4. Conclusions

In this research, we have shown for the first time the use of *Trichoderma reesei* in the extracellular synthesis of silver nanoparticles. In the biosynthesis of metal nanoparticle by a fungus, enzymes are produced which reduce a salt to its metallic solid nanoparticles through the catalytic effect. Compared to other filamentous fungus, the *Trichoderma reesei* is considered to be the most efficient extracellular enzyme producer, and has a long history in the production of industrial enzymes [44].

Extracellular secretion of enzymes offers the advantage of obtaining large quantities in a relatively pure state, free from other cellular proteins associated with the organism, and can be easily processed by filtering of the cells and isolating the enzyme for nanoparticles synthesis from cell free filtrate. Our measurements indicate that extracellular biosynthesis of silver nanoparticle by *Trichoderma reesei* produces AgNPs with the diameters in the range of 5 50 *nm*. In Table 1 we compare the size ranges, methods of AgNP produced through various fungi, together with the environmental, biological and economical implications of the use of each fungus. According to this table biosynthesis of silver nanoparticles by fungus Trichoderma Reesei is preferred from the points of view of safety, economy and the large scale production potential.

As discussed above, we can biosynthesize silver nanoparticles on a large scale through *Trichoderma reesei*, which is a major advantage over other fungus methods. It should be mentioned that *Trichoderma reesei* is not known to be harmful to humans. According to previous studies on *Trichoderma reesei*, the production of extracellular enzyme and nanoparticles in this fungus is more efficient than other fungi. It is also shown that *Trichoderma reesei* has easier and cheaper cultivation requirements and higher growth rates on both industrial and laboratory scales, thereby having a lower cost in large scale production. It should be pointed out that large scale production of silver nanoparticles by other techniques, such as chemical vapor deposition, irradiation, and liquid solution reduction, usually produces particles larger than a few micrometers in size. These other techniques also involve lower production yields and higher expenses [14, 27, 33] compared to large scale biosynthesis through *Trichoderma reesei*. Because of the significant commercial value of the findings reported in this paper a patent application [54] is submitted on this subject.

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Table 1: Comparison of *Trichoderma reesei* with other fungi in regard to AgNP sizes produced, methods of production, and large-scale industrial use implications.

Fungus	AgNP size [*nm*]	Method	Comments	References
Trichoderma reesei	5 - 50	Extracellular	Environmentally and biologically safe, large-scale produced, economical. An industrially important cellulolytic filamentous fungus because of the ease of its downstream processing. Large-scale use unlikely.	Present report
Aspergillus clavatus	10 - 25	Extracellular	Tremorgenic neurotoxicosis in cattle, causes neurological syndrome in dairy cattle. Large-scale production is feasible.	[48]
Aspergillus flavus	8.92 ± 1.61	Extracellular	A plant, animal, and human pathogen that produces the carcinogen, aflatoxin. Its industrial use may be prohibited to control the threat of this fungus and its toxin to human and animal health.	[49]
Aspergillus fumigatus	5 - 25	Intra- & Extracellular	Not safe - Cause disease in immuno-compromised individuals, can produce genotoxic and cytotoxic mycotoxins laboratory scale use only.	[41]
Cladosporium cladosporioides	10 - 100	Extracellular	Can elicit chronic allergy and asthma to humans. Large-scale production is not feasible.	[50]
Filamentous fungus Penicillium sp.	52 - 104	Extracellular	Led to discovery of antibiotics. Large-scale production may be achieved, but it will be much more expensive than *Trichoderma reesei.* Size of AgNPs are rather large.	[51]
Fusarium oxysporum	5 - 50	Extracellular	Infect a variety of hosts causing various diseases. Its large-scale use may be prohibited.	[34-36, 44]
Fusarium semitectum	10 - 60	Extracellular	Often isolated from plants with complex disease and also known to be toxigenic. Its large-scale use may be prohibited.	[52]
Neurospora crassa	~ 11	Intra- & Extracellular	A potentially carcinogen fungus. Used for genetic research. Large-scale industrial use not recommended.	[53]
Phoma species	71.06 ±3.48	Intracellular	Pathogens to plants and humans. Its adverse health factors include allergen, irritant, hypersensitivity pneumonitis, dermatitis. Large-scale use unlikely.	[42]
Verticillium species	25 ±12	Extracellular	Its adverse health factors include allergen, irritant, hypersensitivity pneumonitis, dermatitis. Its industrial use may be prohibited.	[23]

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