Erectile dysfunction: Seaweed drink acts as medicin in erectile dysfunction and most of these are behavioral, such as smoking, alcohol consumption, chronic dehydration, obesity.

Hormones in sea weeds[25-28]

Melatonin: Sea weeds are best source for melatonin. Day time harvested sea weeds possess more amount of melatonin. Brown seaweeds are the only known non-animal sources of thyroid hormones. Fucus species of brown seaweeds have been used as treatment for thyroid disorders. The thyroid hormone present in Fucus is Di-Iodothyronine (DIT). Fucus is used to wean mildly hypothyroid patients off thyroid hormone medication.

Thyroxin: T4 and T3 have been found as the main organically bound iodine compounds in several brown seaweeds, notably Laminaria species and Sargassum species. Up to 10% of Lamiarian iodine may be in MIT, DIT, T3, orT4. Even more in the less commonly available Sargassum. Icelandic kelp, Norwegian kelp, Atlantic kelp, Pacific kelps, Fucus species, Wakame, Sargassum, and Nori are the iodine rich seaweeds used for the treatment of thyroid cancer is one of the fastest increasing cancers in both adult men and women.

Enzyme inhibitors and Stimulants:[29] Fucoidan (Rhipocephalus phoenix) also inhibits cytotoxic and myotoxic activities of several PLA2 myotoxins from crotaline snake venoms that result in muscle necrosis caused by snake bites.

Antilipimic, Hypocholestremic, Hypoglysimic, Hypotensive and Related activities: A crude methanolic extract from Pelvetia babingtonii shows potent α-glucosidase inhibitory activity which could make it effective in suppressing postprandial hyperglycemia (Ohta et al., 2002). Hypolipidemic activities have been identified in ethanolic extracts of Solieria robusta, Iyengaria stellata, Colpomenia sinuosa, Spatoglossum asperum and Caulerpa racemosa, as shown by decreases in the serum total cholesterol.

Anti inflammatory activity and effects on the Immune response:[30] In many red algae, the metabolised products of 20-carbon atom polyunsaturated fatty acids (PUFAs) called oxylipins, resemble eicosanoid hormones in higher concentrations.

The anomalous production of these compounds underlies a number of diseases related toinflammation (Gerwick & Bernart, 1993), and so eicosanoids and their derivatives have received much research attention in the search for development of new classes of antiinflammatory drugs.

Agglutination, coagulation and the stimulation of cell migration: Lectins from Codium fragile subspecies tomentosoides have been developed into a histochemical reagent by coupling them to colloidal gold, forming a lectin-gold conjugate. This conjugate is useful for studies of the surface topography of cells of animal tissues. Lectins are also used to char- acterise cell-surface polysaccharides or to examine cell binding patterns in lectinosorbent assays.

Cosmetics:[31]"Extract of seaweed" is often found on the list of ingredients on cosmetic packages, particularly in face, hand and body creams or lotions. This usually refers to the use of alginate or carrageenan in the product. Mineral-rich seawater is used in a range of therapies, including hydrotherapy, massage and a variety of marine mud and algae treatments.

One of the treatments is to cover a person's body with a paste of fine particles of seaweed, sometimes wrap them in cling wrap, and warm the body with infrared lamps. It is said to be useful in various ways, including relief of rheumatic pain or the removal of cellulite.

Industrial/Machinery

Other industrial applications of sea weeds include

Alginate: Obtained from *Crocystis*, *Laminaria*, *Sargassum*, and *Ascophyllum* used in Food industry (ice cream, dairy products, juice, jam, salad dressing, stabilization agent for canned food), textile industry (bending and forming or stiff), raw material for artificial fiber, clarifier for wine making, sewage purifier, water softener, separating agent for chemical composition, alkaloid refining agent, emulsifier for paint and plastics industry, bonding agent, stabilizer, lubricant and filling agent.

Agar: Obtained from *Gelidium*, *Pterocladiella* and *Gracilaria* used in culture medium for microorganism, food industry (jellies, jams, starch substitutes, stabilizer for canned food, gelling agent), textile industry, paper-making, clarifier for wine making, aids in the making of ultra thin separating film, analytical research (electrophoresis), medicine (gastro-intestinal intolerance, capsules).

Carrageenan: Obtained from *Chondrus, Gigartina, Eucheuma* and *Hypnea* used in food industry (jellies, jams, salad dressing, stabilization agent for canned food, gelling agent), cosmetic industry, paint industry.

Funoran: Obtained from Gloeopeltis used in paper-making industry, textile industry.

Fertilizers and soil conditioners: Species of Ascophyllum, Ecklonia and Fucus have a suitable content of nitrogen and potassium, but are much lower in phosphorus than traditional animal manures and the typical N: P: K ratios in chemical fertilizers. The large amounts of insoluble carbohydrates in brown seaweeds act as soil conditioners (improve aeration and soil structure, especially in clay soils) and have good moisture retention properties.

Biomass for fuel: Gracilarial sea weeds rich in methane.

Packaging: Because of their(Sea weeds) biological biodegradability, the use of bioplastics is especially popular in the packaging sector. The use of bioplastics for shopping bags is already very common. After their initial use they can be reused as bags for organic waste and then be composted. Trays and containers for fruit, vegetables, eggs and meat, bottles for soft drinks and dairy products and blister foils for fruit and vegetables are also already widely manufactured from bioplastics.

Disadvantages

Some disadvantages of bio-plasticsare

1. Bioplastics could have a damaging effect on soil, water usage and quality, and result in higher food prices.

2. Bioplastics are designed to be composted, not recycled. The plant-based material will actually contaminate the recycling process if not separated from conventional plastics such as soda bottles and milk jugs.

3. Home composting may not be an option. Some bioplastics cannot be broken down by the bacteria in our backyards. Polyethylene (PE) made from cane sugar is one example of this. Only bioplastics that are fully biodegradable will break down in a home compost pile, and it could still take up to two years for certain items (e.g., forks and spoons). The rest require the high heat and humidity of an industrial composting facility. There are only about 100 of those in the country, and not all accept bioplastic waste.

4. Plants grown for bioplastics have negative impacts of their own. Bioplastics are often produced from genetically modified food crops such as corn, potatoes, and soybeans, a practice that carries a high risk of contaminating our food supply. Also, corn and soybean producers typically apply large amounts of chemical pesticides and fertilizers that pollute our air and water. To compound matters, the growth of the bioplastics and biofuel industries (both of which currently rely on food crops as their raw material) increases the demand for crops, puts pressure on food prices, and increases the impact of agriculture worldwide.

The main disadvantage with oil-based biodegradable plastics is that when they break down, carbon dioxide is released in the process and contributes to global warming. Another disadvantage with biodegradable plastic is that degradation will happened very slowly underground. Also, biodegradable plastics when mixed with normal plastics would reduce the worth of the plastic itself if it is recycled and make the recycled plastic useless

CONCLUSION

Bioplastics from seaweed may also be expensive but they have gained utmost importance in the recent times because of their advantages over other biological sources which have already mentioned above. Seaweed based bioplastics play a vital role as an environment friendly and biodegradable alternative compared to conventional plastics. The technology routes for the production of seaweed based bioplastics are still under research and the use of biotechnological and genetic engineering techniques play a key role in conducting the feasibility and sustainability studies in seaweed based bioplastics. It is hoped that significant advances made in the bioplastics industry in general will benefit seaweed based bioplastics industry as well and will make seaweed based bioplastics a reality in the distant future.

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