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Nanotechnology and Tea (*Camellia Linn.* spp.)

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ABSTRACT: Fast emerging nanotechnology seems destined to play a significant role in the production, consumption and other activities involving 'tea'. An attempt has been made here to focus upon the areas that offer scope for application of this modern technology in 'tea'.

Biochemical constituents of tea leaf and processed tea used for eco-friendly preparations of nanoparticles of gold, silver, iron, zinc oxide, copper and their application in health and agricultural activities have been outlined, briefly. Application of nano products in tea culture and post-harvest operations has also been discussed.

KEYWORDS: Nanotechnology; Applications; Tea culture; Scope in tea field

Introduction

Tea is a common and widely consumed beverage in the world, attributed with a number of health benefits[1] including health promoting and protective properties. Sarah E. Cross *et al.,* found that 'green tea' and its extract increase the stiffness of cancer cells without altering normal cells; she stated that "FDA approved 'green tea' extract as a drug which is the first natural product that has ever been approved"[2].

Nanotechnology means any technology on a nanoscale i.e. <100nm that has wide applications in the real world. Nanotechnology plays a cucial role in science and engineering technology which include automotive, electronics, personal care/health, clothing and textile, food, food additives, food packing, sports equipments, cosmetics, households, toys and children goods and medical application[3]. Among various fields of application, food and agriculture are the most important areas which need technological innovations to meet requirements of growing world population.

The total global market involving nanotechnology was $ 19.3 billion in 2010 and is growing at a compound rate of 9% to reach a forecast market size of $ 29.7 billion by 2015[4]. It is reported that nanotechnology research was actively pursued in 400 companies in 2006 and is expected to reach 1000 by 2016. Promising areas in agriculture include tools for disease treatment, rapid disease detection, enhanced nutrient uptake, increasing the efficacy of pesticides and herbicides at lower doses and are open to researchers[5].

Continual application of synthetic fertilizers, loss of nutrients from applied fertilizers, pesticide safety, climate change and safe environment are some critical areas in tea Industry that need attention. An attempt is made here to focus upon potential applications of nanotechnology in different aspects of tea production and consumption. Certain strategies are put across for the advancement of this technology in tea research.

Tea Constituents as a Catalyst for Preparation of Nanoparticles

Silver nanoparticles

Nadagouda and Varma were the first to report a simple methodology to prepare silver and palladium nanoparticles employing coffee and tea powder extracts; no surfactant, capping agent and template were used. The nanoparticles thus prepared were in the range of 20 – 60 nm in size[6].

In addition to tea powder, fresh tea leaves have also been used for preparation of silver nanoparticles. The leachate of tea leaves has been used as a catalyst to convert Ag^+ ions into silver nanoparticles with the calculated average particle size of 24.33 nm; they were evaluated for their antibacterial properties[7]. Jing *et al.* reported that the formation of free radicals on the surface of silver nanoparticles was responsible for its antibacterial effect[8].

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Gold nanoparticles

Ethanol extract of tea powder and its tannin-free extract were used for preparing colloidal gold nanoparticles from aqueous $AuCl_4^-$ precursor with average particle size of 10 nm and 3 nm respectively. Gold nanoparticles prepared from tannin- free ethanol extract of tea powder are more stable and no particle agglomeration was noticed during short and/or long storage conditions[9].

The Polyphenol present in young leaves and buds of tea has also been successfully utilized for preparation of gold nanoparticles with the size ranging from 2.94 to 45.58 nm and an average of 13.14nm under room temperature. In addition, the core size of gold nanoparticles decreases as the amount of tea extract increases[10]. Katti *et al.,* demonstrated that the EGCG present in tea as an effective catalyst for preparation of gold nanoparticles[11].

Zinc nanoparticles

Senthilkumar and Sivakumar utilized the aqueous extract of green tea leaves for preparation of zinc oxide nanoparticles, resembling the structure of hexagonal wurtzite with average particle size of 16 nm; it showed antimicrobial effect against gram-negative bacterial species such as *Klebsiella pneumoniae*, *Pseudomonas aeruginosa* and *Escherichia coli,* resistant to synthetic antibiotics, as well as the gram-positive *Staphylococcus aureus*. The fungal strains namely *A. fumigatus* and *Penicillium* spp. are also sensitive to ZnO nanoparticles[12].

Copper nanoparticles

Crystalline copper nanoparticles with an average particle size of 5 nm have been prepared employing tea decoction at a concentration of 10 – 20%. The FTIR spectrum of this particle showed a thin layer of tea decoction molecule on copper nanoparticles which protect Cu^0 from oxidation for 25 days[13].

Sutradhar *et al.,* developed a method to prepare copper oxide nanoparticles with less than 100 nm, employing tea leaf and coffee powder extracts at 1:3 ratio under microwave irradiation. They evaluated the nanoparticles against human pathogens; it is presumed that the conversion of copper ions into copper oxide nanoparticles is due to EGCG present in both the extracts[14].

Iron nanoparticles

Zero valent iron nanoparticles have been prepared with green tea (GT-nZVI), and polyphenol-rich solution to study the effect of soil geochemistry on the transport characteristics of nanoparticles in porous media[15]. They confirmed that the injection of GT-nZVI, lead to a sharp decrease in pH of effluent and increase in the redox potential, which is attributed to the presence of polyphenol in the suspension. Pattanayak and Nayak prepared iron nanoparticles employing black tea and green tea[16].

Application of Tea Nanoparticles

Nano selenium is marketed as an additive to a tea product in China for number of health benefits[17].

Green tea has been ball milled to reduce its size to 1000nm and sieved. This sieved micro-fine green tea powder was moisturized, agitated and heated to above 100° C. Micro-fine green tea powder improved oxygen eliminating efficiency, nutrient digestion and absorption[18].

Ana-Maria Manea *et al.,* prepared solid lipid nanoparticles (SLN) loaded with green tea extract (GTE) to evaluate their antioxidant and antimicrobial properties; cetyl palmitate and glyceryl stearate as solid lipids and Tween 20 and Tween 80 were tested as surfactants. The SLNs prepared with GTE showed an increase in antioxidant activity compared to free SNLs. The SLN – GTE2 prepared with Tween 20 with 0.17% GTE also showed maximum antibacterial activity against *E.coli*[19].

A team led by Christine Dufes at University of Strathclyde encapsulated transferrin and Epigallocatechin gallate extracted from green tea in a vesicle for targeting and treating cancer cells respectively[20]. They claimed that this treatment helped to shrink or vanish the cancer cells[20].

Bhatnagar et al., prepared nanoparticles of theaflavin (TF) and EGCG by encapsulating in Poly using double encapsulation method. These nanoparticles prevent 7, 12 - dimethylbenzanthracene (DMBA) induced DNA damage in mouse skin by 45.34% and 28.32% respectively[21].

Encapsulation of EGCG to form nano-EGCG which is an enhanced stable compound with chemoprevention activity has been reviewed by Wang, *et al.,*[22]. This has increased the activity by ten fold with an advantage of inducing apoptosis, and inhibition of both angiogenesis and tumor growth.

Tea polyphenol/catechins nano-encapsulated with poly (D,L – lactic-co-glycolic acid) (PLGA) prevents diphenylpicrylhydrazyl (DPPH) induced hemolysis of human red blood cells and ensured the slow release of catechins or polyphenol from PLGA with sustained biological activity[23].

The gold nanoparticles prepared employing Darjeeling tea leaf (T-AuNPs) showed remarkable stability under *in vitro* condition; they exhibited significant affinity towards prostate (PC – 3) and breast (MCF–7) cancer cells[24].

Nanoparticles in Tea Cultivation

Elango and Marimuthu developed an eco-friendly method for preparation of silver nanoparticles with a size of 65 – 92 nm from *Trichoderma sp.* and evaluated its efficacy on the control of *Pestalotiopsis* theae causing grey blight leading to die back of tea shoots. Results indicated that 68% and 76% control of pathogen has been observed with 5 ppm and 10 ppm of silver nanoparticles in both *in vitro* and *ex vitro* conditions. No accumulation of silver particles in tea shoots was observed[25 - 26].

Determination of Tea Components using Nano Materials

Compare to other polyphenolic compounds, catechins will develop colour with immobilized 2,2'(1,41,4-phenylenedivinylene) bis-8-hydroxyquinoline (PBHQ) on nano TiO_2. This characteristic has been utilized for selectively determination of catechins[27].

Application of Nanotechnology in Sensory Evaluation

Electronic nose (E-nose) a device is developed to identify the odorant, estimate the concentration of odorant and find characteristic properties of odor in tea just as human nose does[28]. The main component of E-nose is gas sensors composed of nanoparticles like zinc oxide nano wires[29].

Nanotechnology in Agriculture

The Department of Nano-Science and Technology of Tamilnadu Agricultural University is lab-testing a nano-herbicide that is expected to make chemical weeding efficient[30].

Nanopesticides allow the use of pesticides with minimum risk of environmental damage. Commercial pesticide products have been formulated using nano-emulsions. A leading agrochemical corporation produces a quick-release micro-encapsulated product, which is available under the name Karate® ZEON (Source: Internet) which can be applied to tea.

Future Scope of Nanotechnology in Tea Research

Bhagat *et al.,* developed an orange colour nanogel with all – trans tri (p-phenylenevinylene) bis-aldoxime mixed with methyl eugenol a potent pheromone and used it for trapping system for *Bactrocera dorsalis* a fruit fly of Guavas. This gel releases the pheromone even after three weeks and they have evaluated the trap under field conditions. This may be of interest to tea for pest management as well.

Bayer Polymers developed packaging film (Durethan KU2-2601) made from silicate nanoparticles; it prevents drying of food content and protects the food content from oxygen and moisture. This investigation may be implemented for tea packing.

Carbon nano-fiber is used in manufacturing light weight bicycles[31]. Such technology can be adopted for manufacturing light weight mechanical harvesters with increased stiffness.

Conclusion

With the progress of nanotechnology in agriculture, great potential is waiting ahead in tea industry: 1) fast delivery of nutrients for enhanced efficacy and better absorption at reduced dose 2) to detect disease at an early stage and offer early warning (like red root disease, canker, Blister, Pestalotia) and also as preventive 3) nano-pesticides allow the use of pesticides with minimum risk of environmental damage. 4) nano-herbicide to selectively kill the weeds at low dosage rates 5) nano-sensors and monitoring devices at each stage of tea processing as well as for objective assessment of quality.

Nanotechnology has tremendous potential to bring about radical changes, in the years to come, in all aspects of tea industry from soil to cup.

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