ANTIMICROBIAL EFFECT OF SEAWEEDS AGAINST ORAL-BORNE PATHOGENS: A REVIEW

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ABSTRACT

Dental caries is known as the most common and preventable dental disease. This multifactorial disease has been found to be a major concern worldwide. This dental caries has been proved to be caused by the presence of oral pathogen. Seaweeds show many health-promoting effects, including antimicrobial, anti-inflammatory, anti-oxidative and anti-cancer properties. The versatility of the seaweed has attracted many researchers to use seaweed extracts as alternative treatment against multiple diseases. However, little attention has been paid to the application of antimicrobial properties of seaweed against oral pathogenic microorganisms. The substances isolated from red, brown and green seaweeds showing potent antimicrobial activity are polysaccharides, phlorotannins, pigments, fatty acids, lectins, terpenoids, alkaloids and halogenated compounds. Current research is shifting into fully grasping the antimicrobial potential of seaweeds against oral microbes that cause dental caries or periodontal disease. Hence, this mini-review will highlight the antimicrobial properties of three types of seaweed species (red, brown, and green) against selected oral pathogenic microorganisms.

Keywords: antibacterial; anticariogenic; antimicrobial; seaweed

INTRODUCTION

Seaweeds or macro-algae are multicellular plants that grow in salt or fresh water. They are considered as lower plants and composed of a thallus, sometimes a stem and a foot (holdfast), which generally can be categorised into three main groups; red (Rhodophyceae), brown (Phaeophyceae), and green seaweeds (Chlorophyceae) (Mohamed et al. 2012). Red seaweed is the most common group with about 6000 species, followed by brown seaweed with 2000 species and green seaweed with 1200 species (Venugopal, 2011).

Today, seaweeds are not only restricted as a food source for the coastal population but their usage has been extended in health products and cosmetic, especially after having proven to contain bioactive compounds that possess an antibacterial, antifungal, anticancer and antiinflammation properties (Abdel-Raouf et al., 2008; Kuda et al., 2007; Soltani et al., 2012).

Researchers have started to divert their attention to discover the potential of seaweeds against oral pathogens that cause dental caries or periodontal diseases. Seaweed has interest as an adjunct material in the prevention of oral disease as it has been proven to possess antimicrobial properties.

BIOACTIVE COMPOUNDS IN SEAWEED

Seaweeds are rich in lipids, proteins, minerals, dietary fibers, fatty acids, essential amino acids, omega-3, vitamins A, B, C, and E, and polysaccharides (Cerna, 2011; MacArtain et al., 2007; Misurcova et al., 2012). In addition, seaweeds also contain abundant biologically active phytochemicals that play important roles in health-promoting effects such as polyunsaturated fatty acids, terpenoids, xanthophylls, carotenoids, phycobilins, chlorophylls, polysaccharides, vitamins, sterols, tocopherol, and phycocyanins (De Almeida et al., 2011). For example, fucoxanthin, a type of xanthophyll that acts as an accessory pigment in the chloroplasts of brown seaweed, has been reported to contain numerous health benefit properties including anti-microbial and anti-cancer (Kim & Pangestuti, 2011). This marine plant also contains high amounts of polyphenols which exhibit high potential as natural antioxidants. The polyphenols in the seaweeds have been proven as free radical scavengers and antimicrobial agents and are now being used in the treatment of major degenerative and deficiency diseases (Gulcin et al., 2002).

ANTIMICROBIAL ACTIVITIES OF SEAWEED

Antimicrobial properties shown by seaweed have attracted researchers to study the potential of seaweed as an alternative agent in treating oral diseases such as dental caries and periodontal disease. The substances isolated from red, brown and green seaweeds such as fatty acids, phlorotannins, polysaccharides, alkaloids, pigments, lectins, terpenoids and halogenated compounds have been proven to exert potent antimicrobial activity (Perez et al., 2016). Several antimicrobial susceptibility test (AST) have been carried out in order to investigate the potentiality of antimicrobial properties of seaweeds, such as disc diffusion method (zone of inhibition of bacteria), minimum inhibitory concentration (MIC), minimum bactericidal concentration (MBC), synergistic effect of the extract against multiple antibiotics and many more. In this review paper, two types of antimicrobial properties: anti-bacterial and anti-cariogenic properties against oral pathogenic microbes in three types of seaweeds will be further discussed in the next sections. Focus will be paid mainly towards on disc diffusion, MIC, and MBC methods.

Antibacterial Activities of Seaweed Extracts

Various bacteria have been proven to be responsible for many oral infections such as *Pseudomonas aeruginosa, Staphylococcus aureus, Acinetobacter baumannii,* and *Enterococcus faecalis*. The extract of seaweed holds great potential to be used in preventive measures against oral bacterial infection (Je-Hyuk, 2014; Kim et al., 2013; Ravikumar et al., 2002; Sabirin et al., 2015; Salem et al., 2011). Although seaweeds have potent antimicrobial properties, their characteristics differ from one species to another. Several studies report variations in the anti-microbial activities between different groups of seaweeds. This variation might be due to different methods of extraction, solvents used in extraction and different season at which samples were collected (Kandhasamy & Arunaschalam, 2008).

i) Green Seaweed

Studies done by Nagappan and Vairappan (2014) on the antibacterial properties of green seaweeds show that, MIC values of the extracts of Caulerpa species such as *Caulerpa lentillifera* and *C. racemosa* against *S. aureus* were in the range of 125.25 mg/mL^{-1} to 375.75 mg/mL^{-1} . *C. cuppressoides* also recorded high inhibitory activities against *S. aureus* and *P. aeruginosa* which are 6 mm and 8 mm inhibition zones respectively (Ravikumar et al., 2002). These Caulerpa species showed high inhibitory effect against *S. aureus* and *P. aeruginosa*. Apart from that, *Cladophora rupestris* also showed strong antibacterial effect with 16.3 mm and 15.3 mm zone of inhibition against *S. aureus* and *P. aeruginosa* respectively when tested using 1000 ug/mL of *C. rupestris* (Krish & Das, 2014). Additionally, other *Codium* species like *Codium amplivesiculatum, C. cuneatum* and *C. simulans* exhibited high anti-bacterial activity against *S. aureus* which recorded 8.0 ± 0.0 mm, 10 ± 0.0 mm, and 9.5 ± 0.7 mm zones of inhibition respectively.

ii) Red Seaweed

Among red seaweeds, acetone extract of *Laurencia cruciata* recorded strong inhibitory activity with 10 mm clear zone against *P. aeruginosa.* Several red seaweeds have also showed strong antibacterial activities against *S. aureus*, exhibiting clear zones of inhibition including methanolic extract of *Champia parvula* (16.67 ± 0.57 mm), *Alsidium corallinum* (16.67 ± 0.57 mm), *Ceramium rubrum* (25.33 ± 0.57 mm), *Chondrocanthus acicularis* (16.33 ± 0.57 mm), *C. canaliculatus* (9.5 ± 0.7 mm), *Ganonema farinosum* (12.5 ± 2.1 mm), *Gracilaria subsecundata* (13.5 ± 0.7 mm), *Gelidium robustum* (11.0 ± 1.4 mm), *Hypnea valentiae* (8.0 ± 0.0 mm), *Laurencia jonhstonii* (30.0 ± 0.0 mm), *L. pacifica* (21.0 ± 0.00 mm), and *Neorhodomela larix* (12.0 ± 1.4 mm) respectively (Bouhlal et al., 2010; Muñoz-Ochoa et al., 2010; Ravikumar et al., 2002). All these studies show that, many red types of seaweed have the potential to become strong antibacterial agents against bacteria like *S. aureus.*

iii) Brown Seaweed

Crude extracts and isolated compounds of some brown seaweed species are reported to have anti-bacterial properties. Previous studies have reported that the ethanolic extract of *Laminaria japonica* has antimicrobial activity against oral bacterial, as it showed promising minimum inhibitory concentration (MIC) of 250 and 62.5 µg/mL against *Actinomyces naeslundii* and *A. odontolyticus*, respectively, and 250 and 62.5µg/mL against *Fusobacterium nucleatum* and *Porphyromonas gingivalis*, respectively. The minimum bactericidal concentration (MBC) of *A. naeslundii* and *A. odontolyticus* recorded are 500 and 250 µg/mL, respectively. A dose-dependent effect and a change in the cell surface texture of *A. odontolyticus*, and *P. gingivalis* was observed (Kim et al., 2013). The lower the value of MIC and MBC of seaweed extract against the bacteria, the stronger the antibacterial properties of the antibacterial agent. Moreover, *Padina tetrastromatica* and *P. boergesenii* also showed strong inhibitory activity against *S. aureus* with 8 mm and 7 mm zones of inhibition respectively, and 10 mm and 7 mm zones of inhibition against *P. aeruginosa* respectively (Ravikumar et al., 2002). Ethyl acetate extracts of *Sargassum dentifolium* and *P. gymnospora* recorded zones of inhibition of 14.3 and 17.8 mm respectively against *S. aureus* (Salem et al., 2011).

Anti-Cariogenic Activities of Seaweed Extract

The oral cavity provides conditions that are ideal for the growth of bacteria that metabolize sugar to acids. Generally, at body temperature of 37◦C, oral cavities promote oral bacterial growth. The oral cavity contains a wide variety of bacteria, but not all oral bacterial species are cariogenic. Oral bacteria that causes caries are known as cariogenic bacteria. Caries may not necessarily be caused by oral pathogenic bacteria but the presence of cariogenic bacteria does play a major role in the development of caries (Cox et al., 2010). Only a few species of microorganisms have been implicated in the caries process namely *Streptococcus mutans*, *S. sobrinus, S.pyogenes, Lactobacillus spp.*, and *Actinomyces spp*. Anti-cariogenic activities of the three major groups of seaweeds are discussed below.

i) Green Seaweed

Methanolic extract of *C. lentillifera* and *Kappaphycus alvarezii* showed antibacterial activity of 16.3 ± 1.0 mm and 14.3 ± 0.5 mm respectively against *S. mutans* (Sabirin et al., 2015). Besides that, other species of green seaweeds such as *C. cupressoides* and *Chaetomorpha linoides* butanolic extracts recorded maximum inhibitory activity with 8 mm zone of inhibition against *S. pyogene* (Ravikumar et al., 2002). Additionally, other *Codium* species, *C. amplivesiculatum, C. cuneatum* and *C. simulans* exhibited high anti-bacterial activity against *S. pyogenes* as they recorded 13.0 ± 0.0 mm, 14.5 ± 0.7 mm, and 11.5 ± 0.7 mm zones of inhibition respectively (Bouhlal et al., 2010).

ii) Red Seaweed

Among the red seaweeds, *Grateloupia lanceolate* and *Gelidium amansii* both showed 4.0 ± 1.4 mm zones of inhibition against *S. sobrinus* (Je-Hyuk, 2014). Additionally, several red seaweeds showed strong inhibition against the growth of *S. pyogenes* like *Hypnea musciformis* (8 mm clear zone of inhibition), *C. canaliculatus* (10.0 ± 1.4 mm), *G. farinosum* (17.0 ± 2.1 mm), *G. subsecundata* (14.0 ± 0.0 mm), *G. robustum* (22.5 ± 0.7 mm), *H. valentiae* (12.5 ± 0.7 mm), *L. jonhstonii* (38.0 ± 0.7 mm), *L. pacifica* (31.5 ± 2.1 mm), and *N. larix* (11.0 ± 0.0 mm) respectively (Bouhlal et al., 2010; Ravikumar et al., 2002).

iii) Brown Seaweed

Brown seaweed, *S. micracanthum* shows strong anticariogenic activity against several cariogenic bacteria such as *S. mutans*, recording 6.0 ± 1.4 mm zones of inhibition, whereas 7.0 ± 1.4 mm zones of inhibition was exhibited against both *S. pyogenes* and *S. sobrinus*. *Dictyopteris undulata* also reported strong anti-cariogenic activity against *S. mutans, S. sobrinus* and *S. pyogenes* with 5.5 ± 0.7 mm, 6.0 ± 1.4 mm, and 6.0 ± 1.4 mm clear zones of inhibition respectively. *P. arborescens* on the other hand showed inhibitory activities against *S. mutans* and *S. sobrinus* of 4.0 ± 2.8 mm, and 3.5 ± 0.7 mm clear zones of inhibition respectively. *S. muticum* recorded 4.0 ± 0.0 mm clear zone against *S. mutans*. Lastly, *Ishige okamurae* proved to have strong inhibitory activity against both cariogenic bacteria *S. mutans* and *S. pyogenes*, recording 4.5 ± 0.7 mm clear zones against *S. mutans* and 4.0 ± 1.4 mm clear zones against *S. pyogenes* (Je-Hyuk, 2014).

FACTORS AFFECTING ANTIMICROBIAL PROPERTIES OF SEAWEEDS

There are several factors that play major roles in determining the chemical composition of the seaweeds and their antimicrobial activities. The factors are species, physiological status, environmental aspects (location, climate, temperature, and salinity), growth conditions, pollution, collection time, the region of the thallus, and epiphytic organisms (Freile-Pelegrín & Morales, 2004; Trigui et al., 2013). Each seaweed species is differed from one another, as they all have their own unique characteristics. A lot of researches have proven that the antimicrobial action of seaweeds depends on variations in chemical compositions in seaweed according to season. This was supported by another research which claims maximal antimicrobial potential occurs mostly in spring. This is possibly due to the predominance of some active compounds in this season (García-Bueno et al., 2014).

Varied antibacterial activity, antioxidant activity and phenolic composition was observed during spring and summer season. Highest inhibitory activity, phenolic content and antioxidant activity was recorded in late winter (Trigui et al., 2013). As opposed to this finding, study done by Krish and Das (2014), found less inhibitory activity during some seasons, and this was supported by other studies which found no clear seasonal variation of antifungal and antibacterial activities (Dubber & Harder, 2008). For example, green seaweeds were active throughout the year, whereas brown seaweeds showed an absence of activity in particular seasons, and red seaweeds on the other hand showed variations along seasons. This was supported by other research which stated that, the effect of the latitude and environmental factors does give a variation reading on the phlorethol and phenolic content type in brown seaweed like *S. muticum* collected in different European coasts (Padmakumar & Ayyakkannu, 1997).

CONCLUSIONS

Seaweeds have numerous bioactive components that are responsible for their antimicrobial properties. The antimicrobial activity of seaweed depends on the chemical composition of the seaweed, its species, physiological status, environmental condition (location, climate, temperature, and salinity), growth conditions, pollution, collection time, region of the thallus, and epiphytic organisms. The vast antimicrobial properties of seaweeds have great potential as antimicrobial agents against oral pathogenic microorganisms. These bioactive compounds are proven to exhibit antibacterial and anti-cariogenic properties. The use of seaweeds can be broadened to the dental field, such as application of seaweed as mouthwash or toothpaste in order to prevent dental caries and periodontal disease.

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