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BIOGENIC SYNTHESIS OF MYCONANOPARTICLES FROM MUSHROOM EXTRACTS AND ITS MEDICAL APPLICATIONS: A REVIEW

N. Prabhu *, S. Karunakaran, S. Karthika Devi, R. Ravya, P. Subashree and M. Senthil Vadivu

Department of Biotechnology, Vivekanandha College of Engineering for Women, Elayampalayam, Tiruchengode - 637205, Tamil Nadu, India.

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Correspondence to Author:
N. Prabhu

Assistant Professor,
Department of Biotechnology,
Vivekanandha College of Engineering for Women,
Elayampalayam, Tiruchengode - 637205, Tamil Nadu, India.

E-mail: prabhu.aut.26@gmail.com

ABSTRACT: Mushroom extracts such as proteins, amino acids, polysaccharides and vitamins implicated as the reducing, stabilizing and capping agents in synthesis of myconanoparticles. Therefore, it is just a little attempt to study the journalism of this important of myconanoparticle. For this literature survey, basically library data was collected and digital resources were also included. From these sources we obtained reliable information about diverse nanoparticle synthesis from different mushroom species. Myconanotechnology is used in numerous medical applications like diagnosis of various diseases, therapeutic field and other applications like catalysis of bio molecules, microelectronics, biosensing devices, air and water purifiers and paints. Studies by different researchers specify that myconanoparticles possesses various pharma-cological activities such as antimicrobial activity, anticancer activity, anti-proliferative activity, and various other effects like antioxidant activity, cellular uptake, catalytic activity *etc*. There are many literatures demonstrating the various global uses of myconanoparticles. Till date very inadequate information is available from different sources so, we try to assemble this information in one review article. This review article gives an account of updated information on synthesis of various nanoparticles from different species of mushroom extracts and its optimal synthesizing factors and its medical significance.

INTRODUCTION: In latest years, nano-technology is the fast-growing modern science, which has blossomed the human beings in the field of medical, chemical and physical sciences. In this field, synthesis of nanoparticles with erratic size, shape, chemical composition and prohibited poly-dispersity. It has vigorously developed as an important field of modern research with probable effects in electronic and medicine [1].

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Compared to the large particles of bulk materials nanoparticle has novel characteristics because it is tremendously small in size and large surface to volume ratio. Oyster mushroom is considered safe for most people to eat because it is grown in controlled, sterilized environments.

Medicinal mushrooms have been in use for thousands of years. However, it has been only recently that the medicinal values of mushrooms have started to flourish in the western world. Mushrooms are tremendously high in fiber and contain high levels of vitamins such as thiamine, riboflavin, niacin, biotin, ascorbic acid, cobalamins, and minerals like potassium and phosphorus. Recently, medicinal mushrooms have come beneath close examination as a "wonder drug" of the 21st century. There have been claims that mushrooms augment the immune system, inhibit the growth of tumors, and help in eliminating the body of cancer and pathogens. Most of the superior researches are mainly focused on metal nanoparticles synthesized from the mushroom. Recent researches are terminate that large production of nanoparticle is reachable in fungi when compared to bacteria, because it produces large amount of enzymes dependable for nanoparticle production [2] and also using of their extracts *viz*. proteins, amino acids, polysaccharides and vitamins plays an major role as tumbling, stabilizing and capping agents in the process of the nanoparticles [3].

Naturally and artificially producing mushroom indicates that it could be expensive sources of antioxidant, anti-inflammatory, antiviral, anti-bacterial, cardiovascular, hepatoprotective and hypotensive activities in biological system [4] sizes and shape of nanoparticles depends on the preparation temperature and type of mushroom extract. The synthesis of nanoparticles from edible mushroom must be non-toxic for producing drugs. Novel biomaterials were used to biosynthesize of newly metallic nanoparticles bio resources [5].

Nanoparticles of noble metals, *viz*. gold, silver, platinum, and zinc are widely applied in fast moving consumer goods such as toothpaste, soaps, detergents, shoes, cosmetic products and besides their applications in medical and pharmaceutical products. Synthesis of nanoparticles can be performed using several habitually used chemical and physical methods and using fungus *Fusarium*, *Oxysporum*, *Verticillium sp*. Nano-particles can be synthesized using an array of methods including physical, chemical, biological, and hybrid techniques [6, 7, 57] **Fig. 1**.

The present review emphasizes reported mushroom resources for the synthesis of different myco-nanoparticles because edible mushroom has various therapeutic compounds which of being exploited since ancient time as traditional medicine. Here biosynthesis of extra and intracellular synthesis of glyconanoparticles process has been reported [5].

MATERIALS AND METHODS: For this study, fundamentally library data was collected, and digital resources such as Google Scholar, Scopus, PubMed, and Research gate, *etc*. also helped for this literature survey method. Through different journals of synthesis of nanoparticles, books we could gain recent information to continue this work. From these resources, we have reviewed the various works related to synthesis of myco-nanoparticles by using different species of mushroom, mechanism of synthesis and effect of various factors on psychosynthesis of nanoparticles, which are given below.

RESULTS AND DISCUSSION: Biosynthesis of different nanoparticles, the effect of various factors on biosynthesis of glyconanoparticles and mechanism behind mycosynthesis is summarized below.

Biosynthesis of Nobel Metal Nanoparticles by Mushroom: Recently, magnification of nano-particles synthesis in an ecological process is rising. Huang *et al*., reported that the nanoscience and technology field has numerous potential applications in many areas such as drug and gene delivery, diagnosis, tissue engineering, artificial implants, medical diagnostic and chemical, textile, materials industries [8]. Maurya *et al*., reported that synthesis of nanoparticles might be moreover intracellular or extracellular and it's also most favorite during downstream processing as it is cost effectual and less laborious during industrial applications. During nanoparticles synthesis, light plays a key role that the light-sensitive riboflavin presents in mushroom extract plays a major role in the decline process [9].

Mustafa Nadhim Owaid *et al*., reported that a broad variety of mushrooms consists of proteins and polysaccharides that have been utilized in both intracellular and extracellular gold and silver nanoparticles. It has been reported that using extracts of different mushroom species *viz*.

Agaricus bisporus, *Lentinula edodes*, *Pleurotus florida*, *Pleurotus sajor caju*, *Agrocybe aegerita*, *Ganoderma lucidium*, and *Volvoriella volvaceae*, *etc*. confirmed their perspective in reducing in silver ions into silver nanoparticles as well as converting gold ions into gold nanoparticles [10]. The current report on, mycosynthesis of noble metal nanoparticles have been summarized in **Table 1**, **2**. Application of nanoparticles synthesized from mushroom has been summarized in **Table 5**.

Silver Nanoparticles: Silver nanoparticles have been proved to be most effectual to restrain the bacterial and fungal growth due to the synthesis of secure and potent nanoparticles. Mirunalini *et al*. reported that the biosynthesis of silver nanoparticles was approved by using different parts of the mushroom through silver nitrate [12]. Dhanasekaran *et al*. reported that mycosynthesis of the silver nanoparticle is an earlier and most resourceful elementary method have shown powerful antimicrobial activities; thus nanoparticles can be considered for the use in many medicinal drugs. Mushroom AgNPs have a spherical, core-shell shape; the size ranges from 10 to 70 nm [13]. Sudhakar *et al*., and Sanghi *et al*., reported that AgNPs were visually detected due to the color change from yellow to dark brown of the reaction suspension, cell-free filtrate and silver nitrate using SMS showed an organic surface that reduces Ag^+ and stabilizes the Ag-NPs by using a buried mushroom protein [14, 15]. Narayanan *et al*., reported that exceedingly concentrated silver nanoparticles obtained from the aqueous extract from the fruit body of *Agaricus bisporus* [74]. Some other silver nanoparticles produced by mushroom are listed in **Table 1**.

TABLE 1: MYCOSYNTHESIS OF SILVER NANOPARTICLES

Mushroom	Part used	Localization	Nanoparticle type	Size	Shape	Reference
Agaricus bisporous	Fruiting Body	Intracellular	Ag	15-20 nm	Spherical	11
Agaricus bisporous	Fruiting Body	Intracellular	Ag	80-100 nm	Spherical	12
Agaricus bisporous	Fruiting Body	Extracellular	Ag	-	-	13
Agaricus bisporous	Fruiting Body	Extracellular	Ag	30 nm	Spherical	14
Agaricus bisporous	Fruiting Body	Extracellular	Ag	10-20 nm	Spherical	13
Calocybe indica	Fruiting Body	Intracellular	Ag	100nm	Spherical	12
Coriolus Versicolor	Fruiting Body	Intracellular	Ag	10 nm	Spherical	15
Lentinula edodes	Fruiting Body	Extracellular	Ag	-	-	2
Agaricus bisporous	Fruiting Body	Extracellular	Ag	20-44 nm	Dispersed	1
Helvella lacunose	Fruiting Body	Extracellular	Ag	8-50 nm	-	11
Ganoderma appalanatum	Fruiting Body	Extracellular	Ag	15-20 nm	-	16
Pleurotus florida	Fruiting Body	Extracellular	Ag	20-50 nm	-	17
Fomes fomenterieus	Fruiting Body	Extracellular	Ag	8-50 nm	-	2
Pleurotus sajor caju	Fruiting Body	Extracellular	Ag	5-50 nm	-	11
Agrocybe aegerita	Fruiting Body	Extracellular	Ag	-	-	18
Ganoderma applanatum	Fruiting Body	Extracellular	Ag	3-15 nm	Spherical	19
Ganoderma lucidium	Fruiting Body	Extracellular	Ag	10-70 nm	Spherical	20
Pleurotus citrinopileatus	Fruiting Body	Extracellular	Ag	6-10 nm	Core-shell	9
Ganoderma neo-japonicum	Fruiting Body	Extracellular	Ag	5-8 nm	Spherical	21
Pleurotus florida	Fruiting Body	Extracellular	Ag	20 ± 5 nm	-	16
Volvariella volvacea	Fruiting Body	Extracellular	Ag	5 nm	-	22
Ganoderma neo-japonicum	Fruiting Body	Extracellular	Ag	10-70 nm	-	20
Pleurotus ostreatus (grey)	Fruiting Body	Intracellular	Ag	-	-	10
Pleurotus ostreatus (white)	Fruiting Body	Extracellular	Ag	-	-	10
P. comucopiae var. citrinopileatus (bright yellow)	Fruiting Body	Intracellular	Ag	10-20 nm	Spherical	23
P. salmoneostramineus (pink)	Fruiting Body	Extracellular	Ag	-	-	10
Agaricus bisporous	Fruiting Body	Extracellular	Ag	5-50 nm	Spherical	2
Calocybe indica	Fruiting Body	Extracellular	Ag	5-50 nm	Spherical	2
Pleurotus florida	Fruiting Body	Extracellular	Ag	5-50 nm	Spherical	2
Pleurotus platypus	Fruiting Body	Intracellular	Ag	5-50 nm	Spherical	2
Tricholoma matsutake	Fruiting Body	Extracellular	Ag	10-20 nm	-	24
Schizophyllum commune	Fruiting Body	Schizophyllan	Ag	-	-	25
Pleurotus florida	Fruiting Body	Extracellular	Ag	20 ± 5 nm	Spherical	26

Gold Nanoparticles: Bhat *et al*., reported that the synthesis of gold nanoparticles from mushrooms are a more gorgeous member of novel metal nano-particles because of their prospective applications in the fields ranging from catalysis, nonlinear optics, nanoelectronics, gene expression, and disease diagnosis [75]. Zhang *et al*., reported that mushroom gold nanoparticles have spherical, hex-agonal and triangular shapes with sizes ranging from 5 to 150 nm whereas those of the fungus *Flammulina velutipes* have a size ≤ 20 nm [76]. Sen LK *et al*., reported that mycosynthesis of gold nanoparticles have diverse shapes such as spherical, triangular, hexagonal, crystal, *etc*.

In this article reported that mycosynthesizes Au-NPs are spherical and triangular with a varying size of 10-50 nm [77]. Philip *et al*., Navin Jain *et al*., and

Gerike *et al*., reported that diverse sizes and shapes of Au-NPs lies in the varying temperature of the extract [31, 78, 79]. In this article documented that synthesis of AuNPs by edible mushroom *Pleurotus florida*. The synthesized gold nanoparticles from mushroom showed anticancer activity beside human chronic myelogenous leukemia (K562), human cervix (HeLa), human lung carcinoma (A-549) and human adenocarcinoma mammary gland (MDA-MA) under *in-vitro* conditions. Syed *et al*., Ahmad *et al*., and Bhat *et al*., reported that mostly the glucan content of mushroom was responsible for the stability of synthesized AuNPs [80, 81, 75]. Borovaya *et al*., reported that synthesis of gold nanoparticles using *T. cordifolia* mushroom is demonstrated by this article [82]. Some other typical gold nanoparticles produced by microorganisms are summarized in **Table 2**.

TABLE 2: MYCOSYNTHESIS OF GOLD NANOPARTICLES

Mushroom	Part used	Localization	Nanoparticle type	Size	Shapes	Reference
Pleurotus ostreatus	Fruiting Body	Intracellular	Au	22-39 nm	-	27
Pleurotus florida	Fruiting Body	Polysaccharide/glucan	Au	14.93±2.88 nm	Crystalline	28
Pleurotus florida	Fruiting Body	Polysaccharide/glucan	Au	12-15 nm	Crystalline	26
Pleurotus florida	Fruiting Body	Extracellular	Au	10-50 nm	Spherical	26
Pleurotus florida	Fruiting Body	Extracellular	Au	10-50 nm	Triangular	26
Lentinus edodes	Fruiting Body	Intracellular	Au	5-15 nm	Spherical	29
Pleurotus ostreatus	Fruiting Body	Intracellular	Au	5-15 nm	Spherical	29
Grifola frondosa	Fruiting Body	Intracellular	Au	5-15 nm	Spherical	29
Ganoderma lucidum	Fruiting Body	Intracellular	Au	5-15 nm	Spherical	29
Pleurotus ostreatus	Fruiting Body	Intracellular	Au	7.0±0.5 nm	Crystalline	30
Volvariella volvacea	Fruiting Body	Extracellular	Au	20-150 nm	Spherical	16
Volvariella volvacea	Fruiting Body	Extracellular	Au	20-150 nm	Triangular	16
Volvariella volvacea	Fruiting Body	Extracellular	Au	20-150 nm	Prism	16
Volvariella volvacea	Fruiting Body	Extracellular	Au	20-150 nm	Hexagonal	16

Other Nanoparticles: Wong *et al*., Senapati *et al*., Wu *et al*., reported that synthesis of CdTe quantum dots by using fungi [32, 34, 83]. Only two types of mushroom such as *Coriolus versicolor* and *P. ostratus* have been used to form CdS-NPs and were applied in the industrial field. Meng *et al*., reported that a solution of extracellular biomass of *C. versicolor* and cadmium sulfide was effectively used for the formation of NPs; *Coriolus versicolor*-CdS-NPs are 100-200 nm in size and have a spherical shape [84]. Tiwari *et al*., reported that the species of *P. ostratusit*, Cd-NPs has been producing from intracellularly which have the size of 4-5 nm and spherical and used for diverse industrial applications [85]. Gupta *et al*., reported that Se-NPs from mushroom have spherical and moderately spherical shapes with the size of <50 nm using polysaccharide-protein complexes of mushrooms which is effortlessly aggregate and their anti-cancer activity is radically reduced by polysaccharide-protein complexes isolated from species of *Pleurotus tuberregium* [86]. Kowalczyk *et al*., Brice-Profeta *et al*., reported that ZnS-NPs synthesized from mushroom showed sizes from 3 to 201 nm [87, 88]. Faraji *et al*., reported that there are more than a few other metallic nanoparticles were synthesized using fungi such as mushrooms [89]. There are numerous shapes of nanoparticles are synthesized from mushroom extract are summarized in **Table 3**.

TABLE 3: MYCOSYNTHESIS OF OTHER NANOPARTICLES

Mushroom	Part used	Localization	Nanoparticle type	Size	Shapes	Reference
Pleurotus tuberregium	Fruiting Body	Polysaccharides protein	Se	-	-	32
Pleurotus rhinoceros	Fruiting Body	Polysaccharides protein	Se	-	Spherical	33
Agaricus bisporous	Fruiting Body	Extracellular	ZnS	3-201 nm	Cubic	34
Pleurotus ostreatus	Fruiting Body	Extracellular	ZnS	2-5 nm	Spherical with crystalline	35
Oriolus versicolor	Fruiting Body	Extracellular	CdS	100-200 nm	Spherical	36

Factors Affecting Mycosynthesis of Metal Nanoparticles: Baker *et al*., reported that there are numerous factors like pH of the solution, temperature, pressure, time, particle size, pore size, surroundings, concentration of the mushroom extracts used, concentration of the raw materials used and proximity greatly authority the quantity and quality of the synthesized nanoparticles and their categorization and applications [38]. Ajayan *et al*., and Somorjai *et al*., reported that the scenery of the synthesized nanoparticles would be altered with the type of diverse adsorbate and the activity of the various catalysts used in the synthesis process [39, 40]. Pennycook *et al*. reported that to accomplish monodispersity in solution phase of nanoparticles synthesis is challenged one. Some of them have reported the vibrant nature of the synthesized nanoparticles with different types of symptoms and implications by shifting with time, environment, shape and size of the particles and so forth [41]. In the subsequent section, we have recapitulated some of the overriding factors that affect nanoparticle biosynthesis is listed in **Table 4**.

TABLE 4: EFFECTS OF VARIOUS FACTORS (pH, TEMPERATURE, AND CONTACT OR INCUBATION TIME) ON MYCOSYNTHESIS OF PRECIOUS METAL NANOPARTICLES

Factors	Shapes	Nanoparticles types	Reference
pH			
1.6, 7, 12	Crystalline	Au	30
Temperature			
37 ºC	Spherical	Ag	11
28 ± 1 ºC	Spherical	Ag	19
27 ºC	Crystalline	Au	28
37 ºC	Spherical	Au	26
37 ºC	Triangular	Au	26
25 ºC	Crystalline	Au	30
Contact or incubation time			
24 h	Spherical	Ag	11
72 h	Crystalline	Au	26
72 h	Spherical	Au	26
72 h	Triangular	Au	26

Effect of Various Method or Technique: There are various methods for synthesizing nanoparticles, ranging from physical techniques using mechanical procedures to chemical or biological protocols using various organic and inorganic chemicals and living organisms. Pennycook *et al*., and Narayanan *et al*., reported that when to evaluate biological methods with other methods, which has additional benefits and low drawbacks. Then biological methods for nanoparticles synthesis are ecological and more adequate than established methods [41, 42].

Effect of pH: pH may play a crucial role in the biosynthesis of nanoparticles by green technology methods. Gardea-Torresdey *et al*., and Armendariz *et al*., reported that the pH of the solution medium influences the size and consistency of the synthesized nanoparticles [43, 44]. Soni *et al*., reported that the shape and size of the particular nanoparticles are controlled by varying pH range of the solution [45]. Dubey *et al*., reported that as diverse mushroom extracts and even the extracts imminent from different localization of the identical species of mushroom have different pH values, optimization of a synthetic etiquette is needed for the proficient synthesis of nanoparticles. It has been reported by several researchers that larger nanoparticles fashioned at lower pH compare to higher pH [46].

Effect of Temperature: Temperature is one more important parameter that affects the synthesis of nanoparticles using biological methods. When comparing biological method with physical and chemical methods, the synthesis of nanoparticles using green technology requires temperatures less than 100 ºC or ambient temperature. Because the temperature of the physical method requires utmost temperature (>350 ºC) and chemical methods require a temperature fewer than 350 ºC. Rai *et al*., reported that the scenery of nanoparticles would be indomitable by temperature of the reaction medium [47]. Gericke *et al*. reported that gold nanoparticles fashioned with a superior rate at higher temperatures.

Nanorod- and platelet-shaped gold nanoparticles were synthesized at higher temperatures, while spherical-shaped nanoparticles produced at lower temperature [48]. Andreescu *et al*., reported that the silver nanoparticles furthermore synthesized at higher temperatures [49]. Some species of mushroom extract that with an enhance in temperature an increase in the sharpness of absorption peaks were found for both silver and gold nanoparticles. This is so because with an increase in temperature the rate of reaction also increased, which enhances the synthesis of nanoparticles. Fayaz *et al*., and Shaligram *et al*., reported that the sharpness in absorbance peak depends on the size of the synthesized nanoparticles, as with superior temperature [50, 51].

Effect of Pressure: Pressure is essential for the mycosynthesis of nanoparticles. Abhilash *et al*., reported that the shape and size of the biosynthesized nanoparticles would be exaggerated by pressure applied to the reaction medium [52]. Tran *et al*., reported that the rate of diminution of metal ions using biological agents like mushroom extracts has been establishing to be much faster at ambient pressure conditions [53].

Effect of Incubation Time: Lots of research works also recommended that contact or incubation time also affects the mycosynthesis of nanoparticles. This is the period necessary for the achievement of all steps of the reaction. Darroudi *et al*., reported that the eminence and type of nanoparticles synthesized using green technology are deeply influenced by the length of time for which the reaction medium is incubated [54]. Akbari *et al*., and Mudunkotuwa *et al*., reported that correspondingly the characteristics of the mycosynthesized nanoparticles were also altered with a time of incubation and greatly predisposed by the synthesis process, exposure to light, and storage conditions, and so forth [55, 56]. Dubey *et al*., reported that an increase in contact time is accountable for the sharpening of the peaks in both silver and gold nanoparticles [46]. Jayanta Kumar Patra *et al*., reported that long time storage of the mycosynthesized nanoparticles would be distress their shelf life and their probable [57].

Effect of Preparation Cost: The prospective application of nanoparticles in the emergent world uses, the costs associated with their synthesis need to be regulated and controlled. This is a very essential factor that influences nanoparticle synthesis. Yacaman *et al*., reported that when evaluating other methods of nanoparticle synthesis, mycosynthesis of nanoparticles involves less cost and can be performed on a hefty scale [58].

Effect of Particle Shape and Size: The size and shape of the nanoparticles play a significant role in formative their properties. Akbari *et al*., reported that the size of the nanoparticles would be affected by the melting point of nanoparticles [55]. Baer *et al*., reported that diverse arrangement of nanoparticles has analogous energy which makes the conversion of their shape easy [59]. Ruckenstein *et al*., reported that the chemical properties of nanoparticles would be affected by their dynamic scenery and shape [60].

Effect of Other Factors: Park *et al*., reported that the porosity of the mycosynthesized nanoparticles was influenced their quality and application [61]. Various living systems such as mushrooms are wealthy in secondary metabolites that act as reducing and stabilizing agents for the myco-synthesis of nanoparticles. Haverkamp *et al*., reported that the composition of theses metabolites varies depending on the type of different mushroom species and the procedure used for its extraction [62]. Mohanpuria *et al*., reported that different species of mushroom have distinctive intracellular and extracellular enzymes in unreliable quantities that affect nanoparticle synthesis [63]. Baker *et al*. reported that the choice of purification methods of mycosynthesized nano-particles could persuade their quantity and quality [38].

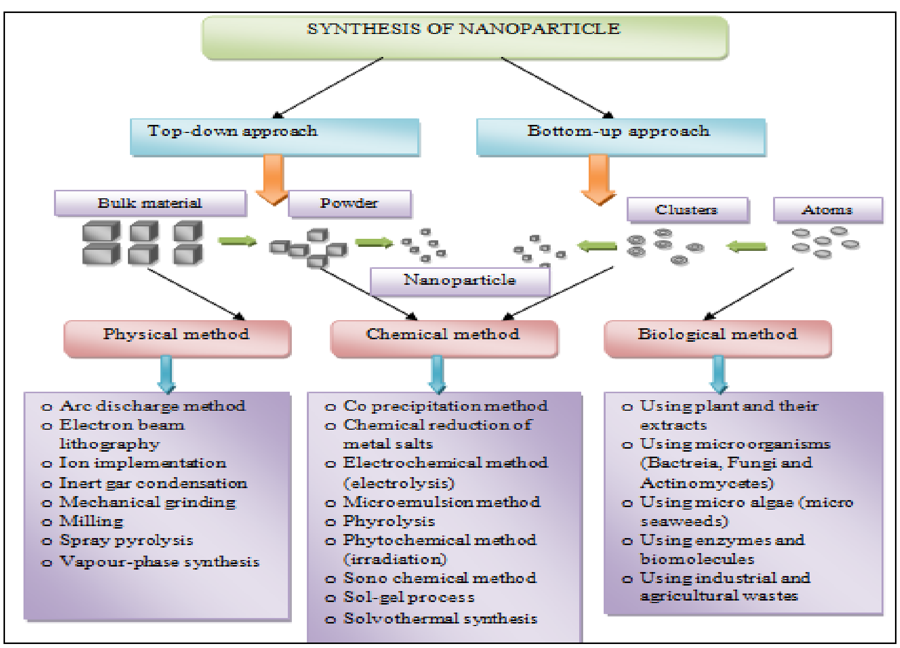

FIG. 1: DIVERSE APPROACHES AND METHODS FOR SYNTHESIZING NANOPARTICLES [6, 7, 57]

The Mechanism Behind Mycosynthesis: While various studies have been commenced on the screening and identification of mushroom species for controlled synthesis of noble metal nanoparticles, extremely little work has been performed to appreciate the genuine mechanism behind the synthesis of nanoparticles **Fig. 2** [64, 65, 66, 36]. Pal Sovan Lal *et al*., reported that nanoparticles can be synthesized throughout two major methods, *i.e*., "top-down" and "bottom-up" approaches **Fig. 1** [67].

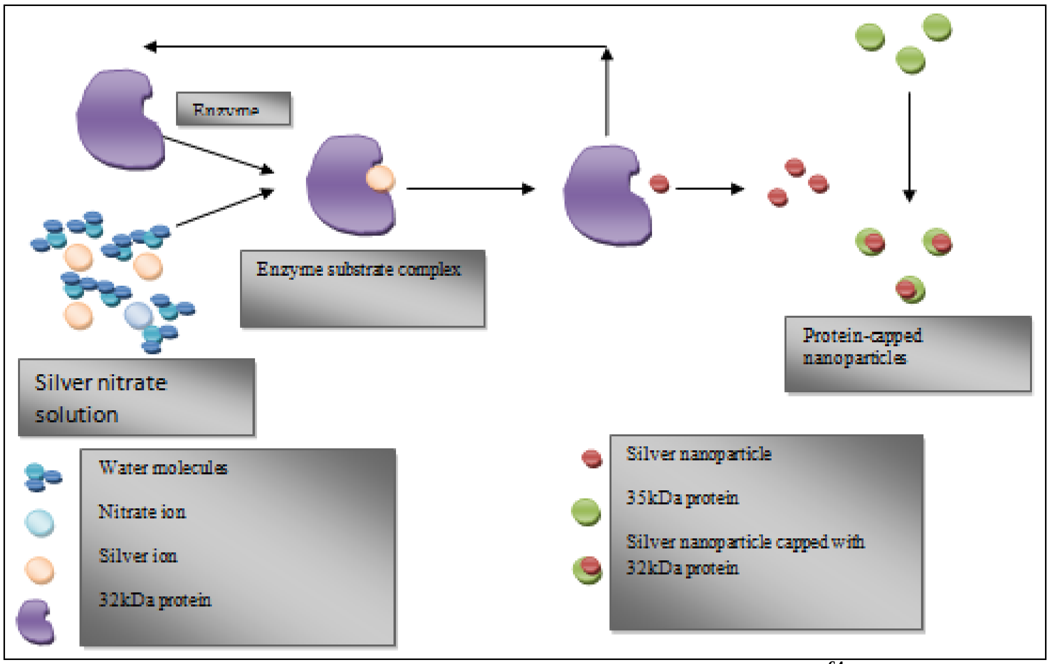

FIG. 2: MECHANISM OF NANOPARTICLE SYNTHESIS [64]

Juhi Saxena *et al*., reported that the top-down approach principally works with a bulk form of material, and their nanoscale of size will be achieved by physical method of size reduction, *e.g*., thermal decomposition, laser ablation, mechanical milling, etching, lithography, and sputtering [68]. Rai *et al*., reported that the bottom-up approach is comprehensively used for the preparation of nanoparticles, where involving a homogeneous system wherein catalysts like biological extracts (*e.g*., reducing agent and enzymes) synthesize nanostructure that are forbidden by catalyst properties, reaction media, and circumstances (*e.g*., solvents, stabilizers, and temperature) [69].

Gade *et al*., reported that the biological synthesis of nanoparticles is more favored than physical and chemical means because of hasty synthesis, better control over size and shape characteristics, cost-effectiveness, less toxicity and ecological approach [70]. Role of fungi such as mushroom is effective nanofactories is communicable consideration from the researchers worldwide. Mycosynthesis of nanoparticles has been well predictable because this totipotent eukaryotic microorganism has numerous incredible features which have been well documented. Gade *et al*., reported that various species of mushroom restrain different types of enzyme-like extracellular, intracellular enzymes and polysaccharides, *etc*., so which can be used to synthesize diverse nanoparticle synthesis. There are various reasons mushroom can be elected as superior nano-factories over bacteria and plants [70]. Kashyap *et al*. reported that mushroom produces huge amounts of extracellular enzymes which catalyze the heavy metal ions and produce nanoparticles. It can produce nanoparticle at an earlier rate than chemical synthesis [71].

Namita Soni *et al*. reported that mushroom could produce nanoparticle extracellularly which is very appropriate for easier downstream processing and handling of biomass [72]. Mushroom can produce nanoparticles together extracellularly as well as intracellularly. The accurate mechanism of mushroom is not understood entirely. Aromal *et al*., reported that putative mechanisms throughout intracellular synthesis comprise heavy metal binding to mushroom's mycelia cell wall by proteins or enzymes present on it via electrostatic interactions. Moreover, the metal ions are reduced by enzymes present in the cell wall. This leads to aggregation of metal ions and configuration of nanoparticles [73]. The different size, shape, and types of nanoparticles will be fashioned by different species of mushroom, which is mentioned in **Table 1, 2** and **3**.

TABLE 5: APPLICATION OF NANOPARTICLES

Type of nanoparticle	Application	Reference
Ag	Antimicrobial activity	12
Au	Anti-cancer activity, catalytic activity	37
CdS	Semiconductor quantum dots	36
Se	Cellular uptake, antiproliferative activity, anticancer activity	32
Fe	-	23
Pd	-	23
ZnS	Selenite uptake rate, nano tunned devixe	34
Chitosan	Antioxidant activity	23

CONCLUSION: This review has summarized the topical research work in the field of mycosynthesis of novel metal nanoparticles and perilously discusses the various mechanisms planned behind it. Owing to the wealthy biodiversity of mushroom species; their potential for the synthesis of novel metal nanoparticles is nevertheless to be fully explored. Enormous numbers of mushroom species are presented in nature, and many of them can be exceptional candidates for nanoparticle synthesis. Clarification of the mechanism behind mycosynthesis of valuable metal nanoparticles is necessary to develop a coherent approach.

A thorough understanding of biochemical mechanisms complicated in the fungi-mediated nanoparticle synthesis is a prerequisite to make this approach reasonably competitive with the conventional methods. Mycosynthesis of metallic nanoparticles (*viz*., Ag-NP, Au-NP, Se-NP, CdS-NP, Fe-NP, Pa-NP, and ZnS-NP) using mushrooms by different routes, and tested for 79% of biomedical and 21% of industrial applications. Mushroom metal-NPs were investigated for industrial applications such as for inorganic NPs, carbon nanotubes and treatment of waste as nano-biosorbents for adsorption of toxic metals for clearout our environment using ecological natural material and reducing environmental pollution in the future.

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CONFLICT OF INTEREST: The authors declare that they have no conflict of interest.

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