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SEAWEED RESEARCH IN INDIA - A NOVEL DOMAIN IN MARINE BIOTECHNOLOGY

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ABSTRACT: Seaweeds are not a common weed, its valued marine plants. In Indian coast around around 800 seaweed species belonging to Chlorophyta, Phaeophyta and Rhodhophyta. Seaweeds constitute one of the commercially important renewable marine living resources. Seaweeds have various commercially valuable products such as pharmaceutical and cosmaceutical compounds, plant growth promoters, Nitrogen fixers, bio-energy and functional foods. The seaweeds are very rich in nutrition level, because of their low content in lipids, high concentration in polysaccharides, minerals, poly-unsaturated fatty acids and Vitamins as well as their content in bioactive molecules, marine algae are known to be a good source of healthy food. The need for marine natural products like Carrageenan, Kainoids, Polycavernoside A, chondriamides A, B and C have grown enormously in the last fifty years. Especially marine macro algae are wonderful salubrious sources of biologically active natural products. This review highlights the current knowledge of seaweed biotechnology in the area.

INTRODUCTION: The extraordinary bio-diversity of the marine research represents a rich natural resource for many biologically and pharmacologically active compounds. The marine organisms face very stressful environment than the terrestrial environments. They have naturally evolved some intricate developing to produce wide variety of primary and secondary metabolites which cannot be found even in some land living organisms.

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Marine-based bioactive compounds can be derived from a vast array of sources, including marine animals, plants, macro and microalgae, microorganisms, etc; all these have unique set of bio molecules [1]. Recently, seaweeds have increasingly become the target of natural products research. Many of them are known to be a rich source of chemically diversified secondary metabolites with often remarkable biological activities. Seaweeds are plant like marine organisms that are botanically classified as macrophytic marine algae. They are primitive plants without any true root, stem, leaves and whole body of the plant is called thallus that consists of the holdfast, stipe and blade. They belong to the division of Thallophyta in plant kingdom.

Marine algae are classified based on the type of pigments, morphological, anatomical and reproductive structures into four groups namely Phaeophyceae (brown algae), Chlorophyceae (green algae), Cyanophyceae (blue-green algae) and Rhodophyceae (Red algae). Bequette and France, [2] reported that the estimated range of seaweeds is probably around 45,000 species. To date, researchers have isolated approximately 7000 marine natural products, 25 percent of which are from algae. Seaweeds are able to produce a variety of secondary metabolites characterized by a broad spectrum of biological activities. Compounds with cytostatic, antiviral, anthelmintic, antifungal and antibacterial activities have been detected in green, brown and red algae [3, 4]. Seaweeds not only show therapeutic value they also used as food, fodder, feed and fertilizer too. They provide home and food for many different sea animals, lend beauty to the underwater landscape, and are directly valuable to man as a food source and as a source to industrial raw materials. They contain different Vitamins, minerals, trace elements, protein, iodine, bromine and bioactive substances [5].

Seaweeds are used in various industries such as, food, textile, pharmaceutical, cosmetic, and bio technological industries. Seaweeds are the only source of phytochemicals namely agar, alginic acid, laminarin, fucoidin, galactans and carrageenan, which are extensively used in various industries such as food, confectionary, textiles, pharmaceuticals, dairy and paper industries mostly as gelling, stabilizing and thickening agents [6]. Industrial macro algal use includes the extraction of phycocolloids and biochemicals. Macro algae produce many biologically active phytochemicals, polyunsaturated fatty acids, polysaccharides, Vitamins, sterols, tocopherol and phycocyanins**.** The benefits of seaweeds as sources of organic matter and fertilizer nutrients have led to their use as soil conditioners for centuries [7-9]. Traditionally, seaweed is a readily available food source that has been consumed by coastal communities since the dawn of time. The incorporation of seaweed into foods has also been shown to have a preservative effect, particularly with regards to Gram-negative bacteria, reducing the need to add salt. The antimicrobial properties of seaweed extracts have been well accepted over the years [10]. Currently, there is growing interest in researching habits to develop agricultural yields in both developed and undeveloped countries. They were searching for new alternative methods to improve crop yields and soil fertility. Seaweeds have been used for many years as a valuable source of organic matter for various soil types and many different fruit and vegetable crops in the coastal regions of world [11].

Seaweeds - Diversity in Marine Ecosystem: The diversity of life in the marine environment is extraordinary; the greatest biodiversity is in the world's oceans, with 34 of the 36 phyla of life represented. The oceans cover more than 70% of the earth's surface and contain more than 300,000 described species of plants and animals. Algae are known to be comparatively sensitive to chemicals. Their ecological position at the base of the aquatic food chain and their essential roles in nitrogen and phosphorus cycling are critical to aquatic ecosystems. Moreover, the alternation of species composition in an aquatic community as a result of toxic stress may affect the structure and function of the whole aquatic ecosystem. The marine environment represents a treasure of useful products awaiting discovery for the treatment of infectious diseases. Ecological pressures, including competition for space, the fouling of the surface, and predation have led to the evolution of unique secondary metabolites with various biological activities. The important role of these secondary metabolites in the control of infectious microorganisms was for many years largely unnoticed.

Global Trade and Economic Importance of Seaweed Production: In round the world there are 46 countries where commercial seaweed activity were represent such as China, Japan, Philippines, North Korea, South Korea, Chile, Indonesia, Norway, USA and India. China leads the first place in cultivation of seaweed, especially *Laminaria* sp, *Kappaphycus*, *Eucheuma*, *Porphyra*, *Undaria* and *Gracilaria*. The most valuable crop is the red alga Nori (*Porphyra* species, mainly *Porphyra yezzoensis*), used as food and feed in Japan, China and Pacific region. Worldwide aquatic plant production is increased from 7.2 million tons to nearly 13.1 million tons (wet weight), upholding US $ 7 billion world trade in 2013, compared to US $ 350 million trade in 2014. The involvement of cultured seaweeds is 25% of total global aquaculture volume (45,715,559 tons) or nearly 5

% of total volume of world fisheries production (141,798,778 tons) for 2012. In most reported, brown algae with 4,906,280 tons (71 % of total production) followed by the red algae (1,927,917 tons) and a small amount of green algae (33,700 tons).

East and South-East Asian countries contribute almost 99% seaweeds production, with half of the production (3.5 million tons) supplied by China. The majority of amount produced is used locally for food, other than there is a growing international trade. Total EU imports of seaweed in 2012 amounted to 65,000 metric tons with the Philippines, Chile and Indonesia as the biggest suppliers. Significant quantities of *Eucheuma* are exported by the Philippines, Tanzania and Indonesia to USA, Denmark and Japan.

In several oriental countries like Japan, China, Korea, etc. seaweeds are a staple part of the diet. Agar is widely used in paper manufacturing, culture media, packaging material, photography, leather industry, plywood manufacturing, preservation of food stuffs, dairy industry, cosmetics industry and pharmaceutical industry. Carrageenan is employed in food industry. Its value in the manufacture of sausages, corned beef, meat balls, and ham preparations of poultry and fish, chocolates, dessert gels, ice creams, juice concentrates, marmalade, sardine sauces is well known. It is also used in the manufacturing of non-food items like beer, air freshners, textiles, toothpastes, hair shampoos, sanitary napkins, tissues, culture media, fungicides, etc. The applications of alginate find place in frozen foods, pastry fillings, syrups, bakery icings, dry mixes, meringues, frozen desserts, instant puddings, cooked puddings, chiffons, pie and pastry fillings, dessert gels, fabricated foods, salad dressings, meat and flavour sauces [12].

Seaweeds in India: More than 7500 km of coastline in India is potential environmental for domin with various ecosystem profiles abundant growth of seaweeds in Tamil Nadu coast, Gujarat coast, Lakshadweep and Andaman Nicobar Islands. Rich seaweed beds occur around Visakhapatnam in the eastern coast, Nagapattinam, Gulf of Mannar, Tiruchendur, Tuticorin and Kerala in the southern coast. Veraval and Gulf of Kutch in the western coast [13-15]. To date, about 844 species of seaweeds are represented however commercial cultivation is yet to take place in India. Among 844 species are red seaweeds, 194 species are brown seaweeds and 216 species are green seaweeds. R & D efforts over the years have resulted in valuable information regarding biodiversity, ecological conditions suitable for farming, species that could be incorporated in the cultivation, etc.

In India more than 60 species were commercially utilized for agar, carrageenan, algin and pharmaceuticals production. Seaweed mariculture is a significant and profitable livelihood option for the coastal fishing community especially for fisher women, who with little effort can earn a substantial income for the household. Previousely Krishnan and Narayana kumar, [16] reported that the estimated potential of seaweed, 1,005,000 tons in six states of India comprising 250,000 tons in Gujarat, 250,000 tons in Tamilnadu, 100,000 tons in Kerala, 100,000 tons in Andhra Pradesh, 5,000 tons in Maharasthra and 300,000 tons in Andaman and Nicobar Islands.

Commercial cultivation of macro-algae has barely begun and is facing continuous regulatory hurdles. Processing of macro-algae is limited to lower grades of agar-agar and alginate and is modest in quantity. Manufacturers of agar-agar are working at less than 50 per cent of their capacity and there is no manufacturer of carrageenans. Instead of being a major global producer and exporter, India remains an importer of macroalgal products. The principal cause for this gap between the potential and the actual results achieved with respect to commercial cultivation and processing of macro-algae is the lack of clearly enunciated policy on cultivation and utilisation of seaweeds.

The agar yielding seaweeds *Gracilaria arcuala* and *G. verrucosa* and carrageenan yielding seaweed *Hypnea valentiae* also occur in harvestable quantities in some estuaries and backwaters of Tamil Nadu and Pondicherry [17]. A great deal of information has been published on the distribution, resource assessment, utilization and cultivation of seaweeds of the Indian coast [18 - 22]. Of particular interest is the southeast coast of Tamil Nadu (Mandapam to Kanyakumari, including the islands in the Gulf of Mannar). Multipotential applications of seaweeds were given in **Fig. 1**.

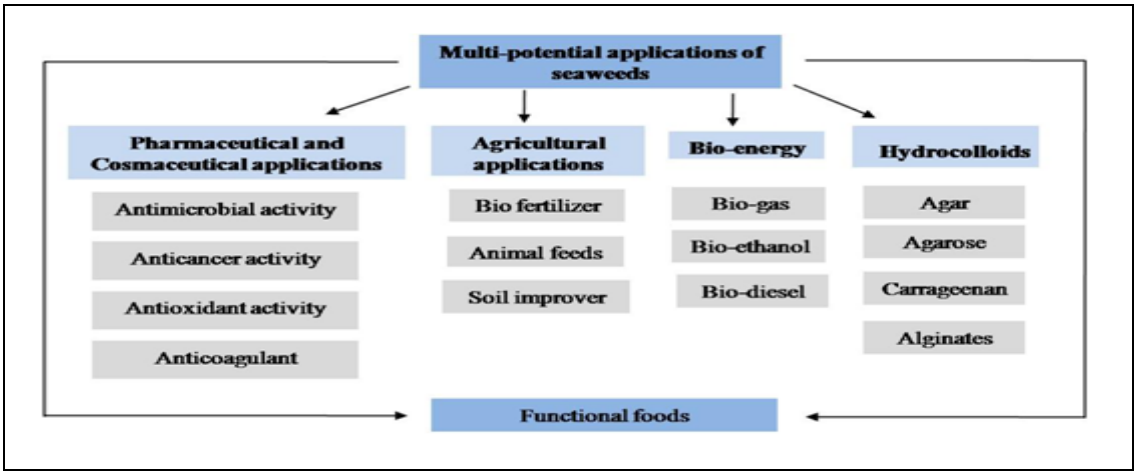

FIG. 1: MULTI-POTENTIAL APPLICATIONS IN SEAWEEDS

Industrial Utilization of Seaweeds in India: Approximately 7.5-8 million tons of wet seaweeds are harvested worldwide per year. In India, seaweeds are utilized by the industries, mainly for commercial production of agar and alginate. These have been used as food for human beings, feed for animals, fertilizers for plants and source of various chemicals. Carrageenan industries are least developed due to non-availability of sufficient raw materials for carrageenan production. Agar production in India started in 1940 on a cottage industry-scale, using *G. edulis* as raw material. Subsequently, a viable cottage industry method for the manufacture of agar from *Gracilaria lichenoides* was developed.

Later a process for industrial manufacture of agar was developed by some researcher using *Gelidium micropterum* as raw material. With the development of this industrial method, a few industries started agar production using either *G. acerosa* or *G. edulis* as raw material. Previously some reports says that there are 46 seaweed based industries – 21 agar and 25 alginate – but not functioning up to their rated capacity, as there has been a short supply of raw materials. Among the 21 agar factories, only ten are presently functioning [23]. Although Indian requirement of agar is about 400 tons per annum, only about 30% of it has been produced indigenously. Among the existing agar industries, M/s Marine Chemicals, Cochin contributes 50% of the indigenous production. Similarly, Indian requirement of alginate is 1000 tons per annum, and indigenous production is less than 40%. In the recent years, seaweed products are used in our daily lives in one or the other way.

For example, some seaweed polysaccharides are employed in the manufacture of toothpastes, soaps, shampoos, cosmetics, milk, ice creams, meat, processed food, air fresheners and a host of other items.

Seaweed Bio Filter: Aquaculture has been supporting human demands for fish products for centuries and is an important industry worldwide [24]. Fish aquaculture production on an intensive scale has caused many environmental problems to reduce the nutrient burden of the fish farm effluents; the integration of seaweed cultivation with fish aquaculture has been proposed [25]. Various strategies for integrating seaweed cultivation with fish culture have been successful [26]. Several species of *Gracilaria* [27], *Ulva* and *Laminaria* and other macro algae [28] have been considered in the integrated bio filter system and showed reasonably high efficiency in the removal of waste inorganic nutrients. Recently, *Porphyra* (known as "Gim" in Korean) has been recommended as an attractive candidate for the integrated aquaculture with salmonids [29]. Seaweeds were used in treatment of sewage and some agricultural wastes to decrease the total nitrogen and phosphorus and it might removal of toxic metals from industrial wastewater.

Seaweed as Bio-fertilizer: There is a long history of coastal people using seaweeds, especially the large brown seaweeds, to fertilize nearby lands. One of the well documented beneficial effects of seaweed extracts is that it enhanced the seed germination and plant growth, act as potential biocide [30] and enhance the standing crop [31-34].

Seaweed as a fertilizer is suitable in organic agriculture [35]. Marine algae consist of macro and micro nutrient amino acid, Vitamins, cytokinins, gibberellins, auxins, auxin-like and other growth-promoting compounds [36].

More over seaweeds are used in soil amendment [37], pests' control [31] and plant diseases management [38]. Liquid extracts obtained from seaweeds have gained importance as foliar sprays and soil drench for several crops including various grasses, cereals, flowers and vegetable species. For example, aqueous extracts of *Sargassum johnstonii* at particular concentration increased the rooting of *Vigna mungo* enhanced vegetative growth (plant height, shoot length, root length, and number of branches) and reproductive parameters (flower number, fruit number, and fresh weight) of tomato [34]. The effect of the extracts of *Sargassum wightii* gave 11% increase in seed germination, a 63 % enhancement in number of lateral roots formation and 46% increase in shoots length of *Triticum aestivun* compared to control [39]. Aqueous extract of *Sargassum wightii* when applied as a foliar spray on *Zizyphus mauritiana* showed an increased yield and quality of fruits [40]. Growth promoting effect of seaweed liquid fertilizer (SLF) (*Enteromorpha intestinalis*) on the sesame crop plant has also been reported [37].

Previously many researches prove that the seaweed liquid fertilizer (SLF) treatment improved the growth parameters significantly when compared to the control on green gram. [41] reported that lower concentration of SLF from *Stoechospermum marginatum* promoted the growth of brinjal [42]. The recent research to introduce new methods the different seaweed preparation as mixed consortium for the application to the agricultural field and for the gainful yield. Some of the seaweeds fertilizers given in **Table 1**.

Plant Growth Hormones: The plant growth stimulating Plant growth hormones (PGH) were found most of the seaweed. Especially auxins, cytokinins and gibberellins. Cytokinins have been detected in fresh seaweed. Cytokinins stimulate rapid cell division and the production of new cell walls, so cytokinins are particularly important for new growth. Other plant hormones present in seaweed extracts auxins, were shown to initiate root formation and inhibit its elongation. Plants are able to synthesize these compounds from tryptophan or indole [53]. The indole-3-acetic acids (IAA) were found in different species of seaweeds such as *Ascophyllum nodosum*, *Porphyra perforata*, *Botryocladia* spp, *Enteromorpha* sp. and in cyanobacteria. Gibberellins are best known for their affects on stem elongation and flower development, but they are also important for breaking seed dormancy. The gibberellins stimulate the dormant seeds to produce enzymes that break down the stored starches into energy molecules needed for respiration. The seed germinating hormones gibberellins was idenfified in *Fucus vesiculosus* and *Fucus spiralis* [33]. Generally in this plant growth hormones extracted from seaweeds it can increase the crop productivity in commercial world. An additional role of this plant regulator is to enhance chlorophyll content in leaves by decreasing its degradation [54].

TABLE 1: SEAWEEDS USE AS A AS FERTILIZER IN INDIA

S. No.	Species
1	*Sargassum wightii* [43]
2	*Rosenvingea intricate* [44]
3	*Ulva lactuca* [43]
4	*Dictyota dichotoma* [45]
5	*Sargassum trichophyllum, S. salicifoloides, S. kasyotenese, S. tenerrimun, S. carpophyllum, S. duplicatum, S. ilicifolium, S. cristaefolium, S. plagiophyllum, S. swartzii, S. polycystum* [46]
6	*U. fasciata* and *Gracilaria corticata* [47]
7	*Zizyphus mauritiana* [23]
8	*Enteromorpha intestinalis* [37]
9	*Kappaphycus*-sap, *Fucus vesiculate* [48]
10	*Enteromorpha clathrata* [41]
11	*Stoechospermum marginatum* [42]
12	*Furcellaria fastigiata* [49]
13	*Ascophyllum nodosum* [50]
14	*Durvillea potatorum* [51]
15	*Padina tetrastomatica* [52]

Seaweeds as Food and Feeds: Food and feed has long been used to improve health, our knowledge of the relationship between food components and health is now being used to improve food. Food components that have been demonstrated to provide specific health benefits beyond basic nutrition. Food components and nutrition science has moved from identifying and correcting nutritional deficiencies to designing foods that

promote optimal health and reduce the risk of disease. Today's science and technology can be used to provide many additional functional foods components, and future scientific and technological advances promise an even greater range of health benefits for consumers. Foods and feeds can provide health benefits by reducing the risk of chronic diseases and enhancing the ability to manage chronic diseases, thus improving the quality of life. Seaweeds are recognized for their enrichness in polysaccharides, minerals and certain Vitamins [6], but they also contain bioactive substances like polysaccharides, proteins, lipids and polyphenols, with antibacterial, antiviral and antifungal properties, as well as many others [55].

This gives seaweed great potential as a supplement in functional food or for the extraction of compounds. Physiologically active compounds in marine algae are classified into two types based on the difference in the mechanisms: Non-absorbed high-molecular materials like dietary fibres and low-molecular materials, which are absorbed and which affect the maintenance of human homeostasis directly [56]. Generally near coastal lived animals like sheep, cattle and horses have been eaten seaweeds in olden days. Nowadays various advanced technologies were applied and produced the animal feeds, the seaweeds were collected and it was washed and dried that has been crushed to a fine powder after that commercialized.

This seaweed feed contains useful amounts of minerals (potassium, phosphorus, magnesium, calcium, sodium, chlorine and sulphur), trace elements and Vitamins. Trace elements are essential elements needed by humans and other mammals in smaller quantities than iron (approximately 50mg/kg body weight), and include zinc, cobalt, chromium, molybdenum, nickel, tin, vanadium, fluorine and iodine. Because most of the carbohydrates and proteins are not digestible, the nutritional value of seaweed has traditionally been assumed to be in its contribution of minerals, trace elements and Vitamins to the diet of animals. Currently the aquatic organisms were cultivation was more in worldwide it might increase economic level of the country, that's the reason to origin, the governmental and non-governmental aquaculture industries were developed. The aquatic organisms especially in fish cultivation were applied in seaweed feeds [57-58].

Pharmaceutical and Cosmaceutical Applications of Seaweeds: To date, researchers have isolated approximately 7000 marine natural products, 25 percent of which are from algae. The antimicrobial properties of seaweed extracts have been well documented over the years [59]. The seaweed extracts were used as a therapeutic and protective agent for various diseases [60] and its ability were viewed such as antibiotics, antihelminthics, cough remediates, antihypertensive, anti tumor and anti diarrhea drugs or compounds. Most of the seaweeds have the bioactive components which inhibit the growth of Gram-positive bacteria as well as the Gram-negative bacteria pathogens. *Bryopsis* sp. was noted for its *in vitro* activity against *Mycobacterium tuberculosis* [61] *Delisea pulchra*.

Effects are seen on the swarming of *Serratia liquefaciens* [62] and the bioluminescence and virulence in several pathogenic *Vibrio* species [63-64]. It also inhibits carbapenem antibiotic synthesis and exoenzyme virulence factor production in the phytopathogen *Erwinia carotovora* [63]. Recently, many researchers have embarked on chemical investigations of marine algae with a special account on their bioactive properties. Several investigations have proved that crude seaweeds and their organic extracts have anti-proliferative activity on human cancer cell lines *in vitro*, as well as inhibiting activity on tumours growing in mice *in vivo.* [65-66] "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 some algae are also potential skin irritants. For example, the phycocyanin present in blue-green algae has been suspected of allergenicity and of causing dermatitis on the basis of patch tests [67].

Extracts of 25 seaweeds from the Indian coast have been put through a broad biological screen which includes tests for antiviral, antibacterial, antifungal, antiprotozoal, anti-fertility activities, and a wide range of pharmacological activities. Significant activity is found in 13 seaweeds. Most promising activity being 100% antifertility (anti-implantation) activity observed in three species [68]. The antiviral

activity observed in *Codium elongatum* and the two species of *Hypnea* was attributed to the poly-saccharides [69] to date, in world wild research-ers are achieved some kind of pharmaceutical valuable activities from seaweeds in this details were clearly shown in **Table 3**. Cosmetic products, such as creams and lotions, sometimes show on their labels that the contents include "marine extract", "extract of alga", "seaweed extract" or similar. This means that one of the hydrocolloids extracted from seaweed has been added. Alginate or carrageenan could improve the skin moisture retention properties of the product. Pastes of seaweed, made by cold grinding or freeze crushing, are used in thalasso therapy, where they are applied to the person's body and then warmed under infrared radiation. This treatment, in conjunction with seawater hydrotherapy, is said to provide relief for rheumatism and osteoporosis [7].

TABLE 2: ANTIBACTERIAL ACTIVITY OF SEAWEEDS REPORTED IN INDIA

S. no	Species
1	*Ulva lactuca*, *Sargassum wightii, Padina gymnospora* [70]
2	Codium adherens, Ulva lactuca, *Halimeda tuna* [71]
3	*Sargassum wightii, Kappaphycus alwarezii*, [72]
4	*Gracilaria edulis, Calorpha peltada* and *Hydroclothres* sp. [73]
5	*Sargassum weigiti, Chaetomorpha antenna, Ulva fasciata, Amphiroa fragillissima, Gracilaria edulis* and *Enteromorpha* sp. [74]
6	*Dictyota humifusa* [75]
7	*Cystoseira barbata, Dictyota dichotoma, Halopteris filicina, Cladostephus spongiosus* [76]
8	*Caulerpa racemosa* and *Ulva lactuca Gracillaria folifera* and *Hypnea musciformis*) *Sargassum tenneerimum* and *Padina tetrastomatica*) [77]
9	*Sargassum ilicifolium, Padina tetrastromatica Gracilaria corticata* [78]
10	*Codium decorticatum, Caulerpa scalpelliformis, Gracilaria crassa, Acanthophora spicifera, Sargassum wightii* and *Turbinaria conoides* [79]

TABLE 3: CARRAGEENAN EXTRACTED FROM SEAWEED IN INDIA

S. no	Species
1	*Acanthphora spicifiera, H. valentiae, Hypnea boergesen, Hypnea musciformia, Laurencia papillosa* [80]
2	*Kappaphycus alvarezii* [81-83]
3	*Laminaria japonica* [84]

Seaweed as Bio-fuels: Bio-fuel from seaweed is produced by converting alginate, mannitol and fiber contained in seaweed into ethanol, butanol, etc. Seaweed is a known potential carbon-dioxide (CO_2) neutral source of second generation bio-fuels. Energy is stored inside the cell as lipids and carbohydrates, and can be converted into fuels such as biodiesel (in the presence of oils) and ethanol (in the presence of carbohydrates). Its high protein content implies that waste from the feedstock conversion process may yield a saleable waste stream as well. Fuels derived from algae generally fall into two groups; oils which are extracted from algae by a mechanical or chemical process; and ethanol resulting from the fermentation of algae in the presence of a yeast, and isolating the ethanol produced. Its use can reduce green house gas emission up to 40% [85].

The ethanol production already reported from *Laminaria hyperborean* extracts was evaluated with yeast *Pichia angophorae* and its possibility of utilizing both mannitol and laminaran as substrates. Seaweed extract showed that *Pichia angophorae* was able to utilize both mannitol and laminaran for ethanol production [86]. Higher yield of ethonal was recorded while using *Saccharina latissima* as a substract [87]. Many researchers reported that seaweeds might better for higher biodiesel production, in this way algae be capable of used as renewable energy [88].

Pigments: The significance of marine algae as sources of natural pigments has been well documented due to their important beneficial effects in food, feed and pharmaceuticals. The colour in crate of green seaweeds is due to the presence of chlorophyll a and b in the same proportions as the 'higher' plants; beta-carotene (a yellow pigment) and various characteristic xanthophylls (yellowish or brownish pigments). The ability of the xanthophylls pigment, fucoxanthin, is responsible for the colour of brown seaweeds. Recently, many potential antioxidant compounds were identified as some pigments (*e.g.* fucoxanthin, astaxanthin, carotenoid) and poly-phenols (*e.g.* phenolic acid, flavonoid, tannins) [89]. Recently, a pigment, carotenoid (fucoxanthin) reported that it could even provide a new functional food and cosmetic ingredient with anti-metabolic syndrome activity (anti-obesity, anti-diabetes) [90].

Among polyphenols phenolic acids, flavonoids, isoflavones, cinnamic acid, benzoic acid, quercetin

and lig-nans can be mentioned [91]. Seaweed extracts contain appreciable amounts of polyphenols, but their content is strongly dependent on the extraction method. *Ascophyllum* spp. has significantly more polyphenols than other sea-weeds, while *Ulva* spp. has the lowest content of these compounds [92].

Hydrocolloids and Foods: Hydrocolloids based gums are a diverse group of long chain polymers characterized by their property of forming viscous dispersions and/or gels when dispersed in water. Most important seaweed hydrocolloids are agars, carrageenans and alginates, which are produced in form of colour less powders. Agar was the first hydrocolloid used as an additive into food in Asian countries 300 years ago. About 90 percent of the agar produced is for food applications, the remaining 10 percent being for microbiological and biotechnology uses. Most of the agars are extracted from the species of *Gelidium gracilaria.*

Agar can be divided into two principal components: agarose and agaropectin. Agarose is the gelling component; agaropectin has only a low gelling ability. High quality agarose mainly has biotechnology applications. Alginate, sometimes present in the cell walls of brown seaweeds, and it is partly responsible for the flexibility of the seaweed. Most carrageenan is extracted from *Kappaphycus alvarezii.* Carrageenans or carrageenins are a family of linear sulphate based polysaccharides that are extracted from red edible seaweeds. They are commonly used in the food industry, for gelling, thickening, and stabilizing properties. Fucoidan is the naturally available marine product of brown algae.

It is applied in medicinal and therapeutics fields. Especially fucoidans from marine algae have been reported to exhibit outstanding biological activities that aid human health [93] fucoidans were extracted from different seaweeds such as *Ascophyllum nodosum, Sargassum stenophyllum, Laminaria japonica* and were reportd to have pharmaceutical potentials [94]. There are several carrageenans, differing in their basic chemical structure and properties, and therefore in their uses. The carrageenans of commercial interest are called iota, kappa and lambda, and it's susceptible to depolymerisation through acid catalysed hydrolysis. At high temperatures and low pH this may rapidly lead to complete loss of functionality [95].

CONCLUSION: The marine environment has great potential for the discovery of lead compounds that could be used. Particularly in seaweeds populations of the aquatic environments provide a vast genetic resource and biodiversity. Scientists have opined that seaweeds can be utilized in a completely different manner in the drug industry. The therapeutic drugs prepared from seaweeds recently, the polysaccharides and peptides, isolated from seaweeds have become a matter of great interest for cancer therapy. The mechanisms of their anticancer activity are related to their ability to suppress the growth of cancer cells. The applications of Seaweed and their usage have not been fully established. The research on seaweeds needs to be conducted for getting more information about their unknown benefits.

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CONFLICT OF INTEREST: Herewith we declare we don't have conflict of interest.

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