Chapter

Biodegradation by Fungi for Humans and Plants Nutrition

Chandan Singh and Deepak Vyas

Abstract

Fungi being achlorophyllous depends on other living organisms for their food either being parasite or saprophyte. Saprophytic fungi are good biodegraders. Through their enzymatic batteries, they can degrade any organic substances. Most of the time during the processes of degradation, macrofungi (mushrooms) are occurred as per the climatic conditions prevailing in the particular locations. Micro and macrofungi are considered a good source of human nutrition and medicine since time immemorial. Some of the fungi which are commonly known as mycorrhizae facilitate nutrients to more than 90% of green plants. Fungi play a basic role in plant physiology and help in the biosynthesis of different plant hormones that provides the flexibility of plant to withstand adverse environmental stress, the whole fungi are more friend than foe.

Keywords: fungal biodegradation, residues, tree internet, mushrooms, biocontrol

1. Introduction

Biodegradation is defined as the biologically catalyzed reduction in the complexity of chemical compounds. Indeed, biodegradation is the process by which organic substances are broken down into smaller compounds by living microbial organisms. When biodegradation is complete, the process is called "mineralization". However, in most cases, the term biodegradation is generally used to describe almost any biologically mediated change in a substrate [1]. Fungal diversity is globally estimated to 1.5 million species and consists of an incredibly diverse group of organisms. Organisms studied by mycologists include members of the fungal Kingdom but also others like Protozoa e.g. slime molds [2]. Biodegradation by fungi is also known as mycodegradation. Likewise, bioremediation in which fungi are employed is sometimes called mycoremediation [3]. Fungi are parasitic, saprophytic, mutualistic, and decomposers and grow faster on their substrate and synthesis metabolites to adjust with all the adverse condition and competitor, therefore it has several secondary metabolites, these metabolites serve as a treasure for the new source of potential drugs for human health and the plant health [4]. Fungi have ancient application in human health and nutrition, it produces several enzymes like cellulase, lipase, ligninolytic enzymes, catalase, laccase, etc., alkaloids, pigments, aroma, and flavors, and used in biological control of nematodes, in plants pest control, health benefits by edible fungi [5, 6]. The diversity of fungi play important role in the environment as it acts as decomposers and recycles the organic matter in nature, provides nutrition to plants through mycorrhization [7, 8], and the enzymes secreted by fungi are investigated for the production of the different by-products out of waste and sludges. Many filamentous fungi are now investigated for the production of biofertilizers [9, 10]. Fungi produce numerous secondary metabolites that are used for human benefit. Despite the benefit of fungi for human health and plant health, it has a negative effect too. The different aspect of fungi effects on human and plant is all due to the potential of the fungi to utilizes the recalcitrants wastes through a process called as biodegradation. In this chapter, the different aspects of fungal biodegradation and its relation to human and plant nutrition have been highlighted.

2. Mechanism of fungal degradation

Fungi have numerous enzyme system and occur under the various climatic condition on a variety of substrates, the mode of nutritious in fungi is always heterotrophic, therefore being a heterotrophic organism they obtain their nutrition either through parasitic or saprotrophic mode and to do so, they employ a series of enzyme reaction on the substrate they grow since the biomass (dead bodies of plants and animals) are complex in chemical composition they are made available to fungi nutrition by converting it to the simpler form [3]. Generally, plant residues are lignocellulosic in nature which is a very complex molecule to digest by any organism, but fungi with the potential to produce enzymes that digest these residues to simpler, the mechanism of fungal degradations depend on the type of substrates and the enzymatic system, for example, lignin degradation by the white-rot fungi is an oxidative process and phenol oxidases are the key enzymes, manganese peroxidases, lignin peroxidases, laccase from the white-rot fungi have been found to play a significant role in lignin degradations [11] (discussed in Section 3.1.), white-rot fungi degrades lignin to use it as a sole carbon and energy source, and it is generally believed that lignin breaks down is necessary to gain access to cellulose and hemicelluloses of the substrates [11].

3. Fungi-mediated biodegradation

Fungal has the potential to degrade organic materials naturally, considering this capacity of fungi to convert organic residue to different simple products are harnessed to produce valuable products for mankind's, which is used under control condition for the production of desired products by humans like production of bread, wine, medicine, and other industrial application, among this cultivation of edible and medicinal mushroom on organic residue is an example of fungal mediated biodegradation. The conversion of lignocellulosic residue to value products involves multi-steps which includes [11]:

a. Pretreatment (mechanical, chemicals, or biological).

b. Hydrolysis of polymers to produce readily metabolizable molecules (eg. Hexose or pentose sugars).

c. Use of these molecules to support microbial growth or to produce chemical products.

d. Separation and purification.

Edible mushroom cultivation is a mediated fungal degradation for the production of non-consumable residue into the consumable source of nutrition riched food, mushrooms are fleshy and saprophytic fungus that utilizes wood trunks of trees, decaying organic matter, and damp soil rich in organic substances for their growth. Cultivation of mushrooms can be viewed as an effective way to utilize bioresources left in agricultural residues and environmental protection strategy [12, 13]. Cultivation of any type of mushroom implies principles of microbiology, environmental engineering, and solid-state fermentation in the conversion of domestic agricultural, industrial, forestry wastes into food for humans. *Pleurotus* mushrooms are simplest and are easily cultivable on the agric residue available on the agric farm, different types of substrate have been used for the cultivations to increase the yield [14–16]. *Pleurotus* is a genus of edible mushrooms widely cultivated throughout the world in a variety of substrates and conditions. This genus consists of more than 200 saprophytic species distributed worldwide in temperate and tropical environments and the most common species of *Pleurotus* genera (Oyster mushroom), are *P. ostreatus*, *P. djamor*, *P. citrinopileatus,* and *P. eryngii*. Among the common substrate used are wheat straw, sawdust, paddy straw, corn cob, sugarcane bagasse, ground nutshell, etc. [15, 17, 18]. *Pleurotus* produces the enzyme system to degraded the lignocellulosic components of the substrates and made them available for the mushroom for their metabolism which makes the mushroom a rich source of protein, dietary fiber, vitamins, and minerals [14, 19, 20]. Apart from oyster mushroom cultivation different variety have been adopted worldwide for the cultivation on the large scale both for medicine and the nutritions like species of *Agaricus, Lentinus*, *Calocybe*, *Volvariella*, *Auricularia*, *Ganoderma*, *Trametes,* etc., are some of the examples of fungal mediated biodegradation for production and utilization of wastes.

3.1 Biodegradation of agricultural waste by fungi

Tons of agricultural residue generated each year from the cropland and some of these residues are used as animal feed and others for industrial use but the majority of the residue is burned in the crop field causing environmental pollution, but using fungal species these are converted into compost or either used for the production of the edible mushroom. Since fungi possess a proficient hydrolytic system that is capable to convert lignocellulosic material to essential metabolites in the form of mushrooms. Usually, fungi (micro and macrofungi) secrete enzymes, including cellulases (cellobiohydrolases, endoglucanases), hemicellulases (xylanases), and β-glycosidases [21, 22]. The recent developments in our understanding of the genetics, physiology, and biochemistry of fungi, has led to the exploitation of fungi for the preparation of different agriculture and industrial products of economic importance [4], therefore the agric residue which is rich in lignocellulose consists of lignin, hemicellulose, and cellulose [11, 23] can potentially be converted into different value-added products as depicted in (**Figure 1**) including biofuels, chemicals, animal feed, textile and laundry, pulp and paper. Production of ethanol and other alternative fuels from lignocellulosic biomass can reduce urban air pollution, decrease the release of carbon dioxide into the atmosphere, and provide new markets for agricultural wastes [21].

As the lignocellulosic biomass is made up of complex carbohydrates, which is a source of the sugars that can be processed to obtain ethanol, but due to the recalcitrant nature of the lignocellulose biomass it is very difficult to produce ethanol out of this biomass, production of ethanol from these biomass involves series of step to convert complex cellulose to simple sugars one of the major steps in the production step of ethanol is pretreatment of the recalcitrants biomass, which raise the cost of production of ethanol. The three methods physical,

Figure 1.
Different value-added products from agric residues.

chemical, and biological methods are used in the pretreatment of the biomass. Pretreatment is done to digest the lignocellulose to produce simpler sugars that are further converted into bioethanol [24]. The biological methods of treatment using microbes are eco-friendly and produce clean fuel, among all microbes fungi have great potential to convert recalcitrants into simpler sugars through enzymatic and hydrolytic methods [25]. The existence of the enzymatic system in the fungi serves as the treasure of the Novo enzyme source for the finding of candidates of the enzyme to digest lignocelluloses, enzymes like catalases, laccase, hemicellulases, ligninases, pectinases play a crucial in the digestion of the recalcitrants biomass [26]. The effectiveness of a biological pretreatment is determined by several factors like composition of biomass, inoculum concentration, aeration rate, moisture content, incubation time, incubation temperature, pH, and the fungi species involved [27]. The most common mechanism of pretreatment is illustrated in **Figure 2**.

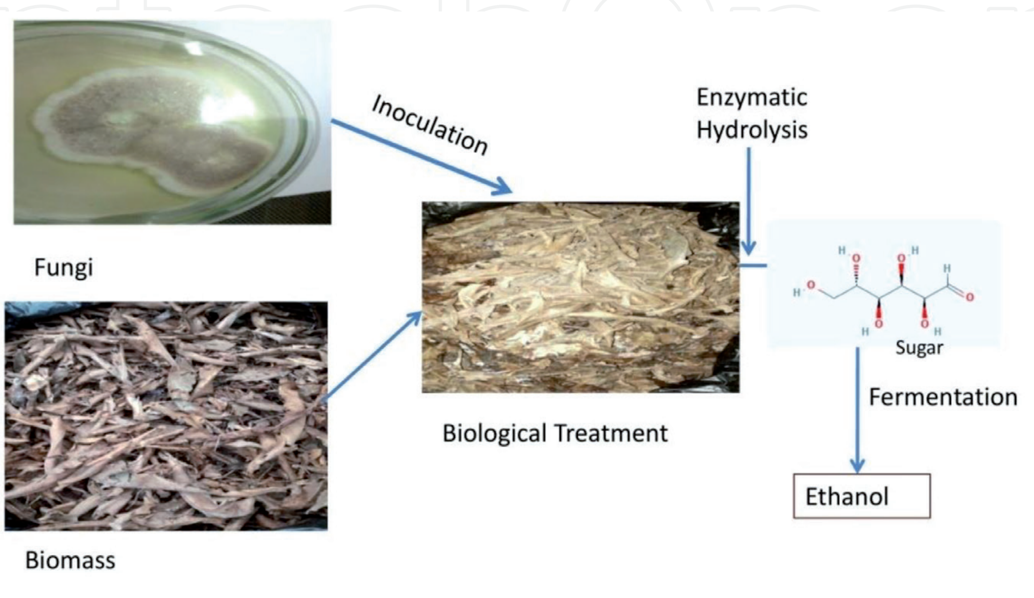

Figure 2.
Schematic diagram for biological treatment by fungi of lignocellulosic biomass.

3.2 Wood decaying fungi

Wood decaying or xylophagous fungi are those fungi that decompose wood dead or alive. These fungi in nature break down complex molecules of deadwood and branches and return their nutrients to the soil [2, 28]. Wood decaying fungi cause brown rot, soft rot, and white rot, with a different set of enzymes, and

Sl. No	White-rot fungi	Enzyme/s	Function	Reference
1.	*Phaberochaete chrysosporium*	Lignin peroxidases	Degradation of Lignin & lignin-like compound, biomineralization of lignin	[11, 23]
2.	*Trametes versicolor*	Lignin peroxidase, cellulase Manganese peroxidases	Degradation of Lignin & lignin-like compound act as a wood decomposer, biomineralization of lignin	[11, 23, 29]
3	*Pleurotus sp*	Lignin peroxidase, Versatile peroxidase, Laccase, Manganese peroxidases	Lignin degradation, production of biofuel, environmental remediation	[23, 34, 35]
4.	*Bjerkandera adjusta*	Lignin peroxidase, Versatile peroxidase, pro-duce some accessory enzymes for H_2O_2 production.	licentious enzyme having Lignin peroxidase acts as a wood decomposer, biomineralization of lignin.	[23, 35]
6.	*Pycoporus cinnabarius*	Laccases, lipase, protease	Biomineralization of lignin and Cellulose, degradation of dyes	[29, 35, 36]
7.	*Schizophyllum commune*	Cellobiose dehydrogenase,	Biomineralization of lignin and cellulose	[29, 35, 36]
8.	*Inonotus hispidus*	Laccases, manganese peroxidases, and lignin peroxidases	Lignin-modifying, Dye decolorization.	[5, 23]
9.	*Lentinus tigrinus*	Laccases, manganese peroxidases, and lignin peroxidases	Degradation of dyes, Biomineralization of lignin and cellulose.	[5, 23]
10	*Ganoderma sp*	Laccases, manganese peroxidases, and lignin peroxidases	Lignin-modifying Dye decolourization	[5, 23]
11	*Coriolus sp*	Laccases, manganese peroxidases, and lignin peroxidases	Lignin-modifying, Dye decolorization.	[5, 23]
12	*Irpex sp*	Laccases, manganese peroxidases, and lignin peroxidases	Lignin-modifying, Dye decolourization	[5, 23]
13	*Laccaria fraterna*	Laccases, manganese peroxidases, and lignin peroxidases	Lignin-modifying, Dye decolorization	[36]
14	*Lentinus polychrous*	Laccases, manganese peroxidases, and lignin peroxidases	Lignin-modifying, Dye decolorization,	[11, 36]

Table 1.
White-rot fungi and lignin degradation enzyme produced by them.

based on the type of decay they cause they are classified as brown-rot fungi, soft-rot fungi, and white-rot fungi [29]. Brown-rot fungi produce hydrogen peroxide that breaks down cellulose and due to this the fungus removes all the cellulose compound from the wood and left the wood brown in color. Soft-rot fungi secrete the cellulolytic enzyme and break down the cellulose of the wood, these fungi are less aggressive than the white-rot fungi, whereas the white-rot fungi break both lignin and cellulose of the wood [5]. White-rot fungi produce laccase enzyme in higher concentrations and therefore they have been investigated for various use in mycoremediation, biofuel production, medical industries [5]. Fungi belonging to ascomycetes and basidiomycetes are generally white rot-fungi and have the potential to produce numerous enzymes of economic importance and hence white-rot fungi are extensively investigated to support the human lifestyle [29], however, these fungi also have adverse effects on our household wooden gadgets.

The wood and the leaf litter biomass have mostly lignocelluloses as the major components produced by the plant photosynthesis and represent the most abundant renewable resource in the soil [11]. Lignocellulose is consists of three types of polymers, cellulose, hemicellulose, and lignin which are strongly linked together by chemical bonds like non-covalent forces and by covalent cross-linkage, very small amount of lignocellulose produced by-product in agriculture or used in industries, and the remaining are considered as residue [11, 30]. Different microorganism degrades residue for the carbon as a source of energy, however, filamentous fungi evolved with the ability to degrade lignin to CO_2 and other compounds as discussed in the above paragraph [31]. Some other lignocelluloses degrading fungi like brown-rot and soft-rot fungi rapidly modify the lignin content and these fungi collectively play an important role in the carbon cycle [1, 11]. Apart from degrading lignin the white-rot fungi also degrade a variety of persistent environmental pollutants [30, 32, 33] like aromatic hydrocarbon, aliphatics hydrocarbon, cyanide compound, pesticides, fungicides, etc. This ability of white-rot fungi is only due to the strong oxidative activity and low substrate specificity of their ligninolytic enzyme (**Table 1**). As discussed above the white-rot fungi most commonly the macrofungi belongings to ascomycetes and basidiomycetes served as the integrated part in an ecosystem service as they produce various enzymatic mechanisms that degrade the wood and helps in maintaining the forest soil healths. Many fungi are the source of food for invertebrates in the forest, the organisms that feed on the fungi are termed as the fungivore. The ecological function of the fungi is strongly linked with the wood decay dynamics in the forest ecosystem [37], in **Table 1** the fungus listed with the enzymes are some most common enzymes produced by these fungi when come in contact with the woods and forest debris to degrade the recalcitrants forest wood and debris, the listed fungi in **Table 1** is mostly common in the forest ecosystem that acts as the decomposers.

4. Role of fungi in human nutrition

Fungi degrade different biomass and obtain nutrition for their growth and development. Fungi occur in diverse climates under different challenging conditions, and therefore they synthesized secondary metabolites to pace with the challenging threats of their life and the secondary metabolites have a broad range from antibiotic to mycotoxin. Fungi mainly use three pathways to synthesized metabolites: i. the mevalonic acid pathway (synthesize terpenoids, steroids, etc), ii. the shikimic acid pathway (synthesize aromatic amino acids, alkaloids, etc), and iii. The acetate pathway (synthesize polyketides, fatty acids, etc). Metabolites have beneficial effects on human health like antioxidants, antibiotics, immunity booster, potent anticancer agents, and reduce stress, etc.

Mushrooms (filamentous fungi) with fruiting bodies show a huge number of pharmacological aspects in human health. Macrofungus like *Ganoderma sp.* and *Cordyceps sp.* used in the traditional medicines, *Ganoderma* (Reishi) mushroom has also been commonly referred to as the "mushroom of immortality", "ten-thousand-year mushroom", "mushroom of spiritual potency", and "spirit plant by the Chinese monk [38, 39]. Generally, Mushrooms seemed to be used for food, medicine, poison, and in spiritual mushroom practices in religious rituals across the world since at least 5000 BC [40]. Gordon Wasson (father of modern Ethno mycology) supposed that the Soma plant used in religious ceremonies, over 4000 years ago, before the beginning of the Christian era, by the people who called themselves "Aryans" was a mushroom [41, 42]. The Vedic juice called "soma rasa" is said to bestow divine qualities on the soul of the consumer,

Macrofungi	Nutritional value-Protein(g/100 g)	Carbohydrate (g/100 g)	Medicinal value
Pleurotus	17–42	37–48	Anticancer, antioxidant,antitumor, antiviral, antibacterial, antidiabetic,antihyp ercholesterolemic, eye health, anti-arthritic, immunomodulatory, hepatoprotective,anti-obesity
Agaricus	56.3	37.5	Anticancer, antidiabetic, antihypercholesterolemic, immunomodulatory, hepatoprotective, antiviral, antimutagenic
Tricholoma	18.1–30.5	31.1–52.3	Antihypercholesterolemic, anti-aging
Lentinus	26.3	65.1	Anticancer, immunomodulatory
Hericium	22.3	57.0	Antihypercholesterolemic

Table 2.
Nutraceutical value of some edible mushrooms.

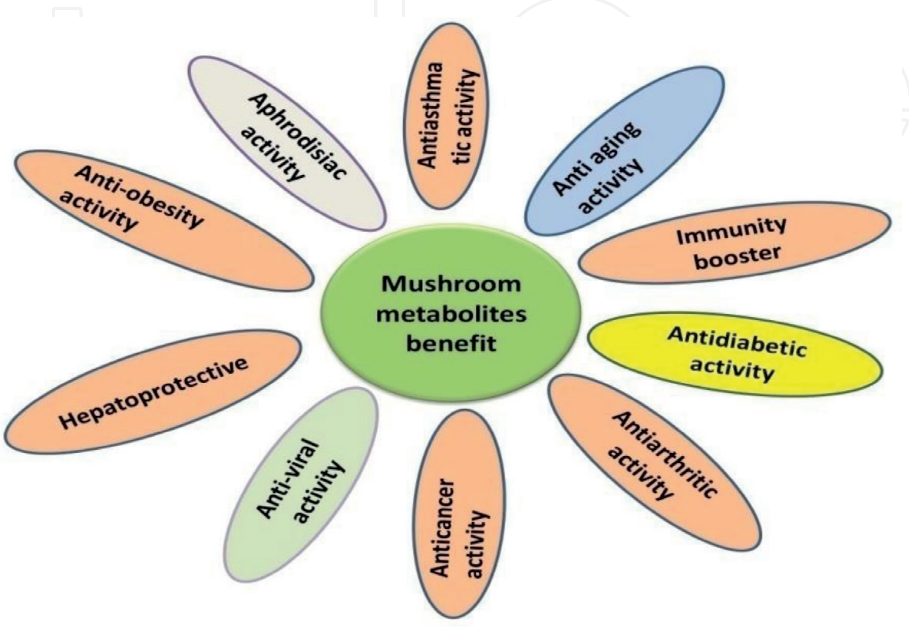

Figure 3.
Schematic illustration of the therapeutic application of secondary metabolites of mushrooms.

even immortality [40, 42]. Mushrooms are considered one of the delicious foods and are commonly produced worldwide. They have been an essential part of the human diet and are used as both food and medicine for centuries. As shown in **Table 2**, they are a rich source of nutrients and bioactive compounds such as carbohydrates, fibers, proteins, vitamins, minerals, and have enormous medicinal attributes such as antibacterial, antiviral, antioxidant, anticancerous, and hypocholesterolemic which are valuable for human health [43]. The mushrooms are rich in protein and carbohydrate content, whereas low in lipid content. They contain essential amino acids, which help in meeting the needs of amino acids in the human body (**Figure 3**). They are also rich in many essential unsaturated fatty acids, such as linoleic and oleic acids, which are necessary for the proper functioning of the body. Apart from this, they contain many essential minerals, which are responsible for the proper metabolism of many pathways. Mushrooms being achlorophyllous therefore, they grow on decayed organic matters, rich in lignin, cellulose, and other important carbohydrates. It is economical, rich in pharmacological properties, easy to cultivate, requires low resources and area, and can be grown all over the world. Nutritional, medicinal, bioremediation, and biodegradation aspects of mushrooms are increasing day by day and have got strong focused in investigation for their hidden metabolic compounds [44, 45].

5. Production of organic fertilizer and biofertilizer using fungi

The substances that fertilize the soil can be called fertilizers. Fertilizer is widely used to supply essential nutrients for plants to increase yield. Many types of fertilizers existed such as inorganic, organic, and biofertilizer, fertilizers that provide nutrients in inorganic forms are called mineral fertilizers, and those derived from plants or animal residue are considered organic fertilizers whereas biofertilizers are products containing living cells of different types of microorganisms that have the ability to mobilize nutritionally important elements from non-usable form to usable form through the biological process [46]. Biofertilizer is well known for its application in sustainable agricultural practices it is a cost-effective, eco-friendly, and renewable source for plant nutrition [10, 47], the ability of the fungi to restrict the growth of other microbes and have potential to control the disease of the plant is termed broadly as biocontrol agents, many fungi like *Trichoderma harzianum*, *Ampelomyces quisqualis*, *Chaetomium globosum*, *C. cupreum*, *Gliocladium virens, Coniothyrium minitans,* etc. are some common example of biocontrol agents and many of the micro and microfungi made the availability of the complex nutritional compounds into a simpler form which is used by plant easily such fungi acts as symbiotic agent. The symbiosis of fungi with the plants helps plants to fix nitrogen, solubilizes phosphate, and other complex compounds of the micro and macronutrient present in the soil as recalcitrants form. Based on the several abilities of beneficial fungi many formulations have been made for the application of the fungal-based biofertilizer in arable soil [48]. Details account of fungi in plant nutrition has been discussed below, production of fungal biofertilizer using mycorrhizal fungi is very selective since AM fungi are obligate symbiotic, they can not be grown without plant host on synthetic media, hence it is produced in association with the host plant. Mass production by pot culture is the most common method used in the production of AM based biofertilizer, no matter what method or formulation is used but for the success of the formulation depends on (a) economic viability of production (b) retention of the inoculum viability after formulation (c) handling and dispersal capacity during application [48, 49]. The formulations are availably available in the form of powder, pellets, gell beads [50]. There are several AM

Figure 4.
Gradual conversion of leaf litter into organic leaf compost, arrow indicates the gradual conversion of leaf into matured compost.

fungi formulations but the efficiency of the applications depends on the products, conditions of the environment, bulking agents, and other variables [3, 10, 47, 48]. However, to produce organic fertilizer the enzymatic system of fungi is used to convert biodegradable substances into compost, in nature, the fungi decompose the recalcitrants substrates into simple form and helps in nutrient recycling. These facts of fungi are used in the production of organic fertilizers, for example, leaf compost where the dead leaf convert into dark brown organic fertilizer see **Figure 4**.

Trichoderma viride is a filamentous fungus widely used as a biofertilizer as a biocontrol agent, this fungus nowadays has gained global market attention as a biofertilizer. *T.viride* acts as an antagonistic fungus, it is effective in controlling seed-borne pathogens as well as soil-borne pathogens. The working mechanism of *Trichoderma* as a biocontrol agent is either direct or indirect, *Trichoderma* restricted phytopathogens growth indirectly by competing for nutrients and space, by modifying the environmental conditions, by promoting plant growth and by plant defensive mechanism and antibiosis, and directly *Trichoderma* controls phytopathogens by a mechanism such as mycoparasitism [51].

5.1 Fungi in plant nutrition

The saprotrophic and AM fungi provide nutrition to the plants. AM fungi increase the growth and productivity of the plant by increasing nutrient uptake, mycorrhizae form mutualistic symbiotic relationships with plant roots of more than 80% of land plants including many important crops and forest tree species [52–54]. The two dominant types of mycorrhizae are ectomycorrhizae (ECM) and arbuscular mycorrhizae (AM) which can improve water and nutrient uptake and provide protection from pathogens but only a few families of plants can form functional associations with both AM and ECM fungi. However, AM fungi are most commonly found in the rhizosphere roots of a wide range of herbaceous and woody plants [49, 55]. ECM fungi help the growth and development of trees because the roots colonized with ectomycorrhiza can absorb and accumulate nitrogen, phosphorus, potassium, and calcium more rapidly and over a longer period than nonmycorrhizal roots [56]. ECM fungi help to break down the complex minerals and organic substances in the soil and transfer nutrients to the tree [54, 57]. AM fungi are a widespread group and are found from the arctic to the tropics and are present in most agricultural and natural ecosystems with different forms and structures see **Figure 5**.

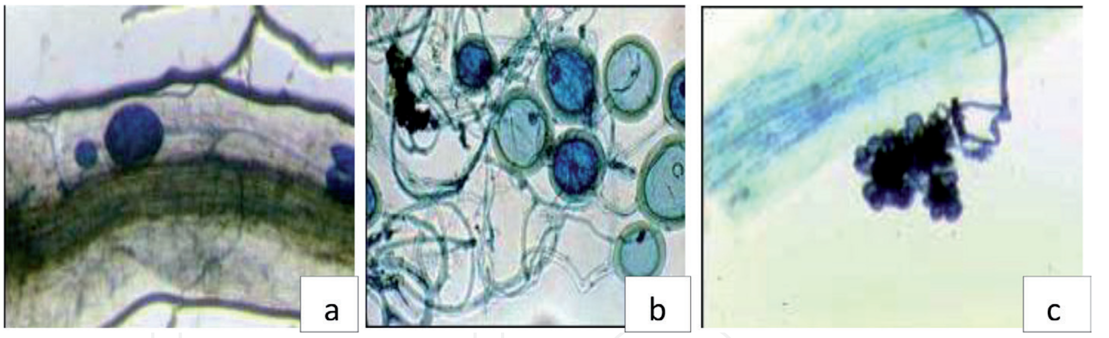

Figure 5.
Endomycorrhizae characterized by structures formed in the root cortex region (a) hyphae, vesicles, and spores in soybean roots (b) external spores (c) cluster of auxiliary cells outside the root.

Cultivars	Spent Substrate		literature
	SMC	SMS	
Amaranthus hybridus	+	—	[60]
Bush Beans, collards, squash, tomato	+	—	[61]
Salvia officinalis	+	—	[62]
Capsicum, Tomato, Cauliflower, Pea, Potato, Ginger, Garlic, Wheat, Paddy, Maize, and Apple.	+	+	[63]
Tomato, Garlic, Onion, Brinjal, Cauliflower, Wheat, Capsicum, maize, Pea, Spinach, Broccoli, Lettuce	+	—	[64]
Beetroot, Cucumber, vineyards, barley, marigold, green gram, sweet potato.	+	+	[65]

Table 3.
Showing application of SMS and SMC in the different horticultural cultivars (source Singh et al. [41]); the positive indicates 'use' and a negative sign indicates 'not known'.

Apart from the fungal biofertilizer and AM fungi, the spent left out after mushroom harvest are a good source of plant nutrition, the spent are commonly known as the Spent mushroom compost (SMC) or spent mushroom substrates (SMS) depending upon process and mushroom species of cultivation, mushroom compost has a major role in the integrated farm system [41, 58, 59]. The application of SMC and SMS have been evaluated on different cultivars which impart significant result in production and yield (**Table 3**).

SMC has organic matters that make them to be used in a large variety of crops including legumes crops such as *Vigna unguiculata* [66], chickpea, pea, soyabeans [63].

5.2 Wood wide web

The evolution of the plant from the water to land some 500 million years ago could not have possible without striking up a relationship with fungi, today almost all plants depend on symbiotic mycorrhizal fungi and some completely depend on the fungal partners and lost the ability of photosynthesis (eg- *Voyria tenella*) and therefore these type of plant obtain their food from neighboring photosynthetic plant through the shared fungal network, shared network of mycorrhizal develops due to the ability of both plant and mycorrhizal fungi to form a relationship with multiple partners [67]. The plants which depend on fungi for its whole life are called as mycoheterotrophs, most of the *orchid* lives as mycoheterotrophs when they are young and later starts photosynthesis as grew older which is known as 'take now, pay later'. A wide range of minerals is transported between plants through a shared network of mycorrhizal fungi. The notion that plants can 'talk' to one another is recently accepted in the mainstream of science, though the plant can not move but they pass their massages through chemical signal(volatile organic compounds) to another plant via a network of connection which is termed as the common mycorrhizal networks (CMN) formed by mycorrhizal fungi and different plants, and this is described as the below-ground internet network which is colloquially called as The Wood Wide Web [68]. The CMN integrate multiple plants and fungal species, that interact, provides feedbacks and adapt, and form complex adaptive social networks, the formation of these networks influenced by various factors, however, CMN provides communication facilities between plants principally by two forms of CMN- arbuscular and ectomycorrhizal, not only CMN provides connectivity among the plants but also provides facilities for the uptake of nutrition and distribution of minerals among the plants. CMN plays a crucial role in soil ecosystem management. It has been established that if a plant is attacked by the plant pathogens it sends the signal to the neighbor plants so that they can prepare themselves to fight against the pathogen by activating various defense mechanisms [68, 69]. Fungal hyphae as a network cable have far-reaching potential in the betterment of plant health systems, but not everything that is transmitted between plants is beneficial to individual plants because toxin (allelopathic chemical) may also be transported via a mycelial network. The whole system is very complex and holistic and research has emerged to understand this at the molecular level.

6. Conclusion

Biodegradation is a natural process executed by microbes. Among the microbes, fungi played vital role in the degradations of complex molecular substances into simpler ones. Here we have attempted to explore how fungi can solve the problem related to human and plant nutrition. Nutrition is a basic requirement of all living organisms. Fungi being heterotrophs act as scavengers utilize waste and bring nutritious food for humans as well as nutrients for the plants. Although many fungi are beneficial for humans and plants but there are notorious fungi which cause disease in human and plants that we have not touched upon.

Conflict of interest

The authors declare no conflict of interest.

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