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Full Length Article

# Functioned silver nanoparticle loaded activated carbon for the recovery of bioactive molecule from bacterial fermenter for its bactericidal activity

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ABSTRACT

A novel continuous production and extraction of bacterial bioactive prodigiosin (PG) from fermented using silver nanoparticle impregnated functioned activated carbon composite is proposed for cost-effective and ecofriendly microbial technique. Hence, in this investigation silver nanoparticle was impregnated onto functioned activated carbon ($[AC]_F$) as a support matrix and to enable the separation of PG conjugated silver nanoparticle from the fermented medium. A laboratory scale experiment was carried out to evaluate the continuous production and recovery of PG using $[AC@Ag]_F$. Ag nanoparticle impregnated $[AC]_F$ ($[AC@Ag]_F$) characterized by FT-IR, XRD, TGA, DSC and SEM. Instrumental analyses confirmed that Ag nanoparticles significantly impregnated on AC through the functionalization of AC with diethanolamine and it enhances the binding capacity between AC and Ag. The various process parameters, such as contact time, pH, and mass of $[AC@Ag]_F$, were statistically optimized for the recovery of PG using Response Surface Methodology (RSM). The maximum extraction of PG in $[AC@Ag]_F$ was found to be $16.2 \pm 0.2\,mg\,g^{-1}$, its twofold higher than $[AC]_F$. Further, PG conjugated $[AC@Ag]_F$ and ($[AC@Ag]_F$-PG) were checked for the growth inhibition of gram negative and gram positive bacteria without formation of biofilm upto 96 h. Hence, the developed matrix could be eco-friendly, viable and lower energy consumption step for separation of the bacterial bioactive PG from fermented broth. In additionally, $[AC@Ag]_F$-PG was used as an antifouling matrix without formation of biofilm.



## 1. Introduction

Prodigiosin (PG) is a bioactive alkaloid, produced by various microorganisms in the stationary phase of fermentation [1]. It has been extensively studied for its promising pharmacological activities [2]. However, the bioactive PG is not being commercialized, due to its high production cost and conception of high energy during the recovery. Generally, raw materials account for 10–30% of cost in upstream process and solvents/filters accounts 60–70% of cost in downstream processing from the overall production cost. The downstream process of PG has been comprehensively studied for its biological activity which includes antibacterial and antifungal properties. There are many conventional methods have been proposed for the recovery of PG such as liquid–liquid extraction (solvent based extraction) and solid-liquid extraction (polymer based extraction) [3–7]. The solid-liquid based extraction is one of the most favorable for PG extraction compared to liquid–liquid extraction because it reduces the solvent usage and energy consumption. The use of polymeric membrane materials were often non-attractive because membrane fouling by non-diffusible components of culture broth which cause the operational problem and more expensive [8]. Moreover, it is inadequate to ensure the efficient recovery of PG by solvents and polymers because of the high cost and low adsorption capacity.

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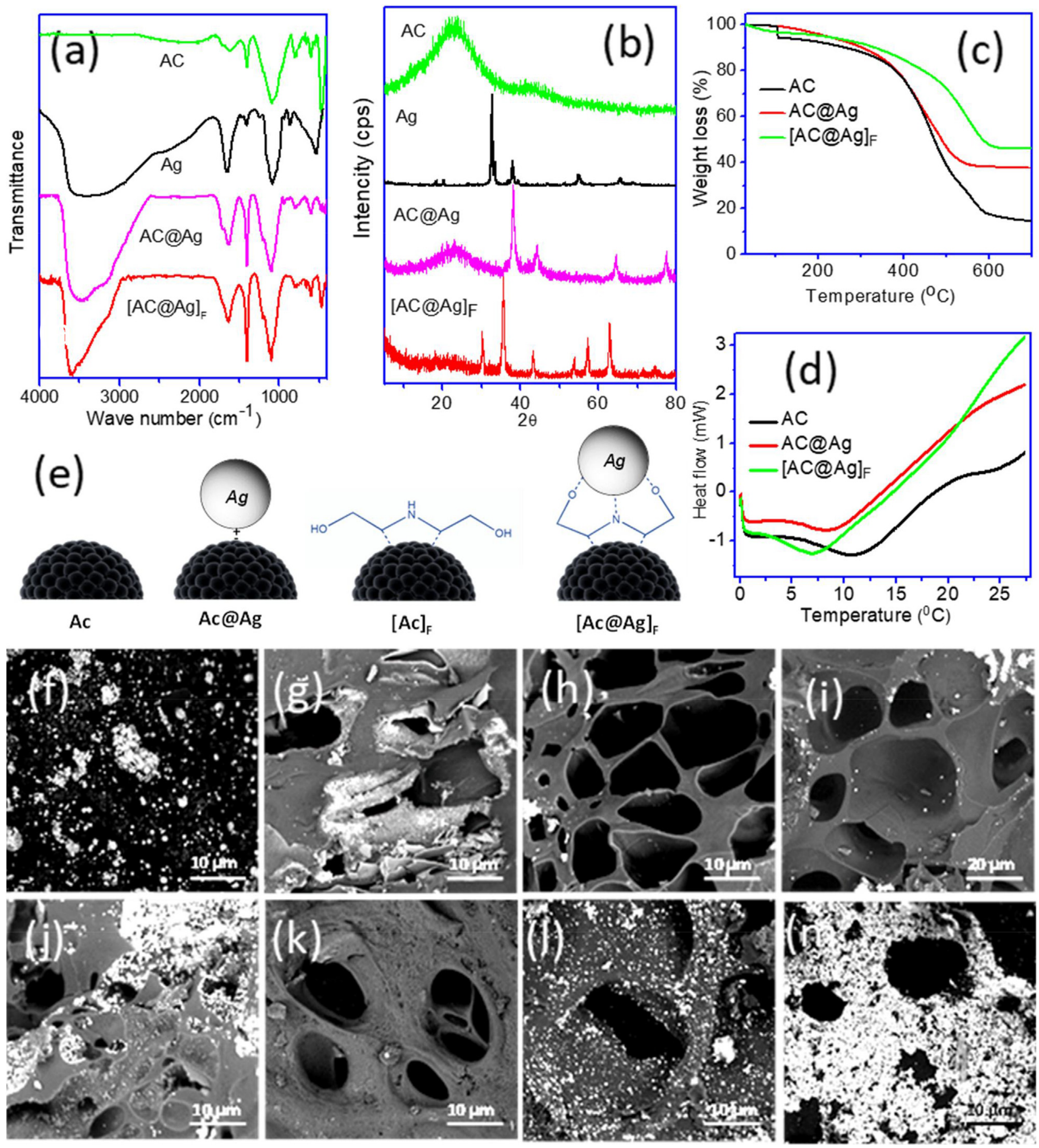


**Fig. 1.** (a) FT-IR and (b) XRD spectrum of AC, Ag, AC@Ag, and $[AC@Ag]_F$. (c) TGA and (d) DSC analysis of AC, AC@Ag and $[AC@Ag]_F$. (e) Molecular diagram of preparation $[AC@Ag]_F$. SEM and microscopic images of (f) Ag, (g) Carbon, (h) AC (i) Ac@Ag, (j) Ac@Ag-PG, (k) $[AC]_F$, (l) $[AC@Ag]_F$ and (m) $[A@Ag]_F$-PG.

Developments in nanotechnology provide new openings to develop cost-effective and sustainable process in biotechnology. Nanostructured adsorbents such as nanofibers, nanotubes, metal nanoparticles, etc. have been currently employed in adsorption of biomolecules. Recently, metal nanoparticle has attracted much attention for adsorption of biomolecules [9–12]. There have been many reports on removal of dye from water/waste water by silver nanoparticle [13–17]. The use of silver nanoparticle has remarkable attention for its biomolecule interaction with unique physical and chemical properties [18–21]. However, the silver nanoparticles alone could not be used for the extraction of PG in the fermented medium due to non-retrieval of the nanoparticle. Therefore, it is proposed to impregnate silver nanoparticle onto activated Carbon to overcome the recovery limitations of silver nanoparticles from the fermenter [22,23]. Activated carbon (AC) having sufficient adsorption capacity towards metal ions coupled with an excellent regeneration property leads to its application in water/waste water treatment [24–26]. The surface modification/functionalization process enhanced the surface area and adsorption capacity of the matrix [27–29].

In the present investigation, functionalized activated carbon was developed from the paddy agricultural waste. Further, the AC