REVIEW ARTICLE

Nutritional, therapeutic, and pharmaceutical potential of plant gums: A review

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Abstract

The present review explains nutritional, therapeutic, and pharmaceutical potential of plant gum that is commonly applied to water-soluble, non-starch polysaccharides of commerce. This article also emphasizes commercial and domestic uses of important products of gum such as chicle and jelutong mainly non-elastic gums or chewing gums. These are also used in food, pharmaceutical, paper textile, and other industries. The present review also explains various biological activities such as antidiarrheic, antitumor, anti-inflammatory, anti-arthritic, antiparasitic, gastrourinary, antitumor, antiparasitic, antioxidant, chemopreventive, and gastroprotective activity of plant gums. These reduce stomach inflammation, system cleansing or to settle the intestines. Other uses for mesquite gum include treatment for lice, sore throat, cough, laryngitis, fever reduction, painful gums, and hemorrhoids and it can be used as a purgative. Gum arabic is a water-soluble dietary fiber rich in Ca^{2+}, Mg^{2+}, and K^{+} that is used for the treatment of chronic kidney disease. It increases creatinine clearance, enhances renal excretion of antidiuretic hormone, Mg^{2+}, and Ca^{2+}, and decreases plasma phosphate concentration as well as urinary excretion of phosphate and Na^{+}. Gums are used as adhesives, crystallization inhibitors, emulsifying agents, emulsion stabilizers, encapsulating agents, film formers, foam stabilizers, suspending agents, suspension stabilizers, or syneresis inhibitors and impart other specific properties. The gum is also used to a limited extent in polishes, contact insecticides and pesticides, photographic emulsions, and pharmaceuticals. This article suggests wider use of plant gums in generation of drug delivery system for cancer and brain tumor therapy. There is no doubt that chemical constituents of plant gums can be largely used for making therapeutic drugs because of their broad-spectrum biological effectiveness.

Key words: Non-starch polysaccharide, nutritional, plant gums, therapeutic, and pharmaceutical potential

INTRODUCTION

Gum is water-soluble, non-starch polysaccharides (NSP) obtained from plants and other sources. In the market, both homemade and commercially generated gums are available. Certain hydrophobic substances, such as chicle and resinous saps, are also called gums. Gums are obtained from both higher land plants and red and brown marine algae/seaweeds. Normally, higher land plants store gum as cell wall constituents, energy-storing/carbon-storing substances that can be extracted from plant tissues, or exudates from wounds in the bark. Vegetable gums, obtained from plants, are solids consisting of mixtures of polysaccharides (carbohydrates) which absorb water and swell up to form a gel or jelly when placed in water. They are insoluble in oils or organic solvents such as hydrocarbons, ether, and alcohol. Upon hydrolysis, gums yield simple sugars such as arabinose, galactose, mannose, and glucuronic acid. Some gums are produced by exudation, usually from the stem of a tree but in a few cases from the root. Gums are also obtained by tapping method either by accidental or caused by insect borers. Seed gums are isolated from the endosperm portion of some seeds. Other vegetable gums can be isolated from marine algae (seaweeds) or by microbial synthesis. The coagulated part of some commercially important latex such as chicle and jelutong are often referred to as non-elastic gums or masticatory

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(chewing) gums, but they are not gums in the proper sense of the word [Table 1].

Plant gums are adhesive substances that are carbohydrates in nature and are usually produced as exudates from the bark of trees or shrubs. Gums are formed from the breakdown of cellulose in the plant cell walls, normally when they are damaged. Plant gums are used primarily to thicken or gel aqueous systems and to control water. Gums are used as adhesives, crystallization inhibitors, emulsifying agents, emulsion stabilizers, encapsulating agents, film formers, foam stabilizers, suspending agents, suspension stabilizers, or syneresis inhibitors and impart other specific properties [Table 1]. Plant gums are high in demand in food, pharmaceutical, paper textile, and other industries. Among food utilizable gums are categorized as food and non-food items, industrially these are technological grade [Table 1]. Gums are used as solidifiers and can be used as food additives in various kinds of confectioneries, foods, and beverages. Major use of gums is non-food industrial applications including gum ghatti and gum talha and a variety of other gums such as tragacanth, gum karaya, and gum carob. Processed natural gums are used to make a wide range of products. In food industry, gums are used as thickening, gelling, and emulsifying agents. Other industrial uses of plant gums are foam stabilizers, adhesives, binding agents, crystal inhibitors, flocculating, swelling, clarifying, and encapsulating agents. Gums also form uncharged or ionic polymers or polyelectrolytes [Table 1]. Some plant gums, such as gum arabic (GA), are soluble in water, dissolving to give clear solutions. Others include gum tragacanth producing mucilages by absorption of large quantities of water.

GA or gum *Acacia* is water-soluble and is locally known as gum "'hashab," is the most widely used. This is produced by *Acacia senegal* only. It is not produced by *Acacia arabica* as the source of GA.[1,2] The gums from *A. arabica* and over 120 other *Acacia* species have been shown to differ greatly from GA in terms of chemical composition and structure.[3] It was exported to medieval Europe through Arabs and its organized trade started in Sudan in 1820,[4] which still dominates the world GA production to the extent of 70-80% and produces the best foodstuff grades. Few other countries such as Chad, Senegal, Nigeria, Tanzania, Mali, and Mauritania also produce GA. It is exported as a primary product to industrial countries, mainly Western Europe and the USA. GA is used in the preparation of confectionery, soft, and alcoholic beverages. Its non-food applications include pharmaceutical, cosmetic, lithographic, and offset preparations. It is extensively used as an adhesive, sizing, and finishing material in the textile industry. However, small quantities continue to be used in paper making. The gum is also used to a limited extent in polishes, contact insecticides and pesticides, photographic emulsions, and pharmaceuticals [Table 1].

Gum Talha

Gum talha is water soluble that is derived from a number of *Acacia* species such as *Acacia seyal, Acacia sieberiana, Acacia hockii, Acacia ehrenbergiana*, and *Acacia karroo*. All these species yield poor-quality gum usually dark, with high tannin content and of poor solubility. "Gum talha" is in effect, simply a generalized trade description for water-soluble gum from any *Acacia* species other than *A. senegal*[3] and is a major source of technological grade gums. It is traditionally used for non-food applications such as lithographic formulations, textile and paper manufacture, foundry molding sands, and explosives. Production of gum talha remains fairly constant at around 6000 tonnes/year.[3] About 3000-5000 ton are exported annually, mainly from Sudan. Gum talha varies considerably in its composition and functions, because of collection from different sources [Table 1]. This makes it unfit for any repetitive commercial process, where consistency is important. Therefore, more self-consistent, but expensive GA ought to be utilized. Gum talha produced from African countries is more self-consistent in composition, quality, and functionality. It is pure and collected from a single botanical source and marketed at high price. The gum traders and collectors will also have to be trained for strict avoidance of admixtures of gum from different sources. These measures can help diversify production and marketing throughout the Sahel.

GA is oldest gum that is widely used in pharmaceuticals and cosmetics; As a thickening agent in syrups, salad dressings, and sauces; in textile sizing; and as an adhesive. It dissolves readily in cold water to give a solution of very high viscosity, which is additionally highly resistant to strong acidic conditions, and the gum is therefore used primarily as a stabilizer and thickener in acid preparations. The best quality gum is tasteless, whitish, yellowish, or pale-brown in color, and translucent in appearance. The lower grades are generally more strongly colored than the higher grades. The gum is obtained in two basic physical forms, namely, ribbons (superior quality) and flakes (inferior quality). These two forms are obtained from different subspecies of the shrub. Both types of the shrubs normally do not grow in the same locality.[5] The best type of gum is obtained from artificial incisions rather than from natural exudations. Abundant rainfall before the tapping season, and dry conditions during the harvesting season, constitute optimum climate for gum production [Table 1].

Gum Combretum

Major source of combretum gum is *Combretum nigricans* plant that found throughout tropical West Africa, particularly in northern Nigeria, Mali, and Niger. The tree is a copious gum extruder and contributes significantly to the gum production in the region. Gum combretum sells at a price of US$ 600 per t. in the international market. Such a low price leads to

Table 1: Major biochemical ingredients found in plant gums, their uses and biological activity

Types of gum	Plant source	Uses
Natural gums from marine weeds	Seaweeds	Used in biofilms and as antibiotics
Polyelectrolytes	Polyelectrolytes are polymers whose repeating units bear an electrolyte group. Polycations and polyanions are polyelectrolytes	These groups dissociate in aqueous solutions (water), making the polymers charged
Agar agar	Gelidium	Vegetarian gelatin substitute produced from a variety of seaweed vegetation. Hardening agent
Alginic acid and SA	Brown algae contains alginic acid, or align or alginate as an anionic polysaccharide	Algicnic acid binding with water it forms a viscous gum. It is also a significant component of the biofilms produced by the bacterium *P. aeruginosa,* the major pathogen in cystic fibrosis. Its color ranges from white to yellowish-brown. It is sold in filamentous granular or powdered forms
Carrageenan	Carrageenans or carrageenins are a family of linear sulfated polysaccharides that are extracted from red edible seaweeds	Carrageenan to gastrointestinal inflammation, including higher rates of colon cancer, in
From non-marine botanical resources		
GA	Sap of *Acacia* trees	Used in Arabian medicines for treatment of patients with CRF
Gum ghatti	Sap of *Anogeissus* trees	Nutraceutical, strong adhesive
Gum tragacanth	Sap of *Astragalus* shrubs	Adhesive
Karaya gum	Sap of *Sterculia* tresses	Adhesive
Uncharged		
GG	From guar beans	Digestion and cholesterol-lowering effects of the water-soluble. GG contains compounds with antiulcer, anti-acid/antipeptic, gastroprotective and/or antiulcer properties of GG and SF cellulose on food intake, stomach emptying and body fat deposition
Locust bean gum	From the seeds of the carob tree	Affect the amount of calcium, iron and zinc available for absorption
Beta-glucan	From oat or barley bran	
Chicle gum	An older base for chewing gum obtained from the chicle tree	Gum chewing may speed the recovery of bowel function after cystectomy and diversion
Dammar gum, from the	Sap of *Dipterocarpaceae* trees	Gum chewing enhances early recovery from POI after laparoscopic colectomy
Glucomannan	From the konjac plant	Glucomannan is a water-soluble polysaccharide that is considered a dietary fiber. It is a hemicellulose component in the cell walls of some plant species
Mastic gum	Mmastic tree	People use the sap (resin) from the trunk to make medicine and chewing. Mastic is used for stomach and intestinal ulcers, breathing problems, muscle aches, and bacterial and fungal infections. It is also used to improve blood circulation
Psyllium seed husks	From the *Plantago* plant	*Psyllium* is a form of fiber made from the husks of the *P. ovata* plant's seeds, an agent that has laxative effects but secondary to increasing fecal size; a gentler laxative relative to chemical agents like caffeine or *S. alexandrina.* It can bind fatty acid and cholesterol from the diet

(Contd...)

Table 1: *(Continued)*

Types of gum	Plant source	Uses
Spruce gum	Chewing gum of American Indians obtained from spruce trees	Mouth washer, spruce gum is a chewing material made from the resin of spruce trees. Spruce gum is primarily used to heal deep cuts and sores in the dene culture. Used in cancer treatment
Tara gum	Obtained by grinding the endospserm of the seeds of *C. spinosa*	Tara gum is approved as a food a additive by the food chemicals codex and functions mainly as thickener and stabilizer
Natural gums	Produced by bacterial fermentation	
Polyelectrolytes		
Gellan gum	Gellan gum is a gelling agent developed specifically for applications where other gelling agents like agar agar and gelatin are not ideal	There are two types of gellan gum: Gels made with low-acyl gellan gum tend to be brittle and firm, while gels made with high-acyl gellan gum are flexible and elastic, It is used in soy milk to keep the soy protein suspended in the milk. It may help relieve constipation
Uncharged		
Xanthan gum	Xanthan gum is a polysaccharide secreted by the bacterium *X. campestris,* used as a food additive and rheology modifier, commonly used as a food thickening agent (in salad dressings, for example) and a stabilizer (in cosmetic products, for example, to prevent ingredients from separating	Is a great thickener and can also be used to make foams and emulsions
PHGG	Decreases the bioaccessibility of both fat and cholesterol	In the treatment of patients with irritable bowel syndrome, relieves symptoms in constipation-predominant IBS and may have prebiotic properties
M. oleifera gums	*M. oleifera* leaves, gums, roots, flowers as well as kernels have been unanimously	Utilized for managing tissue tenderness, cardiovascular and liver maladies, normalize blood glucose and cholesterol. It has also profound antimicrobial, hypoglycemic and antitubercular activities
Mayonnaise containing polysaccharide gum	*M. flagillepes*	Nutraceutical properties
Gum guggul	Gum resin of *C. wightii*	Ayurvedic medicine (guggul) that is used for the treatment of arthritis, inflammation, obesity, lipid disorders, and cardiovascular diseases
Gum resin	Gum resin of *B. serrata* Roxb	Effective against protozoan human pathogens, namely, *T. brucei* rhodesiense (East African Human Trypanosomiasis, sleeping sickness), *T. cruzi* (Chagas' disease), *L. donovani* (Kala-Azar), and *P. falciparum*
GL	*C. mukul*	Indian Ayurvedic medicinal plant has been used to treat a variety of ailments. It shows anticancer effect mainly against human prostate cancer cells
True gum	*L. salicaria*	It is use as an astringent to stop bleeding and a styptic agent. It also showed pro-coagulant activity of restore factors secreted from blood platelets in blood circulation system
Gum resin	The resin of *Balsamodendron mukul*	Inhibit nitric oxide production in lipopolysaccharide-activated mouse peritoneal macrophages

(Contd...)

Table 1: *(Continued)*

Types of gum	Plant source	Uses
Gum resin	Extract of *B. serrata* (Śallakī) stem bark	Used as a traditional Ayurvedic Medicine in India. It shows antioxidative, and antithrombotic, hemostatic, anti-inflammatory properties and cardiovascular health effects
Nicorette gum	Chew nicorette gum	Can taste the nicotine or feel a tingling sensation in your mouth. Stop chewing and park the piece of Nicorette between your cheek and gums. After about a minute, when the tingling is almost gone, start chewing again can be used for differential diagnosis of chronic oral ulcers
Gum C-GG, and its SGG	Gum	Cancer chemopreventive and anti-inflammatory activity. GG was found to be a potent anti-initiator, where it inhibited not only the carcinogen activator enzyme, CYP1A, but also induced the carcinogen detoxification enzymes GSTs
Cellulose or GG	GG	Effect on cecal enzyme activity and cecal SCFAs in young and aged mice. The effect of cellulose on the microflora between the young and aged mice might be different from the effect of GG
Gum fluoride	Fluoride-treated gum	Oral health promotion and prevention of dental diseases, its is used in toothbrushes and interproximal cleaners
	These components include cellulose, hemicelluloses, pectins, lignin, gums, mucilages and, in certain instances, algal polysaccharides	Early digestion of fiber and quick stool passing after addition of gum in diets exert protective effects in the intestine and others may enhance colon carcinogenesis mainly colonic neoplasia in animals and humans
Nicotine gum	Mixed sources	Helps to quit smoking, in continuous gum users
Semisolid gum	Form a novel nanocomposite in the presence of GA by synchrotron X-ray irradiation in an aqueous solution within 5 min	Formation and assembly of Au-SNPs are promising photothermal agents for cancer treatment at the therapeutic level which show lesser toxicity to tissues and cells
Polysaccharide-based hydrogels	Plant gums	Antitumoral drug release

P. aeruginosa: *Pseudomonas aeruginosa*, GA: Gum arabic, SA: Sodium alginate, CRF: Chronic renal failure, SF: Solka floc, GG: Guar gum, POI: Post-operative ileus, *P. ovate*: *Plantago ovate*, *S. alexandrina*: *Senna alexandrina*, *C. spinosa*: *Caesaplinia spinosa*, *X. campestris*: *Xanthomonas campestris*, IBS: Irritable bowel syndrome, *M. oleifera*: *Moringa oleifera*, *M. flagillepes*: *Mucuna flagillepes*, *C. wightii: Commiphora wightii*, *B. serrate*: *Boswellia serrata*, *T. brucei*: *Trypanosoma brucei, T. cruzi*: *Trypanosoma cruzi*, *L. donovani*: *Leishmania donovani*, *P. falciparum*: *Plasmodium falciparum*, *C. mukul: Commiphora mukul*, *L. salicaria*: *Lythrum salicaria*, *B. mukul*: *Balsamodendron mukul*, GST: Glutathione-S-transferases, SCFA: Short-chain fatty acids, Au-SNPs: Small-size gold nanoparticles

marketing attempts to upgrade it under false names such as "gum Niger" or "dark Nigerian GA No. 2" or actually mixing it with GA. A major disadvantage with gum combretum is its marked tendency to "block" in transit or storage; the separate gum pieces filled into a jute sack convert into a solid mass which has to be broken by pick axe or sledge hammer. This is very different from behavior of GA or other gums which are not so hygroscopic. Greater attention to locating natural production areas for top-quality gum combretum of the palest possible color, complete avoidance of dark red or fire-blackened gum, and marketing strategies aimed at keeping *C. nigricans* gum as a separate entity, well-defined commodity available in uniform supply and constant quality, avoiding at all costs its use to adulterate GA, would lead to greater demand of a larger cash flow.

NUTRACEUTICAL PROPERTIES

Plant gums possess wide nutraceutical properties. A low-fat (LF), mayonnaise containing polysaccharide gum has developed gum of *Acacia drepanolobium* and *Crematogaster mimosa*.[6] Similarly, xanthan gum 15 g/kg, citrus fiber 100 g/kg, and variable concentration of guar gum (GG) were used to formulate the optimum ratios of polysaccharide gums as fat replacers. The fat content in LF mayonnaise was

reduced to 50% if compared with full-fat mayonnaise, and the products still maintained ideal rheological properties.[7] Food industry has also developed a LF mayonnaise containing polysaccharide gums as functional ingredients.[7] Similarly, partially hydrolyzed GG (PHGG) affects bioaccessibility of fat and cholesterol. Depletion flocculation antagonizes the emulsification by bile salts and decreases lipolytic activity that reduces fat and cholesterol absorption.[8] Locust bean gum is also used as a milk thickener to prepare easily digestible infant formula because of its high apparent viscosity. Hence, due to the increased volume of the digest and the bulking and trapping effects, digestion and absorption of nutrients and calcium availability in infant is increased. It also form complexes with iron and zinc.[9] GG increases digestibilities of lipids, starch and total amino acids in broiler chickens. When GG added maize diets increase intestinal viscosities.[10] Water-soluble NSP GG and sodium alginate (SA) increase digestion and show cholesterol-lowering effects in laboratory animals. It also increase total output of fecal bile acids in rats fed on 50 g GG/kg and 50 g SA/kg (59 μmol/7 days versus 24 μmol/7 days for control rats). SA also shows a strong hypocholesterolemic effect in rats which is similar to that of GG, and that this effect is most likely to be mediated through an interruption in the enterohepatic circulation of bile acids.[11] GA after fermentation showed energy losses from volatile and gaseous fermentation products but a less utilizable energy 0-4 kcal/g releases in controlled conditions.[12,13] Gum was extracted from some lesser known tropical legumes - *Afzelia africana*, *Detarium microcarpum*, and *Mucuna flagellipes*. Certain functional properties of gums were derived from some lesser known tropical legumes (*A. africana, D. microcarpum*, and *M. flagellipes*) [Table 1].[14]

GA, a soluble fiber with emulsifying properties, enhances intestinal water and electrolyte absorption in normal and secreting rats. GA promotes lumen to blood intestinal transport of water and sodium despite cholera toxin activation.[15] Polysaccharide gum derived from *Mucuna flagellipes* shows emulsifying and suspending properties [Table 1].[16]

GG is a simple characterized branched polysaccharide, which is frequently used in food industries as food additive. It is a complex polysaccharide, primarily indigestible to both humans and animals, not degraded in the intestine, but fermented in the colon under the influence of microorganisms. GG and Solka Floc cellulose affects food intake, stomach emptying, and fat deposition in male Wistar rats.[17] Plant gum is also act as a gelling agent and is used in canned dog food.[18] Gums/mucilages and other non-starch carbohydrates are of structural significance. The ester bound ferulic acid after oxidation *in vivo* generates reactive oxygen species (ROS) that contribute to the fragmentation of NSPs (hemicelluloses), and thereby reduces the product viscosity.[19] Addition of gum to starch makes it fully digestible, shows plasticizing influence on simple molecules such as water and sugars.[19] Hemicellulase supplementation of guar meal (37.0% protein) affects growth, feed efficiency, and egg production and hemicellulase prevented the sticky droppings.[20] The apparent viscosity of the gums was directly proportional to the gum concentration. Plant gum also contains flavonoids.[21] Fermentation of gums led to more propionate and butyrate production. After seeing nutraceutical properties, soy-soluble polysaccharides and flaxseed gum are used as a source of underutilized dietary fibers in food industry. These soluble fibers modulate postprandial glucose and insulin metabolism and show viscous effects in intestine. Gums are also used in gelled dairy products.[22] Phospholipid fraction (gums) derived from soybeans is rich in phospholipids and contains a free amino group, lowering the tendency of gossypol to bind with lysine. It inactivates the gossypol by converting it into a bound form. Available lysine and protein nutritive value of gossypol increases the quality meal treated with gums.[23] *Prosopis* gum is highly elastic followed by sodium carboxymethylcellulose and forms films of equal consistency without pores.[24]

Polyol-containing gums and sucking xylitol-containing candies stimulate salivary flow.[25] The gum obtained from the ripe seeds of *Prosopis africana* showed higher swelling capacity than methylcellulose. Its acid hydrolysates showed that the gum contains glucose, fructose, galactose, and xylose as the monosaccharide components [Table 1].[26] The galactomannans is obtained from the seeds of *Caesalpinia pulcherrima* and *Cassia javanica*.[27] The presence of galactomannans (<1%) significantly improved the freeze-thaw stability and increase in the gelatinization temperature.[28] Locust bean gum and GG mixing in sago starch increase thermal and rheological properties.[29] Gum of *Acacia* is a good source of energy, protein, and minerals and is utilized by patas monkeys (*Erythrocebus patas*) midsized primates[6] while *Cassia* gum is used as a stabilizer (thickening and gelling agent) in the manufacture of canned pet foods (for cats and dogs). *Cassia* gum is generally recognized as safe under conditions of its intended use as a thickening agent in human and pet foods.[30]

The GG-containing meal shows delay in the passage through the stomach and small intestine is probably due to the viscous nature of the meal resisting the propulsive and mixing effects of the gastrointestinal contractions, thereby reducing access of the glucose to the absorptive epithelium and reduce the glucose level.[31,32] Extracts of myrrh and aloe gums effectively increased glucose tolerance in both normal and diabetic rats.[33] Similarly, addition of purified fiber to carbohydrate test meals has been shown to flatten the glycemic response in both normal and diabetic volunteers, reduce the insulin requirement in patients on the artificial pancreas and in the longer term reduce urinary glucose loss and improve diabetes control. In the context of high-fiber–high-carbohydrate diets, these findings have had a major impact in influencing recommendations for the dietary management of diabetes internationally. The mechanism of action appears in part to be due to the effect of fiber in slowing absorption rather than by increasing colonic losses of carbohydrate. Consequently,

postprandial gastroinhibitory peptide and insulin levels are reduced and the more viscous purified fibers (e.g., guar and pectin) appear most effective. In addition, it has been suggested that colonic fermentation products of fiber may enhance glucose utilization. More recently, it has become clear that many aspects of carbohydrate foods (food form, antinutrients, etc.) in addition to fiber may influence the rate of digestion and has led to a classification, especially of starchy foods in terms of glycemic index to define the degree to which equicarbohydrate portions of different foods raise the blood glucose. The use of such data may maximize the effectiveness of high-carbohydrate and high-fiber diets in the management of diabetes and related disorders.[34] GA contains high-molecular-weight natural polysaccharides which are highly soluble in water. The dissolved solutions of these exudates show viscous behavior and exhibit favorable emulsion stability. These exudates have been widely used not only as a medicinal additive, such as a coating agent for tablets and as an emulsifier and stabilizer in beverage and food products, but also for other industrial applications, such as paints and ink. Gum ghatti was originally used as an alternative to GA due to its similar properties to those found in GA. The gum resin of *Commiphora wightii* is an Ayurvedic medicine for the treatment of arthritis, inflammation, obesity, lipid disorders, and cardiovascular diseases and is known as guggul [Table 1]. The chemical characterization of a commercial *C. wightii* resin is also done for its biochemical profiling and biological activities.[35]

MEDICINAL USES

Plant gums are good source of minerals of calcium, potassium, magnesium, sodium, and phosphorus and is used in the preparation of carob syrup, a herbal medicinal product from *Ceratonia siliqua*.[36] PHGG (with 3% and 6% PHGG) lowers the intestinal uptake of fat and cholesterol and reduces the risk of vascular disease when provided in yogurt drink with 3% sunflower oil and 4% egg yolk. PHGG reduces bioaccessibility of fat and cholesterol through the depletion flocculation mechanism and antagonizes the emulsification by bile salts. It decreases lipolytic activity and reduces fat and cholesterol absorption.[8] GA as fetal hemoglobin inducing agent in sickle cell anemia.[37] Gum exuded from the tree trunk of many plant species including *Acacia* is used as eyewash, to treat infection and irritation. Gum is also used for dermatological purposes including treatment for sores, wounds, burns, chapped fingers, and lips and sunburn. Dietary use of gum is good for stomach ailments mainly to treat diarrhea, stomach inflammation, and system cleansing or to settle the intestines. Plant gum from *Moringa oleifera* is used to cure tissue tenderness, cardiovascular, and liver maladies, and to normalize blood glucose and cholesterol. It has also profound antimicrobial, hypoglycemic, and antitubercular activities.[38] It also shows profound antimicrobial, hypoglycemic, and antitubercular activities.[38] Other uses for mesquite gum include treatment for lice, sore throat, cough, laryngitis, fever reduction, painful gums, and hemorrhoids and it can be used as a purgative nicotine gum as a therapeutic agent in smoking cessation therapy.[39] Gum ghatti has been used as a food additive due to its excellent emulsification properties. Certain types of chewing gums increase oral hygiene and reduce microbial plaque formation,[40] using honeysuckle chewing gum inhibits growth of *Streptococcus mutans*.[41] Yogaraj guggulu, a popular Ayurvedic medicine, increases glucose tolerance in human patients [Table 1].[42]

GA, a water-soluble dietary fiber rich in Ca^{2+}, Mg^{2+}, and K^{+}, is used in Middle Eastern countries for the treatment of patients with chronic kidney disease.[43] GA treatment increases creatinine clearance, enhances renal excretion of antidiuretic hormone, Mg^{2+} and Ca^{2+}, decreases plasma phosphate concentration as well as urinary excretion of phosphate and Na^{+}. In diabetic mice, GA treatment increases urinary Ca^{2+} excretion, and decreases plasma phosphate concentration, plasma urea concentration, urinary flow rate, natriuresis, phosphaturia, glycosuria, proteinuria, as well as blood pressure (BP). GA treatment further favorably influences the course of murine malaria. The effects of GA treatment on plasma phosphate concentration, BP, and proteinuria may prove beneficial in chronic renal failure (CRF) and diabetic nephropathy.[43] The effect of GA on intestinal glucose transport may be useful in the prophylaxis and treatment of obesity and diabetes; the effect of GA on angiogenin and β-catenin expression could be exploited for the prophylaxis against colon carcinoma; and the effects of GA on angiogenin expression and dendritic cells may be useful in the treatment of inflammatory disease and malaria.

Gum Composition

Gum ghatti (*Anogeissus latifolia* Wallich) contains arabinose (34.0-38.0%), galactose (21.0-24.6%), mannose (5.3-7.9%), xylose (0.8-1.2%), rhamnose (0.8-1.2%), and glucuronic acid (15.4-18.6%) as constituent sugars, protein (2.7-3.6%), moisture (4.9-8.3%), and tannin (0.041-0.092%) [Figure 1].[44] All the gums were found to contain D-galactose as a major monosaccharide. D-mannose and D-glucose were found in both *D. microcarpum* and *M. flagellipes* while L-rhamnose in *A. africana*. The gum resin of *C. wightii* contains important compounds 20(S), 21-epoxy-3-oxocholest-4-ene(1), 8 β-hydroxy-3,20-dioxopregn-4,6-diene, and 5-(13' Z-nonadecenyl)resorcinol from the ethyl acetate (EtOAc) soluble part. Plant gum oil consists of oleic, tocopherols, stearic, palmitic, behenic, and arachidic acid. Synthesis of general N-glycan core structures can be done by means of Manβ(1→4) Man peracetate derived from a naturally abundant locust bean gum as a key starting material. Phenyl (2-O-benzyl-4,6-O-benzylidine-β-D-mannopyranosyl)-(1→4)-3,6-di-O-benzyl-2-azido-2-deoxy-1-thio-β-D-glucopyranoside facilitated the synthesis of key intermediates leading to hyperbranched N-glycan core structures.[14] Gum exudates of Indian *Acacia*

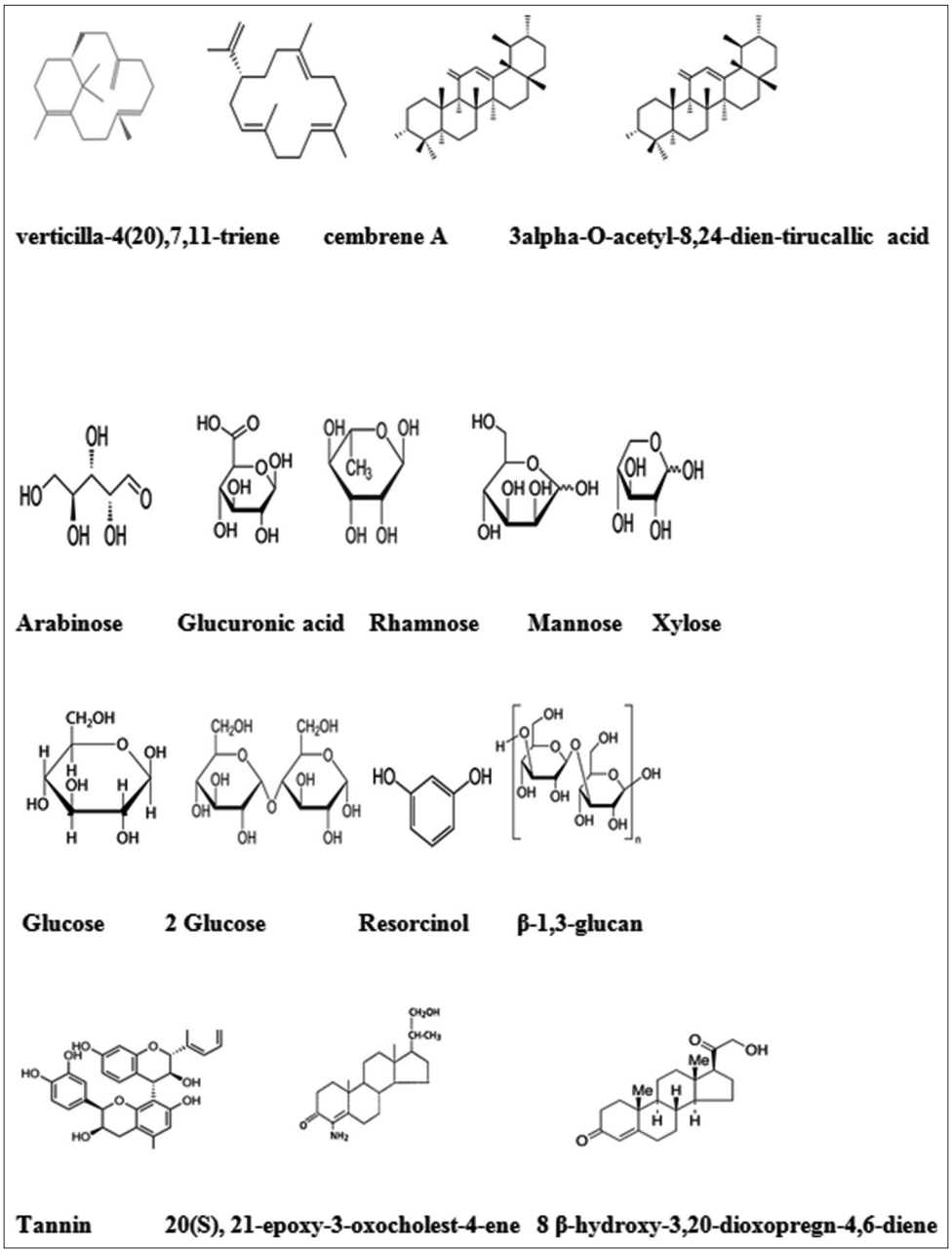

Figure 1: Important bio-organic constituents found in different plant gums

tortilis (Savi) contains 43.6% yield polysaccharides, while monosaccharides, L-arabinose, D-galactose D-glucose, L-rhamnose, and D-mannose are 78.1%, 18.64%, 0.60%, 1.71%, and 0.74% in molar ratio, respectively. Exudate from this plant contains D-galacturonic acid and D-glucuronic as 3.88% and 4.35%.[45] Chitosan-GG-silver nanoparticle-beta glucanase (Ch-GG-AgNPs-βG) beads and Ch-GG-AgNPs-glucose oxidase beads were prepared using β-1,3-glucan from medicinal mushroom *Ganoderma lucidum* during fermentation. Plant gum contains high contents of glucose and β-glucan content can be used for various food preparations with a little modification [Figure 1].[46] Fermentation of GA, a mixture of arabic and guar, and apple pectin resulted in greater short-chain fatty acids (SCFA) production than did fermentation of either oat fiber or corn bran.

PHARMACEUTICAL PROPERTIES

Antitumor Activity

Aromatic gum from *Boswellia carteri* (*Olibanum oleogum*) has long been used in Egyptian traditional medicine.[47] It contains important bioactive compounds, i.e., 3 alpha-O-acetyl-8,24-dien-tirucallic acid, verticilla-4(20),7,11-triene, cembrene A, incensole acetate, and incensole. 3-alpha-O-acetyl-8,24-dien-tirucallic acid and verticilla-4(20),7,11-triene have shown tumor cell proliferation inhibitory effects at 9 µg/mL against Hep-G2 tumor cell line [Figure 1].[47] Gum guar contain compounds with antiulcer, anti-acid/antipeptic, gastroprotective and/or antiulcer properties.[48]

Effect on Concentrations of Urea and Creatinine

GA obtained from *A. senegal* is used in Arabian medicines for treatment of patients with CRF. Providing *Acacia* gum (AG, 10%, w/v) in the drinking water concomitantly with adenine to experimental rats restores CRF and normalizes systolic and diastolic BP and heart rate (HR).[47] Adenine-induced CRF significantly increased the plasma concentrations of urea and creatinine, and reduced creatinine clearance. In addition, it significantly increased both systolic and diastolic BP, with no significant effect on HR)[47] GA shows protecting against renal failure (nephroprotection) and show antioxidant effect and/or anti-inflammatory actions.[47] GA protects against renal failure progression and involve in antioxidant and/or anti-inflammatory activity.[47] Its use in drinking water normalizes plasma concentrations of urea and creatinine (Cr), and Cr clearance, in addition to urinary volume, osmolarity and protein concentrations, and N-acetylglucosamine and lactate dehydrogenase activities.

Effect on Arthritis, Inflammation, Obesity

The gum resin of *C. wightii* ([Hook. ex Stocks] Engl.) is an Ayurvedic medicine (guggul) that is used for the treatment of arthritis, inflammation, obesity, lipid disorders, and cardiovascular diseases. It contains three important compounds 20(S), 21-epoxy-3-oxocholest-4-ene(1), 8 β-hydroxy-3,20-dioxopregn-4,6-diene, and 5-(13' Z-nonadecenyl)resorcinol from the EtOAc soluble part.[35] Few of guggul components were also found in *Mangifera indica* gum, as an adulterant in the commercial guggul sample.[35]

Antiparasitic

Sterculia gum is used to coat ornidazole on poly(vinylpyrrolidone) for its selective release to treat diarrhea.[49] A cembrane-type diterpene serratol isolated from dichloromethane extract of gum resin of *Boswellia serrata* Roxb (*Burseraceae*). It was found active against four protozoan human pathogens, namely, *Trypanosoma brucei* rhodesiense (East African Human Trypanosomiasis, sleeping sickness), *Trypanosoma cruzi* (Chagas' disease), *Leishmania donovani* (Kala-Azar), and *Plasmodium falciparum* (Tropical Malaria) *in vitro* bioassays.[50] It was found active against *T. brucei* and *P. falciparum.* It also showed potential anti-inflammatory and antiprotozoal activity.[50]

Apoptosis Induction

Gugulipid (GL) obtained from extract of Indian Ayurvedic medicinal plant *Commiphora mukul* has been used to treat a variety of ailments. It shows anticancer effect mainly against human prostate cancer cells. Treatment with GL significantly inhibited the viability of human prostate cancer cell line LNCaP (androgen-dependent) and its androgen-independent variant (C81) with an inhibitory concentration 50% (IC_{50}) of ~1 μM (24 h treatment), at pharmacologically relevant concentrations standardized to its major active constituent z-Guggulsterone (z-Gug). The GL-induced growth inhibition also causes apoptosis induction that results in an increase in cytoplasmic histone-associated DNA fragmentation and sub-G(0)/G(1)-DNA fraction, and cleavage of poly(adenosine diphosphate-ribose) polymerase. The GL-induced apoptosis was associated with ROS production and c-Jun NH_2-terminal kinase (JNK) activation. The induction of proapoptotic Bcl-2 family proteins bax and bak and a decrease of antiapoptotic Bcl-2 protein Bcl-2 were observed in GL-treated cells. ROS-dependent apoptosis by GL is regulated by JNK signaling axis.[51] Z-Gug and GL have been used to treat a variety of ailments. These agents target through β-catenin signaling pathway and show GL-induced growth inhibition and apoptosis in human breast cancer.[52]

Blood Coagulant Activity

Lythrum salicaria L. belongs to the small *Lythraceae* family shows worldwide distribution. It is used as an astringent to stop bleeding and a styptic agent.[53,54] It also showed pro-coagulant activity of restore factors secreted from blood platelets in blood circulation system.[55]

Antioxidant Activity

The methanolic extract from guggul-gum resin, the resin of *Balsamodendron mukul*, was found to inhibit nitric oxide production in lipopolysaccharide (LPS)-activated mouse peritoneal macrophages (IC_{50} = 13 μ/mL). From methanolic extract, three new polypodane-type triterpenes, myrrhanol B and myrrhanones B and A acetate, and a new octanordammarane-type triterpene, epimansumbinol, were isolated together with 17 known compounds including progesterone and the related steroids. Many of these constituents showed inhibitory effects on nitric oxide production and induction of inducible nitric oxide synthase.[56] EtOAc extract of *C. wightii* showed cytotoxic due to presence of two ferulates with an unusual skeleton. It also showed moderate free radical scavenging effect against 2,2-diphenyl-1-picrylhydrazyl radicals.[57] Plant derived polyphenols might protect from cancer development through their antioxidant activities. Aqueous extract of carob, gallic acid, and an iron chelator (deferoxamine) significantly reduced the number of human colon cancer HT29 cells.[58]

Hemostatic, Anti-inflammatory, and Cardiovascular

Gum resin extract of *B. serrata* (Śallakī) stem bark is used as a traditional Ayurvedic medicine in India. It shows antioxidative, antithrombotic, hemostatic, anti-inflammatory properties and cardiovascular health effects.[59] Gum resin of *B. serrata* inhibited human monocytic (THP-1) cell activation and platelet aggregation. Addition of dietary fibers decreases

serum cholesterol, triglycerides, increasing the high density lipoprotein cholesterol level, and the management of glycemic indices and obesity.[60] Cholesterol and glucose lowering effects are most often associated with gelling, mucilaginous, and viscous fibers such as GG, an edible thickening agent.[60] Anti-inflammatory effect of gugulipid comparable to nimesulide which suggest potential use of gugulipid in neuroinflammation associated conditions in central nervous system disorders.[61] Tableted GG microspheres of piroxicam directly compressed into matrix tablet and coated with Eudragit S100 are used in targeted adjuvant therapy for colonic adenocarcinomas.[62] Frankincense essential oil obtained from hydrodistillation of *Boswellia sacra* gum resins induces human pancreatic cancer cell death in cultures and in a xenograft murine model. It shows potent anticancer activity in cultured human pancreatic cancer cells.[63]

GA, a nutrient from dried exudate of *A. senegal*, is widely used as emulsifier and stabilizer. It stimulates sodium and water absorption in diarrhea. GA also affect colonic tissue[64] when provided (10% wt/vol) in drinking water. It modifies several tumor-relevant genes and significantly decreased the number of tumors by 70%. GA when provided with nutrients work as good prophylaxis agent against colon carcinoma.[64] Normally, curcumin is used in the treatment of colon cancer, but it shows very poor absorption in the upper part of the gastrointestinal tract (GIT).[65] Curcumin containing polymer (GG)- based matrix tablets are delivered to the colon for effective treatment of colon cancer. As a site for drug delivery, the colon offers a near neutral pH, reduced digestive enzymatic activity, a long transit time and an increased responsiveness to absorption enhancers.[65] Nicorette gum can be used for differential diagnosis of chronic oral ulcers.[66]

Chemopreventive and Anti-inflammatory Activity

Gum C-glycosylated derivative (GG), and its sulfated derivative (SGG), showed cancer chemopreventive and anti-inflammatory activity. GG was found to be a potent anti-initiator, where it inhibited not only the carcinogen activator enzyme, cytochrome P450 1A (CYP1A), but also induced the carcinogen detoxification enzymes glutathione-S-transferases (GSTs), while SGG inhibited both CYP1A and GSTs. SGG was an effective radical scavenger than GG against hydroxyl, peroxyl, and superoxide anion radicals. GG and SGG were found to modulate the macrophage functions into an anti-inflammatory pattern. Both materials enhanced the macrophage proliferation and phagocytosis of fluorescein isothiocyanate-zymosan and inhibited strongly the nitric oxide generation and tumor necrosis factor-alpha secretion in LPS-stimulated RAW macrophage 264.7. There is no doubt that modified gums could be used as an alternative of G in health food industries to provide cancer prevention in risk populations. Gum chewing provides a simple and effective method to improve the post-operative state of patients.[67] A simple chemical modification of the polysaccharides extract (E) derived from *Leucaena leucocephala* seeds was done to prepare C-glycosidic 2-propanol derivative (PE), and its sulfated derivative (SPE). PE acts as a potent anti-inflammatory agent while SPE may act as an inducer of macrophage functions against pathogens.[68] Gum chewing stimulates bowel mobility after surgery for colorectal cancer.

GL, extract of Indian Ayurvedic medicinal plant *C. mukul*, shows anticancer effect mainly against human prostate cancer cells. Treatment with GL significantly inhibited the viability of human prostate cancer cell line LNCaP (androgen-dependent) and its androgen-independent variant (C81) with an IC_{50} of 1 μM (24-h treatment). The GL treatment caused the activation of JNK that functioned upstream of Bax activation in apoptosis response. Moreover, ROS-dependent apoptosis by GL is regulated by JNK signaling axis.[51] Gum guggul is used as a therapeutic agent in the treatment of inflammation, nervous disorders, hyperlipidemia, and associated cardiac disorders such as hypertension and ischemia, skin disorders, cancer, and urinary disorders.[69] It is also used to treat internal tumors, obesity, liver disorders, malignant sores and ulcers, urinary complaints, intestinal worms, leucoderma (vitiligo), sinuses, edema, and sudden paralytic seizures. Oleo gum resin extracted by incision of the bark is a very complex mixture of gum, minerals, essential oils, terpenes, sterols, ferrulates, flavanones, and sterones.[69] It is secreted by *C. mukul*, also known as gum guggul, has been used widely as an Ayurvedic drug. Its active constituents are Z- and E-guggulsterones, which exhibit biological activities by binding to nuclear receptors and modulating the expression of proteins involved in carcinogenic activities. Guggulsterone has been identified as one of the major active components of this gum resin.[70] Guggulsterones have also been reported to regulate gene expression by exhibiting control over other molecular targets including transcription factors such as nuclear factor (NF)-κB, signal transducer and activator of transcription (STAT), and steroid receptors. This steroid also binds to the farnesoid X receptor and modulates expression of proteins with antiapoptotic (IAP1, XIAP, Bfl-1/A1, Bcl-2, cFLIP, and survivin), cell survival, cell proliferation (cyclin D1, c-Myc), angiogenic, and metastatic (matrix metalloproteinase-9, cyclooxygenase 2, vascular endothelial growth factor) activities in tumor cells. Guggulsterone mediates gene expression through regulation of various transcription factors, including NF-kappaB, STAT-3, and CCAAT enhancer binding protein alpha, and various steroid receptors such as androgen receptor and glucocorticoid receptors. Modulation of gene expression by guggulsterone leads to inhibition of cell proliferation, induction of apoptosis, suppression of invasion and abrogation of angiogenesis. Guggulsterone can be used to suppress tumor initiation, promotion, and metastasis.[70]

Clinical Healing Effects

Chewing gums increases saliva production and increase residual secretory capacity than saliva substitutes. It can be used for making an integrated mouth care systems and

oral reservoir devices to solve the problem of xerostomia. Medicated gums available for chewing were found effective in reducing xerostomia, a chronic dry mouth symptom.[71] Medicated gum used in chewing also influences post-operative bowel activity after complete staging surgery for gynecological malignancies and stimulates bowel motility after gastrointestinal surgery.[72] Chewing gum during the post-operative period facilitates the recovery of bowel function and has different efficacy according to operative method used in patients with radical cystectomy. Chewing gum is safe and could be used for post-operative ileus (POI) regardless of the operative method (open radical cystectomy or robot-assisted radical cystectomy).[73]

Gum chewing may speed the recovery of bowel function after cystectomy and diversion. Chewing gum is as an easy and inexpensive way to enhance recovery after surgery.[74] Cigarette smoke contains toxic amounts of acetaldehyde that dissolves in saliva, posing a significant risk of developing oral, laryngeal, and pharyngeal carcinomas. L-cysteine, a non-essential amino acid, can react covalently with carcinogenic acetaldehyde to form a stable, non-toxic 2-methylthiazolidine-4-carboxylic acid. All chewing gums containing cysteine could bind almost the whole of the acetaldehyde in the saliva during smoking. However, elimination of saliva acetaldehyde during smoking does not make smoking completely harmless. Cysteine as a free base would be somewhat better than cysteine hydrochloride due to its slower dissolution rate. Both traditional and direct compression methods to prepare chewing gums can be utilized, and the dose of L-cysteine required is very low (5 mg).[75]

Gum chewing is an inexpensive and physiologic method for stimulating bowel motility. It stimulates gut motility via cephalic-vagal stimulation, and thereby reduces the length of ileus. Gum chewing shows immediate post-operative facilitated recovery from ileus following resection for left-sided colorectal cancer.[76] Gum chewing enhances early recovery from POI after laparoscopic colectomy.[77] It reduces ileus after elective open sigmoid colectomy.[78] Gum chewing should be added as an adjunct treatment in post-operative care because it might contribute to shorter hospital stays.

Gum chewing has been reported to enhance bowel motility and reduce POI. It is a type of sham feeding that aids early recovery from POI and passing stool and length of hospital stay.[79] Nicotine gum failed to significantly reduce smokeless tobacco abstinence effects, although those with high cotinine levels may receive some benefit from nicotine gum. Nicotine chewing gum causes smokeless tobacco cessation.[80] GG is a poor mucoadhesive and lacked sufficient physical integrity for buccal delivery. It is used for sustained release of nicotine.[39] Low levels of nicotine in gum reduce cardiovascular responses and cut down adverse health consequences of smoking.[39] However, it shows symptoms of agitation, lethargy, tachycardia, hypotension, abdominal pain, and vomiting within 30 min of exposure to the gum.[81]

GA causes induction of either microsomal enzyme unrelated to the production of mutagenic aflatoxin metabolites, or of extramicrosomal enzymes in male weanling rat.[82] Painful damaged oral mucosa can be treated by softening, lubricating mouthwashes, or gels prepared from plant gum. Gum constituents can become bioactive saliva substitutes and mouthwashes containing antimicrobial peptides to protect the oral tissues against microbial colonization and to suppress and to cure mucosal and gingival inflammation.[83] The salivary flow increased induced by gum chewing might protect the oral mucosa from lesions due to cancer chemotherapy.[84]

GG is a simple characterized branched polysaccharide and is used in food industries. It also contains soluble dietary fibers which are remnant of plant cells resistant to hydrolysis by human alimentary tract enzymes. These are cellulose, hemicellulose, lignin, pectins, and gums. Intake of dietary fibers or foods rich in dietary fibers decreases the incidence of colorectal carcinoma in populations with diet high in red meat and total fats. Fiber intake is also inversely related to mortality from colorectal carcinoma. Moreover, plant gums, vegetables, and fruits were found inhibitory to colorectal carcinoma due to their fiber contents.[85] Three types of polysaccharides are considered for food purposes, i.e., rhamnogalacturonans (pectins and related gums and mucilages, Type A), acidic arabinogalactans (mainly plant mucilages, gums, and some hemicelluloses, Type B), and neutral glucans and heteroglycans (reserve polysaccharides, Type C) which showed immunomodulatory action.[86] Funoran-containing chewing gum and eucalyptus extract-containing chewing gum showed inhibitory effect of on dental plaque formation.[87]

Effect on Cell Proliferation

Consumption of fermentable (pectin and GG) (0%, 5% or 10% w/w) or nonfermentable (cellulose and lignin) dietary fibers affects cell proliferation in large bowel mucosal crypts of experimental rats. Consumption of fermentable fiber decreased pH in the lumen of the caecum, and glucose, Zn and Cu in serum but increased Ca and Mg in serum. The decrease in cecal pH and serum glucose was significantly correlated with a decrease in midaxial crypt section (MC). Increased intake of the nonfermentable fiber types increased fecal bulk but had no significant correlation with the other measured crypt parameters. Relationships between dietary fiber, aggregate of lymphoid nodules, MC, bioavailability of dietary minerals reduce the chances of initiation of colorectal cancer.[88] Cellulose or GG affects cecal enzyme activity and cecal SCFAs in young and aged mice. The effect of cellulose on the microflora between the young and aged mice might be different from the effect of GG. Beta-glucosidase activity was significantly lower in the aged mice fed the GG diet than in those fed the cellulose diet.[89] GG reduced steroid concentration considerably at all sites of the large intestine, which is consistent with their stool bulking effects. Hence,

multicannulated pig may serve as a useful model of man in chemoprevention studies of colorectal cancer.[90] Cinnamon aldehydes found in cinnamon-flavored gums can incite mucosal alterations at points of contact with the oral mucosa. These alterations may include inflammation and epithelial proliferation, but as a rule, the changes are reversible and promptly resolve when gum-chewing activity makes discontinued.[91]

Oral Health Promotion and Prevention of Carcinoma

Gum is also used in oral health promotion and prevention of dental diseases, if gum fluoride is used in toothbrushes and interproximal cleaners. Other than fluoride preventive agents such as chlorhexidine rinses and xylitol gum they increase risks. Chewing gum or tobacco for 2-3 h after the test meal did not increase N-Nitrosoproline formation or salivary nitrate levels, but salivary nitrite was not taken, chewing tobacco appeared to increase salivary nitrite and nitrate levels. Gum addition reduces the potential production of carcinogenic nitrosamines in the stomach.[92]

Effect on Colorectal Cancer and Colonic Neoplasia

Dietary plant fiber, or plantix, is thought to play a significant role in the pathogenesis of colon cancer in humans. It is a complex polymeric substance that has several distinct components resistant to hydrolysis by the digestive enzymes of humans. These components include cellulose, hemicelluloses, pectins, lignin, gums, mucilages and, in certain instances, algal polysaccharides. Early digestion of fiber and quick stool passing after addition of gum in diets exert protective effects in the intestine and others may enhance colon carcinogenesis mainly colonic neoplasia in animals and humans.[93] Intake of certain amount of dietary fiber reduces the risk of colorectal cancer. In addition, intake of PHGG found useful in promoting bowel movements.[94] Fiber which is associated with high butyrate concentrations in the distal large bowel is protective against large bowel cancer, while-soluble fibers that do not raise distal butyrate concentrations are not protective. Butyrate production from dietary fiber imposes protection against large bowel cancer in a rat model.[95] Thus, butyrate production *in vivo* does bear a significant relationship to suppression of tumor formation. A new delivery system is made for administering salicylic acid for the treatment of *Verruca vulgaris*. Karaya gum patches were treated for wart resolution among volunteers. The cure rate was 69% for warts treated with patches containing salicylic acid, which was significantly higher ($P < 0.01$) than for warts treated with control patches (35%).[96]

Fiber-supplemented diets containing fibers reported to inhibit (wheat bran) or enhance (GG, carrageenan) chemically induced colon carcinogenesis in the rat were selected.[97] GG, in association of dietary fibers show changes in prostanoid contents induced by 1,2-dimethylhydrazine, a carcinogenic agent. For treatment, low doses of aspirin were found effective in the reduction of the risk of fatal colonic cancer. Inhibition of thromboxane B2 synthesis by fiber diet might be involved in the protective effect against the occurrence of colonic cancer.[98] Mainly soluble dietary fibers reduce the adsorption of only highly hydrophobic carcinogens to some insoluble dietary fibers.[99] These also effect colonic cell proliferation in guar- and carrageenan-treated groups.[100] A prolonged glycyrrhizin treatment proved to be effective in modifying the animals' survival pattern.[101] GG matrix tablets release 2-4% of celecoxib (nonsteroidal anti-inflammatory drugs) in the physiological environment of stomach and small intestine.[102] Celecoxib a nonsteroidal anti-inflammatory drugs showed chemo-preventive potential against colorectal cancer after its release. Matrix tablets containing either 20 or 30% of GG are most likely to target celecoxib for local action in the colon.[102] Similarly, GG microspheres containing methotrexate (MTX) are prepared and characterized for local action after release in the colon.[103] GG microspheres were prepared by the emulsification method using glutaraldehyde as a cross-linking agent. MTX-loaded microspheres demonstrated high entrapment efficiency (75.7%). Chewing gum is associated with risk of esophageal and cardia adenocarcinoma[104] with regard to risk of esophageal or cardia adenocarcinoma, gum chewing seems harmless.[104]

USE IN NICOTINE REPLACEMENT THERAPY

Nicotine gum helps to quit smoking, in continuous gum users.[105] It showed significantly more mild side effects than those who used gum intermittently.[106] The use of nicotine gum shows smoking cessation interventions.[107] In smokers, to stop smoking, gum-loaded drugs can be provided for effective increase in cessation rates. It also needs supportive and positive atmosphere with accurate information on withdrawal, weight gain, and nicotine gum should be offered and systematic follow-up.[108]

Effect on Digestion

GG affects colonic microbial fermentation and cancer development. When azoxymethane-treated rats were fed a partially hydrolyzed guar or control diet, they have shown inhibition of colonic neoplasia. Dietary addition of hydrolyzed guar is associated with fecal fermentation low in propionate and high in butyrate; SCFA concentrations greater in proximal part than distal. Butyrate protects against colonic neoplasia, whereas propionate enhances it, and demonstrates that colonic microbiota adapt to produce more butyrate if given time and the proper substrate.[108] Plant gum is also used to prepare mouthwash solutions with antibacterial constituents. It reduces nitrate into nitrite in the oral cavity. The use of a pH-regulating chewing gum resulted in a rise

in the pH in the oral cavity from 6.8 to 7.3. It also makes significant increase in the salivary nitrite concentration, which might be explained by the pH being close to the optimal pH for nitrate reductase.[110] Tragacanth gum when added to the diet it reduces the chances of preneoplastic or neoplastic lesion.[111] Dietary fiber supplementation with 10% pectin or with 10% GG fed during the promotional stage of carcinogenesis was found to suppress colon cancer.[112]

Regular use of GG results in hypoglycemia with prolonged postprandial symptoms.[113] The use of tobacco products or nicotine chewing gum reduces lung cancer risk in non-smokers.[114] GA is used to fight against schistosomiasis and cancer of the bladder[115] while nicotine chewing gum has shown some efficacy in helping well-motivated, nicotine-dependent smokers quit smoking.[116] Nicotine gum is used as a therapeutic agent in smoking cessation therapy.[39] Nicotine replacement therapy is efficacious and doubles the odds of permanently abstain from smoking.[117] Diets containing 25,000 (2.5%) or 50,000 ppm (5.0%) agar, GG, GA, locust-bean gum or tara gum were fed to groups of 50 male and 50 female F344 rats and B6C3F1 mice for 103 weeks. None of the five polysaccharides was carcinogenic for experimental either sex.[118] When 2% safflower oil plus 21.5% safflower or fish oil and 10% cellulose or GG was provided to experimental rats for 4 weeks, they have shown higher release of cecal bile acids and free fatty acids in rats fed GG than in rats fed cellulose.[119]

USE OF GUM IN DEVELOPMENT OF DRUG DELIVERY

For tumor therapeutics, gold nanoparticles (AuNPs) are used to eradicate tumors by means of heat production for photothermal therapy. However, a simple strategy is developed for simultaneous formation and assembly of small-size AuNPs (Au-SNPs) to form a novel nanocomposite in the presence of GA by synchrotron X-ray irradiation in an aqueous solution within 5 min. This novel gold nanocomposite can be promising photothermal agents for cancer treatment at the therapeutic level which show lesser toxicity to tissues and cells.[120] Similarly, surface modified GG NPs (GGNP) have been made by using folic acid (FA) charged with MTX target the colorectal carcinoma. The MTX loaded FA functionalized GGNP (MTX-FA-GGNP) have been prepared by emulsion crosslinking method. The NPs have been found to have average size of 325 nm in diameter having polydispersity index 0.177 indicating mono-disperse particles. The MTX-GGNP protects the release of MTX in upper GIT while maximum release of MTX occurred in simulated colonic fluids of pH 6.8. These NPs successfully release the drug at target site mainly colon colorectal carcinoma. This is better localized and targeted with improved therapy due to over-expression of folate receptors.[121] Similarly, natural polysaccharides are used in drug delivery mainly for treatment of treatment of breast cancer. Tamoxifen citrate (TMX) (a non-steroidal antiestrogenic drug) loaded GGNPs, GGNPs were synthesized after crosslinked with glutaraldehyde[122] and biodegradable NPs. The release of TMX from GGNPs was found to be effected by GG and glutaraldehyde concentration. Thus, controlled release of TMX from GGNPs could be a potential alternative pharmaceutical formulation in passive targeting of TMX in breast cancer treatments.[122]

Green tea polyphenol epigallocatechin-3-gallate was incorporated into a carbohydrate matrix of GA and maltodextrin with an encapsulation efficiency of approximately 85% is also used against colon cancer.[123] Polysaccharide NPs are used to deliver natural antioxidants capable of inhibiting steps of the tumorigenesis process for its chemoprevention.[123] GA glycoprotein -functionalized AuNPs possess optimum sizes (12-18 nm core diameter and 85 nm hydrodynamic diameters) that target individual tumor cells and penetrate through tumor vasculature and pores. These NP GA-198AuNPs are biocompatible and show high tumor affinity in severely compromised immunodeficient mice bearing human prostate tumor xenografts. Intratumoral administration of a single dose of beta-emitting GA-198AuNPs (70 Gy) resulted in clinically significant tumor regression and effective control in the growth of prostate tumors over 30 days.[124]

GA-coated magnetic NPs are used in simultaneous magnetic targeting and tumor imaging.[125] Magnetic iron oxide NPs (MNP) coated with GA, a biocompatible phytochemical glycoprotein widely used in the food industry. GA-coated MNP (GA-MNP) displayed a narrow hydrodynamic particle size, i.e., about 100 nm; a GA content of 15.6% by dry weight; a saturation magnetization of 93.1 EMU/g Fe; and a superparamagnetic behavior essential for most magnetic-mediated applications. The GA coating offers two major benefits: It enhances colloidal stability and provides reactive functional groups suitable for coupling of bioactive compounds. These GA-MNP NPs could potentially be employed to achieve simultaneous tumor imaging and targeted intra-tumoral drug delivery.[125] However, for site-specific delivery of 5-fluorouracil to the colon GG acts as a carrier. Intravenous administration of 5-fluorouracil for colon cancer therapy produces severe systemic side-effects due to its cytotoxic effect on normal cells.[102]

For therapeutic purposes, biocompatible GA-stabilized gold nanocrystals (GA-AuNPs) were prepared and used as X-ray contrast agent in tumor bearing mice and dog. Single intratumoral injections of GA-AuNP resulted in X-ray contrast change of −26 HU in the tumor region after 1 h post-injection period.[126] Similarly, natural biodegradable polymers mainly polysaccharide systems are made with minimal chemical modification. These colon-targeted delivery systems contain bioactives and are used for therapy of colon-based diseases.[127] These polysaccharide based encapsulation and targeted delivery systems are envisaged to have an immense potential for the development of food/nutraceutical formulations for colon-based diseases, including colorectal

cancer.[127] Similarly, a new formulation containing chemically crosslinked GG microspheres loaded with 5-fluorouracil is made for targeting colorectal cancer. The emulsification polymerization method involving the dispersion of aqueous phase of GG in castor oil was used to prepare spherical microspheres.[127] GG-based matrix tablets of rofecoxib were prepared for their intended use in the chemoprevention of colorectal cancer. Matrix tablets containing 40% (RXL-40), 50% (RXL-50), 60% (RXL-60), or 70% (RXL-70) of GG were prepared by wet granulation technique. These are subjected to *in vitro* drug release. GG matrix tablets released only 5-12% of rofecoxib in the physiological environment of stomach and small intestine. This slow release also makes slow absorption of the drug and making it available for local action in human colon.[128] Polysaccharide based hydrogels are also prepared to achieve antitumoral drug release.[129] The achievement of electrochemotherapy was obtained using electrodes covered with GG hydrogel swollen in a sulfate bleomycin solution. The bleomycin delivery into the plasma membranes of cancer cells occurs only when field strength (V/cm) was applied, decreasing the drug contact with healthy tissues. The delivered bleomycin concentrations caused bigger cellular mortality of the tumoral mouse fibroblast NIH3T3 compared with endothelial cells.[130]

CONCLUSION

Plant gums are water soluble, NSPs obtained from plants and other sources. Certain hydrophobic substances, such as chicle and resinous saps, are also called gums. Plant gums are adhesive substances that are carbohydrates in nature and are usually produced as exudates from the bark of trees or shrubs. Gums are formed from the breakdown of cellulose in the plant cell-walls, normally when they are damaged. Gum acacia is usually used to modify the physical properties of foods. It causes cholesterol reduction at a dose of 15 g/day. Gums are formed from the breakdown of cellulose in the plant cell-walls, normally when they are damaged. Plant gums are used primarily to thicken or gel aqueous systems and to control water. These components show lipid-lowering effects, anti-biotic, anti-shistosomiasis, anti-inflammatory, antidiabetic, antitumor, antioxidant and larvicidal activity. GG is a simple characterized branched polysaccharide, which is frequently used in food industries. This is also used as adhesives, crystallization inhibitors, emulsifying agents, emulsion stabilizers, encapsulating agents, film formers, foam stabilizers, suspending agents, suspension stabilizers or syneresis inhibitors and imparts other specific properties. Plant gums are high in demand in food, pharmaceutical, paper textile and other industries. Among food utilizable gums are categorized as food and non-food items, industrially these are technological grade. Gums are used as solidifiers and can be used as food additives in various kinds of confectioneries, foods and beverages. GG affects colonic microbial fermentation and cancer development. It is used in preparations of hydrocolloids and transfer of antitumoral drug release. These polysaccharide based encapsulation and targeted delivery systems are envisaged to have an immense potential for the development of food/nutraceutical formulations for colon-based diseases, including colorectal cancer. A new formulation containing chemically crosslinked GG microspheres loaded with 5-fluorouracil is made for targeting colorectal cancer. The emulsification polymerization method involving the dispersion of aqueous phase of GG in castor oil was used to prepare spherical microspheres GA is used to fight against schistosomiasis and cancer of the bladder. GG also used in hypoglycemia with prolonged symptoms after immediate hyperglycemia, nicotine gum to quit smoking. Matrix tablets containing various proportions of GG were prepared by wet granulation technique using starch paste as a binder. Gum C-GG, and its SGG, showed cancer chemo-preventive and anti-inflammatory properties.

Many higher plants produce economically important gums which can be largely used for preparation of pharmaceuticals, and pesticides. These can be processed to obtain carbohydrates and making nutrient supplement to the culturing plant cells and tissues. Further, new technologies that may extend and enhance the usefulness of plants as renewable resources of valuable chemicals can be discovered. There is no doubt in the future that plant gums may be major group of biologically active plant-derived chemicals that can be expected to play an increasingly significant role in the commercial development of new products. Cholera toxin-induced secretion in rats is reduced by a soluble fiber, GA. Mycotoxins can be detected by using antibody-immobilized conducting polymer-supported electrochemically polymerized AG.[131] This increase in detection efficiency is due to the presence of glycan functional groups in AG molecules that supported the retention of activity of antibodies.[131] After so much work was done on economic aspects of plant gums but therapeutic properties are not so far explored in large. However, new sources of commercially valuable plant gums are to be discovered.

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