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Anti-acne, anti-dandruff and anti-breast cancer efficacy of green synthesised silver nanoparticles using *Coriandrum sativum* leaf extract

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ABSTRACT

In this present investigation, AgNPs were green synthesised using *Coriandrum sativum* leaf extract. The physicochemical properties of AgNPs were characterised using UV–visible spectrophotometer, field emission scanning microscopy/energy dispersive X-ray (FESEM/EDX), Fourier transformed infrared spectroscopy (FT-IR), X-ray diffraction (XRD) and Brunauer-Emmett-Teller (BET) analysis. Further, *in vitro* anti-acne, anti-dandruff and anti-breast cancer efficacy of green synthesised AgNPs were assessed against *Propionibacterium acnes* MTCC 1951, *Malassezia furfur* MTCC 1374 and human breast adenocarcinoma (MCF-7) cell line, respectively. The flavonoids present in the plant extract were responsible for the AgNPs synthesis. The green synthesised nanoparticles size was found to be ≈37 nm. The BET analysis result shows that the surface area of the synthesised AgNPs was found to be 33.72 $m^2\ g^{-1}$. The minimal inhibitory concentration (MIC) of AgNPs for acne causative agent *P. acnes* and dandruff causative agent *M. furfur* was found to be at 3.1 and 25 μg mL^{-1}, respectively. The half maximal inhibitory concentration (IC_{50}) value of the AgNPs for MCF-7 cells was calculated as 30.5 μg mL^{-1} and complete inhibition was observed at a concentration of 100 μg mL^{-1}. Finally, our results proved that green synthesised AgNPs using *C. sativum* have great potential in biomedical applications such as anti-acne, anti-dandruff and anti-breast cancer treatment.

1. Introduction

Silver nanoparticles (AgNPs) are finding rich applications in various area including nanodevices, nanoelectronics, nanosensors, information storage, biomedical treatments and water purification [1–3]. The reduction of various complexes with silver (Ag^+) ions in aqueous solution leads to the formation of silver (Ag^0) atoms, which is followed by agglomeration into oligomeric clusters. These clusters eventually lead to the formation of colloidal AgNPs [4]. Several biological, chemical and physical methods are proposed to generate the nanoparticles [5,6]. However, most of physicochemical strategies are suffering in the application process due to the utilization of high energy, hazardous nature, difficulty in separation and time consuming steps. Interestingly, AgNPs synthesised using enzymes, proteins, microorganisms and plant materials would offer a more biocompatible, eco-friendly, cost-effective, and easy biological approach for large scale production [7,8]. Particularly, plant mediated green synthesis of nanoparticles is an efficacious approach which finds immense application in the field of many modern medicines [9,10]. In addition, plant extracts may act both as reducing agents and stabilizing agents in the synthesis of nanoparticles.

Coriandrum sativum commonly known as coriander is a medicinally important herb of the Apiaceae family. The plant parts of *C. sativum* are highly rich in aromatic flavor and are commonly used for soups in Asian countries. Traditionally, this plant has been used to cure alleviate spasms, gastric complaints, bronchitis, gout and giddiness [11]. The available literatures on this herb confirms their biomedical properties such as antidiabetic, antioxidant, hypocholesterolemic, antihelmintic, antibacterial, appetizer, hepatoprotective, anticancer and anxiolytic activities [12–14]. Phytochemicals present in the plant materials are involved in the prevention of different chronic and degenerative diseases [15]. Flavonoids are a secondary metabolites that occupy an

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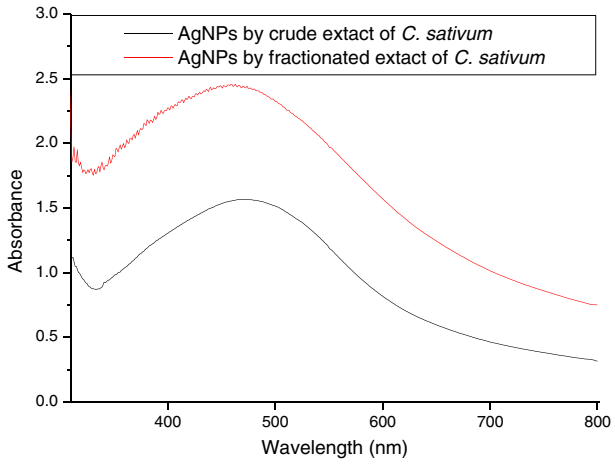

Fig. 1. UV–vis spectrum of green synthesised AgNPs by crude and fractionated flavonoids of *C. sativum* leaf extract.

important position among the phytochemicals, which have proven pharmacological activities such as antiallergic, antibacterial, anti-inflammatory, antiviral and anticancer [16–18]. In addition, flavonoids are considered as free radical scavengers, cyclooxygenase inhibitors and tumor suppressors [19,20].

Acne is a chronic inflammatory disease of the pilosebaceous units, which is characterised by seborrhea, the formation of open and closed comedones, erythematous papules, nodules, deep pustules and pseudocysts [21]. Three major factors are involved in the pathogenic mechanisms for increased sebum production viz. hypercornification of the pilosebaceous duct, an abnormality of the microbial flora (particularly, colonization of the duct with anaerobic diphtheroids *Propionibacterium acnes*) and inflammation. The sebum produced by acne patients are shown to be deficient in linoleic acid, which is directly associated with retention hyperkeratosis of the pilosebaceous follicle. Once the follicles occluded, *P. acnes* inhabit the follicles at puberty, and produce lipases, which hydrolyze sebaceous gland triglycerides into free fatty acids. Further, these acids in combination with bacterial proteins and keratin are extruded through the dilated follicular wall into the dermis, producing a neutrophilic inflammatory response [22,23]. However, there is no ideal treatment for acne, although a suitable regimen for reducing lesions can be found for most patients [24]. Moreover, the treatment of acne with antimicrobial agents has been found to be associated with the development of resistance to these agents by *P. acnes*, leading to treatment failure. Thus, alternative approaches with new biologically active principles for the antimicrobial treatment of acne are needed.

Dandruff is one of the serious troubles in human beings worldwide, characterised by scaling of the scalp and skin. Persistence of dandruff may lead to itching and hair loss [25]. *Malassezia* species such as *M. furfur*, *M. sympodialis*, *M. sloofia*, *M. pachydermatis*, *M. globosa* and *M. restricta* are well recognized as a causative organism for dandruff [26,27]. Association between *M. furfur* and dandruff, and their pathogenic effects in human beings is well documented. In spite of several commercially available ketoconazole based anti-dandruff shampoo, dandruff recurrence is more frequent. Furthermore, resistance of dandruff to antifungal agent is also of immense interest due to the development of resistant strains. Thus, the formulation of an efficient anti-dandruff agent to prevent recurrence is essential.

Breast cancer is the development of cancer in breast tissues. Signs of breast cancer are a lump in the breast, a change in breast shape, dimpling of the skin, fluid leakage from the nipple, or a red scaly patch of skin. Breast cancer is more common in developed countries and leading cancer in women, accounting for 25% of all cases [28]. Thus, there is a need to give much more attention to develop more potent anti-cancer drugs so as to effectively check the increasing prevalence of this cancer.

In this study, AgNPs were green synthesised using *C. sativum* leaf extract and the active phytochemicals responsible for the AgNPs synthesis was assessed. Furthermore, in order to know their anti-acne, anti-dandruff and anti-breast cancer properties, *in vitro* microbial and cytotoxicity studies were performed against *P. acnes* MTCC 1951, *M. furfur* MTCC 1374 and human breast adenocarcinoma (MCF-7) cell line. This is the first report for anti-acne, anti-dandruff and anti-breast cancer efficacy of green synthesised AgNPs using *C. sativum* leaf extract.

2. Materials and Methods

2.1. Chemicals, Medium, Microorganisms and Cell Line

Nutrient agar, brain-heart infusion agar (BHIA), Leeming Notman agar (LNA) and Mueller-Hinton agar (MHA) were obtained from HiMedia (Mumbai, India). Silver nitrate was procured from Merck (Darmstadt, Germany). Dulbecco's modified eagle's medium (DMEM), fetal bovine serum (FBS), ficoll histopaque, potassium bromide and Roswell Park Memorial Institute (RPMI) 1640 medium were purchased from Sigma-Aldrich (St. Louis, MO, USA). *P. acnes* MTCC 1951 and *M. furfur* MTCC 1374 were obtained from the Microbial Type Culture Centre (MTCC, Chandigarh, India). The MCF-7 cell line was received from American Type Culture Collection (ATCC, Manassas, USA). All other reagents used in this study were of analytical grade.

2.2. Plant Material

The well grown plant *C. sativum* was collected from agricultural field near to Periyar University, Tamil Nadu, India. The voucher specimen was identified by Botanical Survey of India, Southern Regional Centre, Coimbatore, Tamil Nadu, India. The reference number of the identified plant is BSI/SRC/5/23/2014-15/Tech-341. The fresh leaves of *C. sativum* were washed thoroughly with double distilled water in order to remove the surface contaminants. The leaf extract of *C. sativum* was prepared from 10 g of fresh leaf boiled in 500 mL distilled water for 5 h. Then, the boiled extract was filtered with Whatman No. 1 filter paper and used for nanoparticles synthesis.

2.3. Green Synthesis of AgNPs

A 50 mL of $AgNO_3$ (1 mM) aqueous solution was mixed with the same volume of *C. sativum* aqueous leaf extract and incubated at room temperature until the brownish color was formed, which indicated the synthesis of AgNPs. The green synthesis of AgNPs in the colloidal solution was confirmed by UV–visible spectrophotometer (PerkinElmer, USA) with distilled water as a reference. The green synthesised AgNPs was centrifuged and washed with Milli-Q water in order to remove the excess Ag^+ ions.

Table 1
Phytochemicals screening of *C. sativum* leaf extract and active fraction involved in the AgNPs green synthesis.

S. no.	Phytochemicals	Crude leaf extract of *C. sativum*	Active fraction involved in AgNPs green synthesis
1	Alkaloids	−	−
2	Carbohydrates	+	−
3	Flavonoids	+	+
4	Glycosides	+	−
5	Phenols	+	−
6	Saponins	+	−
7	Steroids	+	−
8	Tannins	+	−
9	Terpenoids	+	−

(+) denotes the presence of phytoconstituents.
(−) denotes the absence of phytoconstituents.