

REVIEWS

THERAPEUTIC POTENTIAL OF *SPIRULINA PLATENSIS* AND *CHLORELLA VULGARIS* IN DENTAL MEDICINE: BIOACTIVE COMPOSITION, ANTIOXIDANT, ANTI-INFLAMMATORY AND ANTIMICROBIAL PROPERTIES

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ABSTRACT

Spirulina (*Arthrospira platensis*) and chlorella (*Chlorella vulgaris*) are microalgae with significant bioactive potential, showing promising therapeutic effects in dental medicine. These microalgae are rich in bioactive compounds, including pigments, polysaccharides, and protein complexes, which actively participate in modulating inflammatory processes, enhancing antioxidant defences, and maintaining the microbial balance in the oral cavity. Spirulina extracts exhibit potent antibacterial properties that inhibit the adhesion and biofilm formation of key cariogenic and periodontal pathogenic bacteria, thereby potentially reducing the incidence of dental caries and periodontal diseases. The high content of phycocyanins in spirulina (*Arthrospira platensis*) further contributes to the suppression of pro-inflammatory mediators, mitigating tissue destruction in chronic gingivitis and periodontitis. Additionally, the light-absorbing pigments of spirulina enable its application as a photosensitizer in photodynamic therapy, offering a novel approach to the disinfection of periodontal pockets and endodontic treatment. Spirulina-based formulations, such as toothpastes and mouthwashes, support oral health by stabilizing the local microbiome and reducing inflammation. In contrast, chlorella (*Chlorella vulgaris*) compounds have shown the ability to inhibit the growth of pathogenic yeasts and opportunistic bacteria, particularly in conditions such as oral candidiasis and denture stomatitis. The polysaccharides of chlorella (*Chlorella vulgaris*) promote mucosal healing, accelerating the repair of oral tissue after surgical interventions and improving epithelialization of ulcerative lesions. Chlorella's ability to bind heavy metals, especially mercury, is useful in mitigating the risks associated with dental amalgam exposure. By activating local immune responses and reducing oxidative damage, chlorella (*Chlorella vulgaris*) contributes to the maintenance of periodontal health. These findings support the potential of spirulina (*Arthrospira platensis*) and chlorella (*Chlorella vulgaris*) as effective adjuncts in the management of oral diseases, highlighting their therapeutic relevance in modern dental care.

Keywords: spirulina (*Arthrospira platensis*), chlorella (*Chlorella vulgaris*), dental medicine

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INTRODUCTION

The microalgae spirulina (*Arthrospira platensis*) and chlorella (*Chlorella vulgaris*) represent natural sources of biologically active molecules with proven therapeutic potential in dental medicine. Their rich chemical profile includes pigments, polysaccharides, polyphenols, and protein complexes that regulate inflammatory processes, provide antioxidant protection, and modulate the local microbiome (1–8).

Spirulina extracts have been shown to inhibit the adhesion and biofilm formation of key cariogenic and periodontopathogenic microorganisms, thereby reducing the risk of dental caries and periodontitis. The phycocyanins contained in spirulina suppress the secretion of pro-inflammatory mediators and limit tissue destruction associated with chronic gingivitis and periodontitis (9). Moreover, spirulina pigments exhibit strong light-absorbing properties, enabling their application as natural photosensitizers in photodynamic protocols for the disinfection of periodontal pockets and endodontic canals. The incorporation of spirulina extracts into toothpastes and oral rinses supports microbial balance and reduces the frequency of inflammatory episodes (8).

Bioactive compounds present in chlorella (*Chlorella vulgaris*) inhibit the growth of pathogenic yeasts (*Candida* spp.) and opportunistic bacteria, which is particularly relevant for the control of oral candidiasis and denture stomatitis. The biostimulating effects of chlorella polysaccharides promote oral mucosal repair following surgical interventions and accelerate epithelialization in ulcerative lesions. Chlorella's ability to bind heavy metals is especially valuable in dental practice, where chronic exposure to dental amalgams may result in mercury accumulation. It activates local defense mechanisms and limits oxidative damage, thereby contributing to periodontal health.

AIM

The aim of the present review is to evaluate the therapeutic potential of the microalgae spirulina (*Arthrospira platensis*) and chlorella (*Chlorella vulgaris*) in controlling oral biofilms, modulating inflammatory processes, and supporting tissue regeneration in dental medicine, while emphasizing their safety and tolerability.

MATERIALS AND METHODS

This review is based on a thorough analysis of scientific literature focused on the application of the microalgae spirulina (*Arthrospira platensis*) and chlorella (*Chlorella vulgaris*) in dentistry and oral health products. Leading scientific databases were used, including PubMed, Scopus, Science Direct, Web of Science, and Google Scholar. The search was structured using combinations of key terms, includ-

ing: *Arthrospira platensis*, *Chlorella vulgaris*, dental medicine, bioactive molecules, antimicrobial activity, and anti-inflammatory effect. The selected publications primarily cover the past 15 years. However, five earlier studies were also included due to their significant scientific merit and continued relevance to the topic.

The selected publications were critically evaluated in terms of quality, relevance, and scientific rigor. The data were organized into thematic categories, enabling the development of an integrated review encompassing both traditional and contemporary applications of these microalgae in oral health maintenance and dental therapy.

RESULTS AND DISCUSSION

A growing body of evidence highlights the expanding application of spirulina (*Arthrospira platensis*) and chlorella (*Chlorella vulgaris*) in medical practice, particularly in the domain of oral health. Their rich composition of biologically active molecules provides opportunities for their inclusion in various products intended for both prevention and for therapeutic support in a number of oral diseases and conditions.

Application of Algae in Dentistry

According to literature data, spirulina (*Arthrospira platensis*) and chlorella (*Chlorella vulgaris*) are widely used in medicine, especially in oral health. Their rich composition of biologically active molecules offers opportunities for inclusion in a range of products intended for both prevention and therapeutic support in a number of oral diseases and conditions.

Microalgae, with a particular focus on *Arthrospira platensis* and *Chlorella vulgaris*, represent a source of structurally diverse and biologically active metabolites, among which pigment molecules (such as phycocyanins and chlorophylls), water-soluble polysaccharides, phenolic compounds, and highly bioavailable proteins stand out. Accumulated biomedical evidence indicates that these components exhibit a broad range of pharmacological activities, such as antimicrobial effects against oral pathogens, modulation of inflammatory cascades, inhibition of oxidative stress, and stimulation of tissue regeneration.

Empirical data demonstrate that microalgal extracts can inhibit primary microbial adhesion and subsequent biofilm formation by key etiological agents of dental caries and periodontitis, including *Streptococcus mutans* and *Porphyromonas gingivalis*. Bioactive fractions also regulate the expression of pro-inflammatory mediators within the oral mucosa and accelerate proliferation and re-epithelialization processes during post-traumatic and postoperative healing. The phycocyanins characteristic of *A. platensis* exhibit photosensitizing properties and can be integrated into photodynamic disinfection protocols in periodontal and endodontic treatments. In parallel, polysaccharide complexes derived from *C. vulgaris* demonstrate epitheliotropic activity and metal-chelating capacity, potentially reducing the toxic effects of locally accumulated heavy metals.

The formulation of oral care products incorporating microalgal extracts such as toothpastes, oral gels, and antiseptic solutions opens new possibilities for integrating natural agents into routine dental care. These formulations may support oral microbiome homeostasis and enhance preventive and therapeutic strategies against a broad spectrum of oral pathologies. Existing literature data on the mechanistic basis of their biological activity outlines directions for future translational and clinical studies to validate their safety and efficacy for applications in oral medicine.

Chemical Composition and Therapeutic Properties of *Arthrospira platensis*

Arthrospira platensis (spirulina) is a photosynthetic cyanobacterium characterized by an exceptionally complex biochemical composition, making it a valuable resource for applications in food technology, pharmaceuticals, nutraceuticals, and feed production (11). Its biomass contains substantial amounts of proteins, lipids, polysaccharides, vitamins, minerals, and chlorophyll and phycobilin pigments, which collectively underlie its wide range of biological effects (11).

Protein Components and Amino Acid Composition

Proteins represent the predominant macromolecular fraction in *A. platensis*, accounting for approximately 50–70% of its dry mass (12,13). Spirulina is characterized by the presence of all essential ami-

no acids, classifying it as a complete protein source comparable in nutritional value to high-quality animal proteins found in meat and eggs (11).

Analyses indicate that essential amino acids constitute approximately 38.81% of the total amino acid profile, with leucine (7.67%), valine (6.37%), threonine (4.88%), phenylalanine (4.42%), lysine (4.37%), methionine (2.39%), and tryptophan (1.93%) being predominant (14,15). The remaining 61.19% consist of non-essential amino acids, including arginine (7.65%), alanine (7.52%), glycine (5.24%), and serine (4.16%) (15,16), which further enhance the biological value and metabolic utility of the protein matrix of *A. platensis*. The results shown in Fig. 1.

This exceptional amino acid profile makes spirulina an attractive candidate for use as a plant-based alternative to animal proteins, particularly in diets oriented toward vegetarian and vegan nutrition (14). However, the bioavailability of these proteins is limited by the resilient cell wall, composed primarily of peptidoglycan structures (17), which impede effective digestion and the release of nutrients within the gastrointestinal tract (17–19).

Some of the spirulina proteins are located in the thylakoid membranes, where they are bound in stable protein-pigment complexes containing phycocyanin and other phycobiliproteins. This structural arrangement limits their direct extraction without pretreatment (20).

Various mechanical and physicochemical processing methods, such as bead milling, lyophilization, thermal processing, microwave irradiation, ultrasonic disintegration, and extrusion, have been applied to enhance the solubility, degradability, and bio-

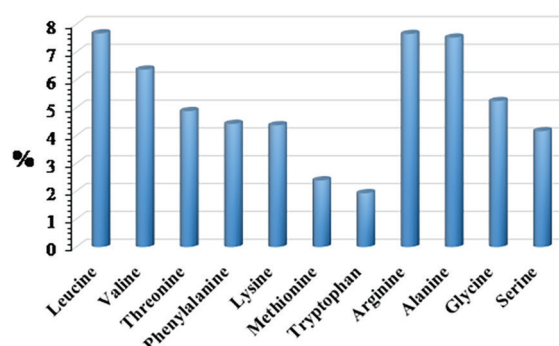


Fig. 1. Percentage content of some amino acids in Spirulina (*Arthrospira platensis*).

availability of protein compounds (18,19). The extrusion method has been shown to be particularly effective in disrupting the cell wall and increasing the bio-availability of bound proteins, even in the absence of enzyme supplementation (18,19). Among these, extrusion has proven particularly effective in disrupting the cell wall and facilitating enzymatic digestion, even in the absence of exogenous enzymes (18–23).

By inducing denaturation and aggregation of structurally significant proteins, including phycocyanin, extrusion facilitates enzymatic attack during the digestive process and ensures a greater degree of nutrient release. This approach enables the incorporation of spirulina into food products with higher protein content without compromising their digestibility or nutritional profile (20–23).

Lipids

The lipid fraction in *Arthrospira platensis* constitutes approximately 5–10% of the alga’s dry biomass and plays an important role in spirulina’s biochemical profile (16). The majority of these lipids consist of polyunsaturated fatty acids (PUFAs), such as γ -linolenic acid (GLA, 18:3n-6), which is a principal omega-6 fatty component known for its anti-inflammatory properties (24). Other significant fatty acids include linoleic acid (18:2n-6), oleic acid (18:1c9), and palmitic acid (16:0), which are key constituents of spirulina’s lipid structure (11, 12). The GLA content varies depending on cultivation conditions and typically ranges between 1% and 2% of the total dry weight. Although *Arthrospira platensis* also contains omega-3 fatty acids, such as α -linolenic acid

(ALA; 18:3n-3), their concentrations are considerably lower than those of GLA and other PUFAs (11).

Carbohydrates

Carbohydrates constitute approximately 15–20% of the dry weight of *Arthrospira platensis*, with the majority present in polysaccharides that perform both structural and energy-related functions within the cell (25,26). Spirulina contains sulfated polysaccharides, such as calcium spirulan (Ca-SP), which exhibit various bioactive properties, including antiviral, anti-inflammatory, and immunomodulatory activities (27–29). The principal monosaccharides constituting spirulina polysaccharides include glucose, rhamnose, xylose, mannose, and galactose, which are assembled into complex molecular structures that reinforce the cell wall and modulate the overall bioactivity of the alga (28). In addition, spirulina contains low-molecular-weight carbohydrates, such as glycogen, which function as intracellular energy reserves (30).

Pigments

Spirulina is well known for its rich pigment composition, which confers its characteristic blue-green coloration and plays a fundamental role in photosynthetic processes. The principal pigment in *A. platensis* is phycocyanin, a blue pigment–protein complex that may account for up to 47% of the dry weight and is recognized for its pronounced antioxidant properties (25,31,32). Chlorophyll is essential for photosynthesis and enables *Arthrospira platensis* to adapt to a wide range of aquatic environments (31). In addition, carotenoids present in spirulina not only support photosynthetic activity but also act as potent

Table 1. Carbohydrate content in *Arthrospira platensis*.

Carbohydrate Type	% dry weight	Characteristics	Benefits
Total carbohydrate content	15–20	Contains a small amount of carbohydrates, which provide energy	Supports normal metabolism, provides energy
Polysaccharides (e.g., fucoidan)	-	Complex carbohydrates that make up the cell wall	Immunostimulating, antioxidant, anti-inflammatory properties
Glucose and fructo-oligosaccharides	-	Easily digestible carbohydrates that provide quick energy	Quickly provide energy, easily absorbed
Fibers	Low content	A small amount of fiber, beneficial for digestion	Maintain intestinal health and regulate digestion

antioxidants, neutralizing free radicals and enhancing the overall health-promoting potential of the alga (32).

Vitamins and Minerals

Arthrospira platensis represents an exceptional source of essential vitamins and minerals. It contains high levels of B-group vitamins, including thiamine (B1), riboflavin (B2), niacin (B3), and folate (B9), which are critical for energy metabolism and cellular function (30,33). Vitamin B12 is also present, although its bioavailability and physiological activity in spirulina remain subjects of ongoing research and discussion (33,34). Among fat-soluble vitamins, spirulina is a particularly rich source of vitamin E (α -tocopherol) and vitamin A in the form of β -carotene, which can be converted in the human body into biologically active retinol.

With regard to mineral composition, spirulina is especially rich in iron, with reported concentrations ranging from 28 to 50 mg per 100 g of dry weight, making it a potentially effective supplement for individuals with iron-deficiency anemia (34,35). In addition, spirulina contains substantial amounts of calcium, magnesium, zinc, and potassium, which play essential roles in maintaining cellular homeostasis and regulating metabolic processes (34). The high bioavailability of these minerals further enhances the nutritional and functional value of spirulina in dietary supplements and functional food products.

Secondary Metabolite

Arthrospira platensis contains a range of secondary metabolites that contribute to its pronounced bioactivity. Among them, polyphenols, sterols, and phenolic acids stand out for their antioxidant, anti-inflammatory, and antimicrobial properties (36). Polyphenols in spirulina include ferulic acid and caffeic acid, which play a role in reducing oxidative stress and protecting cells from free radical damage (36–39). Phenolic acids are typical examples of bioactive compounds found in plant-based products and have significant therapeutic applications (16,40).

The phenolic compounds in spirulina contribute to its anticancer, antimicrobial, and anti-inflammatory effects, for example, through the use of methanolic extracts effective against pathogenic bacteria and fungi. These secondary metabolites enhance spi-

rulina's pharmaceutical potential, adding further value to its applications in medicine and nutraceuticals.

Chemical Composition and Therapeutic Properties of *Chlorella vulgaris*

Chlorella vulgaris is a unicellular microalga characterized by its high nutritional value and diverse range of bioactive compounds. *Chlorella* biomass is extensively utilized in dietary supplements and therapeutic formulations owing to its rich and well-balanced chemical composition. These constituents, including proteins, lipids, carbohydrates, pigments, vitamins, minerals, and secondary metabolites, confer significant therapeutic potential to *Chlorella-vulgaris*. Its biological effects are primarily associated with antioxidant activity, detoxifying capacity, immunostimulatory properties, and beneficial effects on cardiovascular and metabolic functions.

Protein Components and Amino Acid Composition

Chlorella vulgaris contains high levels of proteins, accounting for approximately 50–60% of its dry weight (41). These proteins are of particular nutritional value due to their high content of essential amino acids, including leucine, isoleucine, valine, phenylalanine, and methionine (42). *Chlorella* is among the few plant-based sources that provide all essential amino acids, thereby constituting a complete protein source, especially beneficial for vegetarian and vegan diets. The protein fraction of *Chlorella vulgaris* comprises a variety of enzymes and structural proteins that play important roles in cellular metabolism, tissue maintenance, and regeneration. Moreover, *Chlorella vulgaris* contains a specific bioactive protein known as *chlorella growth factor*, which has been reported to stimulate cell proliferation and enhance energy metabolism.

Lipids

Lipids in *Chlorella vulgaris* account for about 5–10% of its dry weight (43). These lipids predominantly consist of polyunsaturated fatty acids (PUFAs), which play a crucial role in maintaining cellular structure and membrane integrity. *Chlorella* contains appreciable amounts of omega-3 and omega-6 fatty acids, including linoleic acid (C18:2) and α -linolenic acid (C18:3) (44). The polyunsaturated fatty acids in *chlorella* not only support cellular function but also exhibits antioxidant and anti-inflam-

matory effects. They also contribute to improved cardiovascular health and reduced levels of low-density lipoprotein (LDL) cholesterol in the blood.

tural and energy-related functions within the cell. In addition, chlorella polysaccharides exhibit pronounced bioactivity, with experimental studies indi-

Table 2. Lipids content in chlorella.

Lipid Type	Fatty Acids	Dental Health Benefits
Total lipid content	5–10% from dry weight	Lipids support the cellular function and structure of gums and teeth
Unsaturated fatty acids	Omega-3 (ALA), Omega-6 (linoleic acid)	Omega-3 fatty acids help reduce inflammation in the oral cavity, such as gingivitis and periodontitis
Gamma-linolenic acid (GLA)	Low content	Has anti-inflammatory properties that can relieve gum inflammation and speed up recovery after dental procedures
Saturated fatty acids	Palmitic acid	Supports the health of cell membranes in the oral mucosa, but should be taken in moderation so as not to increase inflammation

Carbohydrates

Carbohydrates in chlorella constitute approximately 10–20% of its dry weight and are predominantly present in the form of polysaccharides. The principal monosaccharides identified in *Chlorella vulgaris* include glucose, rhamnose, and mannose, which are linked into complex structural polysaccharides (45). These carbohydrates fulfil both struc-

cating their capacity to positively modulate immune responses by stimulating macrophage activation and phagocytic activity (46). Certain carbohydrate fractions occur in sulphated forms, conferring additional biological properties, including antiviral and antibacterial activities.

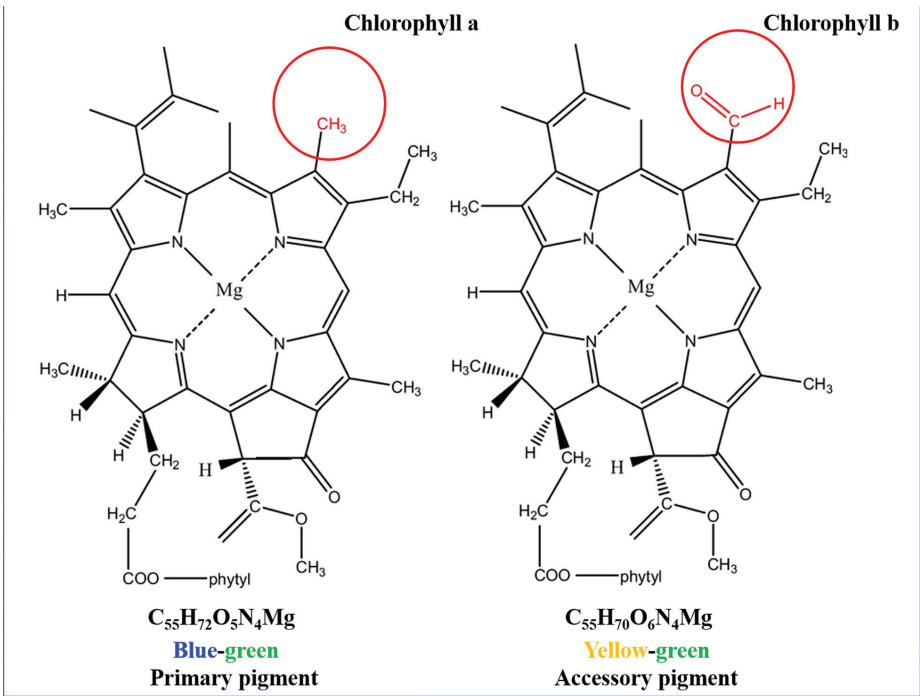


Fig. 2. Structural formula of chlorophyll a and chlorophyll b in *Chlorella vulgaris*

Pigments

The principal pigments identified in chlorella include chlorophyll *a* and *b*, which are essential for the photosynthetic process (47) and are illustrated in Fig. 2. Chlorophyll plays a fundamental role in the conversion of light energy into chemical energy, enabling chlorella to grow and adapt to diverse aquatic environments. In addition to chlorophyll, *Chlorella vulgaris* contains carotenoids such as β -carotene, which exhibit well-established antioxidant properties and can be metabolically converted into vitamin A in the human body (48). Collectively, these pigments contribute to the reduction of oxidative stress and the prevention of free radical-induced cellular damage, thereby playing a significant role in the antioxidant defense mechanisms of the organism.

Vitamins and Minerals

Chlorella is an exceptionally rich source of vitamins and minerals, including B-group vitamins

(particularly B12), vitamin C, vitamin E, and vitamin A (49–51). Vitamin B12 is of particular importance, as it is essential for proper nervous system function and the synthesis of red blood cells. These data are summarized in Table 3. In addition, *Chlorella vulgaris* contains significant amounts of essential minerals such as iron, calcium, magnesium, zinc, and potassium, all of which are crucial for maintaining optimal physiological function. The iron present in *Chlorella vulgaris* is highly bioavailable and may contribute to the prevention of iron-deficiency anemia.

Secondary Metabolites

In addition to its primary nutritional components, chlorella contains a variety of secondary metabolites that exhibit antioxidant, anti-inflammatory, and antimicrobial properties (52). One of the principal secondary metabolites identified in *Chlorella vulgaris* is chlorella sulfate, which demonstrates immunomodulatory activity and the capacity to ac-

Table 3. Vitamins content in *Chlorella vulgaris*.

Vitamin	Content in Chlorella	Dental Health Benefits
Vit. B	Vit. B1, B2, B3, B6, B12, folic acid (B9)	Improves gum health: B vitamins help reduce inflammation in the mouth, such as gingivitis.
		Promotes wound healing: They speed up the repair of damaged tissues in the mouth.
		Improves blood circulation: This is essential for gum health and preventing periodontitis
Vit. C (ascorbic acid)	High content	Supports gum health: Vitamin C is essential for the synthesis of collagen, which is necessary for the strength and elasticity of the gums. Vitamin C deficiency can lead to scurvy, a gum disease in which the gums bleed and become inflamed.
		Antioxidant action: Protects cells in the mouth from oxidative stress, which can cause tissue damage
Vit. E (tocopherol)	Low content	Antioxidant protection: Vitamin E has a strong antioxidant action, which helps protect cells in the mouth from damage caused by free radicals.
		Promotes wound healing: Helps repair damaged gums and other tissues in the mouth.
		Anti-inflammatory: Reduces inflammation in the gums and prevents gum diseases such as periodontitis
Vit. A	High content as β -carotene	Supports epithelial health: Vitamin A is important for the health of the cells of the gums and oral mucosa, helping them recover after trauma or dental procedures.
		Infection prevention: Vitamin A strengthens the immune system, which is important for preventing infections in the oral cavity.
		Dental health support: Helps form healthy dental tissues and is necessary for the normal development of teeth.

tivate macrophages. Other important secondary metabolites include phenolic compounds such as gallic acid and chlorogenic acid, which also display antioxidant and anti-inflammatory properties (53). Collectively, these compounds contribute to the reduction of inflammatory responses, protection against oxidative stress-induced cellular damage, and overall health support.

tracts derived from spirulina that contain sulfated polysaccharides, such as calcium spirulan (Ca-SP), have demonstrated the ability to inhibit viral replication by blocking viral entry into host cells (54). This compound has therefore been identified as a promising candidate for the development of antiviral therapies, particularly in the context of emerging viral infections. In addition, phycocyanin present in spi-

Table 4. Comparison of the two types of microalga.

Characteristics	Chlorella	Spirulina
Origin	Freshwater algae, genus <i>Chlorella</i>	Saltwater algae, genus <i>Arthrospira</i>
Cell size	2–10 µm in diameter	5–10 µm in diameter
Main pigment	Chlorophyll a, chlorophyll b, carotenoids	Phycocyanin, chlorophyll a, carotenoids
Proteins	45–60% of dry weight	55–70% of dry weight
Fatty acids	High in omega-3 and omega-6 fatty acids	High in omega-6 fatty acids
Carbohydrates	10–20% of dry weight (mainly polysaccharides)	15–20% of dry weight (mainly polysaccharides)
Minerals	Fe, Ca, Mg, Zn, K	Fe, Ca, Mg, Zn, K
Vitamins	Vit. B, Vit. C, Vit. E, β-carotene	Vit. B, Vit. C, Vit. E, β-carotene
Antioxidant properties	High levels of antioxidants, such as carotenoids, vitamin C	High levels of antioxidants, such as phycocyanin, carotenoids
Antiviral activity	Studies show activity against viruses such as herpes	Studies show activity against viruses such as HIV
Anti-inflammatory properties	Reduces levels of inflammatory cytokines	Inhibits the production of pro-inflammatory cytokines
Immunomodulatory effects	Stimulates the immune system, increases phagocytosis	Enhances immune response, stimulates T-cell activity
Detoxifying effect	May help eliminate toxins from the body	Contains chlorophyll, which aids detoxification
Application in dietary supplements	Popular in detoxification and immunity-boosting supplements	Popular in supplements for energy levels and immune support
Clinical studies	Numerous studies on effectiveness in diabetes, hypertension	Studies on the effects on cholesterol and cardiovascular disease

Antiviral Activity of the *Spirulina platensis* and *Chlorella vulgaris* Microalgae

Spirulina has been the subject of numerous studies regarding its antiviral properties, particularly against enveloped viruses, including herpes simplex virus, human cytomegalovirus, influenza A, human immunodeficiency virus (HIV), and hepatitis C. Ex-

tracts derived from spirulina that contain sulfated polysaccharides, such as calcium spirulan (Ca-SP), have demonstrated the ability to inhibit viral replication by blocking viral entry into host cells (54). This compound has therefore been identified as a promising candidate for the development of antiviral therapies, particularly in the context of emerging viral infections. In addition, phycocyanin present in spi-

ulina exhibits antiviral activity, likely through the suppression of viral replication by interfering with RNA synthesis under in vitro conditions. Experimental studies have further indicated that spirulina extracts may exert beneficial effects during the early stages of influenza infection by reducing viral load and inhibiting hemagglutination (55). Nevertheless, further well-designed clinical studies are required to

substantiate these findings and to evaluate their potential clinical applicability

Chlorella vulgaris has also been extensively studied for its antiviral properties against various viruses, including herpes simplex virus, human cytomegalovirus, and influenza viruses. Isolated polysaccharides and other bioactive constituents derived from *Chlorella vulgaris* have demonstrated the potential to inhibit viral replication (56). Specific components, particularly sulfated polysaccharides, are capable of blocking viral entry into host cells, thereby reducing infection rates (57). In addition, chlorella extracts contain amino acids and proteins that may enhance host immune responses, thereby contributing to increased resistance against viral infections. Despite these promising findings, further controlled clinical trials are required to confirm the antiviral efficacy of *Chlorella vulgaris* and to establish its therapeutic relevance in antiviral interventions.

Antioxidant Potential of Spirulina and Chlorella in Periodontitis

The antioxidant activity of spirulina has been extensively investigated and is recognized as one of the key attributes of its bioactive compounds. The principal components contributing to this activity include phycocyanin, carotenoids, and chlorophyll,

all of which exert significant effects on reactive oxygen species (ROS) (58). Phycocyanin, the primary blue pigment of spirulina, has demonstrated a strong capacity to neutralize superoxide anions, hydroxyl radicals, and peroxy radicals. Through these mechanisms, spirulina-derived antioxidants play a crucial role in mitigating oxidative stress, which is a major contributing factor to the development of numerous chronic diseases, including cancer, cardiovascular disorders, and neurodegenerative conditions.

Carotenoids such as β -carotene, zeaxanthin, and lutein further contribute to the antioxidant potential of spirulina by scavenging singlet oxygen and other reactive oxygen species (59). Chlorophyll also exhibits antioxidant activity, supporting cellular and tissue protection against oxidative damage. Moreover, methanolic extracts of spirulina have been reported to display pronounced antimicrobial and antioxidant effects, which are largely attributed to their high phenolic content.

Chlorella vulgaris is well recognized for its potent antioxidant properties, primarily attributed to its content of chlorophyll, carotenoids, and various phenolic compounds. Chlorophyll in *Chlorella vulgaris* plays a crucial role in neutralizing free radicals, including superoxide anions, hydroxyl radicals, and

Table 5. Properties of the microalgae.

Characteristics	Spirulina (<i>Arthrospira platensis</i>)	Chlorella (<i>Chlorella vulgaris</i>)
Antiviral activity	Spirulina shows antiviral activity against various viruses, including herpes simplex virus (HSV), hepatitis B, and influenza virus. Contains polysaccharides (such as fucoidan) that enhance the immune response and inhibit viral replication	Chlorella also has antiviral properties, reducing infection by hepatitis C and herpes viruses. It is rich in chlorophyll and antioxidants, which strengthen the immune system and inhibit viral infections
Antioxidant potential	Spirulina has high antioxidant potential due to its content of phycocyanin, which is a powerful antioxidant. Can reduce oxidative stress, protect cells from damage, and improve cell function	Chlorella also has high antioxidant potential, thanks to chlorophyll, vitamin C, vitamin E, and β -carotene. It helps fight free radicals, reduces inflammation and protects cells from oxidative damage
Anti-inflammatory properties	Spirulina contains phycocyanin, which has strong anti-inflammatory properties, reducing inflammation in the body, including in inflammatory diseases such as arthritis and periodontitis. The omega-3 fatty acids in spirulina also have anti-inflammatory effects	Chlorella also shows anti-inflammatory effects thanks to its phytochemicals and gamma-linolenic acid (GLA) content. These ingredients help reduce inflammation in tissues, including inflammation of the gums and joints, and reduce pain in chronic inflammatory conditions

peroxyl radicals. This activity contributes to the reduction of oxidative stress, a major factor involved in the pathogenesis of chronic diseases such as cardiovascular disorders, diabetes, and cancer (60). Carotenoids present in *Chlorella vulgaris*, including β -carotene and lutein, further enhance its antioxidant capacity by scavenging singlet oxygen and protecting cells against damage induced by ROS. Consequently, *Chlorella vulgaris* may play an important role in the prevention and management of oxidative stress-related diseases.

Properties of the *Spirulina* and *Chlorella* Microalgae

Table 5 summarizes the antiviral activity, antioxidant potential, and anti-inflammatory properties of microalgae from both genera.

The anti-inflammatory effects of *Spirulina platensis* are closely associated with its rich composition of bioactive compounds, particularly phycocyanin, which has demonstrated the ability to inhibit the production of pro-inflammatory cytokines, including tumor necrosis factor- α (TNF- α) and interleukin-6 (IL-6). In addition, these bioactive components reduce the activity of key inflammatory enzymes, such as cyclooxygenase-2 (COX-2). Experimental studies have further shown that selenium-enriched *Spirulina* significantly decreases the levels of inflammatory cytokines, including IL-6, interleukin-1 β (IL-1 β), and TNF- α . These findings underscore the therapeutic potential of *Spirulina* in the management of inflammatory diseases, such as arthritis, as well as in the prevention of chronic inflammatory conditions (61,62).

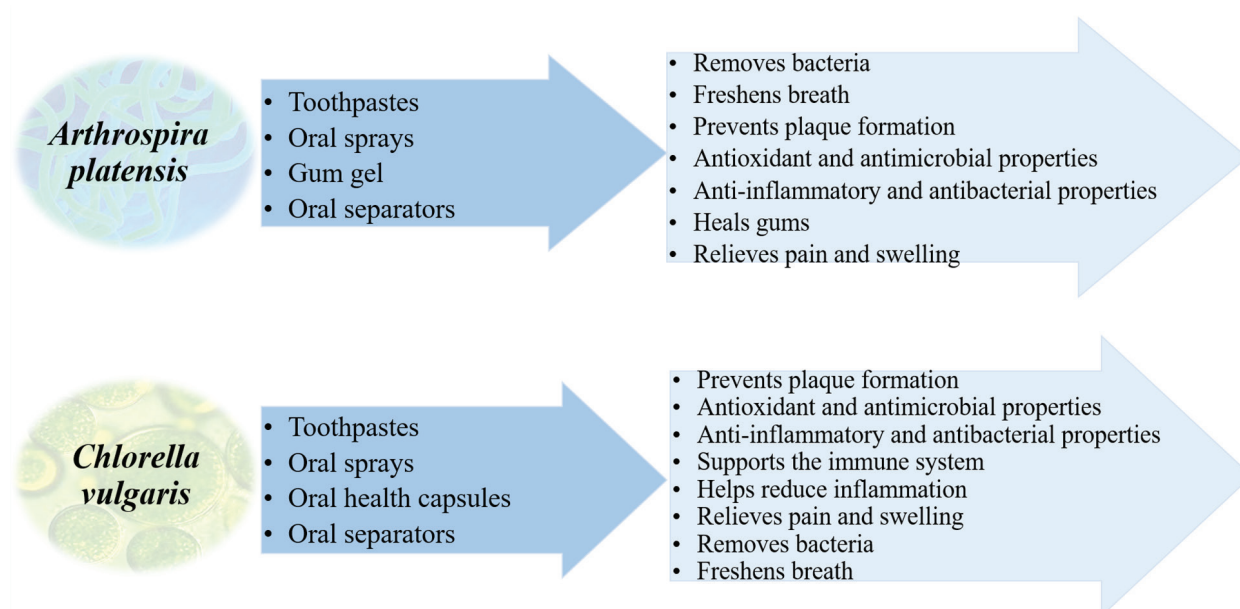
Chlorella vulgaris contains several bioactive compounds with well-documented anti-inflammatory effects. Research evidence indicates that *Chlorella vulgaris* can reduce the levels of pro-inflammatory cytokines, such as TNF- α and IL-6, which play a central role in the pathogenesis of chronic inflammatory conditions. The underlying mechanism of action involves the inhibition of key inflammatory enzymes, including COX-2, which are responsible for the synthesis of inflammatory mediators. Furthermore, *Chlorella vulgaris* has been shown to decrease the activity of oxidative enzymes and to support endogenous detoxification processes, thereby offering potential therapeutic benefits in the management of

diseases associated with chronic inflammation, such as arthritis and cardiovascular disorders (63).

Bioactive Extracts for Dental Products

Spirulina platensis has demonstrated significant potential for oral health applications owing to its antiviral, antibacterial, antifungal, and anti-inflammatory properties. Numerous studies indicate that spirulina may be effective in the prevention of oral infections, including those caused by pathogenic bacteria, viruses, and fungi (64). In addition, *Spirulina platensis* exhibits pronounced antioxidant activity, which may help reduce oxidative stress-induced damage in oral tissues. Experimental evidence further suggests that both micro- and macroalgae may play an important role in the prevention of oral conditions such as oral cancer, dental plaque accumulation, and dental caries. Oral care products containing microalgal extracts, including toothpastes, mouthwashes, and gels, have shown promise in improving oral hygiene and overall oral health. Furthermore, alginate- and agar-agar-based materials derived from algae are widely used in dental practice for the fabrication of dental impressions and restorative applications (65).

Bioactive extracts from *Chlorella* find application in various therapeutic areas due to their antimicrobial, anti-inflammatory, and antioxidant activities. These extracts have shown effectiveness in treating conditions associated with cellular damage, such as diabetes and cardiovascular diseases. *Chlorella* contains polysaccharides and proteins that can enhance the immune response and provide protection against infections (66). The use of *Chlorella* in therapeutics for liver disease and detoxification is particularly promising, with evidence showing improvements in liver function and reduced toxicity from various chemicals and pollutants. *Chlorella* is considered a potential natural source for use in the cosmetic industry, due to its hydrating and regenerative properties, which may contribute to skin rejuvenation. *Chlorella* is widely used as a dietary supplement due to its high content of nutrients, including B-group vitamins, vitamin C, minerals such as iron, magnesium, and calcium, and essential amino acids. Its high nutritional value makes it an effective agent for strengthening the immune system, improving digestion, and supporting metabolic processes in the body. Thanks to its detoxifying properties, *Chlo-*



Scheme 1. Application of microalgae in dental health products.

rella is included in various functional foods and supplements aimed at reducing toxins in the body and maintaining overall health. Applications in the modern food industry also offer potential for developing new products with high added health value.

CONCLUSION

Based on the conducted literature review, there is a clear trend indicating that microalgae can be actively used as key components in various products designed for dental health. The results demonstrating the composition of chlorella and spirulina, as well as their antiviral, antioxidant, and anti-inflammatory activities, confirm their potential beneficial effects in combating dental problems. These studies can serve as a basis for the development and production of new pharmaceutical products aimed at improving oral and dental health.

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