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Seaweeds: Potential Marine Resource for Application in Food Processing Industries

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Abstract

The present review paper deals with the seaweeds, marine macro algae, its availability along Indian coast and application in various industries. Approximately 10,000 seaweeds exist in nature which can be divided broadly on the basis of their pigments into red, brown and green seaweeds. The composition of seaweeds can be summarized as water (90% fresh water), carbohydrates (25-50% dry weight), protein (7-15% dry weight), lipid (1-5% dry weight) and minerals (7-38%) [1]. Seaweeds are rich source of vitamins like A, B1, B12, C, D and E, riboflavin, niacin, pantothenic acid, folic acid and minerals like Ca, P, Na, K, I [2]. In addition to these, seaweeds are also excellent source of dietary fiber, the consumption of which is reported to promote the growth and protection of beneficial intestinal flora, which in turn increase the stool volume and reduce the risk of colon cancer [3].

However, seaweeds are still considered as weeds (unwanted grass) in India and have no utility as a food so far. The importance of seaweeds as a food is realized recently and some species of seaweeds are now used as food in the south East Asia, Europe and America. Seaweeds contain some of the important components like agar, alginate and carrageenan which have several established applications in different industries. However seaweeds also contain phenolic compounds which are secondary metabolites of plant materials and there are reports on its role as natural antioxidant and antimicrobial agents in food products. Those phenolic compounds can be extracted from the seaweeds by using different solvents and used as natural preservative for fresh fish which can extend the shelf life of fish at low temperatures. It was also used for improving the textural properties of fish products.

Keywords: Seaweeds, Nutraceuticals, Phenolic compounds, Agar, Alginate, Carrageenan

Introduction

Seaweed, the multicellular marine algae rich in minerals and vitamins found in marine waters, they grow abundantly in the shallow waters of sea, estuaries and backwaters. They flourish wherever rocky, coral or suitable substrata available for their attachment. It has been an important component of food, feed and medicine in the orient for several centuries; however, very few of the world's available seaweed species are used globally as food sources [4]. Marine environment is important renewable resource for seaweeds. They lives in a harsh environment where they are exposed to a wide range of environmental stress such as light, rapid fluctuations in temperatures, osmotic stress and desiccation. These factors can lead to the formation of free radicals and other strong oxidizing agents but seaweeds seldom suffer any serious photodynamic damage. This fact implies that seaweed cells have some protective mechanisms and compounds [5]. Screening seaweeds for biologically active compounds and use them in food processing has been focus of study for the last decade. There is an increasing interest in the identification of natural therapeutic products for the control of diseases in animal production to avoid the problems associated with excessive use of antibiotics and other bio accumulating chemicals [6]. It is very well documented that seaweeds are natural dynamic additive which performs several functions like antioxidant, antimicrobial, antitumor, antitherpetic, anti-inflammatory, etc. Due to the presence of high amounts of poly phenolic compounds seaweeds are in turn a rich source of natural anti-oxidant [7] and antimicrobial compounds [8]. Seaweeds, worldwide when observed, are mainly utilized for edible purpose especially in Japan, China and Korea. In addition to this they are also used for extraction of phycocolloids, cosmetics, fertilizer and animal feed additive [9]. All over the world aquatic plant production (farmed) and seaweed production (capture) during 2014 was 27 million tonnes [10]. Along the Indian coast seaweeds are abundantly found mainly along Tamil Nadu, Gujarat, Andaman coast in addition to Mumbai and Ratnagiri [11]. Indian seaweed production (capture) during 2014 was 18,650 tonnes (CMFRI 2015-16). In India, seaweeds are mainly exploited for phycocolloids [12]. Researchers have reported positive use of acids and extracts of varieties of herbs and spice as natural preservatives for seafood but report on use of seaweed extract for the same is very limited.

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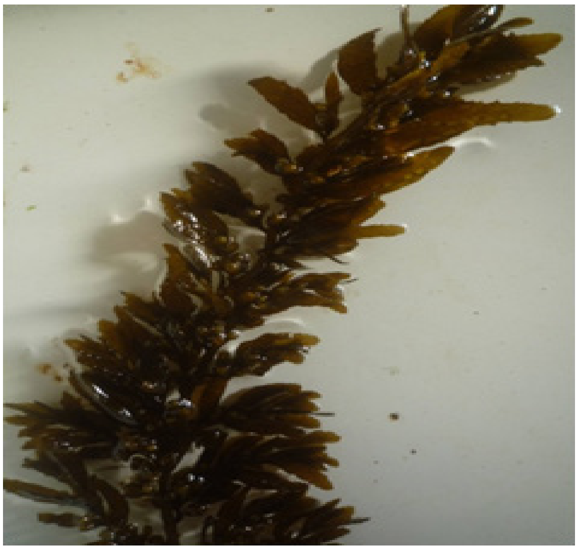
Further consumption of seaweed is almost nil in India and therefore there is a need to develop seaweed based products for human consumption to promote the consumption of seaweeds.

Making the local communities aware of importance of cultivation of some of the economically important seaweeds will not only help the coastal population have another source of income but also increase the overall productivity of the particular coastline. Further development of seaweed based products for direct human consumption will help in promoting the seaweed consumption across India. This will help in augmenting additional income to the fish farmers and prevent post-harvest losses.

Types of seaweeds available in India

Seaweeds are abundant along the rocky coast of India, in the vicinity of Mumbai, Ratnagiri, Karwar, Vizhinjam, Varkala, Visakhapatnam, Chilka lake, Pulicat lake and in Lakshadweep and Andaman and Nicobar Islands [13]. About, 91 microalgal species belonging to 51 genera and 30 families were recorded along Maharashtra coast, lies along central west coast of India between the longitude 150 43' to 200 N and latitude 720 49' to 770 41' E, with 760 km coastline [14]. Along Ratnagiri coast, *Sargassum tenerrimum*, *Padina tetrastromatica*, *Dictyota dichotoma*, *Colpomenia sinuosa*, *Gelidium pusillum*, *Gracilaria corticata* and *Hypnea valentiae* are commonly available [15].

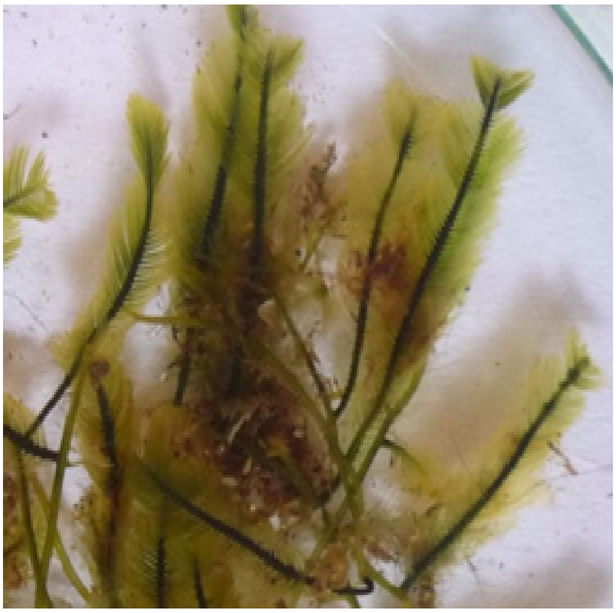


Sargassum tenerrimum

Dictyota dichotoma

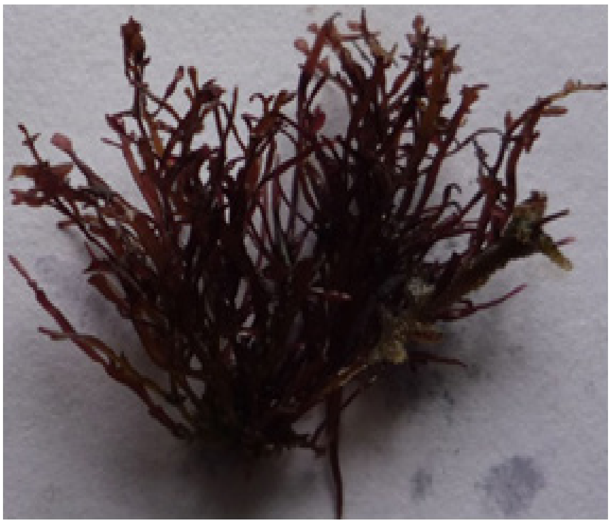
Ulva fasciata

Chaetomorpha spp.



Caulerpa taxifolia

Padina spp.



Gelidium spp.

Main Constituent of Seaweeds

Phenolic compounds:

Phenolic compounds, ubiquitous in plants are an essential part of the human diet [16]. Plant phenolic compounds, also denoted polyphenols, are defined as compounds possessing one or more aromatic rings bearing hydroxyl substituent(s), and which are derived from the secondary metabolism of plants [17]. Balasundram et al., [16] examine the chemistry of phenolic compounds in relation to their antioxidant activity, the occurrence of phenolic compounds in various food and non-food sources, the bioavailability and metabolism of phenolic compounds and also explore the potential use of these compounds as food antioxidants. Seaweeds, identified as a rich source of bioactive compounds [18,19]. It produces a great variety of secondary metabolites characterized by a broad spectrum of biological behavior such as antimicrobial and antioxidant capacities [19]. Brown macro-algae represent a naturally concentrated source of diverse polyphenols, which comprise a wide range of molecules with different biological activities including antioxidant properties [5]. Zubia et al., [20] conducted studies on two species of brown algae from Tahitian coral reefs for their alginate properties, mannitol and phenolic contents, antioxidant and antimicrobial activity determination; the phenolic contents were quite similar in both *Sargassum mangarevense* and *Turbinaria ornate*. The brown seaweed, *Sargassum spp.* (Phaeophyceae), is a potential source of phenolic substances [21].

Polysaccharides:

Carrageenan

Carrageenan is a gelling agent extracted from certain species of red sea plants. It is widely used in the food industry for its unique stabilizing and texturizing effects. Three common types of carrageenan are manufactured commercially: kappa carageenan, extracted from *Euchema cottonii*; iota carageenan, extracted from *Euchema spinosum*; and lambda carageenan, extracted from *Gigartina acicularis,* all have gelling ability [22]. Carrageenan is also known as dietary fiber, potentially beneficial in fish products. Borderias et al., [23] provided a concise synopsis demonstrating that the addition of soluble fibers such as carrageenans from algae, or guar and xanthan from seeds, to fish products improves their functionality. It improves water binding, thickening, emulsion capacity and gelling properties of products made with minced fish muscle, especially where the raw material used is of poor functional quality, but it can cause extensive loss of rigidity and elasticity in muscle protein gels [23,24].

Agar

Agar is a carbohydrate colloid that can be extracted from some red seaweeds and sets to form gel. Basically, freeze/thaw process was used commercially for agar preparation. It is also known as 'kanten' by Japanese. It was mainly prepared from Gelidium spp. and Gracilaria spp. Agar is widely used in paper manufacturing, culture media, packaging material, photography, leather industry, plywood manufacturing, preservation of foodstuffs, dairy industry, cosmetics industry and pharmaceutical industry.

Alginate

Alginate is a polysaccharide used in films & coatings for food products, for microencapsulation of nutraceuticals, and as a carrier of various nutraceuticals and drugs [4]. 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. High affinity of alginate for water makes it useful for controlling moisture in food products.

Application of seaweeds in the development of food products

In western world, seaweed is almost exclusively used for the extraction of important food hydrocolloids, including carrageenan, alginic acid and agar; which can be used for food product development. Proximate composition of seaweed generally indicates their nutritional importance in human diet. Most seaweed species have low protein content, but contain essential amino acids at levels that are sufficient to meet normal nutritional requirements. It contain significant amount of ash and diverse minerals. Edible seaweed contains 33 – 55% total fiber [4]. It is rich in vitamins such as vitamins A, B and E and also many biologically active compounds are present in seaweeds those make them as therapeutic agent and dietary supplements. Those products derived from seaweeds as nutraceuticals and employed as a food supplements & marketed as tablets and pills which provides important health benefits.

Seaweed contains large amount of polysaccharides in its cell wall structures & brown microalgae was recorded as rich in polysaccharides and known for potential therapeutic agents.

Consuming seaweeds as sea vegetables has been a long tradition in the Far East and Pacific while the principal use of seaweeds in Western countries has been as source of thickening and gelling agents for different industrial applications including uses in foods [25]. Seaweeds are traditionally consumed in the orient as part of the daily diet, human consumption of green algae (5%), brown algae (66.5 %), red algae (33 %) is high in Asia [26]. Seafood has high nutritional value and offers more functional properties, but has no fiber content. Fiber is an essential component in human diet. Traditionally, dietary fiber has been defined as 'that fraction of the edible part of plants or their extracts, or synthetic analogues that are resistant to the digestion and absorption in the small intestine, usually with complete or partial fermentation in the large intestine' [27]. The term dietary fibers include polysaccharides, oligosaccharides, lignin and other associated substances [23]. Seaweed contain significant amount of insoluble and soluble polysaccharides, and hence offer potential for fortification of food products with dietary fibers for technological and physiological purposes. Technological functionality includes water holding capacity, fat binding capacity, viscosity, gel-forming capacity, chelating capacity, fermentive capacity, texturizing properties. Physiological functionality includes reduction in cholesterolaemia, modification of the glucaemic response, changes in intestinal function, reduction in nutrient availability, health benefit effects (Borderias et al., 2005). The food industry exploits seaweed gelling, water-retention, emulsifying and other physical properties. In case of fried food, many food ingredients and additives used to improve food quality, but hydrocolloids are the principal category of functional agents that have been used for the past forty years. Hydrocolloids play two main roles in fried food development. One is to form a fine 'invisible' coating, practically on their own, when their main purpose is to avoid excessive oil absorption during the pre-frying and frying processes. On the other, when they are added to the batter among its other ingredients, they are used to avoid oil absorption too, but they also act as viscosity control agents, improve adhesion, pick-up control and freeze-thaw stability or help to retain the crispness of the battered/breaded fried foods [28]. Gomez-Guillen, et al. [29], examines the effect of adding hydrocolloids (iota-carrageenan and starch) alone and hydrocolloids with non-muscle protein (egg-white, soy protein, casein, gluten) on the texture and water-holding ability of gels made with sardine mince of two different qualities and salt contents (2.5% and 1.5%). Addition of hydrocolloids or hydrocolloids and non-muscle proteins to a mince of high gel forming capacity with 2.5% NaCl caused a significant drop in gel strength and hardness but not in elasticity or cohesiveness. In low-salt gels, addition of these ingredients significantly improved folding test scores with respect to control. Low-salt gels with hydrocolloids proved harder but less elastic and cohesive than high-salt gels. Where hydrocolloids were added along with non-muscle proteins in low-salt samples, gels exhibited the same or less hardness, elasticity and cohesiveness as high-salt samples. In a muscle of low gel-forming capacity, addition of hydrocolloids and combinations of hydrocolloids and non-muscle proteins increased hardness, elasticity and cohesiveness of both low and high-salt samples.

Ribeiro et al., [30] reported, red Nori (Porphyra tenera) and brown Hijiki (*Hijikia fusiformis*) seaweed extracts can be used for stability of soybean oil and minced tilapia. The results showed that there is potential for the use of seaweed extracts to increase the oxidative stability of oil, as found in tilapia minced and soybean oil; compared to BHT antioxidant used in control sample. Textural improvement with seaweed was also reported from earlier research work. Santana et al., [31] recorded that, the addition of hydrocolloids such as carboxymethylcellulose (CMC), alginate, and konjac at ~0.5% final concentration can improve the textural and sensory properties of sausages formulated with surimi powder. Samples containing konjac had up to 26% greater gel strength than fish sausages without hydrocolloids. All three hydrocolloids improved the sensory characteristics of sausages formulated with surimi powder, especially hardness and springiness. Konjac, followed by alginate and CMC, are useful additives for improving the physicochemical properties and sensory characteristics of sausages formulated with surimi powder. Perez-Mateos et al. [32] used sulphated polysaccharides (kappa and iota carrageenan) and sodium alginate as thickener or gelling agents added to blue whiting mince and were subjected to different pressure / heat treatments in order to determine the functionality of each one in mince gel. These hydrocolloids are widely known in food processing industries. Seaweed extract was also used for surimi gel strength improvement, as a source of phenolics compound and about 76% gel strength enhancement was observed in sardine surimi by using 2% seaweed extract [33]. Seaweed contains phenol level up to 20 % of their dry weight [34]. Tannin substances with phenolic character occur in marine algae in the physodes of Phaeophyta, such as *Sargassum* species [35]. The bioactive molecules – phenolic compounds i.e. the secondary metabolites, mainly as a phlorotannins are found at high level in marine brown algae [36].

Lekshmi [37] reported the highest value of total phenolic content i.e. 12.60 mg gallic acid/ g dry seaweed in *Padina* when extracted with methanol. She also concluded that a total of 6 days extension was obtained for whole tilapia treated with 1% and 1.5% crude extract of *Padina* under chilled storage.

Chongtham et al., [38] recently reported the fortification of extruded product with brown seaweed and also optimized the process with feed moisture 11-12%, Ulva conc. 6-8% and barrel temperature 135-140 °C. His investigation demonstrated that the nutritional value of traditional extruded snacks, which are considered as junk food, can be enhanced by addition of seaweed as an ingredient without many changes in product properties.

Conclusion

Seaweeds have been used for centuries in coastal areas all around the world as food, feed for animals, fertilizers, etc. Currently food industries use seaweeds as a source for polysaccharides like agar, alginate, carrageenan, konjac flour, etc. Seaweed use in seafood has positive impact on shelf life of product. They may act as antioxidants and antimicrobials. Recent studies show their use in enhancing textural property of foods due to their polyphenolic content. Hence use of seaweeds has potential applications in seafoods.

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