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Research Paper

# Investigation of the effect of pomegranate extract and monodisperse silver nanoparticle combination on MCF-7 cell line

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ABSTRACT

In this study, we aimed to investigate whether the combination therapy of pomegranate extract and silver nanoparticle is effective on MCF-7 cell culture. The pomegranate extract was mixed and incubated with silver nitrate for the microwave assisted green synthesized of silver nanoparticle. Obtained nanoparticles were investigated using X-ray diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR), UV–vis, Field Emission Scanning Electron Microscopy (FESEM), and Transmission Electron Microscopy (TEM) methods The spectroscopic and morphological studies of the monodisperse Ag NPs which have particle size of 15.4 nm indicate the highly crystalline form, well dispersity, and colloidally stable NPs. After fully characterization of prepared nanoparticles, the effectiveness of Ag NPs was determined by evaluating cell viability, nuclear degradation and cell cycle parameters. The results obtained demonstrate that biosynthesized Ag NPs can inhibit the proliferation of human breast cancer cell line MCF-7 in the IC50 at a dose of 12.85 μg/mL and inhibit the proliferation of Ag NPs against anti-growth arresting MCF-7 cell line. This case demonstrates that it may exert its proliferative effect by reducing DNA synthesis and apoptosis-inducing cell cycle stages.

## 1. Introduction

In recent years, nanoparticles and their usage have paid attention as critical technologies in many industrial applications (Saleh and Gupta, 2014, 2012a; Ahmaruzzaman and Gupta, 2011; Gupta et al., 2015; Kouvaris et al., 2012; Parveen et al., 2012; Lead and Ju-Nam, 2008; Kim et al., 2010; Başkaya et al., 2017; Park and Choi, 2011; Hubenthal, 2011; Jin et al., 2010; Karatepe et al., 2016; Noruzi et al., 2011; Chen et al., 2008; Chen and Schluesener, 2008; Viuda-Martos et al., 2010; Arulvasu et al., 2010; Eroles et al., 2012; Rai et al., 2006; Vijayakumar et al., 2013; Tangkanakul et al., 2009; Bakar et al., 2009; Miller, 1959; Goksu et al., 2016; Esirden et al., 2015; Noguez, 2007; Yang and Li, 2013; Philip, 2009; Piao et al., 2011; Asha Rani et al., 2013; Celik et al., 2016a,b,c; Yildiz et al., 2016a,b; Sen et al., 2013, 2012, 2014; Erken et al., 2015; Pamuk et al., 2015; Dasdelen et al., 2017; Castelli et al., 2013; Cheraghia et al., 2017; Shabani-Nooshabadi et al., 2017; Karimi-Maleh et al., 2017a,b; Cheraghi et al., 2017; Sheikhshoaie et al., 2017; Karimi-Maleh et al., 2016; Gupta et al., 2012a; Saleh and Gupta, 2012b; Gupta et al., 1998; Mittal et al., 2010a,b, 2009; Gupta et al., 2011a, 2012b,c; Gupta et al., 2011b; Saleh and Gupta, 2012c; Khani et al., 2010; Karthikeyan et al., 2012; Jain et al., 2003; Gupta et al., 2013). Because of their specific electrical, optical, magnetic, chemical and mechanical properties, nanoparticles are currently used in many high-tech fields such as diagnostics, antimicrobials, medical applications such as drug delivery (Parveen et al., 2012), environmental protection (Lead and Ju-Nam, 2008; Kim et al., 2010) and energy conversion. The synthesis of these types of nanoparticle generally involves the use of a number of physical and chemical methods, such as laser ablation, pyrolysis, chemical or physical vapor deposition, sol-gel and lithography electrostatics, and is generally costly and/or toxic (Park and Choi, 2011). Recently, it has been a great effort to use the biological synthesis of noble metal nanoparticles as an environmentally friendly method (Hubentha et al., 2011), and these have been mostly obtained using plant or fruit extracts (Jin et al., 2010). These green methods offer crystal nanoparticles at low cost, fast, efficient and often in different sizes. This method not only depends on the nature and concentration of plant solubility but also on the pH, temperature and incubation time of the synthesis reaction (Noruzi et al., 2011; Chen and Schluesener, 2008; Chen et al., 2008). Within the scope of this work, nanoparticles are synthesized in conditions as environmentally friendly, stable, reliable, low cost, ultra-fast and easy to synthesize compared to other conventional methods (Viuda-Martos et al., 2010; Arulvasu et al., 2010). P. granatum which is a well-known medical plant belonging to the family Lythraceae have been used for the synthesis of Ag NPs (Eroles et al., 2012). In a recent study, cytotoxic activity of P. granatum against human colon adenocarcinoma and laryngeal cancer cell lines has been

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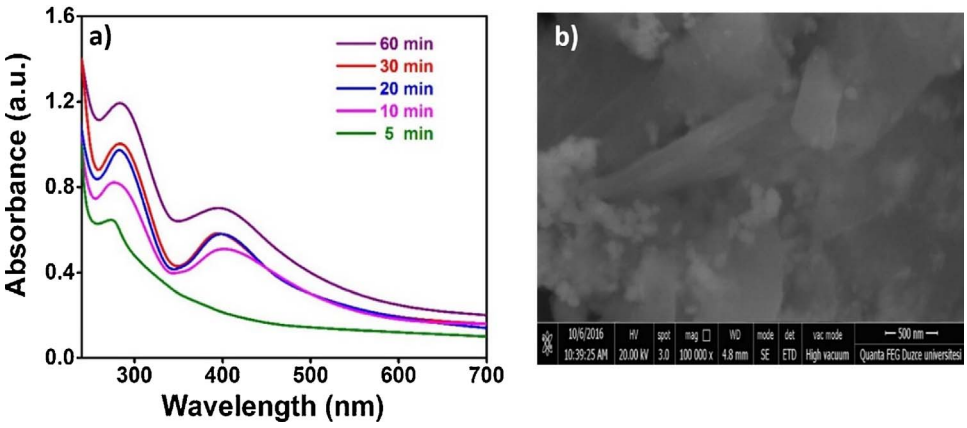


**Fig. 1.** (a) The UV-absorption spectra of Ag NPs synthesized from pomegranate peels (b) SEM image of the produced A gNPs.

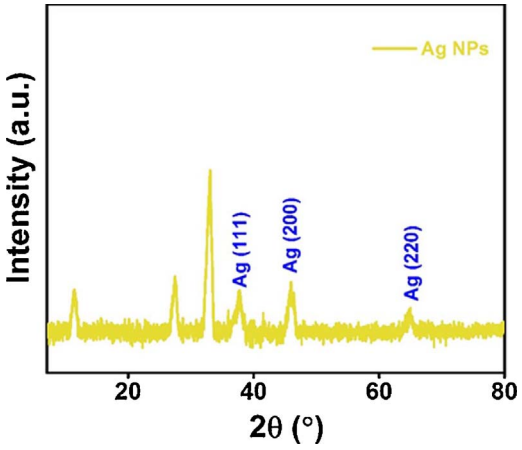


**Fig. 2.** XRD pattern of Ag NPs exhibiting the diffraction of crystalline silver.

reported (Rai et al., 2006). For this purpose, addressed herein, P. granatum was investigated for the microwave assisted green synthesized Ag NPs for antiproliferative effect against MCF-7 cell line.

## 2. Experimental procedure

### *2.1. Microwave assisted green synthesis of AgNPs using pomegranate peel extract*

For green synthesis of Ag NPs in medium, 10 mM aqueous $AgNO_3$ solution was added to 220 mL pomegranate extract and mixed in a vial. Then the vial was placed on the turntable of the microwave oven. The mixture was irradiated for a total of 3 min duration. After irradiation, appearance of a dark brown colour indicates the formation of Ag NPs. Ag NPs were then obtained by centrifugation at 12,000 rpm for 15 min. A pellet was washed three times with ethanol, then dried in a vacuum oven.

## 3. Results and discussion

Mixing the pomegranate extract with the $AgNO_3$ solution at 1 mM resulted in a yellowish-brown color for approximately three minutes, which was thought to be caused by over-induction of plasma vibrations in the surface (Miller, 1959). The whole reaction took about 3 min in microwave condition. Fig. 1a shows the UV–vis spectroscopy of the liquid component as a function of time variation of the pomegranate extract with 1 mM liquid $AgNO_3$ solution. Metal nanoparticles have free electrons, which cause a surface plasmon resonance (SPR) absorption

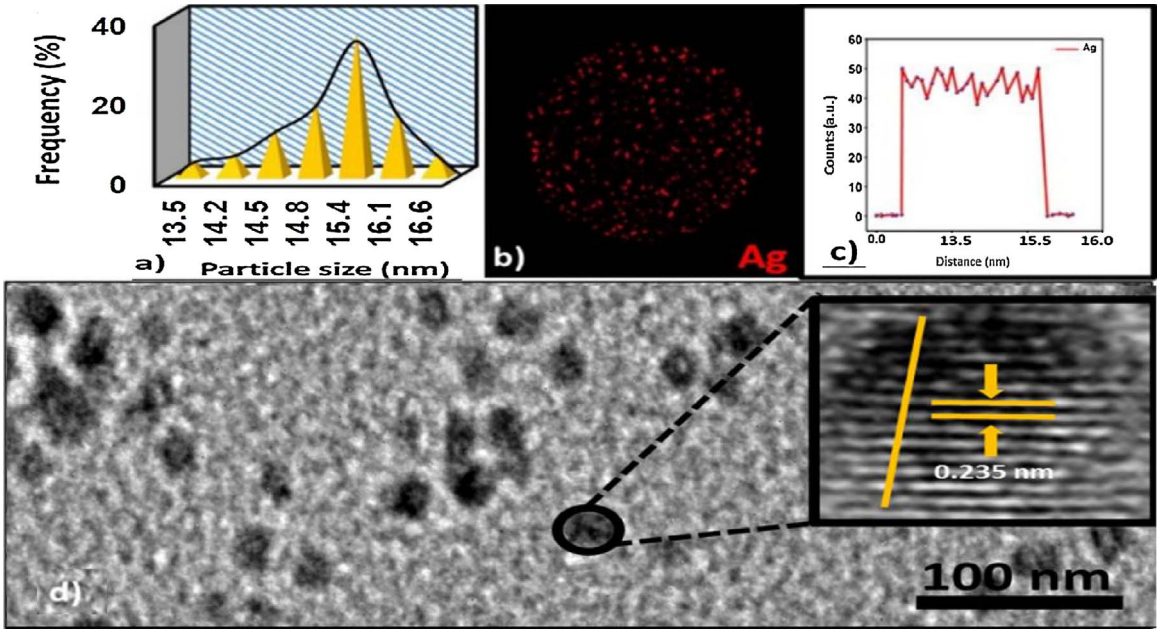


**Fig. 3.** (a) Particle size histogram (b) EELS elemental color-mapping (c) EELS line profile. (d) TEM and HRTEM images of Ag NPs.

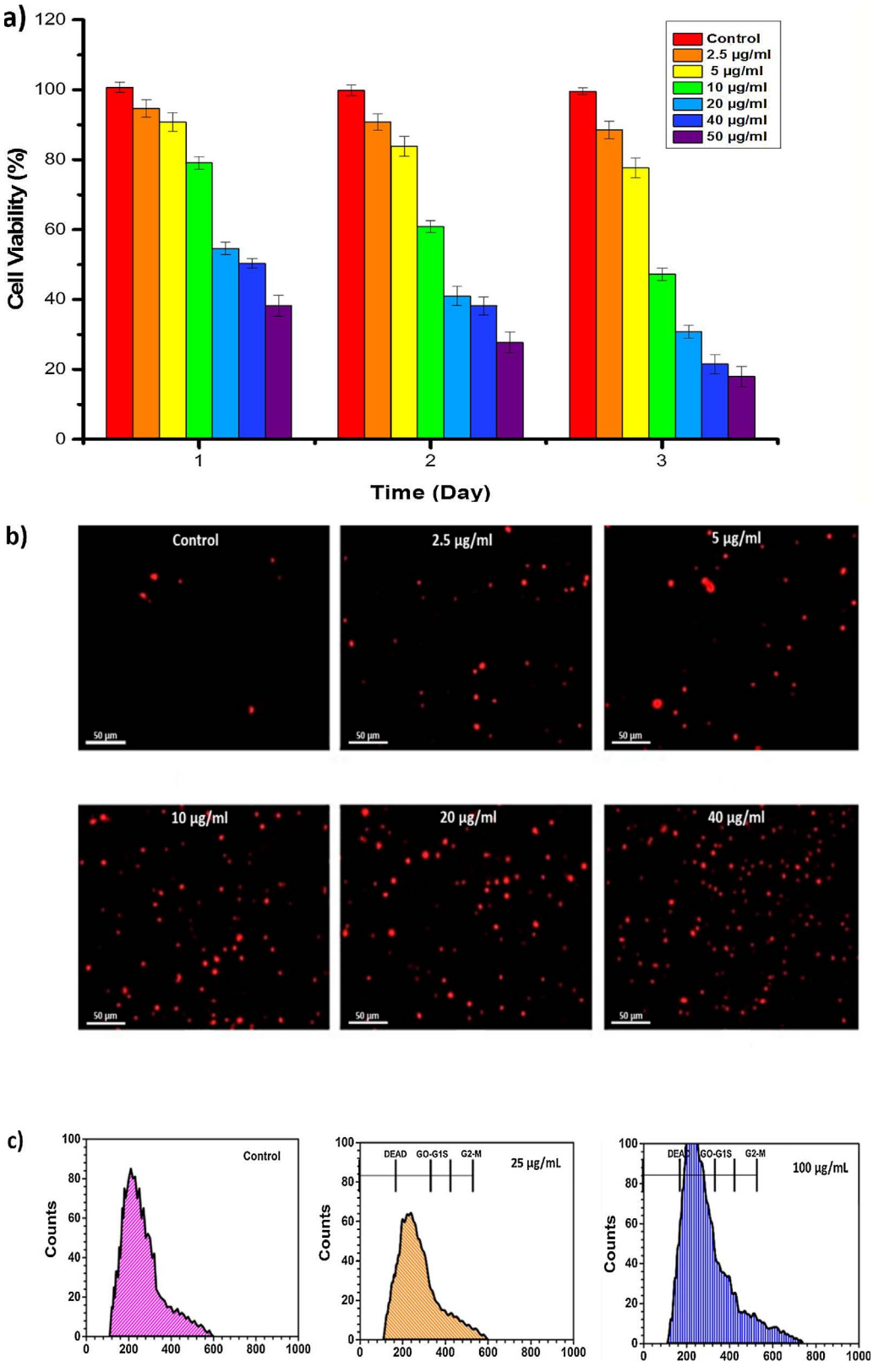


**Fig. 4.** (a) Cell viability following Ag NPs application on MCF7 cells analyzed using MTT method. (b) Propidium iodide (PI) stain exposed to both untreated (control) and AgNPs treated MCF-7 cells. (c) Cell cycle analysis of both untreated and Ag NPs treated MCF-7 cells.

band attributed to the association of vibrating electrons. The SPR band of the biosynthesized Ag NPs was recorded at 420 nm during the reaction at room temperature. Furthermore, FESEM images of synthesized Ag NPs confirms the formation of nanoparticles as shown in Fig. 1b. Silver nanoparticles usually exhibit SPR-related absorption peak at 3 keV energy (Eroles et al., 2012). Besides, Ag NPs have also been characterized by XRD. For this purpose, it's shown the distinct peaks corresponding to (111), (2 0 0) and (2 2 0) in the face centered cubic (fcc) structure of Ag NPs during XRD analysis (Fig. 2). These results were good agreement with previous studies (Rai et al., 2006; Vijayakumar et al., 2013).

Besides, Fig. S1 shows the FTIR results demonstrating the

**Table 1**
The comparison of Ag NPs with the other nanoparticles in literature.

| Nanoparticle | IC 50 | Cell | Reference |
|---|---|---|---|
| Pomegranate-silver nanoparticle | 12.85 μg/mL | MCF-7 | This work |
| Solanum trilobatum-silver nanoparticle | 300 μg/mL | MCF-7 | Ramar et al. (2015) |
| Potentilla fulgens Wall. Hook-silver nanoparticle | 4.91 μg/mL and 8.23 μg/mL | MCF-7 U-87 | Mittal et al. (2015) |
| Turmeric extract-iron | 3.1 ± 0.4 M and 4.9 ± 0.5 M (Photocytotoxicity) | HeLa MCF-7 | Sarkar et al. (2016) |
| Datura-silver nanoparticle | 20 μg/mL | MCF-7 | Gajendran et al. (2014) |

interaction of P. granatum biomolecules with nanoparticles with distinct peaks at 2926, 1682, 1542 and 1334 $cm^{-1}$. As shown in this figure there is a change in the absorption peaks indicating the formation of Ag NPs encapsulated by biocompounds (Tangkanakul et al., 2009; Bakar et al., 2009; Miller, 1959; Bradford, 1976) The distributions determined bonds bound to hydrogen bonded OH stretching (2926 $cm^{-1}$), C=0 stretching (1682 $cm^{-1}$), NH band (1542 $cm^{-1}$) and N=O band (1334 $cm^{-1}$) shows the formation of Ag NPs covered with biocompounds. Lastly, monodisperse Ag NPs has also been characterized by TEM. The morphology and size of the nanoparticles were found to be from 13.5 to 16.6 nm (mostly 15.4 nm) by the help of TEM (Fig. 3). Furthermore, Fig. 3b and c indicates that the EELS mapping and line profile of Ag NPs which also shows the existence of Ag in prepared nanomaterials. Besides, atomic lattice fringes of Ag NPs have also been measured as 0.235 which also indicates the existence of monodisperse Ag NPs.

After the characterization of microwave assisted green synthesized of silver nanoparticle, we have observed that the cytotoxic effect of Ag NPs on the MCF7 cell array increased with increasing concentration of nanoparticles. There was a significant difference in cell viability between the control and the treated groups as shown in Fig. 4a and the IC50 level was found to be 12.85 μg/mL Ag NPs for the MCF7 cells. The effect of Ag NPs on the control cell array is lower compared to the MCF7 cell line in applied dilutions (Bradford, 1976; Noguez, 2007; Yang and Li, 2013; Philip, 2009; Piao et al., 2011; Asha Rani et al., 2013). It's observed that the microwave assisted green synthesized Ag NPs in combination with pomegranate extract caused apoptotic changes in cancer cells, and there was a marked difference compared to the control groups in this regard as shown in Fig. 4b. Furthermore, the antiproliferative effect of Ag NPs biosynthesized from pomegranate extract upon staining with Propidium iodide (PI) showed apoptotic changes and nuclear condensation. In case of control cells, a very negligible number of PI positive cells were noticed. By contrast a progressive increase in the number of PI positive cells was noted in monodisperse Ag NPs treated cells as shown in Fig. 4b. This data suggest that monodisperse Ag NPs scan induce cell death in MCF7 cells through the active oxygen species mediated apoptotic process. The increased ROS levels and subsequent loss of mitochondria membrane potential might be the reason for increased apoptotic morphological changes in Ag NPs treated cells (Castelli et al., 2013; Bilto et al., 2015). Flow cytometry was also used to further investigate whether monodisperse Ag NPs affected the cell cycle as shown in Fig. 4c. By performing of flow cytometry analysis, it's discovered that the treatment with monodisperse Ag NPs for 24 h significantly reduced the DNA content which is good agreement with the literature (Bilto et al., 2015; Guzman et al., 2012). Table 1 also indicates the comparison of Ag NPs with the other nanoparticles in literature for this purpose. As shown in this table current Ag NPs have superior IC 50 values compared to the others in literature.

## 4. Conclusion

Adressed herein, this work explored the formation of microwave assisted monodisperse Ag NPs from environmentally friendly syntheses using pomegranate extract. The average particle size of monodisperse AgNPs is in the range of 13.5–16.6 nm (mostly 15.4 nm) and is regular spherical shape. In addition, the prepared monodisperse Ag NPs have possesses anticarcinogenic activity against MCF-7 cells. It can be concluded that the microwave assisted green synthesized monodisperse AgNPs can be used as potential cancer agents in pharmaceutical industry.

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jbiotec.2017.09.012.

## References

Ahmaruzzaman, M., Gupta, V.K., 2011. Rice husk and its ash as low-cost adsorbents in water and wastewater treatment. Ind. Eng. Chem. Res. 50 (24), 13589–13613.
Arulvasu, C., Babu, G., Manikandan, R., Srinivasan, P., Sellamuthu, S., Prabhu, D., 2010. Anti-cancer effects of *Datura innoxia* P: mill. Leaf extract *in vitro* through induction of apoptosis in human colon adenocarcinoma and larynx cancer cell lines. J. Pharm. Res. 3 (7), 1485–1488.
Asha Rani, P.V., Mun, G.L.K., Hande, M.P., Valiyaveettil, S., 2013. Cytotoxicity and genotoxicity of silver nanoparticles in human cells. ACS Nano 3, 279.
Başkaya, G., Yıldız, Y., Savk, A., Onal Okyay, T., Eriş, S., Sert, H., Şen, F., 2017. Rapid, sensitive, and reusable detection of glucose by highly monodisperse nickel nanoparticles decorated functionalized multi-walled carbon nanotubes. Biosens. Bioelectron. 91, 728–733.
Bakar, M.F.A., Mohamed, M., Rahmat, A., Fry, J., 2009. Phytochemicals and antioxidant activity of different parts of bambangan (*Mangifera pajang*) and tarap (*Artocarpus odoratissimus*). Food Chem. 113, 479–483.
Bilto, Y.Y., Alabdallat, N.G., Salim, M., 2015. Antioxidant properties of twelve selected medicinal plants commonly used in jordan. Br. J. Pharm. Res. 6 (2), 121–130.
Bradford, M., 1976. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. Anal. Biochem. 72, 248–254.
Castelli, R., Gualtierotti, R., Orofino, N., Losurdo, A., Gandolfi, S., Cugno, M., 2013. Current and emerging treatment options for patients with relapsed myeloma. Clin. Med. Insights Oncol. 7, 209–219.
Celik, B., Erken, E., Eris, S., Yildiz, Y., Sahin, B., Pamuk, H., Sen, F., 2016a. Highly monodisperse Pt(0)@AC NPs as highly efficient and reusable catalysts: the effect of the surfactant on their catalytic activities in room temperature dehydrocoupling of DMAB. Catal. Sci. Technol. 6, 1685–1692.
Celik, B., Başkaya, G., Sert, H., Karatepe, Ö., Erken, E., Sen, F., 2016b. Monodisperse Pt (0)/DPA@ GO nanoparticles as highly active catalysts for alcohol oxidation and dehydrogenation of DMAB. Int. J. Hydrogen Energy 41 (13), 5661–5669.
Celik, B., Kuzu, S., Erken, E., Sert, H., Koskun, Y., Sen, F., 2016c. Nearly monodisperse carbon nanotube furnished nanocatalysts as highly efficient and reusable catalyst for dehydrocoupling of DMAB and C1 to C3 alcohol oxidation. Int. J. Hydrogen Energy 41 (4), 3093–3101.
Chen, X., Schluesener, H.J., 2008. Nanosilver: a nanoproduct in medical application. Toxicol. Lett. 176, 1–12.
Chen, H., Roco, M.C., Li, X., Lin, Y., 2008. Trends in nanotechnology patents. Nat. Nanotechnol. 3 (3), 123–125.
Cheraghi, S., Taher, M.A., Karimi-Maleh, H., 2017. A sensitive amplified sensor based on improved carbon paste electrode with 1-methyl-3-octylimidazolium tetrafluoroborate and ZnO/CNTs nanocomposite for differential pulse voltammetric analysis of raloxifene. Appl. Surf. Sci. 420, 882–885.
Cheraghia, S., Mohammad, A.T., Karimi-Maleh, H., 2017. Highly sensitive square wave voltammetric sensor employing CdO/SWCNTs and room temperature ionic liquid for analysis of vanillin and folic acid in food samples. J. Food Compos. Anal. 62, 254–259.
Dasdelen, Z., Yıldız, Y., Eris, S., Sen, F., 2017. Enhanced electrocatalytic activity and durability of Pt nanoparticles decorated on GO-PVP hybride material for methanol oxidation reaction. Appl. Catal. B: Environ. 219C, 511–516.

Erken, E., Pamuk, H., Karatepe Ö, Başkaya, G., Sert, H., Kalfa, O.M., Sen, F., 2015. New Pt (0) nanoparticles as highly active and reusable catalysts in the C1–C3 alcohol oxidation and the room temperature dehydrocoupling of dimethylamine-borane (DMAB). J. Cluster Sci. 27, 9–23.

Eroles, P., Bosch, A., Pérez-Fidalgo, J.A., Lluch, A., 2012. Molecular biology in breast *cancer*: intrinsic subtypes and signaling pathways. Cancer Treat. Rev. 38 (6), 698–707.

Esirden, I., Erken, E., Kaya, M., Sen, F., 2015. Monodisperse Pt NPs@ rGO as highly efficient and reusable heterogeneous catalysts for the synthesis of 5-substituted 1 H-tetrazole derivatives. Catal. Sci. Technol. 5 (9), 4452–4457.

Gajendran, B., Chinnasamy, A., Durai, P., Raman, J., Ramar, M., 2014. Biosynthesis and characterization of silver nanoparticles from Datura inoxia and its apoptotic effect on human breast cancer cell line MCF7. Mater. Lett. 122, 98–102.

Goksu, H., Yıldız, Y., Celik, B., Yazici, M., Kilbas, B., Sen, F., 2016. Eco-friendly hydrogenation of aromatic aldehyde compounds by tandem dehydrogenation of dimethylamine-borane in the presence of a reduced graphene oxide furnished platinum nanocatalyst. Catal. Sci. Technol. 6 (7), 2318–2324.

Gupta, V.K., Srivastava, S.K., Mohan, D., Sharma, S., 1998. Design parameters for fixed bed reactors of activated carbon developed from fertilizer waste for the removal of some heavy metal ions. Waste Manage. 17 (8), 517–522.

Gupta, V.K., Agarwal, S., Saleh, T.A., 2011a. Synthesis and characterization of alumina-coated carbon nanotubes and their application for lead removal. J. Hazard. Mater. 185 (1), 17–23.

Gupta, V.K., Jain, R., Nayak, A., Agarwal, S., Shrivastava, M., 2011b. Removal of the hazardous dye—tartrazine by photodegradation on titanium dioxide surface. Mater. Sci. Eng.: C 31 (5), 1062–1067.

Gupta, V.K., Ali, I., Saleh, T.A., Nayak, A., Agarwal, S., 2012a. Chemical treatment technologies for waste-water recycling—an overview. RSC Adv. 2 (16), 6380–6388.

Gupta, V.K., Jain, R., Mittal, A., Saleh, T.A., Nayak, A., Agarwal, S., Sikarwar, S., 2012b. Photo-catalytic degradation of toxic dye amaranth on TiO2/UV in aqueous suspensions. Mater. Sci. Eng. C 32, 12–17.

Gupta, V.K., Kumar, R., Nayak, A., Saleh, T.A., Barakat, M.A., 2013. Adsorptive removal of dyes from aqueous solution onto carbon nanotubes: a review. Adv. Colloid Interface Sci. 193, 24–34.

Gupta, V.K., Nayak, A., Agarwal, S., 2015. Bioadsorbents for remediation of heavy metals: current status and their future prospects. Environ. Eng. Res. 20 (1), 001–018.

Guzman, M., Dille, J., Godet, S., 2012. Synthesis and antibacterial activity of silver nanoparticles against gram-positive and gram-negative bacteria. Nanomed. Nanotechnol. Biol. Med. 8 (1), 37–45.

Hubenthal, F., 2011. Noble metal nanoparticles: synthesis and optical properties. Compr. Nanosci. Technol. 375–435.

Jain, A.K., Gupta, V.K., Bhatnagar, A., Suhas, 2003. A comparative study of adsorbents prepared from industrial wastes for removal of dyes. Sep. Sci. Technol. 38 (2), 463–481.

Jin, E.S., Ghodake, G.S., Deshpande, N.G., Lee, Y.P., 2010. Pear fruit extract-assisted room-temperature biosynthesis of gold nanoplates. Colloids Surf. B 75, 584–589.

Karatepe, O., Yildiz, Y., Pamuk, H., Eris, S., Dasdelen, Z., Sen, F., 2016. Enhanced electrocatalytic activity and durability of highly monodisperse Pt@ PPy–PANI nanocomposites as a novel catalyst for the electro-oxidation of methanol. RSC Adv. 6 (56), 50851–50857.

Karimi-Maleh, H., Shojaei, A.F., Tabatabaeian, K., Karimi, F., Shakeri, S., Moradi, R., 2016. Simultaneous determination of 6-mercaptopruine, 6-thioguanine and dasatinib as three important anticancer drugs using nanostructure voltammetric sensor employing Pt/MWCNTs and 1-butyl-3-methylimidazolium hexafluoro phosphate. Biosens. Bioelectron. 86, 879–884.

Karimi-Maleh, H., Amini, F., Ahmad, Akbari, Shojaei, M., 2017a. Amplified electrochemical sensor employing CuO/SWCNTs and 1-butyl-3-methylimidazolium hexafluorophosphate for selective analysis of sulfisoxazole in the presence of folic acid. J. Colloid Interface Sci. 495, 61–67.

Karimi-Maleh, H., Ganjali, M.R., Norouzi, P., Bananezhad, A., 2017b. Amplified nanostructure electrochemical sensor for simultaneous determination of captopril, acetaminophen, tyrosine and hydrochlorothiazide. Mater. Sci. Eng. C 73, 472–477.

Karthikeyan, S., Gupta, V.K., Boopathy, R., Titus, A., Sekaran, G., 2012. A new approach for the degradation of high concentration of aromatic amine by heterocatalytic Fenton oxidation: kinetic and spectroscopic studies. J. Mol. Liq. 173, 153–163.

Khani, H., Rofouei, M.K., Arab, P., Gupta, V.K., Vafaei, Z., 2010. Multi-walled carbon nanotubes-ionic liquid-carbon paste electrode as a super selectivity sensor: application to potentiometric monitoring of mercury ion (II). J. Hazard. Mater. 183 (1), 402–409.

Kim, W., Kim, K., Jung, B., Kim, J., 2010. Effects of embedding non-absorbing nanoparticles in organic photovoltaics on power conversion efficiency. Sol. Energy Mater. Sol. Cells 94, 1835–1839.

Kouvaris, P., Delimitis, A., Zaspalis, V., Papadopoulos, D., Tsipas, S.A., Michailidis, N., 2012. Green synthesis and characterization of silver nanoparticles produced using *Arbutus Unedo* leaf extract. Mater. Lett. 76, 18–20.

Lead, J.R., Ju-Nam, Y., 2008. Manufactured nanoparticles: an overview of their chemistry, interactions and potential environmental implications. Sci. Total Environ. 400, 396–414.

Miller, G.L., 1959. Use of dinitrosalicylic acid reagent for determination of reducing sugar. Anal. Chem. 31, 420–428.

Mittal, A., Kaur, D., Malviya, A., Mittal, J., Gupta, V.K., 2009. Adsorption studies on the removal of coloring agent phenol red from wastewater using waste materials as adsorbents. J. Colloid Interface Sci. 337 (2), 345–354.

Mittal, A., Mittal, J., Malviya, A., Kaur, D., Gupta, V.K., 2010a. Decoloration treatment of a hazardous triarylmethane dye, Light Green SF (Yellowish) by waste material adsorbents. J. Colloid Interface Sci. 342 (2), 518–527.

Mittal, A., Mittal, J., Malviya, A., Gupta, V.K., 2010b. Removal and recovery of Chrysoidine Y from aqueous solutions by waste materials. J. Colloid Interface Sci. 344 (2), 497–507.

Mittal, A.K., Tripathy, D., Choudhary, A., Aili, P.K., Chatterjee, A., Singh, I.P., Banerjeen, U.C., 2015. Biosynthesis of silver nanoparticles using Potentilla fulgens Wall. Ex Hook and its therapeutic evaluation as anticancer and antimicrobial agent. Mater. Sci. Eng. C 53, 120–127.

Noguez, C., 2007. Surface plasmons on metal Nanoparticles: the influence of shape and physical environment. J. Phys. Chem. C 111, 3806–3819.

Noruzi, M., Zare, D., Khoshnevisan, K., Davoodi, D., 2011. Rapid green synthesis of gold nanoparticles using Rosa hybrida petal extract at room temperature. Spectrochim. Acta A 79, 1461–1465.

Pamuk, H., Aday, B., Şen, F., Kaya, M., 2015. Pt NPs@GO as a highly efficient and reusable catalyst for one-pot synthesis of acridinedione derivatives. RSC Adv. 5 (61), 49295–49300.

Park, H.H., Choi, Y.J., 2011. Direct patterning of $SnO_2$ composite films prepared with various contents of Pt nanoparticles by photochemical metal-organic deposition. Thin Solid Films 519, 6214–6218.

Parveen, S., Misra, R., Sahoo, S.K., 2012. Nanoparticles: a boon to drug delivery, therapeutics, diagnostics and imaging. Nanomed. Nanotechnol. 8 (2), 147–166.

Philip, D., 2009. Biosynthesis of Au, Ag and Au-Ag nanoparticles using edible mushroom extract. Spectrochim. Acta A 73, 374–381.

Piao, M.J., Kang, K.A., Lee, I.K., Kim, H.S., Kim, S., Choi, J.Y., 2011. Silver nanoparticles induce ovidative cell damage in human liver cells through inhibition of reduced glutathione and induction of mitochondria-involved apoptosis. Toxicol. Lett. 201, 92–100.

Rai, A., Singh, A., Ahmad, A., Sastry, M., 2006. Role of halide ions and temperature on the morphology of biologically synthesized gold nanotriangles. Langmuir 22, 736–741.

Ramar, M., Manikandan, B., Marimuthu, P.N., Raman, T., Mahalingam, A., Subramanian, P., Karthick, S., Munusamy, A., 2015. Synthesis of silver nanoparticles using Solanum trilobatum fruits extract and its antibacterial: cytotoxic activity against human breast cancer cell line MCF 7. Spectrochim. Acta. A. Mol. Biomol. Spectrosc. 140, 223–228.

Saleh, T.A., Gupta, V.K., 2012a. Synthesis and characterization of alumina nano-particles polyamide membrane with enhanced flux rejection performance. Sep. Purif. Technol. 89, 245–251.

Saleh, T.A., Gupta, V.K., 2012b. Photo-catalyzed degradation of hazardous dye methyl orange by use of a composite catalyst consisting of multi-walled carbon nanotubes and titanium dioxide. J. Colloid Interface Sci. 371 (1), 101–106.

Saleh, T.A., Gupta, V.K., 2012c. Column with CNT/magnesium oxide composite for lead (II) removal from water. Environ. Sci. Pollut. Res. 19, 1224–1228.

Saleh, T.A., Gupta, V.K., 2014. Processing methods, characteristics and adsorption behavior of tire derived carbons: a review. Adv. Colloid Interface Sci. 211, 93–101.

Sarkar, T., Butcher, R.J., Banerjee, S., Mukherjee, S., Hussain, A., 2016. Visible light-induced cytotoxicity of a dinuclear iron (III) complex of curcumin with low micromolar IC50 value in cancer cells. Inorg. Chim. Acta 439, 8–17.

Sen, F., Boghossian, A.A., Sen, S., Ulissi, Z.W., Zhang, J., Strano, M.S., 2012. Observation of oscillatory surface reactions of riboflavin, trolox, and singlet oxygen using single carbon nanotube fluorescence spectroscopy. ACS Nano 6 (12), 10632–10645.

Sen, F., Boghossian, A.A., Gibbons, B.M., Sen, S., Faltermeier, S.M., Giraldo, J.P., et al., 2013. Application of nanoparticle antioxidants to enable hyperstable chloroplasts for solar energy harvesting. Adv. Energy Mater. 3 (7), 881–893.

Sen, F., Ulissi, Z.W., Gong, X., Iverson, N., Boghossian, A.A., Godoy, L.C., et al., 2014. Spatiotemporal intracellular nitric oxide signaling captured using internalized, near-infrared fluorescent carbon nanotube nanosensors. Nano Lett. 14 (8), 4887–4894.

Shabani-Nooshabadi, M., Roostaee, M., Karimi-Maleh, H., 2017. Incorporation of graphene oxide-NiO nanocomposite and n-hexyl-3-methylimidazolium hexafluoro phosphate into carbon paste electrode: application as an electrochemical sensor for simultaneous determination of benserazide, levodopa and tryptophan. J. Iran. Chem. Soc. 14, 955–961.

Sheikhshoaie, M., Karimi-Maleh, H., Sheikhshoaie, I., Ranjbar, M., 2017. Voltammetric amplified sensor employing RuO2 nano-road and room temperature ionic liquid for amaranth analysis in food samples. J. Mol. Liq. 229, 489–494.

Tangkanakul, P., Auttaviboonkul, P., Niyomwit, B., Lowvitoon, N., Charoenthamawat, P., Trakoontivakorn, G., 2009. Antioxidant capacity, total phenolic content and nutritional composition of Asian foods after thermal processing. Intern. Food Res. J. 16, 571–580.

Vijayakumar, M., Priya, K., Nancy, F.T., Noorlidah, A., Ahmed, A.B.A., 2013. Biosynthesis, characterization, and anti-bacterial effect of plant-mediated silver nanoparticles using *Artemisia nilagirica*. Ind. Crops Prod. 41, 235.

Viuda-Martos, M., Fernández-López, J., Pérez-Álvarez, J.A., 2010. Pomegranate and its many functional components as related to human health: a review. Compr. Rev. Food Sci. Food Saf. 9, 635–654.

Yang, N., Li, W.H., 2013. Mango peel extract mediated novel route for synthesis of silver nanoparticles and antibacterial application of silver nanoparticles loaded onto non-woven fabrics. Ind. Crops Prod. 48, 81–88.

Yildiz, Y., Aday, B., Ulus, R., Eris, S., Sen, F., Kaya, M., 2016a. One-pot, efficient and green synthesis of acridinedione derivatives using highly monodisperse platinum nanoparticles supported with reduced graphene oxide. New J. Chem. 40 (1), 748–754.

Yildiz, Y., Pamuk, H., Karatepe, O., Dasdelen, Z., Sen, F., 2016b. Carbon black hybrid material furnished monodisperse platinum nanoparticles as highly efficient and reusable electrocatalysts for formic acid electro-oxidation. RSC Adv. 6 (39), 32858–32862.