

A Review on Antimicrobial Activity of Vegetables, Herbs and Spices Against Cariogenic Bacteria

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ABSTRACT

Dental caries is one of the most prevalent oral diseases. It is observed in the sexes, all races, all socioeconomic classes and all age groups. Dental caries is a process where the enamel and the dentine are demineralized by the products of bacterial fermentation. Restorative or pulp therapy is involved in the treatment of dental caries. This therapy is not only expensive but also painful. So, proper application of preventive methods right from childhood can reduce incidence of dental caries.

The most common methods for maintaining good oral hygiene are brushing and washing the mouth with tooth pastes and mouthwashes that have antimicrobial properties and can prevent the degradation of tooth enamel. Commercially available dentifrices contain chemical agents, which are known to produce harmful side effects on prolonged use. Hence, dentifrices that contain extracts of medicinal plants and herbs are becoming popular.

Since ancient times medicinal plants have been employed for prophylactic and curative purposes. Many reports of the researchers have revealed the antimicrobial nature of vegetables and spices against *Streptococcus mutans*, which is known to be the main cause of dental caries. The present article provides an account of the antimicrobial activities of a few vegetables, herbs and spices against cariogenic bacteria.

INTRODUCTION

Plant derived products have been used for therapeutic and prophylactic purposes for centuries. At present, it is estimated that about 80% of the world population rely on botanical preparations as medicines to meet their health needs [1-6]. Herbs and spices are generally considered to be safe and proved very effective against most of the microorganisms. They are extensively used, particularly, in most of the Asian, African and other countries. In recent years, in view of their beneficial effects, use of spices/herbs has been gradually increasing in developed countries also.

Countries like India fulfill the requirement of medicinal sources mainly from plants to cure infectious diseases [7]. Egyptians had implicated plant extracts for preserving the dead bodies [4]. Africans have also practiced plant medicines for the treatment of many diseases and infections since ancient times [8]. The oldest and greatest history has been recorded in China as the country implicated herbal medicine practices for more than 5000 years ago. Concurrently, many herbs/spices and plant derived products have been used extensively in the field of medicine for both prophylaxis and treatment from ancient era to present. It has been proven to cure certain illness in replacement of chemical compounds or antibiotics particularly in many Asian, African and other countries.

Dental caries is an infectious process that ends up in the destruction of hard dental tissue. It results from the accumulation of plaque on the surface of the teeth and biochemical activities of complex microorganisms. The four main criteria for caries formation are: a tooth surface (enamel or dentin); cariogenic (or potentially caries-causing) bacteria; diet or fermentable carbohydrates (such as sucrose); and time.

Mouth contains a wide variety of bacteria, but only a few specific species of bacteria are believed to cause dental caries.

Streptococcus mutans and *Lactobacilli* are the most important among them. Particularly for root caries, the most closely associated bacteria frequently identified are *Lactobacillus acidophilus*, *Actinomyces viscosus*, *Nocardia* species, and *Streptococcus mutans*.

Bacteria in a person's mouth convert sugars (glucose and fructose, and most commonly sucrose or table sugar) into acids such as lactic acid through a glycolytic process called fermentation. If left in contact with the tooth, these acids may cause demineralization, which is the dissolution of the mineral content of the tooth. The process is dynamic, however, as remineralization can also occur if the acid is neutralized; suitable minerals are available in the mouth from saliva and also from preventative aids such as fluoride toothpaste, dental varnish or mouthwash. The advance of caries may be arrested at this stage.

Recently, many phytochemicals, including antibacterial agents, have been clarified from edible plants [9-11]. There are also numerous reports on the components of plants, which have revealed antibacterial activities against *Streptococcus mutans*, which is widely known as a cause of dental caries [12-15]. Many vegetables and fruits have antimicrobial components which can help in improving human health.

Cabbage

The presence of antibacterial activity was first demonstrated by Sherman and Hodge and since then it has been the subject of many studies [16-21]. Sherman and Hodge [22] and Pederson and Fisher [20] had reported that the antibacterial activity of cabbage was destroyed on heating.

Yildiz and Westhoff [17] had reported that fresh, filtered and sterilized cabbage juice was a better growth media for lactic acid bacteria when compared to that of heated cabbage juice. According to Pederson and Fisher [20] cabbage juice was inhibitory to Gram negative bacteria than Gram positive bacteria. Among the cabbage components, glucosinolate hydrolysis products were reported to be antimicrobial in nature [23,24]. Zsolnai [23] had reported that glucosinolate hydrolysis products inhibited the growth of Gram positive bacteria and fungi than Gram negative bacteria.

Beetroot

Beetroot (*Beta vulgaris* L. ssp. *vulgaris*, Chenopodiaceae) has been ranked among the 10 most powerful vegetables with respect to its antioxidant capacity containing a total phenolic content of 50–60 µmol/g dry weight [25,26]. Beetroot is a great source of valuable water-soluble nitrogenous pigments, called betalains, which consists of two main groups, the red betacyanins and the yellow betaxanthins. As they are free radical scavengers, they prevent active oxygen-induced and free radical-mediated oxidation of biological molecules [27].

Betalains have been extensively used in the modern food industry. They are one of the most important and the earliest natural colorants used in food systems [28,29].

A more recent investigation reported that total phenolics content decreases in the order peel (50%), crown (37%), and flesh (13%). The peel also consists of the main portion of betalains with up to 54%, their content being less in crown (32%) and flesh (14%) [30]. The coloured fraction consists of betacyanins and betaxanthins, whereas the phenolic portion of the peel consists of l-tryptophane, p-coumaric and ferulic acids, as well as cyclodopa glucoside derivatives [30,31]. Beetroot also contains a significant amount of phenolic acids: ferulic, protocatechuic, vanillic, p-coumaric, p-hydroxybenzoic, and syringic acids. The high content of folic acid amounting to 15.8 mg/g dry matter is another nutritional feature of the beets [32].

Dietary inorganic nitrate (NO_3^-) and its reduced forms nitrite (NO_2^-) and nitric oxide (NO), respectively, are of critical importance for host defense in the oral cavity. High concentrations of salivary nitrate are linked to a lower prevalence of caries due to growth inhibition of cariogenic bacteria. A study by Barbara et al. [33] results show that, in comparison to a placebo group, consumption of beetroot juice that contains 4000 mg/L NO_3^- results in elevated levels of salivary NO_2^- , nitrite NO_3^- , and NO. Furthermore, we determined an increase of the mean pH of saliva from 7.0 to 7.5, confirming the anti-cariogenic effect of the used NO_3^- rich beetroot juice.

Carrot

The carrot (*Daucus carota* subsp. *Sativus*) is a plant belonging to the family Apiaceae. It is grown throughout the temperate regions for its roots that are consumed both raw and cooked. Carrot is rich in nutrients like carbohydrates, carotenes, vitamins and minerals. Carrots are used in many food preparations especially in the preparation of salads, soups, juices etc. Carrot juice is considered as one of the healthiest drinks. It is beneficial for human beings particularly in fresh state as alone or even when carrot juice is mixed with other fruit juices or milk.

Carrot is rich in Vitamin A which is useful for healthy vision. The antioxidant properties help to preserve food from the risk of oxidative contaminants [34]. The carrots are reported to have medicinal properties like hypotensive, diuretic, carminative, stomachic and antilipemic [35-37]. Carrot and its extracts can be used as antiseptic for wounds and anti-inflammatory especially for tonsillitis. It also has hepato-protective nature and therefore, can be used in the treatment of jaundice and dermatitis [34,38]. It has also been reported that the carrot and its extracts are effective against the microorganisms such as bacteria and fungi [34,38-40].

Recently it has been proved that carrots have a strong effect against tumors especially the tumor of urinary tract and skin [34,38]. It is due to the presence of carotol, sitasterol-juicosidies, fatty oils, flavonoids, polyacetyenes, β -carotenes, furocoumarins and other compounds [38].

Cucumber

Cucumber is the edible fruit of the plant *Cucumis sativus*, which belongs to the family Cucurbitaceae. The cucumber plant is an annual climber. It grows to a height of 15-30 cm and has large leaves that form a canopy over the fruit. Cucumbers usually contain more than 90% of water. The cucumber plant is a climber which bears cylindrical edible fruit.

The juice obtained from cucumber fruit is used in many beauty products [41]. It has been reported that *Cucumis sativus* fruit possess various activities such as cytotoxic and antifungal activity [42], antacid and carminative activity [43], hepatoprotective activity, hypoglycemic and hypolipidemic activity [44], wound healing activity [45].

Cucumis sativus fruit is also known to possess biological activities such as antihyperglycemic activity [46], inhibitory effects on protein kinase C (PKC) activity [47], anti-oxidant activity [48-50], amylolytic activity [51], anticancer activity, anti-clastogenic activity [52], and anti-mutagenicity activity [53,54].

The ethanol and water extracts of the fruits of cucumber possess significant inhibitory activities against both the gram-positive and gram-negative bacteria as well as fungi. The antimicrobial activity of the ethanolic extract of the fruits of *Cucumis sativus* may be due to the presence of 2,3-Dihydro-3,5-dihydroxy-6-methyl-4H-pyran-4-one, 5-(Hydroxylmethyl)-2-furancarboxyaldehyde, 4-Hydroxy-3-methyl-2-butenyl-acetate, 2-(2-Methylcyclohexylidene)-hydrazinecarboxamide, 1,2-Benzene dicarboxylic acid diisooctyl ester which were found by GC-MS.

Researchers investigated the effects of the cucumber volatiles (E,Z)-2-6-nonadienal (NDE) and (E)-2-nonenal (NE) on various pathogenic bacteria, including *Bacillus cereus* (*B. cereus*), *Escherichia coli* O157:H7 (*E. coli*), *Listeria monocytogenes* (*Listeria*), and *Salmonella Typhimurium* (*Salmonella*). The pathogens were exposed to various levels of the volatiles in an infusion solution. Researchers found exposure to either NDE or NE caused a reduction in the colony forming unit (CFU) of each organism. Exposure to 250 and 500 ppm NDE fully eradicated viable *B. cereus* and *Salmonella* cells, respectively. *Listeria* was the most resistant to eradication by NDE, though it had a significant kill rate on *E. coli* cells. NE was also found effective in inactivating all the pathogenic bacteria tested; however, a higher concentration of NE—1,000 ppm—was required to kill *E. coli*, *Listeria* and *Salmonella* compared with NDE.

Lemon

Citrus fruits have always been an important component of human diet. Lime (*Citrus aurantifolia* Linn.) is an essential ingredient in the preparation of most herbal concoctions [55]. They provide a variety of constituents which are very important for human health. These constituents mainly include Vitamin C (ascorbic acid), folic acid, potassium, flavonoids, coumarins, pectin and dietary fibers [56]. Flavonoids in citrus consists of a broad spectrum of biological activities, which include antibacterial, antioxidant, antidiabetic, anticancer, analgesic, antiinflammatory and anti-anxiety activity [57].

Lemon juice in general is used to suppress stomach ache, added to honey and palm oil it relieves cough, and the mesocarp is also used as a good facial scrub to prevent pimples [58]. Its antimicrobial activities were found effective against a good number of bacteria, as well as *Candida albicans* [59]. Lemon juice is used as a mouth wash, which removes plaque, whitens the teeth and strengthens the enamel. Pure lemon juice is acidic in nature which makes it injurious to the teeth. So it should not be taken in concentrated form.

Tomato

Tomatoes (*Solanum lycopersicum*) are consumed throughout the world, and their consumption is believed to benefit the heart, among other organs. In addition to its flavor properties, tomatoes are reported to possess numerous beneficial nutritional and bioactive components that may also benefit human health. These include the nutrients vitamin A, vitamin C, iron, and potassium; nonnutritive digestible and indigestible dietary fiber; the antioxidative compounds lycopene, β -carotene, and lutein [60] and the cholesterol lowering components [61]. These considerations suggest that edible tomato contains antimicrobials which may have multiple benefits [62].

Mint

Mentha piperita (Lamiaceae), the peppermint (mint) plant is an aromatic perennial herb which is cultivated in most parts of the world, have traditionally been used in folk medicine. Leaves of mint plant are frequently used in herbal tea and for culinary purpose to add flavour and aroma. The distinctive smell and flavour, a characteristic feature of *Mentha* species is due to the naturally occurring cyclic terpene alcohol called menthol. Menthol is prescribed as a medicine for gastrointestinal disorders, common cold and musculoskeletal pain [45]. The mint plants are rich sources of iron and magnesium, which play an important role in human nutrition [63].

The presence of tannins and flavanoids in the methanolic mint leaf extract has been reported by Kaur et al. [64]. A correla-

tive relationship has been reported between the phytochemicals such as tannins and flavanoids and the free radical scavenging activity and antibacterial activity [64].

Tannins and flavanoids have therapeutic uses due to their anti-inflammatory, anti-fungal, antioxidant and healing properties [65]. The antibacterial activity of *Quercus* species bark is related to the richness of phenolic compounds such as flavanoids and tannins [66,67]. Thus, the antibacterial and antifungal activity of methanolic leaf extract of *M. piperita* is attributable to the presence of tannins and flavanoids. Nowadays, menthol is added in commercial tooth pastes to offer protection against oral microbial infections.

Pramila et al. [68] has proven the antibacterial activity of mint leaves against the selected oral pathogens. They conducted a study on oral pathogens such as *Escherichia coli*, *Acinetobacter* sp., *Staphylococcus* sp. isolated from a dental patient and known strains of *Candida albicans* and *Candida glabrata*. They found that the antibacterial and antifungal activity of methanolic leaf extract of *M. piperita* was attributable to the presence of tannins and flavanoids. Nowadays, menthol is added in commercial tooth pastes to offer protection against oral microbial infections. Their study indicated the antibacterial activity of mint leaves against the selected oral pathogens. Frequent and continued intake of mint leaves in daily diet may prove beneficial in keeping the pathogenic microbes below the threshold level.

Coriander

Coriandrum sativum (L.) (Umbelliferae-Apiaceae) (Coriander, cilantro) was introduced to Chinese cooking and medicine around AD 600, since when it has been known as hu, ÔforeignÕ. In the Chinese Materia Medica, it was recommended for certain types of non-pathogenic food poisoning caused by decaying matter. Coriander parts such as its leaves, seeds and oil are very useful. The fresh leaves and ripe seeds have quite different aromas and uses. Both the leaves and seeds are rich in volatile oils and act mainly on the digestive system, helping to stimulate the appetite and relieve irritation. They also act as an expectorant. The oil is fungicidal and bactericidal.

Coriandrum sativum (coriander) is considered both as an herb and a spice. Both its leaves and seeds are used as seasoning condiment. Coriander seeds have health supporting reputation that is high on the list of healing spices. It has traditionally been referred as antidiabetic, anti-inflammatory and cholesterol lowering [69]. In addition, it is also used as carminative, diuretic, stimulant, stomachic, refrigerent, aphrodisiac, analgesic [70], antihelminthic [71] and hypoglycemic [72].

Some researchers have found that *C. sativum* has strong antibacterial activity against both Gram positive and Gram negative organisms [73]. Similarly, the compounds aliphatic 2E-alkenals and alkanals, isolated from the fresh leaves of *C. sativum* were found to possess bactericidal activity against *Salmonella choleraesuis* [74].

Ginger

Ginger is a rhizomatous plant grown throughout South-eastern Asia, China and in parts of Japan, Austria, Latin America, Jamaica and Africa. Ginger has been used as a spice and medicine in India and China since ancient times. Ginger plants were grown in pots and carried to abroad on sea long voyages to prevent scurvy. The spice was known in Germany and France in the ninth century and in England in 10th century for its medicinal properties.

Many oils exhibit antimicrobial properties due to the presence of components such as thymol, eugenol, 1,8- cineole, α - and β - pinenes, linalool, α - terpineol etc. Since these compounds and their relative concentration vary from oil to oil and from different oils which accounts for a varied antimicrobial activity [75,76].

Over three quarters of the world population still rely on plants and plant extracts for health care. Ginger is widely used in ayurvedic medicines and in folklore medicines [77]. About 8000 herbal remedies have been codified in ayurveda and are still used throughout India. Most of the ayurvedic preparations contain dry pepper and ginger. Some reports are available on the antimicrobial property of the volatile oil from the rhizomes of ginger [78-85,43]. The essential oil from ginger was studied for antimicrobial activity against *Aspergillus niger*, *Saccharomyces cerevisiae*, *Mycoderma* species, *Lactobacillus acidophilus* and *Bacillus cereus*, as determined by paper agar diffusion method [78].

Another study performed by Ficker et al. [82] reports on the bioassay-guided isolation of antifungal compounds from an African land race of ginger, *Zingiber officinale* Roscoe, and the identification of 6, 8 and 10-gingerols and 6-gingerdiol as the main antifungal principles. The compounds were active against 13 human pathogens at concentrations of <1 mg/ml.

Clove

Cloves (*Syzygium aromaticum*, syn. *Eugenia aromaticum* or *Eugenia caryophyllata*) are the aromatic dried flower buds of a tree belonging to the family Myrtaceae [86,77]. Cloves have been used in Ayurveda and Chinese medicine since ancient times.

Cloves are used as a carminative, to increase hydrochloric acid in the stomach which ultimately leads to improve peristalsis [87]. It is also used in dentistry where the essential oil of clove is used for dental emergencies [88,89]. In addition, the cloves possess other properties like anti-mutagenic [90], anti-inflammatory [91], antioxidant [86], anti-ulcerogenic [92,93], anti-thrombotic [77] and anti-parasitic [94].

Several researchers have demonstrated potent antifungal^[95-98], antiviral^[86] and antibacterial effects of clove^[89,92,93,99-101]. The antimicrobial activity of clove is due to the presence of several constituents, mainly eugenol, eugenyl acetate, beta-caryophyllene, 2-heptanone^[102], acetyl- eugenol, alpha-humulene, methyl salicylate, iso-eugenol, methyl-eugenol^[94], phenyl propanoides, dehydrodieugenol, trans-confireryl aldehyde, biflorin, kaempferol, rhamnocitrin, myricetin, gallic acid, ellagic acid and oleanolic acid^[89]. The main constituents of essential oil are phenyl-propanoides such as carvacrol, thymol, eugenol and cinnamaldehyde^[77].

CONCLUSION

The present article revealed that all the vegetables, herbs and spices being discussed possess antimicrobial properties. These plant products are not only potential antimicrobial agents but also provide other health benefits. Therefore this review suggests that these vegetables, herbs and spices can be used as ingredients in mouth wash formulation and regular use of mouth-wash which could be easily prepared at home using vegetables and spices could control dental caries. Natural antimicrobial agents are preferred for their beneficial aspects compared to their chemical counterparts.

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