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Seaweeds- A Source of Potential Bioactive Compounds

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ABSTRACT

Seaweeds as a potential source of diet have been used in Japan, Korea and China since prehistoric times. In fact the usage of kelps dates back to 5^{th} century in China. Seaweeds are having unique bioactive compounds and its composition, and nutritional benefits, its structures have been widely studied and are currently being therapeutically used for many medical conditions. Their sustainability in harsh environmental conditions is another unique characteristic that is of researcher's interest. In the current review, we have gathered important information on various bioactive compounds such as Complex Polysaccharides, Unsaturated Fatty Acids, Dietary Fibres, Polyphenolic compounds from seaweed, Phloroglucinol derivatives, Porphyrin derivatives, Proteins and Mineral constitutions, and other Seaweed Phytochemicals. Although are part of daily food in coastal regions of west, not much research is focused in Indian coastal areas to extract these bioactive components or to utilize these algal blooms. We need to utilize our regional algal blooms and proper techniques must be developed and streamlined for using our natural bioresource.

***Key words**: Algal blooms, Seaweeds, Bioresource, Bioactive compounds*

Introduction

Since historic times, there has been a traditional use of seaweeds as food in China, Japan and the Republic of Korea [http://www.fao.org/3/y4765e/y4765e0b.htm]. It has now gained more acceptances globally for its high nutritious value and being exotic component in menu. Literature suggests that around 21 species are used in everyday cuisines in Japan, six of them since the 8th century. Seaweeds accounted for more than 10% of the Japanese diet reaching out to 20% increase in its usage for the last 10 years. Seaweeds are currently pointed as the plant-origin sea greens from the future, earning already the status of "superfoods", which is a market term currently used due to consequence of their superior nutritional profile and richness in bioactive phytochemicals (Yuan *et al*., 2018; Pereira *et al.,* 2012; Pirian *et al*., 2017). Seaweeds are now commercially important, renewable resource. Seaweeds are known to contain significant quantities of proteins, lipids, minerals and vitamins (Norziah *et al., 2002*; Sanchez-Machado *et al.,* 2004; Van Ginneken *et al*., 2011). Seaweeds are very low in fat, high in mono and polyunsaturated fatty acids, and are very rich in carbohydrates, dietary fibers, proteins, containing all the essential amino acids, and vitamins such as A, B, C, E, those are usually absent in vegetables (MacArtain *et al*., 2008). In addition edible seaweeds are more enriched with several minerals, like sodium (Na), potassium (K), magnesium (Mg), phosphorous (P), iron (Fe), iodine (I), and zinc (Zn) (Rupérez *et al.,* 2002; Bocanegra *et al.,* 2009). Seaweeds also contain bioactive compounds in the form of polyphenols, carotenoids, vitamins, phycobilins, phycocyanins, and polysaccharides, among others those are known to benefit human health (Kadam *et al.,* 2010). Several authors report the consumption of seaweeds could contribute to higher intakes of K, that help to balance dietary Na/K where the higher levels of Na in seaweeds could be a therapeutic use for no salt replacement (Circuncisão *et al.,* 2018). In this review, we try gathering information and important literature on the bioactive molecules those make seaweeds unique and nutritious.

Protein

Since seaweeds are recognized as novel functional foods there is a need to characterize the composition of seaweeds (Harnedy *et al.,* 2011; Greenwood *et al.,* 1951). The protein content is recently noticed as it gives the emerging challenges to improve food security by identifying alternative and sustainable protein supplements. According to some studies, protein content ranges from 0.67% to 45.0% in red seaweeds; 5.02% to 19.66% in brown seaweeds; and from 3.42% to 29.80% in green seaweeds. On a gram-for-gram basis, seaweeds have protein and amino acid contents those are comparable to those of beef; however, seaweeds are consumed in much smaller quantities (Lourenço *et al.,* 2002; EFSA Panel on Dietetic Products, 2010; Misurcova *et al.,* 2014; Qasim, 1991). It is important to understand that the amino acid composition of proteins present in seaweed is critical to determine the value of proteins to the human diet, particularly in achieving an acceptable intake of essential amino acids. However, the digestibility of seaweed protein must be thoroughly studied as those proteins within the gastrointestinal tract will significantly affect the nutritional value of the protein asthe protein–polysaccharide interactions is known to reduce digestion efficiency considerably. Thus in recent years research is being carried on the amino acid compositions of the seaweeds. Studies suggest seaweeds are rich sources of lysine an essential amino acid often present in limited quantities in plant protein sources such as corn, maize, soy, rice, and wheat (Galland-Irmouli *et al.,* 1999; Cherry *et al.,* 2019).

Complex Polysaccharides

Among marine resources, seaweeds are well known natural sources of polysaccharides. Sulfated polysaccharides are of the most common polysaccharides found in the cell walls of seaweeds. Seaweeds contain 2.97-71.4% complex polysaccharides such as alginate, fucoidan, and laminarin in brown seaweeds; xylan and sulphated galactans, such as agar, carrageenan, and porphyran in red seaweeds; whilst ulvan and xylan are found in green seaweeds. Seaweed polysaccharides are atypical in structure when compared to terrestrial glycans. These are known to resist gastric acidity, horde digestive enzymes, and gastrointestinal absorption. Seaweed glycans therefore serve as fermentation substrates for specific gut microbial flora or facilitate substrate cross-feeding such as oligosaccharides and metabolic cross-feeding of SCFAs to root indirect proliferation of specific bacteria's (Rose *et al.,* 2009; Timm *et al.,* 2010; Belenguer *et al.,* 2006; Macfarlane *et al.,* 2012; Ríos-Covián *et al.,* 2016). Alginate, an algal polysaccharide is widely used for various purposes in the food industry such as a stabilizer, thickening or emulsifying agent. As it is an indigestible polysaccharide, alginate may also be considered as a source of dietary fiber. Till date the bioactivities reported in the literature from red seaweeds such as *Palmariapalmata* and *Porphyraspp* and from brown seaweeds such as *Undariapinnatifida* and were associated with antihypertensive, antioxidant, and antidiabetic effects. Other published works has suggested that dietary fibers may protect against a number of cardiovascular and gastrointestinal diseases. Therefore these complex polysaccharides from seaweeds hold promise as a dietary source, providing their bioactivity is validated in humans (Goñi *et al.,* 2002; Urbano *et al.,* 2002).

Polyphenols

Seaweeds are a rich source of polyphenols, such as catechins, flavonols, and phlorotannins. Red and green seaweeds are also a source of bromophenols, phenolic acids, and flavonoids. Phlorotannins are the most abundant polyphenol found in brown seaweeds. Most polyphenols of plant originmust undergo intestinal biotransformation by endogenous enzymes and the gut microbiota prior to absorption across enterocytes and are converted to glycones and aglycones by endogenous β-glucosidases in the small intestine. The purported bioactivities of seaweed polyphenols include potential anticancer, antimicrobial and antioxidant activities. Few studies have reported inhibition of digestive enzymes, which may prevent lipid absorption and help maintain glucose homeostasis (Murugan *et al.,* 2015; Wan-Loy *et al.,* 2016; Fernando *et al.,* 2016; Yang *et al.,* 2010; Farasat *et al.,* 2014; Machu *et al.,* 2015; Murray *et al.,* 2018).

Recent studies report that seaweed extracts containing high polyphenol content that could reduce fasting blood glucose, total cholesterol, and LDL-C in humans, but the few interventions conducted in humans have reported inconsistent findings for the effect of seaweed polyphenols on other biomarkers associated with risk of type 2 diabetes and cardiovascular disease, including postprandial blood glucose, fasting insulin, HDL-C, and triglycerides (Lee *et al.,* 2012; Ko *et al.,* 2013; Murray *et al.,* 2018; EFSA Panel on Dietetic Products, 2010, 2011; Gall *et al.,* 2015; Yoon *et al.,* 2017; Li *et al.,* 2017; Cherry *et al.,* 2019).

Terpenoids

In seaweeds, the main carotenoid and tetrapenoid compounds with potential application in the food industry is fucoxanthin and is widely used as preservative for prevention of lipid peroxidation in meat. There have been a lot of studies performed using Fucoxanthin *in vivo*. Results have shown to reduce the risk of diabetes and obesity, and accumulation of lipid in the liver; to decrease insulin resistance; and to improve the plasma lipid profile (Bedoux *et al.,* 2006; El Gamal, 2010). Thus consuming seaweeds have potential effects on anti-diabetic, antiobesogenic and antioxidant bioactivities. Seaweeds also contain carotenoids present in seaweeds, such as lutein, β-carotene, zeaxanthin, echinenone, violaxanthin, and neoxanthin, investigation for their potential antiobesogenic, antidiabetic, or antioxidant bioactivities.

Dietary Fibres

Dietary fibre is an important factor for our digestive health and regular bowel movements. These dietary fibres also helps you feel fuller, can improve cholesterol and blood sugar levels and thus indirectly assist preventing diabetes, heart disease, bowel cancer and improving satiety, interactions with gastrointestinal hormones, suppressing post-prandial lipaemia, reduced glycaemic and insulin levels, as well as reduction of low grade inflammation. Many seaweed species contain similar or higher total fibre content compared with their terrestrial plant sources (Woerle *et al.,* 2006; UKPDS, 1998; Pan *et al.,* 1997). Our daily intake of food is failing to meet daily requirements for dietary fiber intake. The potential functional properties of dietary fiber are directly related with the viscous and water-binding properties of fibers present in the gastrointestinal tract. Dietary fiber components improve health through fermentation process by the colonic microbiota, which can enhance alterations in gut microbial composition and increase the production of health-associated volatile fatty acids such as acetate, propionate, and butyrates. These fiber-induced alterations to the microbiota composition and the associated metabolites produced are naturally altered increasingly those relate with the promotion of gastrointestinal, cardiometabolic, immune, bone, and mental health (EFSA Panel, 2012, 2017; Scientific Advisory Committee on Nutrition, 2015; Clark *et al.,* 2013; Gibson *et al.,* 2017).

Unsaturated Fatty Acids

Unsaturated fats are well known as 'healthy' fats and they're important to include as part of a healthy diet. These fats reduce the risk of high blood cholesterol levels and have other many health benefits when they are replaced with intake of saturated fats in the diet. Many studies have confirmed that Seaweeds are rich in unsaturated fatty acids and thus have been considered its utilization as nutraceutical product (Kendel *et al.,* 2015; Vessby *et al.,* 1980; Borkman *et al.,* 1991).

MUFA

Seaweeds are known for its utilization as nutraceutical due to its richness in nutritionally beneficial components compounds such as proteins, carbohydrates, antioxidants, minerals, dietary fibers, vitamins monosaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs) (Garg *et al.,* 1992; Riserus *et al.,* 2009). MUFA is linked to changes in incretin responses and emptying gastric troubles, where in it elevates dietary MUFA the glucagon-like peptide (GLP-1) in both healthy and diabetic subjects which keeps the risk of T2DM low. In addition, it is also known to increase levels of adiponectin that reduces risk of T2DM (Dimopoulos *et al.,* 2006; Thomsen *et al.,* 2003).

PUFA

Since the healthy diets are already very rich in n-6 PUFAs, greater focus needs to be placed on incorporating n-3 PUFAs into the diet. The main challenge remains that dietary sources of n-3 PUFAs are readily available but in limited quantities. Also when compared to MUFA, polyunsaturated fatty acids (PUFA) play an important role in biological functions both structural and physiological in nature (Esposito *et al.*, 2009).

Seaweed species encompass phyla those contain good source of dietary PUFA as their omega-6 and omega-3 fatty acids ratio ranged from 0.29 to 6.73. Foods rich in omega-6 PUFA have improved insulin sensitivity. Omega-3 PUFA also influences expression in lipid and carbohydrate metabolism (Esposito *et al.*, 2009).

Conclusion

Seaweed is rich source of nutrition containing both macro and micronutrients in abundant quantity than any land vegetables. It is an excellent source of macronutrients such as dietary fibres, protein, complex polysaccharides and micronutrients including B12, folate, calcium, magnesium, zinc, iron, and selenium. Also seaweed is a known to have great source of iodine. With all these excellent qualities, cultivation of seaweeds and regular intake of them is highly recommended. Not much research is done in including them under regular food diet. Also not much of them are quantified and utilized. In India there are rich algal blooms in south coastal zone, however not even 05% of the population utilize it under the diet unlike few countries like Japan. In this review we try gathering the most beneficial bioactive components of Seaweeds so the awareness is increased and may be its utilization under diet is introduced in India. Natural resource with abundant nutritional benefits must be considered to be cultivated and industries must work on developing the combinational diet supplements.

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