Hong Kong Student Science Project Competition 2023

Extended Abstract (Investigation)

Team Number: SBBC114

Project Title: An Eco-friendly Way to synthesize Silver-nanoparticle Antibacterial Film

Project Type: Investigation (*To our best knowledge, there are no similar works in the field.)*

I. Background

Silver nanoparticles have gained widespread attention as an **antibacterial agent** in biotechnological and biomedical fields in recent years.

The common practices of making silver nanoparticles use high radiations and toxic chemicals that are non-renewable and non-biodegradable, leading to biological and environmental risks.

The main objective of our project is to **investigate the possibility of synthesizing a silver-nanoparticle antibacterial film in an eco-friendly way**. Moreover, we want the antibacterial film to have desirable properties so that it can be **applied in food packaging and wrapping of medical devices**.

With reference to several online articles, we realize that **some natural biodegradable polymers such as alginate and chitosan** are the potential candidates for being the reducing agent and the stabilizing agent of the synthesis.

However, using alginate alone will form a gel instead of a film, while using chitosan alone will form a film that will swell and dissolve easily in acidic aqueous solution.

With further studies on Material Chemistry, we learn that **alginate polymers can form cross-links with chitosan polymers to produce a polyelectrolyte complex (PEC)**, which should in turn form an insoluble film with certain mechanical strength.

Therefore, we come up with the idea of **using BOTH alginate and chitosan** to synthesize a silver-nanoparticle antibacterial film that can potentially serve our objective.

II. Objectives

1. To explore the possibility of synthesizing a silver-nanoparticle antibacterial film in an eco-friendly way.
2. To determine the optimal conditions for the synthesis of the antibacterial film, such as the temperature and concentrations of the reactants.
3. To test the performance of the antibacterial film such as its antibacterial activity, its water uptake ability, its tensile strength and its shelf life.

III. Hypothesis

1. A silver-nanoparticle antibacterial film can be synthesized in aqueous medium, using two natural alginate and chitosan as the reducing agent and the stabilizing agent.
2. The optimal conditions of the synthesis can be determined by carrying out fair tests using traditional analytical methods such as agar diffusion method and colorimetry.
3. The film produced has significant antibacterial effect against E. coli. The film is water-insoluble, water-resistant, tough and has a long shelf life.

IV. Methodology

1. **Preparation of silver-nanoparticle antibacterial film**

Step 1: Mix 2.0 cm^3 of 0.01M silver nitrate solution with 50.0 cm^3 of 0.2% (w/v) sodium alginate solution. Heat the reaction mixture at 90°C for 1 hour with constant stirring.

Step 2: Add 100.0 cm^3 of 0.1% (w/v) chitosan solution slowly into the cooled reaction mixture. Stir the resultant suspension at room temperature constantly for 30 minutes.

Step 3: Pour the resultant suspension into 3 plastic dishes equally. Put the dishes in a 37°C incubator for at least 72 hours until the suspension turns into dry films.

2. **Determining the optimal conditions for the synthesis**

Objective	Fair test	Desired result
To find the optimal temperature for the synthesis	***Independent variable:*** Carry out step 1 at different temperatures (room temperature, 60°C, 70°C, 80°C and 90°C). ***Dependent variable:*** Measure the absorbance of the orange reaction mixture at 440nm.	The higher the absorbance, the higher the colour intensity of the orange reaction mixture, and therefore the higher the concentration of silver nanoparticles formed. The highest absorbance should be obtained at the optimal temperature.
To find the optimal alginate concentration	***Independent variable:*** Carry out step 1 using different concentrations of sodium alginate solution (0.05%, 0.1%, 0.2%, 1% and 2%). ***Dependent variable:*** Measure the absorbance of the orange reaction mixture at 440nm.	A higher absorbance indicates a higher concentration of silver nanoparticles is formed. The highest absorbance should be obtained with the optimal alginate concentration.
To find the optimal silver ion concentration	***Independent variable:*** Carry out step 1 – step 3 using different concentrations of silver nitrate solution (0.001M, 0.005M, 0.01M, 0.05M and 0.1M). ***Dependent variable:*** Compare the size of the inhibition zones in the antibacterial activity test	The larger the size of the inhibition zones, the greater the antibacterial activity of the silver-nanoparticle film. The largest inhibition zone should be obtained with the optimal silver ion concentration.

3. **Testing its antibacterial activity:** Agar diffusion method

Testing its water uptake ability: Water uptake % = [(wet mass – dry mass) / dry mass] x 100%

Testing its tensile strength: Tensile strength (Nm^{-2}) = total weight of the paper clips & standard masses / cross-sectional area of the film being pulled

Testing its shelf life: The antibacterial effect of the film after three months of storage at room conditions will be evaluated.

V. Results

1. After carrying out Step 1 to Step 3, **a greyish brown film is successfully formed** after the suspension is dried. The film is expected to contain silver nanoparticles capped in a polyelectrolyte complex of alginate and chitosan.
2. **Optimal temperature: 90°C**, at which the highest concentration of silver nanoparticles can be obtained while at the same time the aqueous solution has not boiled.
   Optimal alginate concentration: 0.2% (w/v), as the concentration of silver nanoparticles does not increase further when the alginate concentration reaches 0.2%.
   Optimal silver ion concentration: 0.01 M, as the antibacterial property has reached the peak at that concentration and is not further increased even when the concentration is increased by 10 times (0.1 M).
3. **Antibacterial activity: excellent**, a very clear inhibition zone is formed around the film in agar diffusion method.
   Water uptake percentage: 0%
   The antibacterial film is found to be water-resistant and water-insoluble.
   Tensile strength: 8.2 MPa, comparable to that of LDPE, which is commonly used as packaging film.
   Shelf life: long, the antibacterial effect of the film does not decrease after storing for 3 months at room conditions.

VI. If your team will compete the Sustainable Development Award, please indicate the specific sustainable development goal the project is related to, and provide justification for competing for this award. *(Word limit: 300 words)*

The common practices of making silver nanoparticles use high radiations and toxic chemicals that are non-renewable and non-biodegradable, leading to biological and environmental risks.

Our project presents an eco-friendly way to synthesize silver nanoparticles in aqueous medium at a low temperature (90°C), using two natural carbohydrate-based polymers (alginate and chitosan). They are non-toxic, renewable, biocompatible and biodegradable.

Therefore, our way of synthesizing silver nanoparticles will adopt the following green chemistry principles: using less hazardous chemical syntheses, using safer solvents and auxiliaries, designing for energy efficiency, using renewable raw materials & designing degradable chemical products.

Moreover, alginate is commonly used as food additive or thickening agent while chitosan can be derived from the outer skeleton of shellfish, including crab, lobster, and shrimp.

In view of that, we propose the government can try to **sort out the kitchen waste and extract alginate and chitosan from the waste**. For example, alginate can be extracted from soups and sauces, and chitosan can be extracted from seafood shells.

Therefore, our project can contribute to the **sustainable development of synthesizing silver nanoparticles**, which are proven to be a very effective antibacterial agent in biotechnological and biomedical fields.

VII. Conclusion

Our project presents an eco-friendly way to synthesize silver nanoparticles in aqueous medium at a low temperature (90°C), using two natural carbohydrate-based polymers (alginate and chitosan).

Alginate can form cross-links with chitosan to produce a polyelectrolyte complex (PEC) to cap the silver nanoparticles. A stable water-insoluble film can be successfully formed after the PEC is dried.

We have determined the optimal conditions for this synthesis (i.e. optimal temperature = 90℃; optimal silver ion concentration = 0.01M; optimal alginate concentration = 0.2%) by carrying out fair tests.

The silver-nanoparticle film made under such conditions has a long shelf life and is found to have significant antibacterial effect against E. coli. Besides, the film is found to be water-insoluble, water-resistant and tough. Therefore, we believe that the film can potentially be used for food packaging and wrapping of medical devices.