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# *Lagerstroemia speciosa* fruit-mediated synthesis of silver nanoparticles and its application as filler in agar based nanocomposite films for antimicrobial food packaging

Khusbu Basumatary[a], Pallabi Daimary[a], Shon Kumar Das[a], Mala Thapa[b], Mukesh Singh[b], Avik Mukherjee[a], Santosh Kumar[a,*]

[a] *Department of Food Engineering and Technology, Central Institute of Technology, BTAD, Kokrajhar, Assam, 783370, India*
[b] *Department of Biotechnology, Haldia Institute of Technology, Purba Medinipur, Haldia-721657, India*

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ABSTRACT

Agar based nanocomposite films were developed by incorporation of silver nanoparticles (AgNPs) as filler. The AgNPs were synthesized using aqueous fruit extract of *Lagerstroemia speciosa*, an abundantly available medicinal plant in North-Eastern part of India. The synthesized silver nanoparticles were characterized by UV–Vis spectroscopy and transmission electron microscopy (TEM) analysis. TEM results showed that most of the particles were hexagonal in shape with size range of 32–62 nm. Incorporation of AgNPs improved the antimicrobial property, thermal stability, elongation at break and appearance of the composite films, whereas tensile strength (TS) decreased. The FTIR analysis of the films showed that the AgNPs had good compatibility with agar matrix. The orange-brown colour of the composite films may help to protect wrapped (packed) food products from UV rays. The composite films showed good antibacterial activity against Gram-negative foodborne pathogen *Aeromonas hydrophilla*, and may have potential for food packaging applications.

## 1. Introduction

The use of plastics in food packaging is growing at an accelerated rate due to their lower cost and better physical, chemical and mechanical properties making them suitable for packaging applications. However, excessive use of synthetic plastic materials, which are non-degradable in nature, cause a massive accumulation of plastic wastes in the environment (Cha & Chinnan, 2004). Consumers' demand for healthy and safe foods free from synthetic additives (e.g. plasticizers in plastic polymers), and environmental concerns during the past decades have led to the development of environment-friendly packaging materials (e.g. biopolymers). Numerous polysaccharides such as starch, chitosan, agar, guar gum, and carrageenan have been studied by researchers for potential applications in packaging (Basu, Kundu, Sana, & Halder, 2017; Castillo, Farenzena, Pintos, & Rodríguez, 2017; Thakur, Pristijon, Golding, & Stathopoulos, 2017).

Agar is one such highly attractive polysaccharide for food packaging application. It is synthesized by red algae of the class Rhodophyceae, and is composed of agarose and agaropectin. Till date, numerous agar-based food packaging films have been investigated (Kanmani & Rhim, 2014; Malagurski, Levic, Nesic, & Mitric, 2017). However, there are certain limitations for their application in the food packaging industry due to their poor mechanical, optical and thermal properties (Othman, 2014). In addition, agar based packaging films lack antimicrobial activity. These limitations can significantly affect food quality, shelf-life and consumer acceptability. More research is needed to overcome such limitations in order to make them appropriate for food packaging.

The limitations may be effectively addressed by incorporation of silver nanoparticles (AgNPs) in biopolymer based packaging materials (Othman, 2014). To make the biopolymer-nanoparticles composite film non-toxic, economic, environmentally benign and compatible to food, they should be synthesized by green protocol (Dhand et al., 2016). In recent years, plant-mediated, environment-friendly synthesis of silver nanoparticles has received much attention due to easy and inexpensive method (Ahmed, Murtaza, Mehmood, & Bhatti, 2015; Ghaffari-Moghaddam, Hadi-Dabanlou, Khajeh, Rakhshanipour, & Shameli, 2014; Pugazhendhi, Kirubha, Palanisamy, & Gopalakrishnan, 2015; Rajan, Vilas, & Philip, 2015).

In this study, fruit extract of *Lagerstroemia speciosa*, locally known as "Jarul" was used for the phyto-synthesis of silver nanoparticles. The Jarul plant belongs to Lythraceae family, and is mostly used as an ornamental plant (Liu et al., 2001). The plant and their various parts

* Corresponding author.
*E-mail address:* s.kumar@cit.ac.in (S. Kumar).

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contain a wide range of biologically active components such as alkaloids, glycosides, flavonoids, tannins, terpenoids, phenols, saponins, alkaloids, and vitamins (Saisaraswathi, Tatsugi, Shin, & Santhakumar, 2017). Due to presence of these biologically active components, *L. speciosa* exhibits numerous functionalities like anti-bacterial (Laruan, Balangcod, & Balangcod, 2013), anti-arthritic (Saisaraswathi, Himaja, Saravanan, Chaitra, & Chanchal, 2015), anti-diabetic, anti-obesity (Klein, Kim, & Himmeldirk, 2007), anti-inflammatory, free radical scavenging and antioxidant activities (Priya, Sabu, & Jolly, 2008).

The objectives of the present research were to synthesize silver nanoparticles by green route using *Lagerstroemia speciosa* fruit, and to develop agar-AgNPs composite film for antimicrobial food packaging application. The antibacterial properties of the developed film were tested against a Gram negative foodborne pathogen, *Aeromonas hydrophila.* It is one of the most common pathogens present in fruits and vegetables, which causes septicemia and gastroenteritis in human (Elhariry, 2011).

## 2. Materials and methods

### 2.1. Materials and reagents

Fresh fruits of *L. speciosa* were collected from campus garden of Central Institute of Technology Kokrajhar, Assam (India). Agar powder and extra pure $AgNO_3$ (99.5%) was procured from SRL Chem, Mumbai, India. Glycerol (98%) was procured from Merck, India. All reagents provided were of analytical grade. The inoculum of *A. hydrophilla* was isolated from partially putrid vegetables, and was characterized by optical microscopy, biochemical tests and molecular assay in our previous work (Singh & Sahareen, 2017).

### 2.2. Preparation of aqueous fruit extract

The dried fruits were grinded using mixer-grinder, and then sieved to separate out the finest powder. The powder was stored in sealed air-tight glass container. Hot water extraction method was used to brew the fruit powder. Five grams (5 *g*) of fruit powder were mixed into100 mL of double distilled water ($ddH_2O$), and the mixture was heated at 70 °C for 15 min. The extract was centrifuged in a cold centrifuge at 10,000 rpm for 10 min at 25 °C. The supernatant was collected and stored at 4 °C for further utilization.

### 2.3. Synthesis of silver nanoparticles (AgNPs)

The synthesis of nanoparticles was carried out using the procedure, as described by Saha, Begum, Mukherjee, and Kumar, (2017) stalk solution of $AgNO_3$ (1.0 mM) was prepared. In a typical synthesis, 19 mL of the solution was taken in 100 mL air-tight glass container, and heated on hot plate magnetic stirrer (REMI, India) at 70 °C with continuous stirring at 500 rpm. Aqueous fruit extract (0.1 mL) was gradually added into the container while heating. The color of the solution began to change from colorless to yellowish brown within 5 min of adding the aqueous fruit extract. The change in color that signified progress of synthesis was monitored by measurement of absorbance of the reaction mixture in a UV–vis spectrophotometer at regular interval upto 3 h. The amount of added aqueous fruit extract in $AgNO_3$ solution varied from 0.1 mL to 1 mL (i.e. 0.1 mL, 0.2 mL, 0.4 mL, 0.6 mL, 0.8 mL and 1 mL, respectively). In each case, the final volume of reaction mixture was maintained at 20 mL by adding $ddH_2O$. One control was also prepared by taking 19 ml of $ddH_2O$ and 1 mL of fruit extract without $AgNO_3$.

### 2.4. Characterization of the synthesized AgNPs

The UV–vis spectra were used to determine the optical properties of the samples in order to observe the reduction of silver ions ($Ag^+$) and stabilization of particles by the action of fruit extracts. The reaction

**Fig. 1.** *Lagerstroemia speciosa* fruit (Inset- Dried fruit powder).

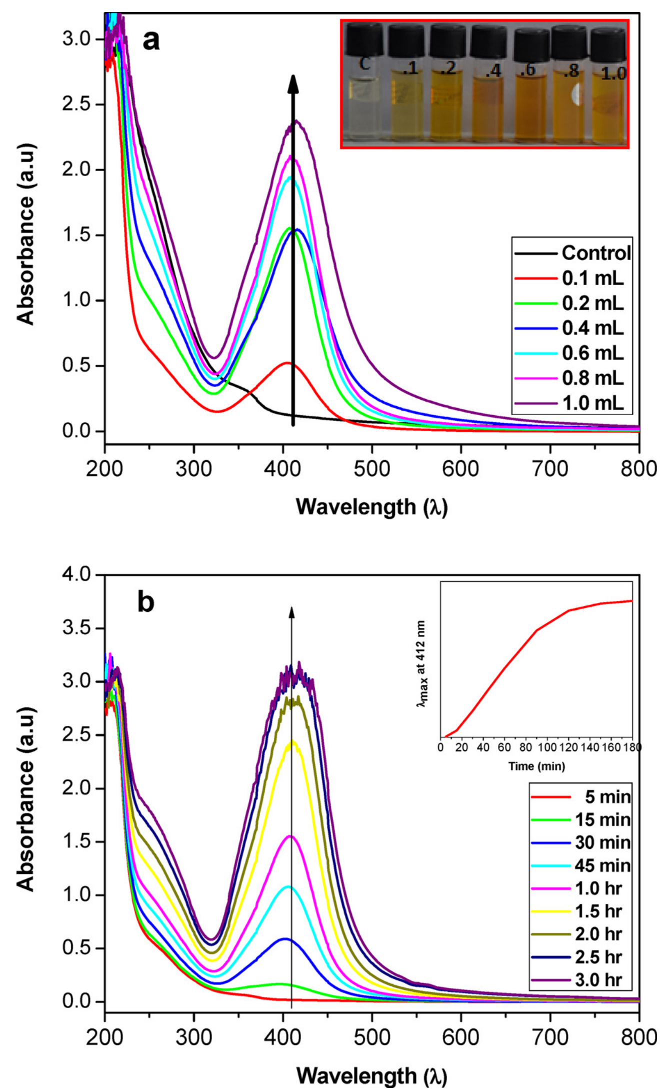


**Fig. 2.** UV–vis absorption spectra of reaction mixture of $AgNO_3$ solution and aqueous fruit extract (a) as a function of amount of aqueous fruit extract added; after 60 min heating (Inset; color of reaction mixture) and (b) as a function of time of reaction; for sample having 0.2 mL of aqueous fruit extract.