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The synthesis of oxalate-modified pyrite/chitosan as an antibacterial composite

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The combination of organic and inorganic components has produced bioactive materials with excellent properties. Chitosan is a widely used organic component that has received recognition as a biocompatible material. In contrast, naturally occurring pyrite has so far received limited exposure as a biomaterial, despite its great antibacterial activity. Hence, the incorporation of pyrite into the chitosan matrix is expected to highlight the usage of pyrite as a bioactive material, particularly in antibacterial response. In this research, chitosan and oxalate-modified pyrite were combined to form beads at wt% pyrite loadings of 1, 3 and 5%. Energy-dispersive X-ray spectroscopy analysis could confirm the loading of pyrite into the bead matrix. The beads exhibit a high water absorption ability. With the addition of pyrite, the absorption of water could increase up to 37% compared with that of blank chitosan beads. The immersion of beads in simulated body fluid shows the bioactivity of beads by formation of apatite. Microbial activity against *Escherichia coli* and *Staphylococcus aureus* is exhibited by all composite beads containing oxalate-modified pyrite, particularly by beads containing 5 wt% oxalate–pyrite.

Keywords: anti-bacterial/bioactive/chitosan/E. coli/pyrite/S. aureus

Notation

S	percentage of swelling
t	time
W_d	mass of the dried sample
W_s	mass of the swollen sample

1. Introduction

The development of composite materials has ventured into bioactive materials with an excellent response to biological systems through modified surface reactivity and strong interactions with biological substances. The organic–inorganic interactions of biomaterials can be traced back to natural biological structures such as bone, which consists of hydroxyapatite as the inorganic component and collagen fibrils as the organic component. The synergy between the inorganic and organic constituents contributes to the excellent mechanical strength and resistance of tension in bone.[1] The current research is progressing in modification of inorganic materials by altering their components and conferring smart capabilities. In combination with an organic material, the composite will exhibit an improved response and biocompatibility with biological systems.[2] Among organic materials employed as biomaterials, chitosan has gained popularity due to its high versatility to be modified as fibers, beads, film and so on;[3] its non-toxicity, biocompatibility, and excellent antibacterial activity cannot be overlooked.[4]

Chitin as a mucopolysaccharide consists of β-1,4-linked glucosamine units with a sugar backbone.[5] It has a high degree of acetylation, which can be derived from the exoskeleton of crustaceans or fungal cell walls.[5] Chitosan as a polysaccharide is an alkaline deacetylated product of chitin. The applications of chitosan in the biomedical industry are extensively researched, as it is a bio-compatible, non-toxic, biodegradable, antibacterial and antioxidant material. The antibacterial activity of chitosan is affected by its polyelectrolyte structure. If the structure is protonated, the antibacterial activity will increase.[6] The inclusion of inorganic materials into the chitosan matrix has been widely researched, particularly with apatite and clay. The binding between chitosan and apatite can be facilitated through hydrogen bonds between hydroxy groups or amino groups in chitosan and hydrogen bonds on the periphery of apatite.[7]

As part of inorganic material, pyrite (FeS_2) is a type of iron sulfide widely available in nature. The structure of pyrite is similar to that of sodium chloride (NaCl) with the sulfide (S^{2-}) placed in the center of the cube.[8] Pyrite has shown antibacterial