5 Biocidal Activity of Biodegradable Polymers

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5.1 Introduction

Interest in the production of eco-friendly consumer products will continue to increase as more focus is placed on decreasing the rate at which global warming, pollution and landfill are affecting the world. Polymers are considered to be the most vital materials available to science and technology in the 21st century [1], and are the building blocks of all living systems, such as plants, animals and microorganisms. The biological world is made up of a number of polymers such as proteins, polysaccharides, polynucleotides, polyamides, cellulose, starch, polylactic acid (PLA), cis-polyisoprene, lignin and so on. Thus, biopolymers belong to a group of macromolecules formed under natural conditions during the growth cycles of all organisms and exhibit both biocompatible and biodegradable properties. Biopolymers are regarded as a green source of energy as they are unlimited, self-sustaining natural resources, which are in harmony with nature, and are gaining a huge market in the modern world due to their degradable and cost-effective nature. The diverse properties and versatility of these materials have made them an integral part of our daily life, and as a result, they play a vital role in industry and the economy. They also play important roles in maintaining cell viability by conserving genetic information, storing carbon-based macromolecules, producing either energy or reducing power and protect organisms from hazardous environmental factors.

Polymers are broadly classified as synthetic and natural polymers. Synthetic polymers have become significant since the 1940s and continue to replace glass, wood, constructional materials and metals in many industrial, domestic and environmental applications [2–5]. Synthetic polymers are made from hydrocarbons derived from petroleum. Some of these polymers, such as nylon, polyethylene, polyurethane and so on, are an indispensable part of our daily lives. Due to their stability and durability they offer good mechanical and thermal properties [6], making them suitable for a variety of applications, e.g., in automobiles, cosmetics, medicines, biosensors,
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data storage devices and so on; thus, polymers pervade every aspect of modern society. The disadvantages of synthetic polymers are due to the fact that they are not biodegradable and are difficult to dispose of; in addition, synthesis involves the use of toxic compounds or the release toxic by-products. Therefore, these polymers have raised concerns from both an environmental and health point-of-view; hence, the discovery of safe and environmental friendly alternatives is crucial.

Over the past two decades, there has been growing scientific interest regarding the use and development of biopolymer materials, which must retain the desired chemical and physical properties of conventional synthetic plastics, as a viable alternative; thus offering a solution to the serious problem of plastic waste disposal [4, 7–9]. Modern approaches, such as biotechnology and genetic manipulation, have enabled the production of these biopolymers on an industrial scale using optimised parameters for their production. These biopolymers have good chemical, thermal and mechanical properties, in addition, they are biodegradable and eco-friendly and can be used as adhesives, adsorbents, cosmetics, drug-delivery vehicles, high strength structural materials and so on.

Biopolymers are a renewable material as they are produced from natural materials which can be replenished on an annual basis; they can be produced from natural raw materials such as starch, sugar, cellulose and so on. Biopolymers are thus possible alternatives to the traditional, non-biodegradable petrochemical-derived polymers and offer a positive attribute in terms of green chemistry. Biopolymers are degradable polymers which can be broken down by the action of naturally occurring microorganisms, such as bacteria, fungi and algae. Polymer degradation can be defined as a change in the properties of the biopolymer, such as tensile strength, colour, shape and so on, under the influence of one or more environmental factors, such as heat, light or chemicals. The biodegradability of the biopolymer is determined by the molecular structure, hence some biopolymers degrade in a few weeks, while others take several months. The end products formed as a result of biopolymer degradation are stable and can be recycled or reused, hence reducing environmental pollution by polymer waste. The advancement of technology has enabled the production of sufficient quantities of biopolymers from renewable and easily available resources, such as microbes (Table 5.1).
<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Biopolymer</th>
<th>Source</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Xanthan</td>
<td><em>Xanthomonas campestris</em></td>
<td>Salad dressings, emulsions, pharmaceutical combinations, textiles, agricultural products</td>
</tr>
<tr>
<td>2</td>
<td>Dextran</td>
<td><em>Leuconostoc mesentecosides</em></td>
<td>Gelling agent in confectionary, crystallisation inhibitor, blood transfusions as a plasma volume extender, antithrombolytic agent</td>
</tr>
<tr>
<td>3</td>
<td>Curdlan</td>
<td><em>Alcaligenes faecalis</em> var.</td>
<td>Pharmaceutical industries, food industries, construction fields, drug delivery and so on</td>
</tr>
<tr>
<td>4</td>
<td>Pullulan</td>
<td><em>Aureobasidium pullulans</em></td>
<td>Food industry, cosmetics, drug and gene delivery, tissue engineering, wound healing</td>
</tr>
<tr>
<td>5</td>
<td>Gelrite</td>
<td><em>Pseudomonas</em> species</td>
<td>Thickening or adhesive agent in foods, soil protection</td>
</tr>
<tr>
<td>6</td>
<td>Cellulose</td>
<td><em>Gluconacetobacter</em></td>
<td>Diet foods, speaker diaphragms, medical pads, artificial skin</td>
</tr>
<tr>
<td>7</td>
<td>Chitin and CS</td>
<td>Shells of crabs, lobsters, shrimps and insects</td>
<td>Cosmetics, manufacture of artificial skin and absorbable sutures, synthesis of water-soluble prodrugs</td>
</tr>
<tr>
<td>8</td>
<td>Polyhydroxyal-kanoate</td>
<td><em>Pseudomonas</em> Bacillus</td>
<td>Packaging materials, pressure sensors for keyboards, stretch and acceleration measuring instruments, in agriculture as a coating for urea fertilisers and so on</td>
</tr>
<tr>
<td>9</td>
<td>Polyglycolic acid</td>
<td><em>Lactobacillus delbrueckii</em></td>
<td>Fibres and fabrics, packaging materials, interference screws in ankle, knee and hand, tacks and pins for ligament attachment, rods and pins in bone and plates and so on, and surgical sutures, implants and drug-delivery systems</td>
</tr>
<tr>
<td>10</td>
<td>Hyaluronan</td>
<td><em>Streptococcus equi</em></td>
<td>Tissue engineering, intradermal, injection, cosmetics in ophthalmology and in wound healing, topical delivery of drugs</td>
</tr>
</tbody>
</table>
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Biodegradable polymers accelerate the degradation of bacteria or pathogens due to the hydrophilic backbone chain of polymers which contain atoms, such as O, N, S, in the polymer chain. The amorphous nature, small size and high porosity of biodegradable polymers are the factors which disrupt the outer bacterial membrane.

5.2 Biodegradable Chitin and Chitosan Polymer Material

Chitin and chitosan(s) (CS) are biopolymers that have received considerable attention due to their numerous applications in agriculture, food, textile, the paper industry, the food industry and biomedicine and so on.

Chitin is the most abundant biopolymer on earth except for cellulose. This polymer was an unused natural resource for a long time, but interest has increased in recent years due its physiological inertness, biodegradability, hydrophilicity and biocompatibility and so on [10, 11]. Chitin is a polysaccharide made of N-acetyl-D-glucosamine units connected by β(1→4)-linkages. Chitin is found in fungi and in the shells of crustaceans and molluscs, in the backbone of squids and in the cuticle of insects [12]. Long chitin molecules are linked by covalent bonds and together they form a complex structural network.

![Structure of chitin](image)

**Figure 5.1** Structure of chitin
Chitin and CS have similar chemical structures (Figures 5.1 and 5.2). Chitin is made up of a linear chain of acetyl glucosamine groups, while CS is obtained by removing enough acetyl groups (CH$_3$-CO) for the molecule to be soluble in most dilute acids, this process is called deacetylation; hence, the actual difference between chitin and CS is the acetyl content of the polymer. The most useful derivative of chitin is CS containing a free amino groups.

Industrial chitin is obtained from marine food production waste, i.e., crustacean shells from shrimp, crab or krill [13, 14]. The processing of shrimps for human consumption generates 40–50% of the total mass of marine food production waste, which is considered to be one of the main pollutants in coastal areas, as it is dumped into the sea [15]. A small part of the waste is dried and used as chicken feed [14]. The major components (on dry mass basis) of shrimp waste are chitin, minerals, carotenoids and proteins; thus, the utilisation of this shell food waste as an alternative source to produce chitin may help solve environmental problems related to waste generation.

In recent years, the production of chitin and CS from fungal sources has been the centre of attention due to potential advantages over other sources, such crustaceans and shrimps. Crustacean waste is seasonal and a limited amount is available from fishing industry locations. An excessive amount of inorganic materials present in the crustacean waste means that a demineralisation treatment is required prior to use. In the case of fungal sources, the fungal mycelium can be obtained via simple fermentation regardless of geographical location or season [16], and it contains lower levels of inorganic materials compared with crustacean shells, thus reducing the demineralisation process [17]. Chitin is produced by many fungi occurring in Basidiomycetes, Ascomycetes and Phycomycetes where it is a component of the cell walls and structural membranes of mycelia, stalks and spores [18]. The chitin content of the cell walls is generally higher in the genus Zygomycetes, which include species of Mucor, Rhizopus and so on [19]. Kishore and co-workers [20] examined
the synthesis of CS from the mycelia of *Absidia coerulea*, *Mucor rouxii*, *Gongronella buttieri*, *Phycomyces blakesleeanus* and *Absidia blakesleean*. Wang co-workers [21] determined the physical properties of fungal CS from *Absidia coerulea*, *Mucor rouxii* and *Rhizopus oryzae*. *Aspergillus niger* was also reported to produce CS effectively [22]. The pileus and stipes of fungal fruiting bodies such as *Agaricus bisporus*, *Pleurotus ostreatus* and *Lentinula edodes* produce chitin and it was reported that *Agaricus bisporus* had a higher chitin level than *Pleurotus ostreatus* and *Lentinula edodes* [23]. The production of chitin from waste material generated from stalks and mushrooms with irregular dimensions, which are not suitable for commercial use, have also been reported. The waste generated from *Agaricus bisporus* culture farms was used for the cost-effective manufacturing of commercial chitosans [24, 25]. *Rhizopus oryzae* was reported to produce chitin when potato peel was used as the substrate [26]. A chitin and glucan complex was isolated from the biomass of *Armillaria mellea* and the yellow morel *Morchella esculenta* by Ivshina and co-workers [27].

To obtain the maximum yield of chitin and CS, fungi were harvested at their late exponential growth phase after culturing in media such as yeast peptone glucose broth, potato dextrose broth or molasses salt medium [28]. There are a variety of means for the detection of chitin from fungal samples; however, the best quantitative detection is *via* the enzymatic method, which involves the hydrolysis of chitin to its oligomers *via* chitinase. The oligomers are further hydrolysed to monomeric N-acetylglucosamine by N-acetyl-glucosaminidase. This method is very selective as only chitin is degraded even in the presence of other polysaccharides. The final products, i.e., glucosamine units, can be used to estimate the amount of chitin or CS in the material under investigation [29].

CS is insoluble at neutral and alkaline pH, but is soluble in organic and inorganic acids including acetic, formic, hydrochloric, glutamic and lactic. CS exhibits a variety of physico-chemical and biological properties, which can be used in various fields including the edible film industry, as additives to enhance the nutritional quality of foods, for the recovery of solid materials from food processing waste and in the purification of water [30]. These properties make CS commercially vital as do the properties of biodegradability and biocompatibility in both plant and animal tissues. These materials have the ability to be transformed into gels, beads, fibres, colloids, films, flakes, powders and capsules [30–33]. Additional exclusive characteristics of CS are its non-digestibility and bland taste, which make it an excellent choice as a food additive component, predominantly in the preparation of low-calorie foods [34].

Over 150,000 tonnes of chitin is currently harvested by utilising a by-product of the seafood industry, making it available throughout the year. Chitin and CS are currently in the spotlight due to their numerous applications in biomedicine, waste water treatment, food, cosmetics and the fibre industry [35–39]. The high nitrogen
content (6.89%) and other excellent properties, such as biodegradability, non-toxicity, biocompatibility and adsorptive abilities, make chitin and CS more commercially important than other biopolymers [40, 41].

CS is an exciting and promising material in tissue regeneration applications as these biopolymers can be easily constructed into various forms and their derivatives are biodegradable by lysozomal enzymes.

Chitin and CS are basic in nature. CS in solution at pH values below 6.5 carries a positive charge, which makes it readily react with a variety of negatively charged materials or polyanions. The high content of primary amino groups with a pKa of 6.3 is responsible for most of these characteristic properties. The amino groups are also responsible for enabling several chemical modifications of CS, which is a crucial factor in its ongoing development for many applications. The soluble–insoluble transition of CS occurs around pH 6.0–6.5 at the pKa of its primary amino groups. At low pH, the positive charge on the amino groups converts CS to a water-soluble cationic polyelectrolyte and when the pH increases above 6.0 the positive charge on the amino groups is lost and CS becomes insoluble [41]. The degree of N-acetylation is dependent on the pKa, hence the solubility of CS is dependent upon the degree of deacetylation and the method of N-deacetylation. The chemical structure of chitin allows easy specific modifications at the C-2 positions, making it a suitable candidate for further development in comparison to other polysaccharides such as cellulose, starch, agar and so on. CS bioplastics fully degrade within two weeks and release nutrients that support plant growth, making it eco-friendly in nature.

CS forms water-soluble salts with inorganic and organic acids including glyoxylate, pyruvate, tartarate, malate, malonate, citrate, acetate, lactate, glycolate and ascorbate. Natural CS showed more solubility in organic acids when the pH of the solution was less than 6.5. Facile water-miscible salts of CS are formed by neutralisation with acids such as lactic, hydrochloric, acetic or formic.

These reactive CS functional groups can be readily subjected to chemical modifications which alter the physico-mechanical properties of CS [42]. CS triplyphosphate has the capacity to form a chelated complex with transition metal ions such as silver (Ag⁺), copper (Cu²⁺), zinc (Zn²⁺), manganese (Mn²⁺) and iron (Fe²⁺) [43].

The applications of CS are dependent upon the degree of acetylation and its molecular weight (MW) [44]. The degree of deacetylation is an extrinsic property which can be increased by increasing the temperature or strength of the alkaline solution. The viscosity of CS also influences its biological properties, such as wound-healing properties as well as biodegradation by lysozyme.
5.2.1 Antimicrobial Activity of Chitin

The antimicrobial activity of CS is associated with its MW, degree of acetylation, concentration of CS and bacterial inoculum size, as described by Chen and Fernades [45–47]. It was reported that lower MW CS is strongly effective against Gram-negative bacteria, whereas high MW CS is effective against Gram-positive bacteria. CS has several advantages over other types of disinfectants as it exhibits higher antibacterial activity, a broader spectrum of activity and a lower toxicity to mammalian cells [48].

The antimicrobial activity of CS increases with decreasing pH [49–52], which is due to the fact that the amino groups of CS become ionised at pH values below 6 and carry a positive charge. Unmodified CS does not exhibit antimicrobial activity at pH 7, as it does not dissolve and it does not contain any positive charge on the amino groups [53, 54]. The antimicrobial activity of CS is enhanced upon increasing the degree of deacetylation, due to increasing the number of ionisable amino groups [55].

Several studies report the use of CS as an antimicrobial agent [58, 56]. The antimicrobial activities of CS against foodborne pathogens have been extensively investigated in the food industry [28, 57–60]. Nguyen and co-workers [50] reported that a CS solution can inhibit the growth and development of food-contaminating microbes such as Aspergillus niger, Staphylococcus aureus and Pseudomonas aeruginosa.

Wu and co-workers [24] examined the bioactivity of chitin and CS obtained from Aspergillus niger and Mucor rouxii against the foodborne pathogen Salmonella Typhimurium and plant pathogens Botrytis cinerea and Penicillium expansum. The biological properties were compared with commercial CS obtained from crustacean shells. The antimicrobial activity of the isolated chitin and CS was similar and comparable with that obtained from commercially purified crustacean CS. The isolated CS exhibited strong antimicrobial activity against both Gram-negative and Gram-positive bacteria such as Escherichia coli, Salmonella Typhimurium, Staphylococcus aureus and Listeria monocytogenes, respectively [28, 51, 52]. Gram-positive bacteria appeared to be more susceptible to CS compared with Gram-negative species [28, 51]. It has been suggested that the interaction between positively charged CS molecules and negatively charged microbial surfaces results in disruption of the cell membranes, leakage of intracellular constituents and ultimately microbial cell death [61]. CS oligomers are believed to penetrate into prokaryotic cells and interfere with the transcription of ribonucleic acid and protein synthesis [62]. CS also exhibit a potent plaque-reducing action, as well as in vitro antibacterial activity, against several oral pathogens such as Actinobacillus actinomycetemcomitans, Streptococcus mutans and Porphyromonas gingivalis, which are implicated in plaque formation and periodontitis [63, 64].
It was found that antimicrobial activity of CS could be tremendously enhanced by the introduction of quaternary ammonium functional groups. Guo and co-workers [65] reported the enhanced antifungal activity of quarternised CS derivatives against plant pathogenic fungi *Botrytis cinerea* and *Colletotrichum lagenarium*. Jia and Xu [66] reported that CS derivatives, such as *N*,*N*,*N*-trimethyl CS, *N*-propyl and *N*-*N*-dimethyl CS, exhibited stronger activity against *Escherichia coli* compared with that of unmodified chitin. Zivanovic and co-workers [67] reported that CS polysaccharides exhibited stronger bactericidal effects towards *Listeria monocytogenes* and *Salmonella enterica* serovar Typhimurium strains, compared with the CS oligosaccharide. Coma and co-workers [32] reported that CS films completely inhibited *Listeria monocytogenes* growth for at least 8 days.

5.2.2 Antioxidant Properties of Chitosan

Oxidative stress occurs in biological systems if the balance between oxidant formation and the endogenous (internal) antioxidant defence mechanism is disturbed [68]. During aerobic metabolism, reactive oxygen species and free radicals are generated naturally in the body which cause the oxidation of lipids, proteins, sugars, sterols and nucleic acids. During the ageing process, the antioxidant defence system weakens, resulting in the accumulation of reactive oxygen species and free radicals. The formation of these free radicals are toxic as these cause cellular damage leading to many pathological conditions such as arthritis, cancer, stroke, atherosclerosis, retinal damage, diabetes and heart attack [69, 70].

Chitin and its derivatives have received considerable attention as they are non-toxic and can be easily delivered into living systems and used in food technology. The antioxidant properties of chitin and CS depend on the degree of deacetylation and MW (*Table 5.2*); CS with the lowest degree of deacetylation exhibited the best scavenging activity [71–73]. In order to improve the antioxidant properties of CS, various modifications were applied to CS molecules to overcome its solubility limitation. Sulfation represents a very important family of CS derivatives with enhanced biological activities, especially antioxidant properties. It has been shown that sulfated CS and sulfanilamide CS have significantly better free-radical scavenging activities than unmodified CS [72, 74].
Table 5.2 Modified derivatives of chitin/CS

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>CS derivatives</th>
<th>Preparation method</th>
<th>Advantage of modified chitin/CS</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>O and N carboxy methyl CS</td>
<td>Reductive alkylation Direct alkylation</td>
<td>Formation of an amphoteric polymer which extends the range of pH, enhancing CS solubility in different solvents</td>
<td>Modified drug delivery pH responsive drug delivery DNA delivery Targeted drug delivery Permeation enhancer Cosmetics</td>
</tr>
<tr>
<td>2</td>
<td>CS 6-O-sulfate</td>
<td>Esterification using inorganic acids</td>
<td>Polyampholite soluble in water</td>
<td>Anticoagulant Haemagglutination inhibition activities Antisclerotic Antiviral Antihuman immunodeficiency virus Antibacterial Antioxidant Enzyme inhibition activities</td>
</tr>
<tr>
<td>3</td>
<td>N-methylene phosphonic CS</td>
<td>Phosphorylation of amino groups using phosphoric acid and formaldehyde</td>
<td>Amphoteric, good cation complexing efficiency for cations such as Ca^{2+} and transition metals (copper (II), cadmium (II), zinc (II) and so on)</td>
<td>Development of prodrugs (used for the corrosion of iron-oxide-based prodrugs) Protects metal surfaces</td>
</tr>
<tr>
<td>4</td>
<td>Trimethylchitosan ammonium</td>
<td>Quaternisation of CS with methyl iodide in sodium hydroxide under controlled conditions</td>
<td>Water-soluble over all the practical pH range</td>
<td>Used in the paper industry due to good flocculating properties</td>
</tr>
<tr>
<td>5</td>
<td>Quaternised CS and N-alkyl CS</td>
<td>Alkylation of CS followed by quaternisation</td>
<td>Higher aqueous solubility in a much broader pH and concentration range</td>
<td>DNA delivery</td>
</tr>
<tr>
<td>6</td>
<td>Hydroxyalkyl CS</td>
<td>Reacting CS with epoxide</td>
<td>Marked surface activity and foam-enhancing properties of CS</td>
<td>Antimicrobial, temperature sensitive injectable carrier for cells</td>
</tr>
<tr>
<td>7</td>
<td>Sugar-modified CS</td>
<td>Reductive N-alkylation using sodium cyanoborohydride and unmodified sugar or sugar-aldehyde derivative</td>
<td>Enhance water solubility</td>
<td>Drug targeting</td>
</tr>
</tbody>
</table>
An oligosaccharide prepared from CS containing a 10% degree of deacetylation displayed free-radical scavenging activity [75]. Xie and co-workers [76] reported that the free-amino groups in chito-oligosaccharides react with free radicals forming a stable macromolecule radical which results in antioxidant activity. Low MW CS are reported to be more effective antioxidants than high MW CS.

5.3 Facile Synthesis and Importance of Biopol [Poly(3-hydroxybutyrate-co-3-hydroxyvalerate)]

Poly(3-hydroxy butyric acid) and poly(3-hydroxyl valeric acid) copolymers are formed by the fermentation of glucose with the aid of Alcaligenes eutrophus species. As a result of using copolymers, PHBV is synthesised via polymerisation (Figure 5.3).

Poly(3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV) is a soft, malleable and thermosoftening biodegradable polymer material. It can be easily converted into films, which are applicable for packaging, carry bags, disposable bottles and so on. The hydrophilic backbone chain of the polymer, which contains atoms of oxygen in the polymer chain, accelerates the degradation of bacteria and pathogens.

PLA is widely used in medical and packaging industries and has received considerable attention due to its mechanical and physical properties. PLA/nisin is used as an antibacterial food packaging material and this combination shows positive results against Gram-positive bacteria such as Clostridium bacillus, Staphylococcus and so on. PLA/silver films were effective against Escherichia coli (Gram-negative bacteria) and Staphylococcus aureus and Vibrio parahaemolyticus [77, 78].
5.4 Antibacterial Importance of a Biodegradable Polypyrrole/Dextrin Conductive Nanocomposite

The polypyrrole (Ppy)/dextrin nanocomposite is synthesised via in situ polymerisation and the preparation of this nanocomposite is shown in Figure 5.4. The backbone chain of this nanocomposite polymer contains hydrophobic side chains, which disrupt the microbial cell membrane leading to leakage of the cytoplasm in bacteria including Escherichia coli, Pseudomonas aeruginosa, Staphylococcus aureus and Bacillus subtilis. This material can be implemented in the fields of biomedicine, biosensors and food packaging due to the biodegradable property of dextrin as well as the antibacterial properties of the Ppy [79].
5.5 Antibacterial Biodegradable Polymer–nanocomposite

Pande and co-workers reported biodegradable polymer–nanocomposites that exhibit antibacterial activity, e.g., a gum tragacanth-zinc oxide nanocomposite which showed antibacterial activity against *Escherichia coli* [80]. Gum tragacanth exhibits high solubility in water and is a novel route to prepare zinc oxide nanoparticles using economical natural polysaccharide binders. This polysaccharide chain contains D-galactameric acid, L-fucose, D-xylose and D-galactose, and has an O atom in the polymer chain along with zinc oxide NP, which helps to penetrate the outer membrane of *Escherichia coli*. In addition, an *Abelmoschus esculentus*-silver nanocomposite has shown antibacterial activity against *Escherichia coli* (Gram-negative), *Staphylococcus*...
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*aureus* (Gram-positive) and *Candia* (fungi) [81]. An easily synthesised *Abelmoschus esculentus*-iron nanocomposite has shown antibacterial activity against *Escherichia coli* and *Staphylococcus aureus* [82], as a result of the folic-acid-containing N and O atoms, which help to disrupt the outer membrane of bacteria.

5.6 Conclusion

Chitin is a natural polymer with unique structural and multidimensional properties with wide-ranging applications in the biomedical and pharmaceutical fields. The chemical structure of chitin and CS allows specific modifications at the C-2 position, which reflects its advantages over other polysaccharides such as cellulose, starch, galactomannans and so on. The chemical structure of chitin and CS is also responsible for their solubility in aqueous or organic solvents, which further enhances their biocidal activities, potential biomedical applications and simple synthesis. Chitin is biodegradable, renewable and exhibits antimicrobial properties, in addition, it has biomedical applications and thickening properties as discussed in this chapter. The huge market potential of these polymers, due to their unique properties and wide-ranging applications in various sectors, suggests that research work should be intensified on exploring the availability of raw materials that could be a source of chitin and CS. Biodegradable polymer–nanocomposites are the focus of research into developing eco-friendly medicinal applications.

References


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