

A Systematic Review on Gold Nanoparticles Extracted from Fungi and their Potential Applications in Food Industry

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ABSTRACT: Rapid advancement in nanotechnology has improved the food and agriculture sector by smart and active packaging, nanofertilizers and nanosensors invention. These new technologies have contributed to enhancement of food, safety of crops, and helped in monitoring of the environment. Gold nanoparticles from fungi can be an alternative in food and agriculture sectors for sustainable development. However, questions related to its performance, toxicity, disposal and regulatory measures are some of the challenges which are faced by nanomaterials. This review paper is a conscious effort which throws light on the synthesis and various applications of gold nanoparticles extracted from fungi in the food sector.

KEYWORDS: Nanoparticles, packaging, stability, pathogens, preservation, toxicity, nanocarriers, reduction, co-precipitation

I. INTRODUCTION

Nanoparticles are microscopic particles with at least one dimension less than 100nm and have properties that are unique to them. Nanoparticles are also called as nano powder or nano cluster or nano crystal and they differ from their macroscale counterparts in surface to volume ratio and properties such as colour, solubility and mode of action. Nanoparticles in the food industry play a vital role in detecting microbial contamination and chemicals which deteriorate the quality of food products. Gold nanoparticles are of vast use in food industries because of their biostability, easy availability, easy functionalization, oxidative resistance, and biocompatibility. Due to higher metal tolerant capacity of fungi than bacteria and the ability to produce extracellular redox proteins in excess which later produce nanoparticles, Fungi are highly used in food processing sector metal tolerant capacity of fungi than bacteria and the ability to produce extracellular redox proteins in excess.

NANOTECHNOLOGY IN FOOD SECTOR

Recently a lot of developments have been seen in the food technology sector due to the vast applications in nanotechnology. Some of these are:-

a) Nanoparticle delivery system: - Using colloidal phenomena of food particles, and applying the knowledge of colloidal science the shelf life and quality of foods have been increased. Many next generation delivery systems have been developed such as mixed nanoparticle systems, environment friendly nanoparticles, and trojan horse particles to ensure food safety and productivity. [1]

b) Nanoencapsulation:-Nanoencapsulation is a technique where the bioactive component of food is modified in such a way that the quality of food is not deteriorated even in harsh climatic conditions or other damaging factors. During olden times, micro encapsulation techniques were limited to some conventional processes such as spray drying, coacervation, extrusion, emulsion technique and liposomes.

There are many types of nanoencapsulation techniques applied in food industry:-

- Lipid Based nanocarriers

These include nanoemulsions which are modified by oil, fats, surfactant molecules and biopolymers and depending on the bioactive ingredient they can be either hydrophobic or hydrophilic in their coating structure. Another example of lipid based carrier is nanoliposomes which have constitutive elements such as solvent mixture, phospholipids and oil in different proportions. The membrane of nanoliposomes may be single bilayered or double layered for the encapsulation of hydrophobic components. [2]

- Nature inspired nanocarriers

These are nanovehicles which are present naturally in their original form in nature and act as encapsulation for various bioactive ingredients such as Casein and amylase.

- Artificially produced nanocarriers

These nanocarriers are artificially produced by highly specialized techniques such as electro spraying, micro-fluidics systems, sonication devices, high pressure homogenizers, and nano-fluidics systems.

- Formulated nanocarriers

These are biopolymer nanoparticles which could be modified through a single biopolymer nanoparticle such as protein desolvation or carbohydrates precipitation.

. They can also be modified into nano-gels of specific biopolymers, nanotubes or nanofibrils.

- Miscellaneous nanocarriers

These nanocarriers include niosomes, cubosomes, nano structured surfactants, nanoparticles made from chemical polymers and nanocrystals. These nanocarriers are vastly used in pharmaceutical fields and are also used in preparation of nutraceuticals and food industry. [3]

c) Nanopackaging:- Nanopackaging of food particles increases the shelf life of packaged food, prevents spoilage of food, improves consumer health and alerts costumers of contamination either by microorganisms or by other agents. These nanotechnology based packing can be categorized into three classes:-

- Improved packaging

A polymer chain is mixed with food which has several advantages in food preservation. Some advantages of improved packaging are that it enhances the gas barrier properties as well as stabilizes the temperature, humidity and resistance of packaging.

- Smart packaging

Also called intelligent packaging, this technique helps in detection of microbial spoilage of food or the biochemical changes which will result in deterioration of food. It helps in the analysis of the specific microorganism which will affect the quality of food. Similarly, the gases responsible for altering the nature of packaged food are determined by Smart packaging.

- Active packaging

This type of Nanopackaging helps in direct interaction of food with nature or nanoparticles providing better protection and resistance from harmful microorganisms. Some nanoparticles such as nano copper oxide, nanosilver serve as antimicrobial agents and thus help preserve the quality of the product. [4]

d) Development of Functional foods: - Functional foods are mixed with food additives through various nanotechniques such as nanodelivery system to improve the quality and taste of food products. This not only enhances their market value but also attracts customer by their appearance or texture. The most common food additives used are anti-browning, antioxidant property, anti-caking property, resistive property, antimicrobial property, and added flavors such as chocolate, vanilla etc.

e) Nanoceuticals:- They are nano-sized particles which have the ability to directly pass through membranes and are absorptive in nature. On the basis of their dissolution rate they are classified into hydrophilic or lipophilic nutraceuticals. The dissolution capacity of hydrophilic nutraceuticals is very high compared to lipophilic nutraceuticals but is less permeable than lipophilic nutraceuticals. They are used in many types of food supplements such as:-

(a) carotenoids nanoparticles in juice

(b) Canola oil based nanoparticles used in vitamins and mineral supplements.

TABLE 1:- Currently available active packaging system [5]

TYPE	TRADENAME	PRINCIPLE	MANUFACTURER
Antimicrobial packaging	Agion	Silver based	Life materials technology limited, USA
Antimicrobial packaging	Biomaster	Silver based	Addmaster limited, USA
Ethylene scavenger	Evert fresh	Activated zeolites	Evert fresh corporation, USA
Ethylene scavenger	Neupalon	Activated carbon	Sekisui Jushi Ltd., Japan
Ethylene scavenger	Peakfresh	Activated clay	Peakfresh products ltd., Australia
Heat resistance	PLA	Lactic acid based	Natureworks LLC, USA
Heat resistance	POSS	Silicon based	Hybrid plastic Inc., USA
Interleavers	SANICO	Antifungal coating	Laboratories STANDA, France
Moisture absorber	Dri-Loc	Absorbent pad	Sealed air corporation, USA
Moisture absorber	Tenderpac	Dual compartment system	SEALPAC, Germany
Oxygen scavenger	Ageless	Iron based	Mitsubishi Gas Chemical Co. Ltd., JAPAN
Oxygen scavenger	Bioka	Enzyme based	Bioka Ltd., Finland
Oxygen scavenger	Freshlizer	Iron based	Toppan Printing Co. Ltd., Japan
Oxygen scavenger	Freshmax, freshpax	Iron based	Multisorb technologies, USA
Oxygen scavenger	Oxyguard	Iron based	Toyo Seikan Kaisha Ltd., Japan
Oxygen scavenger	Zero2	Photosensitive cells	Food Science Australia, Australia

TABLE 2:- list of Nanoparticles approved for use in food sector [6]

Sl.no	Nanoparticles	Applications
1	Titanium dioxide	<ul style="list-style-type: none"> Used as white pigment in cake decorations, baking industry, candies. Used in food additives
2	Silver nanoparticles	<ul style="list-style-type: none"> Used as antimicrobial in food industry Food packaging Food contact materials for purpose of disinfection
3	Ag/LDPE(low density polyethylene)	<ul style="list-style-type: none"> Used as food composites
4	CuO/LDPE	<ul style="list-style-type: none"> Used as antimicrobial agent in food industry
5	TiO ₂ /LDPE	<ul style="list-style-type: none"> Added stability to food
6	ZnO/LDPE	<ul style="list-style-type: none"> Reduces chance of migration of metal ions into stored food
7	ZnO/Gelatin	<ul style="list-style-type: none"> Food packaging
8	ZnO/Polycarbonate	<ul style="list-style-type: none"> Food packaging
9	ZnO/Polylactic acid	<ul style="list-style-type: none"> Food packaging
10	ZnO/isotactic polypropylene	<ul style="list-style-type: none"> Food packaging
11	ZnO/graphene oxide/Polylactic acid	<ul style="list-style-type: none"> Food packaging
12	Cu/Chitosan	<ul style="list-style-type: none"> Inactivate food pathogens
13	SiO ₂ /gallic acid	<ul style="list-style-type: none"> Novel antioxidants
14	Nano ZnO coated active packaging	<ul style="list-style-type: none"> Improve shelf life properties of ‘Fuji’ apples , anti-browning agent



15	SiO ₂ nanoparticles	<ul style="list-style-type: none"> Provides fragrance or flavors to food products
16	TiO ₂ /SiO ₂	<ul style="list-style-type: none"> Food color additive
17	SiO ₂ (in powdered food materials)	<ul style="list-style-type: none"> Anti-caking agent Thickening pastes Food containing E551on consumption exposes SiO₂ to gut epithelium
18	Chitosan /nano silica coating	<ul style="list-style-type: none"> Preserve quality of fresh foods
19	Nano Ag	<ul style="list-style-type: none"> Preservation of fruits
20	Gold	<ul style="list-style-type: none"> Food safety screening

II. MATERIALS AND METHODS

TABLE 3:- list of fungi synthesizing gold nanoparticles

Sl.no	Fungal species producing gold nanoparticles	reference
1	<i>Fusarium oxysporum</i>	[7]
2	<i>Colletotrichum sp.</i>	[8]
3	<i>Trichothecium sp.</i>	[9]
4	<i>Penicillium brevicompactum</i>	[10]
5	<i>Penicillium rugulosum</i>	[11]
6	<i>Candida albicans</i>	[12]
7	<i>Epicoccum nigrum</i>	[13]

Methods of synthesizing gold nanoparticles

The most common method of synthesizing gold nanoparticles chemically is the wet synthesis method where nanoparticles are generated by reduction or co-precipitation process. The main disadvantage of this method is that harsh chemicals and organic solvents used in this process make it harmful for handling and toxic residues produced during manufacturing are difficult to dispose of. The synthesis of nanoparticles by fungi can be grouped under 2 main categories:-

A) IN-VIVO

The nanoparticles are produced intercellularly within the living mycelia. The advantage of this technique is that the transition metal ions which are toxic to organisms are converted to a less toxic form which can then be easily drawn up by the organisms. The mycelia are washed and are directly used to extract nanoparticles intracellularly. The extraction process is the most crucial as the nanoparticles in the purest form can then only be used in further application processes. [14]

B.IN VITRO METHOD

The synthesis of gold nanoparticles here is done by using fungal cell free extracts. There are three possible methods under in vitro where fungal nanoparticles can be synthesized:-

- The fungi is kept for fermentation and then it is centrifuged later to collect the supernatant of the fermented fungi. The extracellular proteins and other synthesized materials present in the supernatant can be used for extraction of gold nanoparticles.

The disadvantage of this technique is that the residues of the fermentation media may alter in the extraction process and make it less sensitive.

- The 2nd method of producing gold nanoparticles is from the aqueous extract where the mycelia were kept suspended. The disadvantage of this method is that the sterile conditions are difficult to maintain where mycelia will be washed and resuspended. Bacterial contamination can also affect the extraction process. The contamination may be avoided by addition of antibiotics but the use of antibiotics is not environment friendly.
- The 3rd method of producing gold nanoparticles from fungus is by autolysis of cells or rupture of cells during incubation followed by protein and carbohydrate dissolution into aqueous medium.

ADVANTAGES OF SYNTHESIZING NANOPARTICLES

- Due to the small size of nanoparticles, they can be easily taken up by cells.
- Efficient drug administration at target sites.
- Development of nano diodes, nano transistors and OLED.
- Development of small size batteries, solar cells which will be more effective in work.
- Useful in the manufacture of nanogels, nanotubes etc.
- Nanoencapsulation provides good protection to encapsulated drug.
- Increased drug stability.
- Biosafety.
- Economic advancement.

DISADVANTAGES OF SYNTHESIZING NANOPARTICLES

- Loss of traditional and convenient methods of food production and in the agriculture sector.
- Atomic weapons can be easily made by use of nanoparticles.
- Toxicity issue.
- Increased health risk.
- Pollution of air and water.
- Expensive.
- Due to small size it can cause inhalation or skin problems. [15]

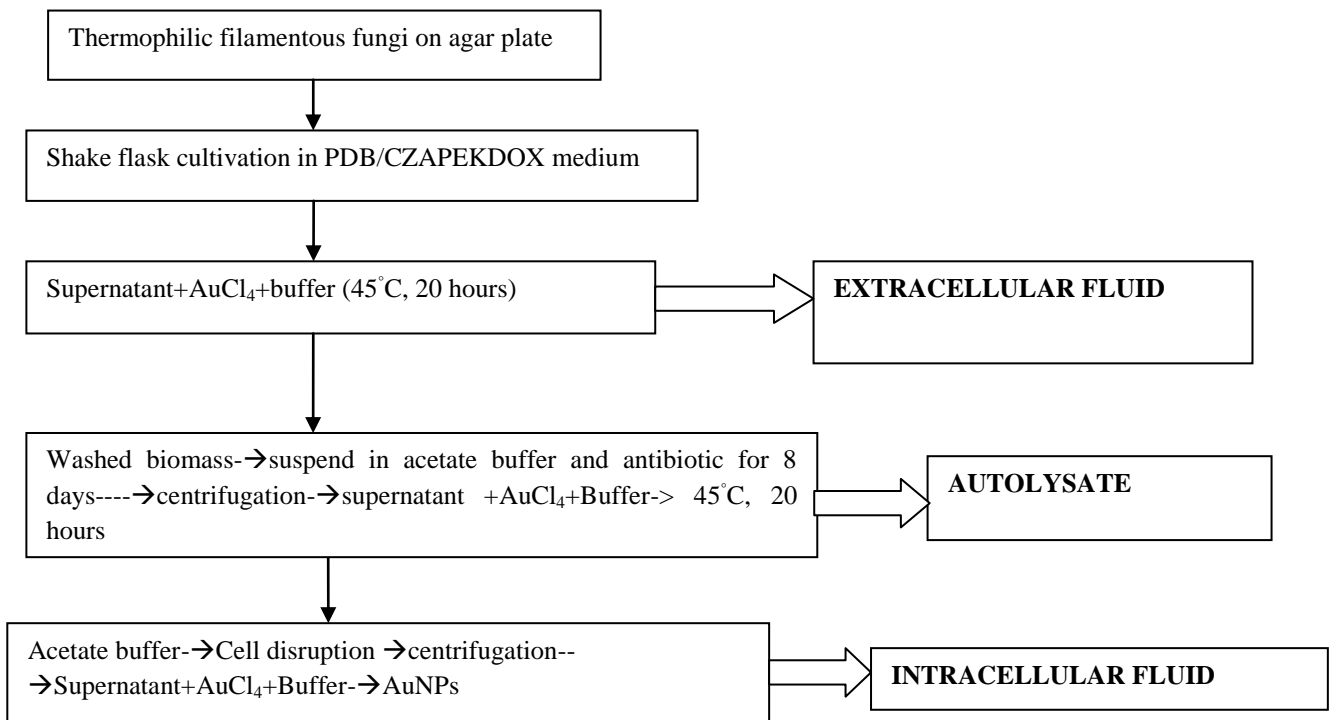


FIGURE 1:- Synthesis of gold nanoparticles (AuNPs) by different methods through different extracts from fungi using:-1. Extracellular extract, 2. Autolysate, 3.Intracellular fluid [16]

III. APPLICATIONS OF GOLD NANOPARTICLES

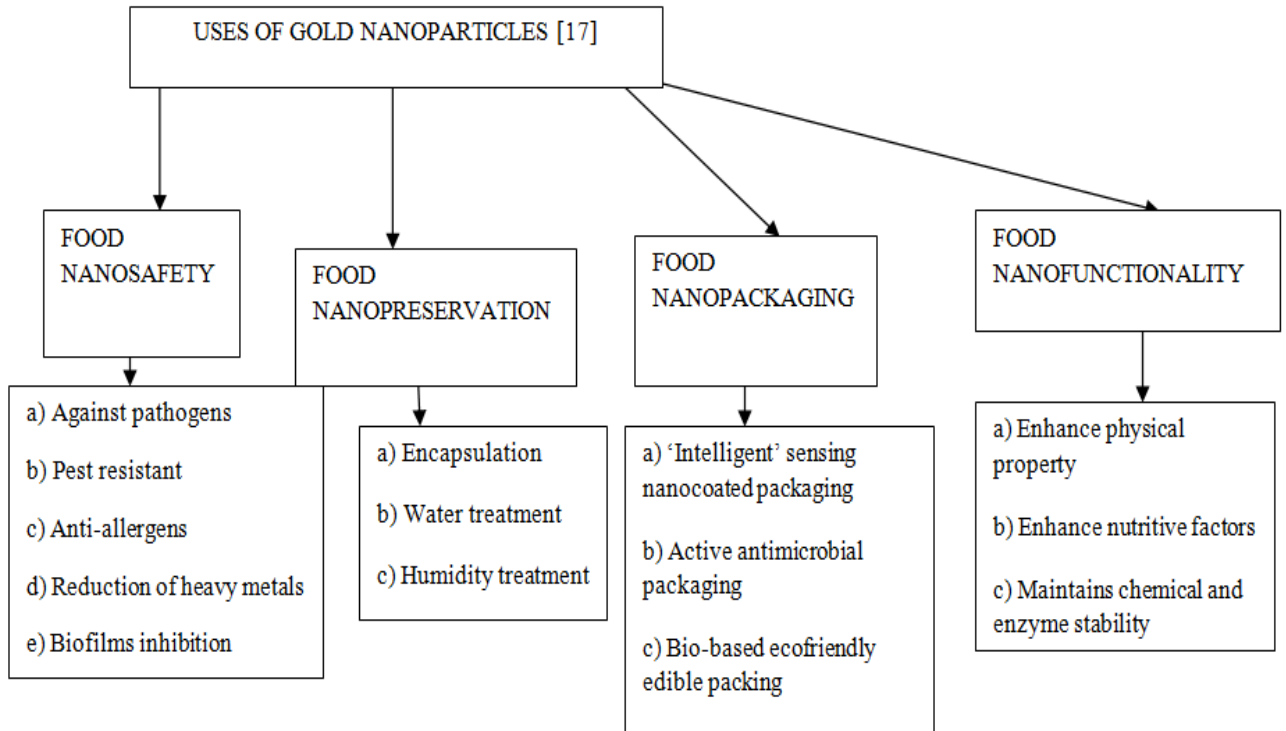


TABLE 4:- GOLD NANOPARTICLES USED IN DETECTION OF FOODBORNE PATHOGENS

Nanoparticles	pathogens	Detection limit	reference
Gold nanoparticle	<i>Salmonella enterica serotype Typhi</i>	98.9 CFU/ml	[18]
Gold /silicon nanorod	<i>Salmonella enterica serotype Typhi</i>	Not reported	[19]
Gold nanorod	<i>Escherichia coli O157:H7</i>	1-10 CFU/ml	[20]

IV. CONCLUSION

Application of nanotechnology in food processing industries has led to immense help in food safety, ensuring quality of food products and maintaining stability of food. Even though nanotechniques are rising as an emerging trend in the food sector with numerous advantages, there are several disadvantages to it which harm the environment directly or indirectly. So, the careful use of nanotechniques with proper handling methods and awareness should be followed so that it doesn't affect human health.

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