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Research Article

Novel Approaches for Encapsulation of Plant Probiotic Bacteria with Sustainable Polymer Gums: Application in the Management of Pests and Diseases

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The unique attributes, biodegradability, biocompatibility, perfect accessibility, and low production costs led to the use of natural gums in a different section of our lives. Among them, we can mention gums obtained from microorganisms (xanthan gum and gellan gum), plant tissues (Arabic gum and gum tragacanth), seeds (konjac gum and guar gum), seaweeds (alginates, agar gum, and carrageenans). Gums have essential applications in the medical and pharmaceutical, food, biotechnology, and critical agricultural industries. Encapsulation is one of the new methods to increase the stability of bioactive compounds during processing and storage. Encapsulation technology using natural gums is a new way to improve the performance of microbial agents in various sciences, especially agriculture, which represents a bright future in this field.

1. Introduction

Plant exudates are substances secreted from crevices in the trunks and branches of plants that harden in the air and have applications in various industries [1]. These substances are sometimes secreted naturally (due to mechanical damage, insect damage, or disease) and mainly by human intervention (razor and wound the plant). Many people are surprised to see the plant sap leaking out and worry about the tree's health. You may be watching the plant's juice; you may think about what this substance is? The liquid of wood cells is primarily collected from water and contains hormones, minerals, and nutrients. The liquid of phloem cells is mainly composed of water plus some sugar, hormones, and minerals dissolved. The plant's liquid flows through the tree's bark, producing carbon dioxide. Sometimes this carbon dioxide increases the pressure inside the tree. Figure 1 shows the secretion of gum from trees. In this case, if there is a wound or pore in the tree's bark, this pressure will eventually apply a force to the sap that will cause it to leak out. Leakage of tree gum may also be related to temperature. While many trees are still dormant in early spring, temperature fluctuations may affect sap flow inside the tree. For example, in warmer climates, pressure is created inside the tree. This pressure sometimes causes sap tissue to flow out of the pores or cracks in the tree. When the temperature drops below freezing in cold weather, the tree draws water through the roots and replenishes the lost sap. This cycle continues until the air is stable and perfectly normal. Sometimes trees suffer from blistering or abnormal

Figure 1: Tree with gum exudates.

and undesirable sap exudation. Abnormal discharge of tree sap may be due to various diseases such as fungal diseases, pests, or other diseases. On average, however, the tree usually does not secrete gum unless it is damaged.

The most crucial plant secretions are gums, resins, and manna. Of course, oils, latexes, waxes, and mucilage are also classified as plant extracts with less than the first three industrial applications. Gums are a large group of polysaccharide compounds that dissolve quickly in water and produce high viscosity. Gums are widely used in the food, pharmaceutical, and agricultural industries to make gels and stabilizers (Table 1). Tragacanth, gum Arabic, xanthan, guar, carrageenan gum, Karya, and anzaroot are plant gums, the most common of which include Arabic gum and tragacanth gum [2, 3].

Resins are a group of plant secretions composed of terpenoid or phenolic compounds that are mostly insoluble in water but easily soluble in alcohol, ether, and chloroform. These compounds are slightly sticky and usually have a pungent odor, making them suitable for use in the perfume industry.

Manna is the sweet-smelling secretion of a plant that, due to the nutritional activity of some insects on the young organs of plants, has a unique effect on the outside of your body and tissues. Certain, insects suck the sap, and after digesting and absorbing the substances they need, they expel the excess sugar and other sap substances that they do not need out of their body. Unlike other plant secretions, manna is not directly obtained from the plant [1].

2. Some Natural Gums Used in Encapsulation

2.1. Arabic Gum or Acacia. Arabic gum is the oldest and best-known natural gum secreted and obtained from the stems and branches of *Acacia senegal* or *Acacia seyal* (legumes group) (Figure 2). After collection, the gum can be further broken down and be processed [2]. Arabic gum is a natural source of fiber, mineral salts, and carbohydrates. It is water-soluble and contains potassium, magnesium, calcium, and carbohydrates called arabinose and galactose.

Arabic gum is a complex combination of glycoproteins and polysaccharides and is primarily used in the food industry as a stabilizer. Arabic gum is widely used as a source of soluble fiber in diet drinks [4]. This gum is mainly used in the confectionery industry and is also used as a thickener and emulsifier in the beverage industry [5]. Arabic gum used to be widely used in the pharmaceutical industry to fortify tablets. Still, it has been replaced by cellulose and modified starches in the pharmaceutical industry. Of course, Arabic gum is still used to concentrate some syrups [6]. Today, gums are widely used in the modern agricultural industry to produce microcapsules containing bacteria. To evaluate the quality of gum Arabic, parameters such as color, viscosity, pH, moisture and ash content, tannins, and concentrations of other metals are used [7]. Minerals such as calcium, potassium, sodium, phosphorus, copper, zinc, lead, cadmium, manganese, chromium, and nickel are found in gum Arabic. The solution of this gum also has high concentrations of Ca^{2+}, Mg^{2+}, and K^{+} [8]. Arabic gum acts as a reducing and oxidizing agent, so it is vital for the molecular functionalization of nanomaterials. The function of this biopolymer improves stability, pathogen detection, elimination of toxicity, and better dispersion of nanoparticles in water [9]. For example, magnetite nanoparticles (one of the iron oxides) were encapsulated in Arabic gum to increase the agent's stability [9]. Because gold nanoparticles (AuNPs) are resistant to oxidation, nanoparticles containing AuNP are now depleted due to toxicity [10].

2.2. Tragacanth Gum. Tragacanth gum (Figure 3), like Arabic gum, has an ancient history that is a dry exudate from the stems and branches of *Astragalus gummifer* (and other Asian species of *Astragalus* (legumes group)) [2].

The secretion of tragacanth gum is caused by injuring (pruning) various plants that are collected after drying. Tragacanth, when dissolved in water, forms a thick, sticky solution. This product is one of the most resistant gums to acid, especially in high viscosities in the range of 2 pH to 10. This makes it widely used in the pharmaceutical, food, and agricultural industries. It is also an excellent emulsion agent for oil-in-water emulsions [11].

2.3. Gellan Gum. One of the extracellular polysaccharides secreted by *Pseudomonas elodea* is gellan gum. Gellan is

Table 1: Molecular structure and origin of Arabic gum, tragacanth gum, xanthan gum, guar gum, carrageenan gum, and the source.

Polysaccharide	Structure	Origin	Source
Arabic gum	Compact and complex	*Acacia senegal*	[21]
Tragacanth gum	Circular	*Astragalus gummifer*	[2]
Xanthan gum	Helical	*Xanthomonas campestris*	[22]
Guar gum	Linear	*Cyamopsis tetragonolobaII*	[21]
Carrageenan gum	Helical	*Red seaweeds (Rhodophyceae)*	[23]

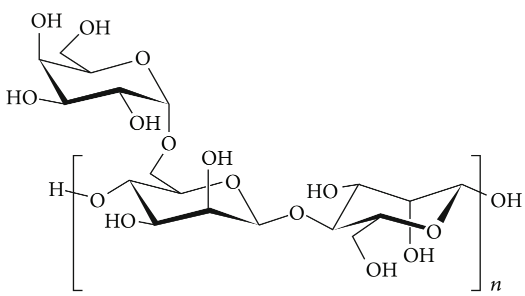

Figure 2: Arabic gum structure.

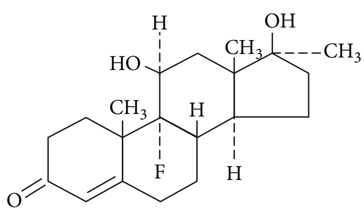

Figure 3: Tragacanth gum structure.

produced commercially by a fermentation process and is a linear, anionic exopolysaccharide, with the repeating unit containing D-glucose, D-glucuronate, and a-L-rhamnose (Figure 4) [12]. The form of gellan gum has two types of acyl substituents, namely, acetyl and L-glyceryl [13]. It is a good substitution for other gelling agents because it is efficient in minimal amounts and creates a clear gel that is not susceptible to heat. It is used to stabilize, bind, or texturize processed foods in the food industry. Gellan gum has applications in various foods, including confectioneries, fruit and vegetable products, sauces and spreads, beverages, and packaged foods. Specific gelling attributes in various sciences led to the development of controlled-release formulation based on gellan. Different formulations have been studied, including ophthalmic, oral, and nasal. Recent reports showed that gellan-based materials could also be used in medicine, food, and agriculture sciences [12].

2.4. Xanthan Gum. Xanthan gum is produced using various compounds and inexpensive nutrients such as whey, sugarcane molasses, and sucrose. Xanthan gum is the first new generation of extracellular polymorphism in biotechnology produced by bacteria like *Xanthomonas campestris* [15]. The constituent units of this gum are glucose, mannose, and di-glucuronic acid (Figure 5). Despite having high molecular weight, this gum dissolves easily in hot and cold water and, even in small amounts, produces a very concentrated solution. As a result of stirring, its viscosity decreases. Changes in the pH of the pewter have little effect on it. The gum is used in many industries, including chemicals, petroleum products, and cosmetics [14]. This gum is used in various beverages, canned food, and frozen foods [15]. Factors such as pH, temperature, high pressure, carbon sources, the effect of polymer concentration, and the development of salts and viscosity in the presence of galactomannan are influential in the production of xanthan gum [16]. Various compounds and inexpensive nutrients are used to produce xanthan gum, such as whey, sugarcane molasses, and sucrose as a source of carbohydrates and ammonium and nitrate, yeast extract, and soy as a source of nitrogen [17, 18].

2.5. Carrageenan Gum. Carrageenan gum is a polysaccharide with low molecular weight (16-44 kDa) containing ions of various metals, including K+, Na+, Ca2+, and Mg2+, and polysaccharide-protein in gum gives it emulsifying properties (Figure 6) [19]. Carrageenan gum from (*Anacardium occidentale* L.) is secreted [20]. This gum is dissolved at room temperature; however, heating it improves its dissolution. Carrageenan gum can be an excellent alternative to Arabic gum. However, almond gum is a perfect emulsifying agent [19].

3. Encapsulation

Encapsulation involves placing and combining nutrients, cells, enzymes, natural polymers, and other materials in tiny capsules made from proteins, natural and modified polysaccharides, lipids, synthetic polymers, alginates, and starches. Applications of this method in addition to food and pharmaceutical industries are also increasing in the agricultural sector because the encapsulated materials can be protected against environmental conditions such as heat, cold, humidity, or other conditions. Therefore, this method increases their stability and long-term durability.

Early microcapsules made about 30 years ago were impermeable and often broken by mechanical agents [24]. Two other scientists, Seiss and Divies [24], suggested using this bacterial encapsulation in yoghurt.

Forms of encapsulation can include simple membrane coating, spherical or irregular coating, and multilayer coating with different compositions.

3.1. Materials of Encapsulation. Another ingredient used in the coating of capsules is starch from potatoes, wheat, rice, corn, and its derivatives. Alginate is another available and

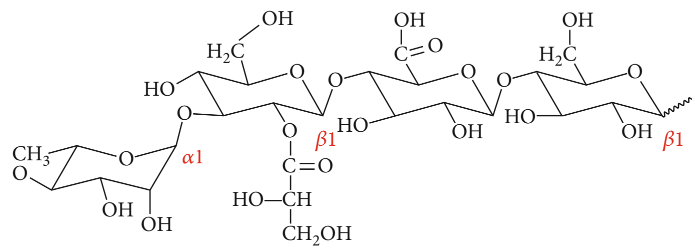

Figure 4: The structure of gellan gum.

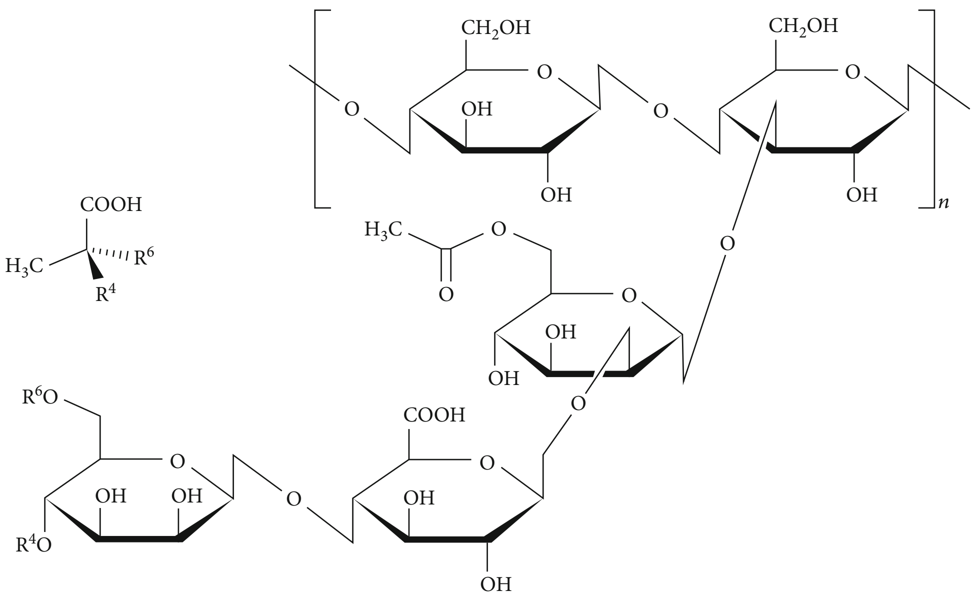

Figure 5: Xanthan gum structure.

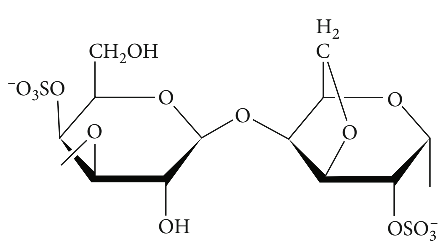

Figure 6: Carrageenan structure.

inexpensive compound used in tablets that are extracted from brown algae and can produce stable gels by reacting with calcium ions [25–27]. Protein-containing compounds and substances such as soy protein, polypeptide, gelatin derivatives, and milk derivatives can form stable emulsions with volatile flavors and high water solubility [28].

3.2. Encapsulation Techniques. Different methods and techniques are used to create a capsule; here is a name and a brief description of the tasks of each.

Spray dryer drying, spray cooling, fluidized bed coating, extrusion method, centrifugal extrusion, coagulation, complexation, liposome entrapment, and rotational suspension separation are some of such techniques. [29]. Emulsion, extrusion, and spray dryer are more critical among these methods.

3.2.1. Extrusion Technique. The extrusion technique is one of the most straightforward and efficient methods for encapsulating bacterial compounds. Encapsulation by the extrusion method applies high pressure to the core and coating materials [30]. One of the advantages of this method is its oxidation resistance. The internal pores of the extrusion machine pump the material in the core, which can be suspended bacteria, while the outer pores of the device pump the wall compounds to create an extruded rod of core material and wall covering and, finally, particles [31]. For example, the extrusion method encapsulated *Bacillus subtilis* Vru1 with ALG-bentonite. The results showed that this type of formulation could control *Rhizoctonia solani* root rot disease [32]. Alginate and Arabic gum were used as wall materials for encapsulation of *Streptomyces fulvissimus* Uts22 by extrusion technique; the results indicated that this formulation has a high ability to control *Pythium aphanidermatum* in cucumber [33]. A team of researchers used the extrusion method to encapsulate *Raoultella planticola* Rs-2 with alginate and bentonite. This formulation is interesting as it facilitates biofertilizer production with reduced costs [34].

3.2.2. Emulsion Method. In various industries such as food, pharmaceutical, and agricultural sectors, materials and compounds with high solubility in water are usually used to produce functional compounds. However, water-in-oil emulsions are more commonly used to produce microcapsules [35]. In this method, small amounts of biopolymer suspensions such as gum Arabic, ALG, or gelatin and some pure oils are mixed. The size of the microcapsules obtained in the emulsion method varies greatly depending on the type of emulsion produced and the stirring speed. For example, for encapsulation of *Pseudomonas fluorescens* VUPF5 by emulsion method, alginate with soybean oil has been used [25]. Tu et al. (2015) prepared bacterial formulation by encapsulation technology. In this research, alginate and gelatin were used for wall materials to encapsulate *Bacillus subtilis* SL-13 by emulsification method [36].

3.2.3. Spray-Drying Technique. Drying with a spray dryer is the most common method of producing encapsulated compounds, especially for encapsulating bacteria and fungi [37]. This device increases the speed of work and preparation of microcapsules. The size of the obtained particles is the same and small. It can adjust the temperature, especially for living organisms and bacteria that are sensitive to heat. It is also an economical technique [38]. Other advantages of using this method include the high produced capsules, high stability, and fast solubility [39]. For example, microencapsulation of chitosan-glean gum with *Streptomyces fulvissimus* Uts22 showed that after two months of microcapsule storage, the bacterial population was approximately 10^8 CFU g^{-1} [39]. The spring dryer method is an economical and effective technique for protecting materials. It is mostly used in the food industry to encapsulate flavors and prepare substances such as powdered milk. Campos et al. (2014) reported the *Enterobacter* sp. encapsulated using sodium alginate and maltodextrin, and the bacterial survival was 91% after spray drying (outlet temperature of 65°C and inlet temperature of 100°C) [40]. The spray-drying method was used to encapsulate *Collimonas arenae* Cal35 as an antifungal bacterium in an alginate matrix. The results showed that this bacterium maintained its antifungal activity after spray drying [41].

To control the loss of *Plutella xylostella*, *Bacillus cereus* was encapsulated with gelatin polymer and gum Arabic using the spray dryer technique. The formulation particles maintained their stability during the exposure period and controlled the population decline to 75% [42]. Also, to control *Aedes aegypti*, encapsulation of oil, cashew gum, and chitosan polymer with *Bacillus cereus* bacterium was used by spray dryer technique, and this formulation was able to control the drop in population up to 70% of the pest population after 72 hours [43]. Warehousing pests cause a lot of damage to food products every year. The use of chemical toxins causes poisoning of products as well as consumers. One of the new and efficient solutions is to use bacteria encapsulation and natural polymers to eliminate these pests. For example, the use of gum Arabic with polymer chitosan and bacteria of the *Bacillus* group such as *Bacillus cereus* in the form of encapsulation prepared by spray method was used against the decline of *Tribolium castaneum* and was able to reduce this decline by up to 80% of the population [44].

3.3. Methods of the Release of Ingredients from Capsules. The release of compounds can be diffused through the capsule wall or make a membrane that covers the wall. The membrane's permeability also controls the compounds, and the capsule wall's solubility affects the diffusion rate. The compounds released must be soluble in the capsule coating. That is why choosing the right cover is so important. Morphology, chemical nature, and transfer temperature can affect diffusion. However, the choice of capsule coating is minimal due to the safety of core compounds, including food, bacteria, and other compounds. The best-controlled-release method is to mix the material with a solvent. Other release mechanisms include the melting of the capsule wall, which is made up of lipids or waxes, yeasts, salts, nutrients, and flavorings. Low-viscosity capsule coatings also perform better for release [29].

However, due to the slow release of compounds into the capsule, the produced microcapsules can be exposed to weather and environmental conditions for a more extended period and impact bacteria from inside the capsule.

Disadvantages of encapsulation include limitations in encapsulation production techniques, costs, and shortage of required materials. However, much research is needed to overcome these limitations. For example, malt dextrin with starch and Arabic gum with starch is very beneficial as encapsulation materials [45].

Recent advances in micro-/nanotechnology in producing more efficient formulations have overcome some of the obstacles and problems in this field, such as the formulation's instability and loss of bacterial activity against pests. One of the compounds used to prepare capsules is plant gums, which have been considered due to their abundant availability and cost-effectiveness [46].

4. The Use of Gums in the Control of Plant Diseases and Pests

One of the most widely used bacteria in encapsulations is *Bacillus thuringiensis*, which has a special place in pest management and crop production due to its many advantages, such as its specific effect on pests and low cost of production, high pathogenicity, and ease of use. It is healthy and organic (Table 2). Also, as a nature lover, it does not hurt the environment, and it is beneficial for insects and humans.

Spodoptera exigua (Lepidoptera: Noctuidae) is one of the most important pests of sugar beet, which causes a lot of damage every year. A formulation based on *Bacillus thuringiensis* (BT) bacterium with a population of 8.1×10^{-11} (CFU) g was produced with Arabic gum and starch [37]. The final product is a dry powder with a particle size of about 13 micrometers and moisture of 7.29% produced by the spray device. The formulation prepared against the larvae of the second generation of the pest, which is the harmful stage, was used for seven and 14 days and was examined. The results showed that the mortality rate compared to the control plant was 75.65% on the seventh day and 86.09%

Table 2: Use of different gums and polymers to encapsulate other bacteria against pests.

Gum	Bacteria	Pest	Reference
Arabic gum-starch	*Bacillus thuringiensis*	*Spodoptera exigua*	[40]
Arabic gum-gelatin	*Bacillus thuringiensis*	*Popillia japonica*	[40]
Gum Arabic	*Bacillus thuringiensis*	*Helicoverpa armigera*	[47]
Arabic gum-gelatin	*Bacillus thuringiensis*	*Oryzaephilus surinamensis*	[49]
Arabic gum-chitosan-sodium casein	*Pseudomonas* spp.	*Tetranychus urticae*	[30]
Arabic gum-chitosan	*Pseudomonas putida*	*Bemisia tabaci*	[30]
Arabic gum -chitosan	*Pseudomonas putida*	*Helicoverpa armigera*	[50]
Arabic gum and chitosan	*Pseudomonas putida*	*Myzus persicae*	[50]

on the fourteenth day. In general, this encapsulation affected 87% of the biological activity of the larvae [40].

To fight *Popillia japonica* (Coleoptera: Scarabaeidae) in 2018, Xin et al. encapsulated BT bacteria along with Arabic gum and gelatin and used it against adult insects on the bean plant. In this encapsulation process, parameters considered pH, temperature, and concentration of gelatin and Arabic gum were evaluated after optimization of microcapsules. The population of BT bacteria in this formulation is 10^{-9} CFU/mL^{-1}, and the output of the formulation from the powder spray dryer is the size of particles 12.7 μm through which the results of SEM are obtained. Despite this encapsulation, the mortality rate of adult insects was about 88% [40].

Another microencapsulation produced for pest control is the encapsulation of chitosan polymer with Arabic gum and BT bacteria, which was studied against larvae of *Helicoverpa armigera* (Lepidoptera: Noctuidae) on cotton [47]. The particle size obtained by the spray dryer is 32 nm, and the results show that even the use of this encapsulation in low doses has significantly reduced the larval population. Due to the capsule coating around the bacterium, BT bacteria have been available to the insect for a more extended period. When the microcapsules enter the larval gastrointestinal tract, it causes the inactivity of the proteins in the gastrointestinal tract and is not digested, and the larvae are killed [48].

One study used encapsulation of BT bacteria with gelatin and Arabic gum to control *Oryzaephilus surinamensis* (Coleoptera: Silvanidae) on peanut seeds. Insect morphology, encapsulation efficiency, and shelf life of the compounds were formulated at 25°C on 30-day-old peanut seeds. The particle size obtained from the spray dryer was 22 μm, and they were able to kill about 80% of adult insects [49].

Tetranychus urticae mites (Trombidiformes: Tetranychidae) cause extensive annual damage to summer crops and greenhouses by laying leaves on car leaves and sucking on cellular contents, destroying the green epidermis of the leaves and leaving small pale spots or sores. In 2018, Oliveira and her colleagues developed a formulation that can be used to control tick damage. This formulation containing chitosan polymer, Arabic gum, sodium casein, and *Pseudomonas* spp. was prepared by encapsulation method and used against adult mites on tomato and pepper plants. The shape of the prepared capsules is spherical, and the diameter between them was 145 nm, and this microencapsulation reduced the activity of ticks and spawning of the female. Experiments have shown a 90% effect on insect biology and have been able to have a significant impact on their control compared to control plants that have a capsule-free formulation [30].

Encapsulation of *Pseudomonas putida* with chitosan nanoparticles and Arabic gum was used to control *Bemisia tabaci* (Hemiptera: Aleyrodidae) in the nymph stage of tomato. The capsule can protect the active compound and bacteria against UV damage, rain, wind, and other environmental factors. It causes the combination to have a long shelf life on the plant and can be available to insects for a more extended period. The diameter of the particles encapsulated by the spray dryer is approximately 200 nm. Their shelf life in the environment has been reported on the plant for 90 days, which has reduced the population of eggs and nymphs by up to 95% [30].

Another study used plant growth-promoting bacteria encapsulated with gum Arabic, using *Pseudomonas putida* with sodium alginate, chitosan, and Arabic gum against *Helicoverpa armigera* (Lepidoptera: Noctuidae), one of the most important pests of cotton counted and used [50]. The powder particle size obtained by the spray dryer was about 69 nm. This microencapsulation controlled up to 90% of the larval population of this pest because the coating of chitosan and Arabic gum created a large thickness and was able to increase bacterial survival [51]. The exact encapsulation was also used against *Myzus persicae* (Hemiptera: Aphididae) observed on potato plants [51]. This encapsulation was able to control 95% of the pest and reduce spawning, and after 12 days, the *Myzus persicae* was maintained on the lower plant.

Agriculture forms a wide part of the world's business [52]. A significant portion of the available agricultural yield is lost because of plant diseases and threatens food security worldwide. Farmers use various methods, such as chemical toxins application, to manage plant diseases. Nevertheless, almost 35% of the product is lost each year because of biotic stresses [53]. The application of chemical toxins is very incompetent. Nearly 90% of the chemical toxins do not attain their purposes and are lost because of vaporization, drift, surface run-off, chemical transformation, hydrolysis, and microbial degradation [40, 54, 55]. Researchers provided two approaches to make the effects of chemical toxins on the environment and human health most minor. The first approach is to achieve highly effective toxins against target pests and has no or minimal effect on the nontarget. In the second approach, researchers are developing formulations that are more effective at delivering the target material. Encapsulation is a novel technology in various research and industrial fields [56]. Several materials have produced controlled-release capsules in different sizes and usage types. Arabic gum has up to 50% w/v water solubility [57]. It is a suitable wall material for bacterial encapsulation due to its unique structure, such as low viscosity and high solid content. Today, Arabic gum is mixed with another polymer, such as polysaccharides, in encapsulation technology, especially in the spray-drying technique [58]. Encapsulation based on xanthan gum mixed with other polymers is suitable for a variety of compounds such as enzymes [59], secondary metabolites [60], and microorganisms [61].

The essential function of gellan gum is to maintain small particles in suspension without significantly changing viscosity [62]. Because enzymes do not easily degrade gellan gum, it is a good candidate for encapsulating bacterial agents. Gums mostly have also been found to contain sugars, starches, and cellulose, oxidation products of these gums, minerals, salts, and protein. Also, this material can bind with water and form a gel, and this structure supports the activities and stability of microorganisms. These attributes could make various gums a good candidate as a growth enhancers for bacteria. Due to the positive effects that gums have shown in the encapsulation of bacterial agents in multiple sciences, their use is expected to significantly affect the encapsulation of biocontrol bacteria and increase their performance in the control of plant diseases. In this regard, Saberi Riseh and Moradi pour 2021 encapsulated the *Streptomyces fulvissimus* Uts22 with chitosan and gellan gum and studied its effects on wheat plant growth and control take-all disease on wheat. Greenhouse assessments indicated that wheat plants treated with *S. fulvissimus* Uts22 microcapsules could control the take-all disease by about 90%, and the highest growth factors were observed in this treatment [41].

5. Advantages and Limitations of Using Gums to Encapsulate Plant Probiotic Bacteria

Most gums are polysaccharides that dissolve quickly in water and, when interacting with water, produce viscous solutions and gels. Benefits that have led to the widespread use of these compounds in encapsulation include biocompatibility, flexibility, availability, ease of use, and biodegradability. Therefore, according to these characteristics, it is expected that gums are a good candidate for encapsulation of biocontrol agents, which, while increasing the efficiency of the formulation in controlling pests and plant diseases, reduce the cost of the formulated product [63].

The use of gums can have disadvantages that limit their use in encapsulation technology, some of which are mentioned below.

Some types of gums contain toxic chemicals that can have side effects on some natural polymers. Sometimes the consumption of gums causes allergies and sensitivities. During production, if exposed to the external environment, there is a possibility of microbial contamination; however, with the correct use of this matter, synthetic preservatives can be used as a controlled method for producing formulations containing gum. Production of natural gums in nature depends on environmental and seasonal factors due to differences in the set of natural materials at different times, and differences in area, species, and climatic condition percentage of chemical compounds in a given substance may vary uncontrolled [64]. Usually, when are in contact with water, increased viscosity of the formulation the nature of gum (monosaccharide to polysaccharides and their derivatives) was found to decrease after storage [64].

6. Application of Gums in Other Industry

The probiotic bacteria are susceptible to different environmental factors and apply limitations on their health and functional effectiveness. Therefore, one of the critical factors in the application of probiotic products is the use of the delivery system to protect viable cells during transmission in the human digestion system. According to Ta et al. (2021), *Lactobacillus casei* 01 was well encapsulated into gellan gum-xanthan gum, and nonspherical capsules were formed, which increased bacterial viability [65]. Nag et al. (2011) reported sodium caseinate mixed with gellan gum is an ideal wall material for *Lactobacillus casei* encapsulation [66]. Encapsulated *Lactobacillus plantarum* ATCC 8014 with whey protein isolate and Arabic gum had the highest viability in Iranian white cheese [67]. *Bifidobacterium lactis* encapsulated in gellan, and xanthan gums were suitable for incorporation into foods and beverages [68].

7. Conclusion

Today, natural gums have a special place in various sciences. Since these compounds are biodegradable, they have opened their way to different agricultural parts and are considered by researchers. Since pests and plant diseases cause a lot of economic damage to agricultural products annually, it is essential to find solutions to reduce this damage. Using a combination of natural gums in the encapsulation of microbial agents can increase the performance of biocontrol agents for biological control of plant pests and diseases and improve their chances of survival by gradually releasing them.

Data Availability

Data available on request.

Conflicts of Interest

The authors declare no conflict of interest.

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