PHYTOCHEMICAL PROFILING AND BIOMEDICAL USES OF EDIBLE SEAWEED PALMARIA PALMATA: A SYSTEMATIC REVIEW

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ABSTRACT

The growing demand of human beings for an improved healthy life and increased longevity has led them to explore and utilize nutritious foods with plentiful sources of bioactive compounds and other nutraceuticals. Among these renowned natural resources, seaweeds are considered as one of the most priceless natural resources for macronutrients such as carbohydrates, proteins, and lipids, micronutrients such as vitamins and minerals, and other significant bioactive substances for animal and human health. Seaweeds are eukaryotic organisms typically found and live in salty water. Traditionally, they are consumed as food, fodder, fertilizer and as a source of medicine since ancient times. Macroalgae are marine photosynthetic organisms or marine seaweeds belonging to the domain Eukarya and the kingdoms Plantae. These macroalgae are classified into 3 main classes i.e. red algae (Rhodophytes), brown algae (Phaeophytes), and green algae (Chlorophytes). The red seaweed (Rhodophyta) is one of the major phyla of macroalgae, typically classified as non-vascular plants from the Primoplantae clade and contains approximately 6100 species. *Palmaria palmata* (L.) O. Kuntze is commonly known as dulse or sol. commonly grows on the larger marine plants such as Laminaria spp. or on rocks in the littoral and sub-littoral zones of the north Atlantic seacoasts. It is a well-known red seaweed among the species of (Rhodophyta). This systematic review is designed to provide a deep knowledge and information about famous red seaweed *Palmaria palmata* with special emphasis on its phytochemical characteristics and biomedical uses.

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INTRODUCTION

The concept of using natural resources as medicines is as old as mankind [1]. One of the most precious gift nature has given to human beings are nutritive and medicinal plants [2]. These natural sources are the most valuable nature's reward to mankind so that humans can live a healthy and disease free life [3][4]. Marine plants are natural herbs that habitually grow in or near aqueous environment and are considered as one of the most primitive form of food and medicine used by the human beings [5]. Seaweeds are eukaryotic organisms typically found and live in salty water. Traditionally, they are consumed as food, fodder, fertilizer and as a source of medicine since ancient times [6]. Evidences of seaweeds utilization as medicines have been reported 2500 years ago. In comparison to other natural resources such as plants and animals, seaweeds possess a substantial value in traditional and alternative medicine system because of its amazing health benefits and nutrient rich compositions [7]. These seaweeds are renowned due to their nutrient rich nature as they are an excellent source of both water and fat soluble vitamins including Vitamin B_1, B_2, B_9, B_{12}, Vitamin C and Vitamin-A, D and E, some vital minerals including iodine, iron, calcium, phosphorus, selenium, potassium, magnesium, copper, zinc, floride etc., dietary fibers, polyphenols, proteins and some essential aminoacids [8]. Since last 3 decades, massive research has been done to investigate and determine the therapeutic potential of these seaweeds and till date plentiful active metabolites and compounds have been isolated from these seaweeds with distinct biological and pharmacological activities [9].

All over the world, consumption of marine seaweeds has become a multi-billion dollar business. These marine seaweeds has attracted food, nutraceutical, cosmeceutical and pharmaceutical industries because of their unique characteristics, physico-chemical properties, bio-chemical composition and therapeutic properties. Many industries are utilizing seaweeds due to their suitable physical nature such as gelling, emulsifying property and water retentive nature. Pharmaceutical industries have been massively screening and exploring these seaweeds to discover novel therapeutic agents and establish novel pharmacological uses [9].

Macroalgae are aquatic photosynthetic organisms or marine seaweeds belonging to the domain Eukarya and the kingdoms Plantae. These macroalgae are classified into 3 main classes i.e. red algae (Rhodophytes), brown algae (Phaeophytes), and green algae (Chlorophytes). Figure 1 and 2 illustrates the 3 major classes of macroalgae and examples of their common species. Green macroalgae belongs to phylum Chlorophyta, and their pigmentation is similar to that of vascular plants (chlorophylls a and b and carotenoids), Red macroalgae are included in phylum Rhodophyta; they contain chlorophyll a, phycobilins, and some carotenoids as photosynthetic pigments. Brown macroalgae is included in phylum Ochrophyta, their pigments are chlorophylls a and c and carotenoids (where fucoxanthin predominates and is responsible for their brownish color) [10][11][12][13].

The red seaweed (Rhodophyta) is one of the major phyla of macroalgae, among the groups Phaeophyceae (brown) and Chlorophyta (green) seaweeds [14]. They are classified as non-vascular plants from the Primoplantae clade and contains approximately 6100 species with a wide variety of sizes and shapes. Red seaweeds are photosynthetic, possess chlorophyll a and d, as well as essential pigments including carotenoids and phycobiliproteins (phycoerythrin, phycocyanin, and allophycocyanin) but lack flagella. Red seaweeds have a unique polysaccharide composition and lack starch in chloroplasts, using floridean starch from cytoplasm as reserve [15]. *Palmaria palmata* (L.) O. Kuntze is commonly known as dulse or sol. typically grows on the larger marine plants such as Laminaria spp. or on rocks in the littoral and sub-littoral zones of the north Atlantic seacoasts. It is a well-known red seaweed among the species of (Rhodophyta) [16]. This systematic review is designed to provide a deep knowledge and information of famous red seaweed *Palmaria palmata* with special emphasis on its Phytochemistry and medicinal uses.

Figure 1: Macralgae Major Classes: 1) Green algae, 2) Red algae, 3) Brown algae [10]

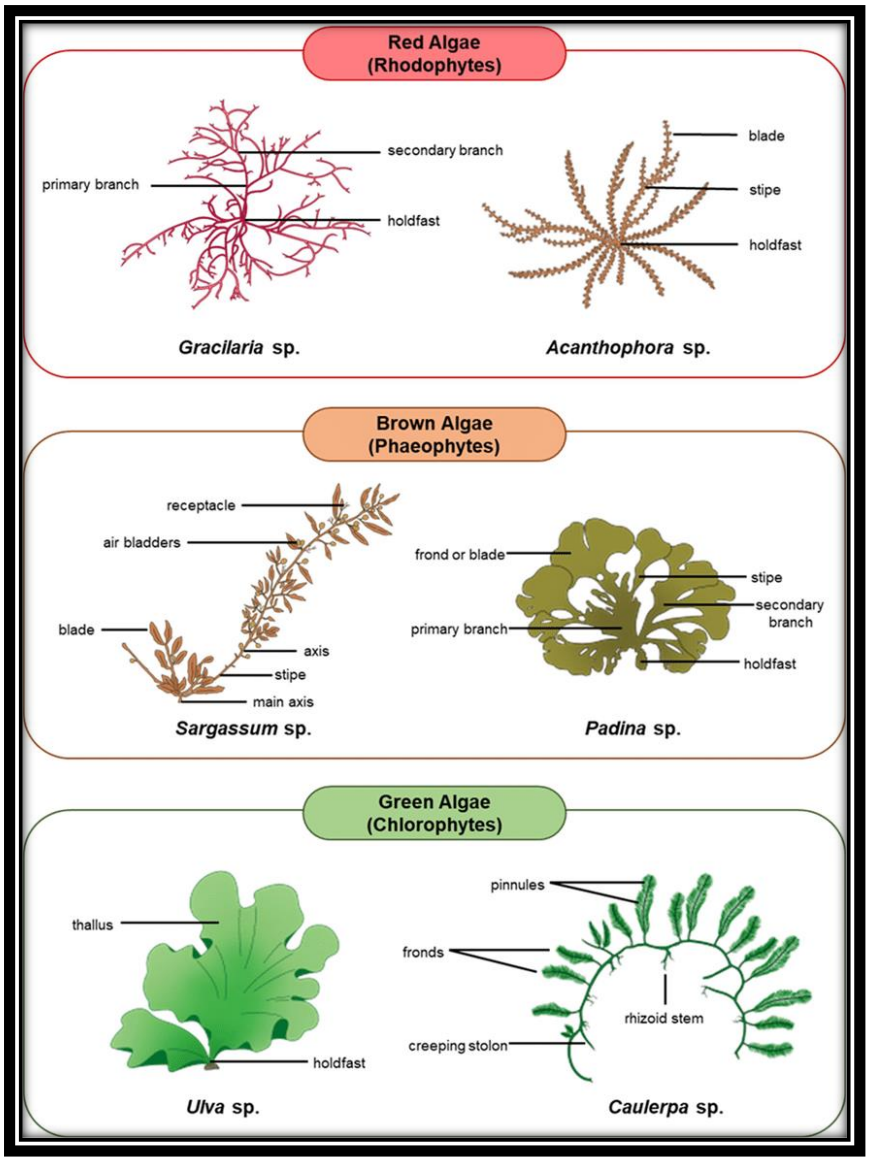

Figure 2: Major Classes of Macroalgae and examples of their species [11]

METHODOLOGY

This systematic review is written after thoroughly reviewing peer-reviewed publications of well-known and authentic online databases including Elsevier, Scopus, Web of Science, Pubmed etc. Records from 2000 to present has been reviewed and considered to constitute this review. English records were extracted using the list of search terms: * Rhodophyta, * Red seaweeds, **Palmaria pulmata*, *Macroalgae etc.

PULMARIA PULMATA

TAXONOMICAL CLASSIFICATION

Taxonomical classification of *P. Pulmata* is described in table 1 [17].

Table 1: Classification of *P. Pulmata*

Kingdom	Plantae
Phylum	Rhodophyta
Subclass	Nemaliophycidae
Order	Palmariales
Family	Palmariaceae
Genus	*Palmaria*
Species	*Palmaria palmate*
Subclass	Nemaliophycidae

MORPHOLOGICAL CHARACTERISITICS

P. Pulmata is a red alga with smooth, leathery branches that are palmate (hand-like) shaped a shown in figure 3. Branches color vary all over the year such as deep red/purple in autumn and winter, greenish-yellow in the summer. The holdfast is typically short and disc shaped. The stipe is small measuring about 1-2 cm in length. Older or damaged alga produce small blades from the edge of the main frond. The size of this red algae depends on the environmental factors, they reach a maximum length of 50 cm but their usual size is between 10 - 20 cm. The bigger seaweeds are more commonly found in semi-wave-exposed areas [17][18][19].

Figure 3: *Pulmaria Pulmata* [17]

DISTRIBUTION AND HABITAT

P. palmata (Linnaeus) typically grows and distributed in the North-East Atlantic i.e. from Norway to Atlantic Spain and Portugal and Azores) and in the North-West Atlantic. It is commonly found in mildly to moderately exposed shores and in regions exposed to tidal currents instead of waves. *P. palmata* is typically found and distributed in the cold waters of the North Atlantic and Arctic Oceans but despite its high affinities for cold water, *P. palmata* also occurs in warm temperate waters far south as New Jersey in the western Atlantic Ocean. The seaweeds can be found growing directly on rocks/boulders or on other seaweeds such as wrack (Fucus species) and kelps (Laminaria hyperborea). *P. palmata* is a perennial species with new growth of fronds every year [20][21][22].

TRADITIONAL USES

The red seaweed *Palmaria palmata* also known as dulse seaweed is highly delectable for human consumption with a great and fairly unexplored potential for its use in the cuisine both in home cooking as well as in gastronomy. It is used as a whole as a salad or as an ingredient in making

different recipes. It is used as a condiment with milk, butter and bread in some regions of Ireland. It is also added as an ingredient in making stew and soup recipes and is also eaten in raw form between two pieces of buttered bread. In Norway, it is added in animal food to feed cows and horses. In Iceland, dried and salted dulse is used as a snack. In some recipes it is also cooked and served with potatoes and turnips. Fried dulse is an acceptable and agreeable alternate of bacon in many cuisines. In some regions, it is also used for garnishing purpose [23][24].

NUTRITONAL IMPORTANCE

Dulse seaweed *Palmaria palmata* is considered as one of the most nutritious seaweed among marine sources. Its high protein content and amino acid composition makes it a very unique seaweed. Fronds are the richest source of proteins possessing as much protein as 30%. It is good source of both essential and non-essential amino acids. Raw dulse seaweed is salty in taste but has low sodium content. Dulse is rich in calcium, potassium, iron, Vitamin A (as carotene), Vitamin C, iodine, and trace elements. Its significant levels of calcium and potassium help strengthen your bones and make them more resilient. A little quantity of *P. Pulmata* can provide as much as 100% of the RDA (Recommended Daily Allowance) of Pyridoxine (Vitamin B6) and 66% of the RDA of iron, Cobolamin (Vitamin B12) and fluoride. Among essential amino acids, Dulse seaweed is a good source of cysteine, isoleucine, leucine, lysine, methionine, phenyl alanine, tyrosine, threonine and valine whereas among non-essential amino acids, it is a source of alanine, arginine, aspartic acid, glutamic acid, glycine, histidine, proline, serine etc. It is also a good source of ω-3 fatty acids (especially EPA and DHA) and five essential minerals including iodine, iron, copper, zinc, and selenium [25][26][27][28].

PHYTOCHEMISTRY

P. Pulmata is a rich source of bioactive compounds including carotenoids, polyphenols, β-carotene and α-tocopherol. It contains sulfated polysaccharides (SPS) responsible for variety of biological applications in nutraceutical, pharmaceutical and cosmeceutical industries. As discussed earlier, it contains proteins and both essential and non-essential amino acids with numerous health benefits. It is also a moderate source of fatty acids, glycolipids, phytosterols, phospholipids and fat-soluble vitamins. It also contains chlorophylls a, c, or d, and phycobilins. Phenolic acids, tannins, flavonoids, and catechins are some of the phenolic compounds found in Dulse seaweeds with sligjt variantions in the content with respect to its area. Polyphenols isolated from seaweeds are responsible for variety of biological activities including antimicrobial, anticancer, antiviral, anti-obesity, antitumor, antiproliferative, antidiabetic, anti-inflammatory, or antioxidant effects It is also a rich source of water and fat soluble vitamins including vitamin B6, Vitamin B12, Vitamin C, Vitamin A, E and K respectively. It is also a rich source of iron and manganese. It also contains Floridean starch and pentoses [29][30][31][32].

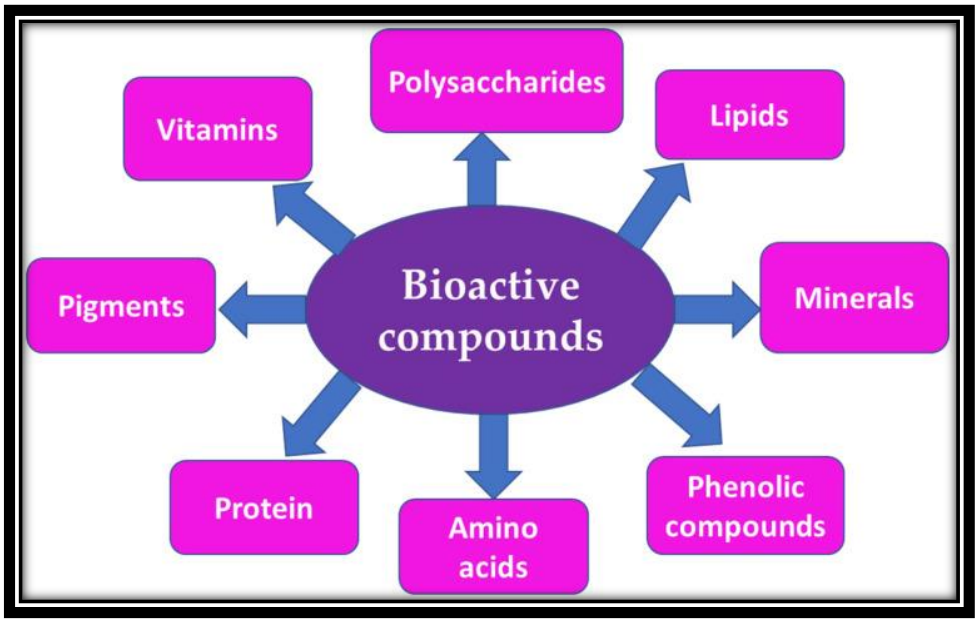

Figure 4: Bioactive components in *Pulmaria Pulmata* [31]

MEDICINAL/THERAPEUTIC USES

Dulse seaweed is considered as a renowned edible seaweed with numerous health promoting and therapeutic benefits due to its unique chemical composition and presence of plentiful bioactive compounds. It showed potent anti-oxidant activity both in-vivo and in-vitro. In-vitro studies has confirmed its anti-hypertensive and anti-diabetic effects. Anti-hypertensive activity was found to be due to renin and ACE inhibitory actions whereas antidiabetic activity was due to DPP IV inhibitory action. Clinical studies have reported anti-triglyceridemic effects in humans. Recent study has established a new role of *Pulmaria Pulmata* in regulation of pathogenesis of health disorders in which neutrophils play an active role such as atherosclerosis. Dulse seaweed also exhibits anti-inflammatory activity most probably due to its content i.e. phycobiliprotein and chlorophyll *a*. Recently its beneficial effects in multiple sclerosis has been established which might be due to its propensity to promote microbiota alterations, its antioxidant activity, and its content of −3 fatty acids [33][34][35][36][37][38].

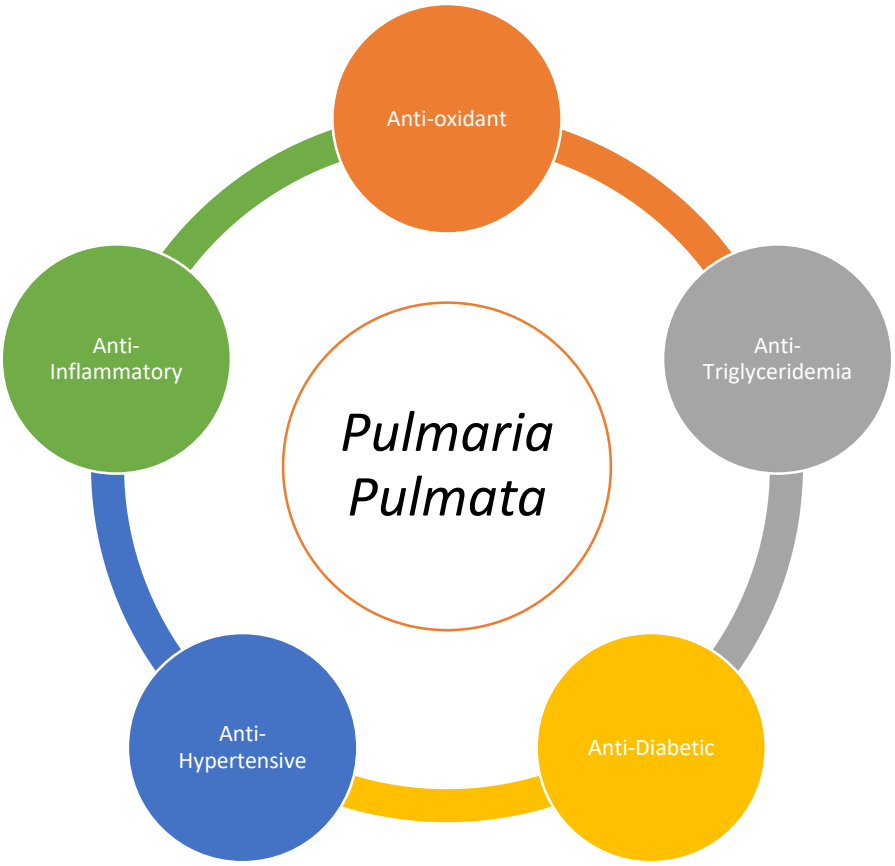

Figure 5: Biomedical uses of *Pulmaria Pulmata*

CONCLUSION

Seaweeds are currently very frequently and extensively explored and screened as novel and sustainable sources of bioactive compounds. Due to their nutritional rich contents and presence of valuable bioactive compounds they exhibit significant biological and pharmacological activities. This review has discussed nutritional value, phytochemical characteristics and biomedical applications of renowned red seaweed *Pulmaria pulmata*. As per the discussed details, this seaweed is famous because of its unique chemical composition and bioactive compounds. This marine seaweed should be critically screened and explored in future to determine its true efficacy in human beings in different pathological

conditions and to discover novel medicinal activities, bioactive compounds and drugs from it.

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