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Antimicrobial and anticancer activities of porous chitosan-alginate biosynthesized silver nanoparticles

Jayachandran Venkatesan[a], Jin-Young Lee[b], Dong Seop Kang[b], Sukumaran Anil[c], Se-Kwon Kim[b], Min Suk Shim[a,**], Dong Gyu Kim[d,*]

[a] Division of Bioengineering, Incheon National University, Incheon 406-772, Republic of Korea
[b] Institute for Life Science of Seogo (ILSS), Kolmar Korea Co, Seoul 137-876, Republic of Korea
[c] Department of Preventive Dental Sciences, College of Dentistry, Prince Sattam Bin Abdulaziz University, Al-Kharj, Saudi Arabia
[d] Specialized Graduate School Science & Technology Convergence, Pukyong National University, Busan 608-739, Republic of Korea

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ABSTRACT

The main aim of this study was to obtain porous antimicrobial composites consisting of chitosan, alginate, and biosynthesized silver nanoparticles (AgNPs). Chitosan and alginate were used owing to their pore-forming capacity, while AgNPs were used for their antimicrobial property. The developed porous composites of chitosan-alginate-AgNPs were characterized using Fourier transform infrared spectroscopy (FT-IR), ultraviolet-visible spectroscopy, X-ray diffraction (XRD) analysis, and scanning electron microscopy (SEM). The FT-IR results revealed the presence of a strong chemical interaction between chitosan and alginate due to polyelectrolyte complex; whereas, the XRD results confirmed the presence of AgNPs in the composites. The dispersion of AgNPs in the porous membrane was uniform with a pore size of 50–500 μm. Antimicrobial activity of the composites was checked with *Escherichia coli* and *Staphylococcus aureus*. The developed composites resulted in the formation of a zone of inhibition of 11 ± 1 mm for the *Escherichia coli, and* 10 ± 1 mm for *Staphylococcus aureus*. The bacterial filtration efficiency of chitosan-alginate-AgNPs was 1.5-times higher than that of the chitosan-alginate composite. The breast cancer cell line MDA-MB–231 was used to test the anticancer activity of the composites. The IC_{50} value of chitosan-alginate-AgNPs on MDA-MB–231 was 4.6 mg. The developed chitosan-alginate-AgNPs composite showed a huge potential for its applications in antimicrobial filtration and cancer treatment.

1. Introduction

Nanotechnology is an emerging field of research, where the main concern is the fabrication of nanomaterials for diverse applications, including medicine, cosmeceuticals, paints, displays, batteries, catalysis, sensors, food, agriculture, and construction areas [1]. Among the various nanomaterials, silver nanoparticles (AgNPs) gained much attention due to their unique biological, chemical, and physical properties in contrast to their micro and macro counterparts. Owing to their unique antimicrobial properties, AgNPs have secured an important place in several applications including medicine and food [2]. AgNPs can be synthesized by different methods that include physical, chemical [3], and green synthesis [4–6]. These AgNPs can be incorporated into polymeric or ceramic biomaterials and could be utilized in wound healing, water filtration membrane, and antimicrobial filtration. Adding AgNPs in polymeric membranes (biological macromolecules) is easy and efficient in controlling microbial pathogens [2].

Chitosan is a cationic polysaccharide. It is a copolymer of *N*-acetyl glucosamine and glucosamine unit obtained mainly from *N*-deacetylation of chitin. It has been extensively employed in biological and biomedical applications owing to its biocompatibility and biodegradability. Chitosan has an antimicrobial activity and can be developed into any shape and size, such as films, microspheres, nanoparticles, porous membranes and scaffolds. Chitosan has been used in medical fields such as wound healing, tissue engineering, and drug delivery [7–12].

The addition of antimicrobial AgNPs in chitosan further enhanced the antimicrobial efficacy of the chitosan. Table 1 enlists chitosan-based composites with Ag, which were used for antimicrobial activity, wound dressing, and water disinfection applications.

Alginate is an anionic polysaccharide, which is mainly composed of L-guluronic acid and D-mannuronic acid in different proportions [8]. Amine groups of chitosan and carboxylic groups of

* Corresponding author.
** Corresponding author.
E-mail addresses: msshim@inu.ac.kr (M.S. Shim), dgkim@pknu.ac.kr (D.G. Kim).

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Table 1
Chitosan-silver based composites and their applications.

S. No	Composite materials	Drugs/Metal NPs	Applications	Refs.
1	Chitosan	Ag	Wound dressing	[13]
2	Chitosan	Ag	Anti-toxoplasma	[14]
3	Chitosan	AgNPs	Water disinfection	[15]
4	Chitosan	AgNPs	Apoptosis	[16]
5	Chitosan	AgO	Antibacterial	[17]
6	Chitosan	$AgNO_3$	Antimicrobial	[18]
7	Chitosan	Ag	Antimicrobial and anticancer	[19]
8	Chitosan oligomer	$AgCl_2$	Healing of burns	[20]
9	Carboxymethyl Chitosan	AgNPs	Antibacterial	[21]
10	Chitosan-PVA	Ag/Curcumin	Antimicrobial	[22,23]
11	Chitosan-sago starch	Ag	Wound dressing	[24,25]
12	Chitosan-PEG	Ag	Antibacterial	[26]
13	Chitosan-hyaluronic acid	Ag	Wound dressing Antimicrobial/vascular graft	[27,28]
14	Chitosan-chondroitin sulfate	Silver sulfadiazine	Wound dressing	[29]
15	Chitosan-cellulose	Ag	Antimicrobial	[30,31]
16	Chitosan-guar gum	AgNPs	Sensor	[32]
17	Chitosan-gelatin	AgNPs	Wound dressing/bone tissue regeneration	[33–35]
18	Chitosan-TPP	AgNPs	Wound dressing	[36]
19	Chitosan–PEO	AgNPs	Antibacterial	[37]

Table 2
Alginate-silver-based composites and their applications.

S.No	Composite materials	Drugs/Metal NPs	Applications	Refs.
1	Alginate	Ag	Antibacterial	[41,42]
2	Alginate/silver	AgNPs	NA	[43]
3	Alginate-PVP	Ag	Wound dressing	[44,45]
4	Alginate-gelatin	AgNPs	Wound dressing Antimicrobial	[46,47]
5	Alginate-gelatin	Silver sulfadiazine	Wound healing	[48]
6	sodium alginate-PVA	AgNPs	Antibacterial	[49]
7	sodium alginate/cellulose	Silver sulfadiazine	Antibacterial	[50]

Table 3
Chitosan-alginate-based composites and their applications.

S.No	Composite materials	Drugs/Metal NPs	Applications	Refs.
1	Chitosan-alginate	None	Wound dressing	[7,51–55]
2	Chitosan-alginate	None	Sensor applications	[58]
3	Chitosan-alginate	None	Bone tissue regeneration	[59]
4	Chitosan-alginate	Paracetamol	Wound dressing/tissue engineering	[60]
5	Chitosan-alginate	Silver Sulfadiazine	Wound dressing	[8,61]
6	Chitosan-alginate	Ag	Antibacterial	[62]
7	Chitosan-alginate	AgNPs	Wound dressing	[34]
8	Chitosan-alginate	Curcumin	Wound dressing	[63]
9	Chitosan-alginate	AgNPs	Cancer therapy	[64]
10	Chitosan-alginate	Minocycline	Dental applications	[65]
11	Chitosan-alginate	Nisin	Antimicrobial	[66]
12	Carboxymethyl chitosan/organic rectorite and alginate	None	Antibacterial	[67]
13	Carboxymethyl chitosan-alginate	$AgNO_3$	Antibacterial	[68]
14	*N,N,N*-trimethyl chitosan/alginate	AgNPs	Bacterial/anti-tumor properties	[69,70]

alginate easily form chitosan-alginate polyelectrolyte complexes. These polyelectrolyte complexes have been extensively utilized in the medical field, particularly in wound dressing, tissue engineering, and drug delivery [8,38–40]. Alginate and its composites with silver have been employed for antibacterial and wound healing applications (Table 2).

Some researchers have used the chitosan-alginate polyelectrolyte complex for wound dressing [7,51–55]. The results show that chitosan-alginate polyelectrolyte complex hydrogels are highly biocompatible, degradable, non-toxic, antimicrobial, and can effectively enhance the wound healing. Various chitosan-alginate-based composites with Ag and drugs utilized for wound dressing, sensor, bone tissue engineering, antimicrobial, anticancer, and dental applications are listed in Table 3. In addition to strong antibacterial activity of AgNPs [56], they can also induce apoptosis in cancer cells, leading to efficient anticancer activity [57]. Therefore, various composites containing AgNPs have been developed for anticancer therapy [16,19].

We propose that chitosan-alginate-AgNPs composites can also be used as an antimicrobial filtration system. Recent studies revealed that air conditioners are breeding grounds for bacteria in hot conditions and rainy days. Even health officials warn that potential pathogenic bacteria can grow in the air conditioner. These bacteria can cause fever and ache. Installing an efficient microbial filter in the air conditioning system is the only option to prevent these harmful microbes [71,72]. We have developed an inexpensive material composed of chitosan-alginate with biosynthesized AgNPs for the antimicrobial filtration system.

In the present work, we aimed to prepare a porous chitosan-alginate polyelectrolyte complex containing biosynthesized AgNPs to develop composite materials with antimicrobial and anticancer properties. The developed highly porous composite materials were characterized by ultraviolet-visible spectroscopy, Fourier transform infrared (FT-IR) spectroscopy, X-ray diffraction (XRD) analysis, and scanning electron microscopy (SEM). Further, the prepared composites were tested against bacterial pathogens such as