Fabrication of High Efficiency Mycelium Brick with a Topical Coating of Silver Nanoparticles – A Boon for Sustainable Environment

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ABSTRACT

Oyster mushroom, Pleurotus ostreatus was cultivated using paddy straw as the substrate. The cultivated oyster mushroom was utilized for the preparation of mycelium bricks. Mycelium bricks are organic bricks synthesized from organic wastes and fungal mycelia including cultivated mushrooms and/or mushroom spawn. Mycelia are thin root like fibers from fungi which run underneath the ground. When dried they can be used as a super strong, water, mould and fire resistant building material that can be grown into specific forms thereby reducing the process requirements. Mycelium bricks are non pollutant, eco-friendly and more efficient. Mycelium bricks are novel constructs which alleviates the problems arising during construction such as poor quality raw materials, reduced strength, low water absorption capacity and decreased shelf life due to increase in the internal as well as external cracking. Mycelium bricks helps to overcome the environmental threats posed by the conventional brick making methods. They are a novel class of renewable biomaterial prepared using fungal mycelia and low-value non-food agricultural materials thereby contributing to sustainable agriculture or sustainable environment. Mycelium bricks are also susceptible to microbial contamination. Hence, a topical coating of microbially synthesized silver nanoparticles was applied on the surface of the mycelium bricks in order to enhance its purity. The synthesized nanoparticles were characterized by UV visible spectrophotometry, Transmission Electron Microscopy, Fourier Transform Infrared Spectroscopy and X Ray Diffraction analysis. The compatibility of the synthesized mycelium bricks were determined by carrying out tests such as compressive strength test, water absorption test and drop test. These mycelium bricks are strong, cost effective, eco-friendly, biodegradable and replenishable giving rise to an efficient brick formulation which can serve as a suitable next generation alternative for construction.

Key words: Oyster Mushroom; Pleurotus Ostreatus; Mycelium Bricks; Eco-Friendly; Silver Nanoparticles; Topical Coating

I INTRODUCTION

Oyster mushroom (*Pleurotus* sp.), popularly regarded as "dhingri" in India grows naturally in the temperature and tropical forests on lifeless and decaying timber logs and additionally in decaying natural matter.

It is one of the most sustainable fungal organisms for producing protein rich meals from various agro-wastes or woody wastes. The fruiting body of mushrooms are shell or spatula shaped with various kinds of colorations such as white, cream, grey, yellow, pink or light brown depending upon the species.

Among all the cultivated mushrooms, *Pleurotus* has maximum number of commercially cultivated species suitable for cultivation throughout the year.

Oyster mushroom (*Pleurotus* sp.) was commercially important in the mushroom market and several species have been grown commercially on large scale and small scale in many countries.

Oyster mushrooms are the third largest among the cultivated mushrooms. China is the greatest producer of oyster mushroom (85%). The current production of this crop in India is solely round 1500 tonnes due to low home demand. Mushroom cultivation in India is growing regularly as a choice source of earnings for many people.

The race to find the next sustainable technology or material that will greatly reduce our ecological footprints as well as improve our environment is causing countless new materials to develop which hold the possibility of helping to achieve this generation's sustainability goals. One of the newest and most promising is the mycelium brick. A mycelium brick is an organic brick that is formed from organic waste and mycelium of fungi. Mycelia are the thin root like fibers from fungi which run underneath the ground. When dried it can be used as a super strong, water, mould and fire resistant building material that can be grown into specific forms thereby reducing the process requirements.

There is accelerated need to locate sustainable building materials for the construction industry as we face challenges such as global warming, fast depletion of natural resources and fossil fuels. Inexpensive and eco-friendly construction materials is the need of the hour.

The mycelium brick reduces air pollution as it is synthesized from the agricultural wastes whereas the standard bricks produced from brick kilns causes air

pollution thereby resulting in environmental degradation due to emission of significant quantities of gaseous and particulate pollutants. Brick kilns' emission consists of mainly fine particles of coal, dust particles, organic matter and small amounts of gases such as SO_2, NO_x, H_2S, CO etc.

Mycelium bricks are low weight green building materials. They are eco-friendly compared to standard bricks. They are used to replace concrete, thermocol and many other materials that cause harmful effects to our environment. Moreover, the mycelium bricks are susceptible to microbial contamination. Hence the amalgamation of nanomaterials and non-fired clay bricks incorporated with fungal mycelia can be used as an advanced option to synthesize high purity as well as high quality mycelium bricks. Silver nanoparticles have received considerable attention due to their attractive physicochemical properties such as its high toxicity towards most bacterial and fungal cells cells due to their high reactivity, which in turn is due to the large surface to volume ratio. Silver nanoparticles possess unique properties which find myriad applications such as antimicrobial, anticancer, larvicidal, and catalytic and wound healing activities. Hence a class of novel, eco-friendly and efficient bricks known as mycelium bricks can be synthesized by using mushrooms and/or fungal mycelia and by incorporating a topical coat of silver nanoparticles over it.

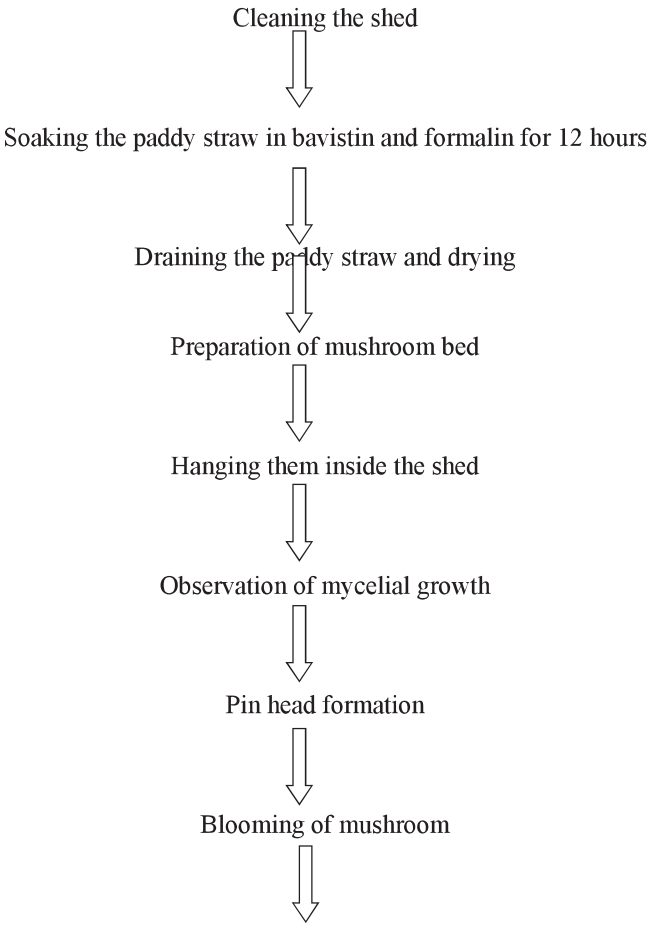
II OBJECTIVES

(a) Cultivation of oyster mushroom using a variety of substrates.
(b) Preparation of mycelium brick using the mushrooms and/or fungal mycelia.
(c) Compatibility tests for the synthesized mycelium bricks.
(d) Microbial synthesis of Silver nanoparticles from actinomycetes.
(e) Characterization of synthesized Silver nanoparticles by UV visible spectrophotometry, Transmission Electron Microscopy and Fourier Transform Infrared Spectroscopy.
(f) Antimicrobial activity of synthesized Silver nanoparticles.
(g) Application of Silver nanoparticles as a coat over the mycelium bricks.

III MATERIALS AND METHODS

(a) Production of Oyster mushroom

- **Flow chart for production of mushroom**



Harvesting of mushroom

⇩

Packing of mushroom

⇩

Marketing

(b) Construction, Sterlization and cleansing of shed - The mushroom shed about 10 X 30 feet was laid with completely constructed irrigated system.Good ventilation with diffused light are very much essential for oyster mushroom growth.The shed should be cleansed by spraying 100 ml of formalin + 200 ml of malathion + 5 g of bavistin mixed in water to get rid of microbes inside the shed and it should be left for a day.

(c) Sterilization of straw - The straw must be completely sterilized. Hence it is soaked in 400 L of water containing 200 ml of formalin and 15 g of Bavistin for 12 hours. After 12 hours, the soaked straw is drained completely and then dried in sunlight until the moisture content is 60%.

(d) Preparation of bed - A spawn packet (300g) can be used for making 2 beds.Polythene bags of 12 X 24cm were used for making beds. Polythene bags were tied with the thread at the bottom. The sterilized straw was placed at the bottom as a first layer and ensure that the straw is fully tightened so as to fit the polythene bag. Now the spawn is spread around it and the second layer is made with paddy straw and spawn in a similar manner. The process is continued until 6 layers are made**.** The bags are tied with thread after completion of 6 layers. Now 5 to 6 holes are made in the bed for aeration. The beds are hanged inside the shed after their preparation.

(e) Irrigation - One irrigation per day was done for the first 8 days after hanging the beds in the shed. Regular irrigation is very important for oyster mushroom cultivation. Drip irrigation was done inside the shed. Drip pipe lines were placed on the top of the hanged beds . Water must be sprayed twice a day.

(f) Observation - Mycelial growth and mushroom growth and development were noted for observations. Mycelial growth has been observed from 15th day. Pin head formation started from 22nd day.

Fig. 1 Mycelium growth

Fig. 2 Measuring pinhead formation

(g) Height of mushroom - Three beds were selected at random to analyze the height of the mushroom. The average height of mushroom was calculated from the bag

$$\text{Mean} = \frac{\text{Number of observations}}{\text{Total number of observations}}$$

(h) Harvesting and Packing - Harvesting starts from 34th day. Harvesting must be done in the early morning and packed immediately for sale. Three to four harvests is taken from a bag on alternative days.After harvesting, the bunch of mushroom is cut into single piece and weighed for packing.After weighing, the pack is sealed and ready for sale.

Fig. 3 Harvesting

Fig. 4 Cutting and Weighing

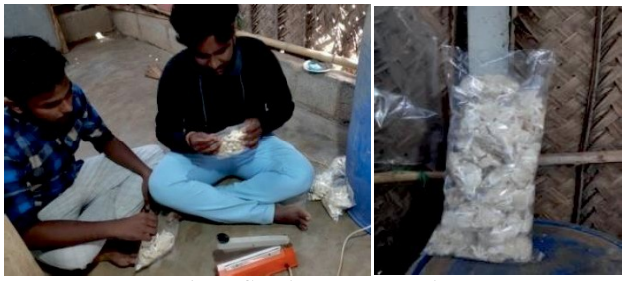


Fig. 5 Sealing and Packing

- **Methodology for Making Mycelium Brick - Flow chart for preparation of mycelium brick**

Mycelium developed bags were taken after harvesting mushrooms

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Mycelium mixed with straw is separated from the mushroom bag

⇩

Grinding the mycelium mixed straw

⇩

Placing the mixture in the brick mould to get definite shape

⇩

Drying under sunlight for 10 to 12 days

⇩

Hardening of brick

⇩

Testing of mycelium brick

(i) **Preparation of mycelium brick**

- **Mixing and Grinding -** Initially the harvested mushroom bags were obtained and the mycelium mixed straw substrate is removed from the polythene bag. The straw is separated from the bag because it results in better product formation. Along with the mycelium, the straw is also utilized for brick

making in order to get definite shape and structure. Hence the mycelium and straw are completely ground and made into a paste.


Fig. 6 Waste bag


Fig. 7 Brick mould


Fig. 8 : Mycelium mixed straw waste


Fig. 9 Separation of mycelium straw


Fig. 10 Grinding

(j) **Moulding -** The brick mould is mainly used for getting the definite shape of the brick. The ground mycelium and straw semi-solid paste is placed in the brick mould and after leveling the mixture in the mould, the brick mould is removed.


Fig. 11 Placing of grinded mixture in brick mould

(k) **Hardening -** Now the brick is placed under the sunlight to get rid of the wetness and also to make it strong. It takes 10 days for the mycelium brick to become stronger.

Fig. 12 Hardening

Fig.13 Normal brick and Mycelium brick

- **Compatibility tests for mycelium bricks:**
  - ✓ **Drop test:** The drop test was done by dropping both the mycelium and normal brick. The two bricks were dropped from 3 feet above the ground level and then the breakages were observed.

Fig. 14 Mycelium brick and normal brick dropped from 3 feet

✓ **Water Absorption test:** The brick was dried in a ventilated oven at 105 to 115^{0}C. The brick was cooled at room temperature and the mass was obtained. The brick was immersed in clean water at room temperature at 27 ± 2^{0}C for 24 hours. The brick was wiped with damp cloth and the mass was obtained again.

Fig. 15 Placing the brick in water

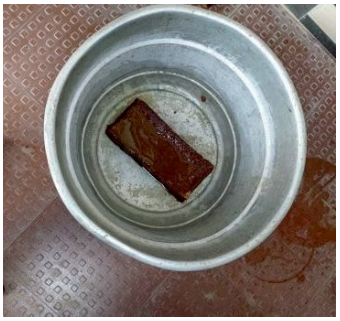


Fig. 16 Floating of brick

✓ **Fire resistance:** Fire resistance is the ability of the product i.e. mycelium brick to withstand fire. The mycelium brick was flamed and its burning properties was noted.

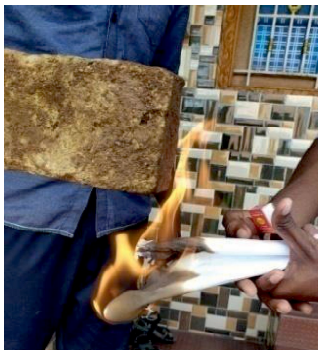


Fig. 17 Burning of brick

✓ **Compressive Strength Test -** Unevenness observed in the faces of mycelium bricks is removed to provide two smooth and parallel faces by grinding. It is immersed in water at room temperature for 24 hours. The brick is then removed and any surplus moisture is drained out at room temperature. It is stored under the damp jute bags for 24 hours followed by immersion in clean water for 3 days. The specimen is placed with flat faces horizontal, and mortar filled face facing upwards between two to three plywood sheets each of 3 mm thickness and carefully centered between plates of testing machine. Load is applied axially at a uniform rate of 14 N/mm^2 per minute till failure occurs. The maximum load at failure is noted down. The load at failure is considered the maximum load at which the specimen fails to produce any further increase in the indicator reading on the testing machine.

The Strength is Calculated the following formula:

$$\text{Compressive Strength Test } (N/mm^2) = \frac{\text{Maximum load failure in N}}{\text{Average area of bed faces in } mm^2}$$

✓ **Determination of Efflorescence -** The end of the mycelium brick was placed in water; this was performed in a warm ventilated room until the water was absorbed by the brick. The brick was covered using suitable glass cylinder. After the complete absorption of water by the brick equal amount of water was placed in the same dish and was evaporated. This was compared to determine the efflorescence.

(l) Microbial synthesis of Silver nanoparticles from actinomycetes

- 100 ml of Starch Casein Nitrate broth was prepared and autoclaved at 15psi for 15 minutes.
- The actinomycetes was inoculated in the prepared Starch Casein Nitrate broth.
- This culture was kept on rotary shaker at 28^0 Celsius for 98 hours at 120 rpm
- After 98 hours of incubation period the cells were separated using Whatmann filter paper.
- The mycelia which were obtained was washed with distilled water.
- 10g of the wet mycelia was taken and re-suspended in 100mL distilled water and this was kept on the rotary shaker for 3 days.
- 100 ml of the filtrate was taken from the above conical flask to which 1mM of aqueous 50ml $AgNO_3$ was added.
- This was kept on rotary shaker in the dark for 120 rpm at 28^0 Celsius. The obtained $AgNO_3$ nanoparticles was characterized.

(m) Characterization of synthesized Silver nanoparticles

- The synthesized $AgNO_3$ was characterized using UV visible spectrophotometry, Transmission Electron Microscopy (TEM), Energy Dispersive X-ray detector (EDX) and Fourier Transform Infrared Spectroscopy (FTIR) to obtain the appropriate size and constituents.

(n) Antibacterial activity of synthesized Silver nanoparticles

- **Minimum Inhibitory Concentration (MIC)**
- Tube diffusion method
- Mueller- Hinton broth was prepared and autoclaved.
- Dilutions of the nanoparticles were made which was added to the tubes containing the culture
- These tubes were incubated for 24 hours at 36^0C
- These tubes were observed and compared with the control.

(o) Antifungal activity of synthesized Silver nanoparticles

- Mueller-Hinton agar plates were prepared and fungal culture strains were inoculated onto these plates.
- Paper disc was loaded with synthesized nanoparticles.
- The plates were incubated at 36^0C for 2 days and then compared with the control.

(p) Application of Silver nanoparticles as a topical coat over the mycelium bricks - The synthesized Silver nanoparticles was applied as a topical coat over the bricks to increase the efficiency of the synthesized mycelium bricks.

IV RESULTS & DISCUSSION

Growth parameters were observed after seeding or spawning. Partial mycelium growth was observed 15days after spawning and the mycelium was fully spread throughout the bag on 21st day. Initial bud formation was observed on 23rd day. On 25th day pinhead formation was observed. The initial stage of mushroom growth began on 30th day and the full maturation began on 34th day.

Table 1
Mycelium and mushroom growth observation from bag hanging till harvest

S. No	Growth	Observation period (days)
1	Partial mycelium	15th day
2	Fully spreaded mycelium	21st day
3	Initial bud formation	23rd day
4	Pin head formation	25th day
5	Initial bunch of mushroom growth	30th day
6	Fully matured bunch of mushroom	34th day

The height of mushroom (cm) after bud initiation was measured. 0.9 cm of bud was formed on 23rd day, 2 cm of growth was observed on 25th day, 4.8 cm of growth was formed on 30th day, 9.9 cm on 32nd day and 16.20 cm on 34th day respectively. The height of mushroom after spawning includes the initial bud formation and pinhead formation that occurs on 25th day. The height of mushroom gradually increases and attains maximum at the harvest on 34th day.

Table 2
Measurement of mushroom growth after bud initiation

S. No	Observation period (days)	Measurement in cm
1	23rd day	0.9
2	25th day	2.0
3	30th day	4.8
4	32th day	9.9
5	34th day	16.2

The total yield of oyster mushroom obtained was about 63.6 kg, including four harvests. The yield obtained during the first harvest was higher when compared to the other three harvests. It is evident that the yield of mushroom obtained during the first harvest is higher (around 65 Kg), followed by a gradual decline in yield in the subsequent harvests.

Table 3
Mushroom yield during various harvests

S. No	Harvest	Yield (kg)	Yield per bag (kg)
1	1st	25.5	0.510
2	2nd	18.6	0.372
3	3rd	10.5	0.210
4	4th	9.0	0.180
		Total 63.6 kg	

Mushroom cultivation is simple, cost effective and labor intensive thereby providing employment for rural people. Awareness and training in mushroom cultivation enables the rural women to obtain revenue in addition to their conventional activities. Farmers realized the importance of mushroom and incorporated it in their diet (Biswas, 2014). Training programmes prior to mushroom cultivation gave better knowledge about oyster mushrooms. Mushroom farming investment in small-scale operation leads to better yield and higher profits (Saurab, 2019). Mushroom production is the most efficient way to obtain profit with minimum investment.

Oyster mushroom is a protein-rich product which helps in solving the issues such as malnutrition. Cultivation of oyster mushroom using different agricultural wastes provides income and a variety of value-added products (Josephine, 2015). Regular consumption of oyster mushroom gives good health benefits to human beings. Oyster mushroom cultivation (*Pleurotus sajorcuju*) was done using different substrates such as paddy straw, wheat straw, sugarcane bagasse and banana leaves. Among these substrates, paddy straw provided maximum yield, better profits and a more appropriate benefit-cost ratio.

Oyster mushroom (*Pleurotus ostreatus*) was cultivated utilizing different substrates such as paddy straw, wheat straw, paddy straw + wheat straw, paper, sugarcane bagasse and saw dust. Among the substrates, paddy straw was found to be the best with maximum yield and biological efficiency. Nutritional composition of oyster mushroom obtained from paddy straw was found to be better and therefore cultivation of oyster mushroom using paddy straw has become on of the most profitable agri-business (Sharma et al., 2013).

The marketing and the commercial growth of mushrooms were developed in different countries. The marketing of oyster mushrooms at wholesale level is still at its peak with good values.

(a) Cost of production of oyster mushroom

Cost of production of oyster mushroom was Rs. 6650 (Fixed cost – Rs. 4500; Variable cost – Rs. 2150).

Table 4
Cost of production for oyster mushroom - Fixed Cost

S. No	Input	Quantity	Cost (Rs)
1	Polythene bag	55 covers	275
2	Paddy straw	175 kg	2800
3	Seed	25 spawn packets	1075
4	Formalin	900 ml	300
5	Bavistin	100 mg	100
		Total	Rs. 4550

Table 5
Cost of production for oyster mushroom - Variable Cost

S. No	Input	Quantity	Cost (Rs)
1	Malathion	250 ml	150
2	Irrigation	Regular irrigation was applied	1000
3	Electricity	-	100
4	Labor cost	2 workers (2 days)	600
5	Packing polythene covers	5 packets	250
		Total	Rs. 2100

(b) Testing of Mycelium bricks:

- **Drop test:**

The drop test was done by dropping both the mycelium and normal brick. The two bricks were dropped from 3 feet above the ground level and then the breakages were observed.

Table 6
Drop test - Comparison between the normal brick and mycelium brick

S. No	Brick type	Drop result - 1	Drop result - 2	Drop result - 3
1	Normal clay brick	Breakage found	Breakage found	Breakage found
2	Mycelium	No breakage	No breakage	Breakage found

(c) Water Absorption test:

The brick was dried in a ventilated oven at 105 to 115^{0}C. The brick was cooled at room temperature and the mass was obtained. The brick was immersed in clean water at room temperature at 27 ± 2^{0}C for 24 hours. The brick was wiped with damp cloth and the mass was obtained again.

Table 7
Absorption test for different bricks

S. No	Brick type	Weight before absorption of water (W1)	Weight after absorption of water (W2)	Water absorption in % W2/W1
1	Mycelium brick	0.7 kg	1.1 kg	15.7
2	Normal brick	2.66 kg	3.4 kg	12.7

(d) Fire resistance:

Fire resistance is the ability of the product i.e. mycelium brick to withstand fire. The mycelium brick was flamed and their burning property was noted.

(e) Compressive Strength test

The compressive strength of both normal and mycelium bricks were analyzed. The normal brick was found to possess higher compressive strength than the mycelium brick.

Table 8
Compressive strength analysis of different bricks

S. No	Brick type	Weight (kg)	Failure load (KN)	Compressive strength (N/mm^2)
1	Mycelium brick	0.7 kg	6.6	0.47
2	Normal brick	2.66 kg	9.2	0.65

Table 9
Measurement of bricks

S.No	Parameters	Mycelium bricks	Normal bricks
1	Length	21.1 cm	22.5 cm
2	Breadth	9 cm	11.2 cm
3	Width	5.4 cm	7.5 cm
4	Weight	700 g	2.66 kg

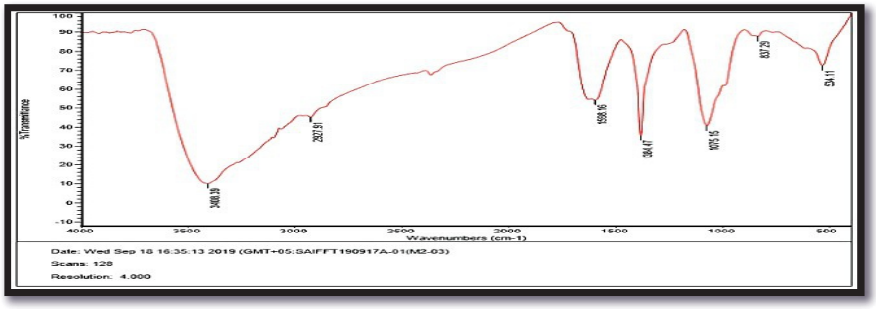
(f) Microbial synthesis of silver nanoparticles from actinomycetes - $AgNO_3$ nanoparticles were synthesized using actinomycetes cultured in Potato dextrose broth (PDB). The synthesis of nanoparticles was indicated by color change of the medium i.e. from yellow to brown.

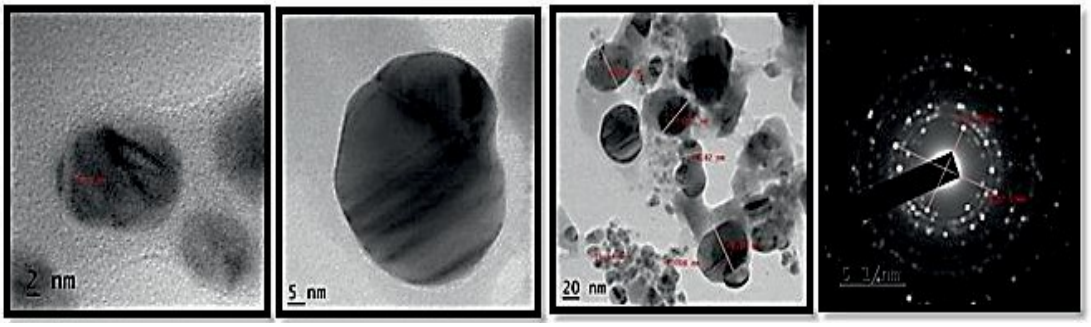
(g) Characterization of synthesized silver nanoparticles-

- **Transmission Electron Microscopy (TEM) analysis -** TEM analysis of the silver nanoparticles showed that the reduced form of silver nitrate solution through bio reduction are clearly distinguishable owing to their size difference. It is clear from the TEM image that silver particles in the bio reduced colloidal suspensions measured 2 nm - 51nm (2 nm, 10 nm, 20 nm, 51 nm) in size. The particles were spherical in shape, well defined and separated.

Characterization of silver nanoparticles using Transmission electron microscopy (TEM)

FTIR (Fourier Transformation Infrared Spectroscopy) Analysis





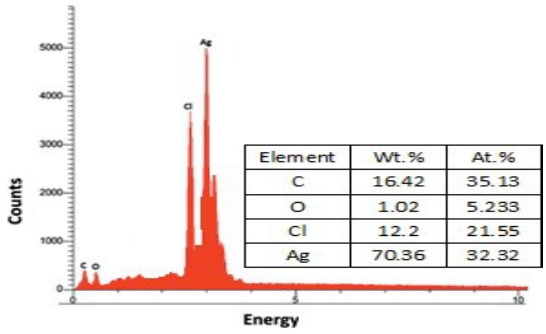
(h) Characterization of silver nanoparticles using FTIR to elucidate the functional groups present in it

Table 10
FTIR results illustration

Absorption cm^{-1}	Functional Group	Compound Class
3550-3200	O-H stretching	Alcohol
3000-2840	C-H stretching	Alkane
1650-1580	N-H bending	Amine
1380-1385	C-H bending	Alkane
1085-1050	C-O stretching	Primary alcohol
840-790	C=C bending	Alkene (trisubstituted)
600-500	C-I stretching	Halo compound

The synthesized nanoparticles were characterized by FTIR analysis to determine the various functional groups present in it. The graph of wavenumber vs. % transmittance showed various peaks indicating the presence of functional groups such as alcohol, alkane, amine, alkene, halo compounds etc.

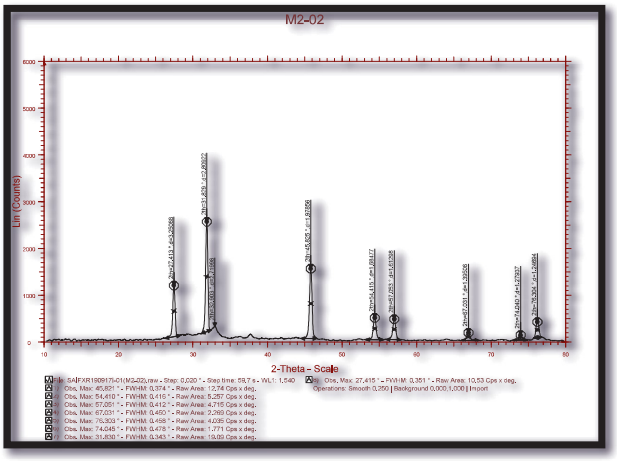
- **EDX-** The EDX spectra recorded from silver nanoparticles revealed that the weight percentage of silver was 70.56%.



(i) Zeta potential of silver nanoparticles - Zeta potential is used to obtain further information about the stability of microbially synthesized silver nanoparticles. The magnitude of zeta potential gives an idea about the potential stability of silver nanoparticles. Zeta potential technique is used to indicate the changes in surface charge with time. The metal nanoparticles with a large positive or negative zeta potential tend to repel each other and they do not show any disposition to come together. But in the case of low absolute zeta potential values, these particles aggregate and flocculate due to the absence of the repulsive force which prevents such agglomeration. Nanoparticles with zeta potential values more positive than +30 mV or more negative than -30 mV are considered to be stable. The zeta potential of silver nanoparticles synthesized from actinomycetes was found to be -26 mV. This indicated good stability of the synthesized silver nanoparticles.

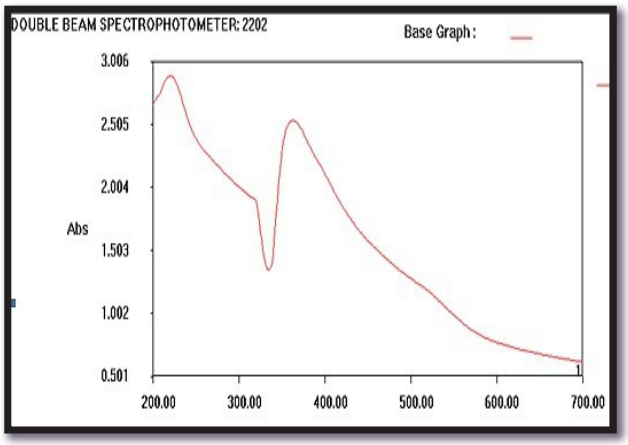
(j) X-ray Diffraction Analysis (XRD) - The powdered XRD pattern of synthesized $AgNO_3$ nanoparticles using actinomycetes is shown. The major characteristic peaks of the nanoparticle corresponds to the crystalline structure of the Silver Nitrate nanoparticle. The XRD pattern clearly shows main peaks at (2θ) 45.14, 53.86, 54.48, 67.86, 74.24 and 76.4 corresponding to various planes. By determining the width of Bragg's reflection, the estimated average size of the particle is 25nm. In addition, two unassigned peaks appeared at $28.84^0$and 32.26^0. These peaks were weaker than those of silver. This may be due to the bioorganic compounds occurring on the surface of the silver nanoparticles.

XRD analysis of silver nanoparticles synthesized from actinomycetes



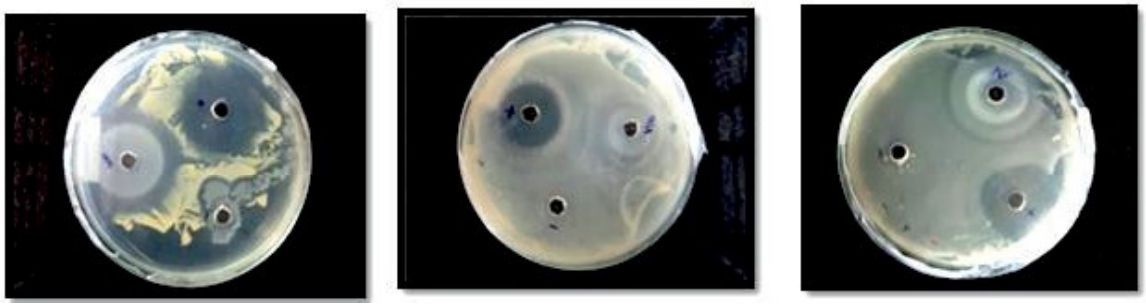
UV Visible 3.4.6 Spectrophotometric Analysis

The synthesized nanoparticles were characterized using UV Visible double beam spectrophotometer and the peak obtained between 350- 400nm indicated the presence of silver nitrate nanoparticles.



Characterization of synthesized silver nanoparticles by UV visible spectrophotometer

(k) Antibacterial activity of silver nanoparticles



Against S. aureus **Against E. coli** **Against B. subtilis**

Table 11

ZONE OF INHIBITION (mm)			
	Staphylococcus aureus	**Escherichia coli**	**Bacillus subtilis**
$AgNO_3$ Nanoparticle	37	17	31
Streptomycin(positive control)	35	28	29

The synthesized $AgNO_3$ nanoparticles showed remarkable antibacterial property when compared to streptomycin (positive control) and double distilled water (negative control). Measuring the zone of inhibition, it was evident that Silver nanoparticles had highest activity against *Staphylococcus aureus* followed by *Bacillus subtilis* and *Escherichia coli.*

(l) Antifungal activity of silver nanoparticles

Against *Candida* sp. **Against *Penicillium* sp.** **Against *Aspergillus niger***

Table 12

Zone of inhibition by the Silver Nitrate nanoparticles against Candida sp, Penicillium sp, and A. niger

ZONE OF INHIBITION (mm)			
	Candida sp.	***Penicillium sp***	***Aspergillus niger***
$AgNO_3$ Nanoparticle	13	11	9
Streptomycin (positive control)	20	-	-

The synthesized $AgNO_3$ nanoparticles showed antifungal property when compared against Fluconazole (positive control) and double distilled water (negative control). Measuring the zone of inhibition, it was evident that silver nanoparticles had highest activity against *Candida sp.* followed by *Penicillium sp.* and *Aspergillus niger.*

(m) Application of silver nanoparticles as a topical coat over the mycelium bricks

The synthesized silver nanoparticles were applied as a topical coat over the mycelium bricks using a brush.

(n) Cost of mycelium brick

The normal brick costs Rs. 8 whereas the mycelium brick costs Rs. 4. This indicates that the mycelium brick is cost effective.

When drained in sunlight, mycelium bricks exhibit better insulating properties. There is increasing demand for the bio-based mycelium bricks possessing better self-insulating properties (Mosur et al., 2017; Dahmen, 2017). The mycelia is used as binding material in brick production (Ongpeng et al., 2020). Mycelium bricks prepared from paddy straw possessed good binding properties and good insulating properties (Allam and Garas, 2010).

V CONCLUSION

Edible mushrooms possess good economical and ecological values and medicinal properties. They are able to grow under different climatic conditions with moderate cost and in controlled conditions with easily available raw materials. Mushrooms belonging to the genus *Pleurotus* has been cultivated across the globe. Specifically, *Pleurotus ostreatus*, known as "Oyster Mushroom" requires shorter growth time than other edible mushrooms. Easily available materials are used as a substrate for oyster mushroom cultivation. Paddy straw is the preferred substrate as the fruiting bodies of oyster

mushrooms are not often infected by diseases and pests and it can be cultivated in a simple and easy way by maintaining in hygienic condition. Compared to other edible mushrooms, *Pleurotus ostreatus* have good mycelium growth and most of the paddy straw substrate are converted into fruiting bodies and Oyster mushroom possess good medicinal and health benefits to human beings. Oyster mushroom provides yield higher than other edible mushrooms, which results in generation of increased profits. Hence, *Pleurotus ostreatus* is an excellent choice for mushroom cultivation.

Mycelium bricks are a novel class of renewable biomaterials made from fungal mycelia and low-value non-food agricultural materials. Switching towards the synthesis of mycelium bricks can be a better option over the cemented bricks overcoming the failures offered by the latter. Mycelium bricks are made by using agricultural wastes. These bricks are good for constructional purpose and are available at low cost than other bricks. It can also be used to make chairs, tables and insulation boards. The use of mycelium brick could revolutionize the construction industry. Applying microbially synthesized silver nanoparticles topically can improve the purity of the brick and avoid bacterial as well as fungal contamination. Hence a high efficacy, low cost, high purity, eco-friendly mycelium brick can be a next generation alternative towards conventional bricks.

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