Original Research Article……….

International Journal of Agricultural Invention

(online available at www.agriinventionjournal.com)

***International Journal of Agricultural Invention* 5(1): 64-71: June, 2020**

ISSN: 2456 – 1797 (P)

Study on the efficacy of untapped resources of Mushroom

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ARTICLE INFO

Original Research Article
Received on Feb 02, 2020
Revised on Feb 19, 2020
Accepted on March 04, 2020
Published on March 13, 2020

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PUBLICATION INFO
International Journal of Agricultural Invention (IJAI)
RNI: UPENG/2016/70091
ISSN: 2456-1797 (P)
Vol.: 5, **Issue:** 1, **Pages:** 64-71
Journal Homepage URL
http://agriinventionjournal.com/
DOI: 10.46492/IJAI/2020.5.1.9

ABSTRACT

Mushroom could be considered as ‘white vegetables’ or ‘boneless vegetarian meat’ owing to their peculiar taste, nutritive value and palatability. They can be defined as “A unique fruiting body that produces either epigeous or hypogenous spores, large enough to be seen with naked eye.” They usually behave as an organisms that are devoid of chlorophyll and vascular system, heterotrophic, saprophytic, absorb O_2 and release CO_2 which depicts that there characteristics are much more closely related to animal cells rather than plants. Mushrooms have various applications in both agricultural as well as in pharmaceutical sector. In agriculture they are used as soil conditioner, biofertilizer and in bioremediation while in pharmaceutical sector they possess antioxidant, anti-tumour, anti-hypertensive, anti-nociceptive and hypo-cholesterolaemic / anti-atherogenic properties, that are good for diabetic patients. Owing to the growing awareness regarding its beneficial properties, there has been a dramatic increase in the interest, popularity, and production of mushrooms farming worldwide. The present review discuss about the multidimensional nature of the global mushroom cultivation industry, its role in addressing critical issues faced by humankind, and its positive contributions they have immense prospective for generating socio-economic impact in human welfare.

KEYWORDS

Mushroom, Cultivation, Lignocellulose Waste, Dietary Supplements, Nutriceuticals, Non-Green Revolution

HOW TO CITE THIS ARTICLE

Chaudhary, P., Fatima, F., Kumar, A., Kumar, A. (2020) Study on the efficacy of untapped resources of Mushroom, *International Journal of Agricultural Invention,* 5(**1**): 64-71. **DOI:** 10.46492/IJAI/2020.5.1.9

Mushroom are not only a good sources for nutritious protein-rich food, they also contribute in the production of effective medicinal products (Chang and Wasser, 2012, Wasser, 2014). Another significant aspect of mushrooms which come into existence is its ability to reduce pollutants within the environment. Bioremediation ability of mushroom mycelia are responsible to remove and break down contaminants and will eventually absorb the pollutants (Dai, 2016, Miller, 2013, Stamets, 2005). There scope and importance leads to open a new pathway for mushroom cultivation. Mushroom cultivation has now become popular all over the world as it doesn’t have any adverse legal, ethical, or safety effects.

This form of bioconversion technology has not only found favourable for socio-economic, nutritional, and health benefits, but also raise employment possibilities (increases job opportunity) and have a positive impact on environment (Mshigeni and Chang, 2013). Usually mushrooms are part of fleshy fungal biota with stalks and caps used for either edible or in medicinal purposes. The mushroom industry in the United Kingdom and other western countries is dominated nearly 100% by *A. bisporus*. This could lead to the mistaken idea that this is the only species regarded as mushroom. Several industries even consider brown mushroom as exotic.

According to mycologists, there are numerous different species of mushroom found. These specialists classify mushroom as a group of macro fungi, which have larger, distinctive fruiting bodies (Chang and Miles, 1992). The vegetative part of the fungus, called the *mycelium*, comprises a system of branching threads and cord-like strands - called *hyphae* that branch out through the soil, compost, wood logs, or other lignocellulosic material, in which the fungus may grow. After a period of growth, and under favourable conditions, the established (matured) mycelium produces the fruit structure, which we used to call mushroom. This is reflected in a great range of morphology, s mushroom possess various morphology such as umbrella-shaped, with a pileus (cap) and a stipe (stem), [*Lentinula edodes*] volva (cup), [*Volvariella volvacea*] annulus (ring), *Agarius campestris*, or have both, as in *Amanita muscaria* pliable cups, golf balls, small clubs, coral yellow or orange jelly-like globs; and some even closely resemble the human ear.

In fact, their shapes and forms are limitless and contain numerous colours. Furthermore, mushrooms are devoid of vascular system [xylem and phloem] and chlorophyll-containing leaves which makes their survival on organic matter synthesized by the surrounding green plants including organic products contained in agricultural crop residues. By secreting several degrading enzymes that helps in decomposing the complex food materials present in the biomass making them to generate into simpler compounds, which was further absorbed and then transformed into fresh new mushroom tissues. Due to lack of true roots, they anchor themselves with tightly interwoven thread-like mycelium which helps in colonization of the substrates and in degradation. The organic substrate on which mushroom grows, can be decomposing material present in natural ecosystems, forest floors containing by-products, wastes from industry, households, and agriculture.

On the basis of human utility, mushroom can be classified into four categories *i.e.* fleshy and edible mushroom, medicinal, poisonous mushrooms, other mushroom. On the basis of ecology, they are categorized into saprophytic and soil-based (living on dead organic matter), mycorrhizal (symbiotic relationship with mushroom mycelia and roots of almost all green plants), lignicolous (living on wood of trees or other substances containing lignin; some are found on living plants and are called parasitic), entomogenous (associated with insects), and coprophilous mushroom (which grow on the dung of different animals). Hawksworth (2012) stated that **o**ut of the 1.5 million estimated fungi species, 160,000 species produce fruiting bodies of sufficient sizes and suitable structures to be considered as macrofungi. Among the recognized mushroom species, about 7,000 species (50%) are considered to possess varying degrees of edibility, and more than 3,000 species from 231 genera are regarded as prime edible mushroom (Wasser, 2002, 2010, Wasser and Weis, 1999).

Usually 200 species of the prime edible mushrooms are experimentally grown, 100 species are economically cultivated, around 60 species are commercially cultivated, and more than 10 species are produced on an industrial scale. Out of the 16,000 mushroom species, approximately 700 species are considered to be safe species having medicinal properties (Wasser, 2010). The number of poisonous mushroom approximates ranges approx 500 species. It has also been stated that some wild unidentified mushroom can be poisonous and lethal.

Significance of Mushroom in Medicinal and Pharmaceutical Sector

Medicinal property of mushroom has established a history of their utility in traditional oriental therapies. Numerous mushrooms have been used in traditional medicine for thousands of years in Asia, Europe and Africa that have valuable health benefits. They contain several biologically active substances (in fruit bodies, cultured mycelium, cultured broth, and spores) including high-molecular-weight polysaccharides (mainly β chitinous substances peptidoglucans, heteroglucan proteogluc, -D-glucans linked to proteins), lectins, RNA components, dietary fiber, and secondary metabolite organic substances, such as lactones, terpenoids, steroids, phenols, alkaloids, antibiotics, and metal chelating agents. A total of more than 130 medicinal functions are thought to be produced by medicinal mushroom including antitumor, immune modulating, antioxidant, radical scavenging, cardiovascular, anti-hypercholesterolemia, antiviral, antibacterial, anti-parasitic, antifungal, detoxification, hepato-protective, anti-diabetic, and many other effects.

The best known medicinal mushroom are: *Ganoderma lucidum*, *Lentinula edodes*, *Grifola frondosa*, *Cordyceps* species (caterpillar mushroom), *Trametesversi color* (turkey tail), *Flammulina velutipes* (winter mushroom), *Agaricus brasiliensis* (royal sun mushroom), *Pleurotus* species (oyster mushroom), *Hericium erinaceus* (lion's mane), *Hypsizygusm armoreus* (beech mushroom), *Tremella mesenterica* (yellow brain mushroom), *T. fuciformis* (silver ear mushroom), *Phellinus linteus* (black hoof mushroom), and *Inonotus obliquus* (chaga). Not only this, they are highly rich in proteins, chitin (dietary fibers), vitamins, and minerals, unsaturated fatty acids, and contain no cholesterols.

As for the characteristics of taste, mushrooms serve as a delicious foodstuff and also as a source of food flavouring substances (because of their unique flavours). In addition to the volatile eight-carbon compounds, the typical mushroom flavour consists of water-soluble taste components such as soluble sugars, polyols, organic acids, and free amino acids.Not only this, they also have low energy level, which is beneficial for weight reduction and diabetic patients, containing very low sodium concentration makes it beneficial for the diet of persons suffering from high blood pressure. All these characteristics make the mushroom as pharmaceuticals ("real medicines") or botanical drugsor dietary supplements, mycochemicals, tonics, functional foods, nutraceuticals, nutriceuticals, phytochemicals, bio chemo - preventives, and designer foods.

Now a day, several types of medicinal mushroom products are available on the market in the form of artificially cultivated fruit body powders, hot water or alcohol extracts, dried and pulverized preparations of the combined substrate, mycelium, and mushroom primordial, naturally grown, dried, mushroom fruit bodies in the form of capsules or tablets, spores and their extracts.

Medicinal mushroom dietary supplements are present in the form of immune modulators known as Biological Response Modifiers (BRM), or adaptogens, or immune ceuticals, which are capable of stimulating immune functions. It has been noticed that regular intake of medicinal mushroom dietary supplements may enhance the immune response, increasing disease resistance and helps in maintaining the correct balance between cellular and humoral immunity.

They are also helpful in preventing on cogenesis, show direct antitumor activity against various synergetic tumours, and prevent tumour metastasis. Their activity is especially beneficial when used in conjunction with chemotherapy. The best implementation of medicinal mushroom dietary supplements have been in preventing and maintaining immune disorder of the immune system diseases, including autoimmune disorders, especially for immuno- deficient and immuno-depressed patients, patients under chemotherapy or radiotherapy, different types of cancers, chronic blood-borne viral infection of Hepatitis B, C, and D, different type of anaemia, the human immune deficiency virus/acquired immune deficiency syndrome (HIV/AIDS), Herpes simplex virus (HSV), chronic fatigue syndrome, Epstein Bar virus, patients with chronic gastritis and gastric ulcers, caused by *Helicobacter pylori*, and patients with dementia (especially Alzheimer's disease).

Significance of Mushroom Cultivation on Environment

Technologies and innovations for human development are expanding every day. However, our world's inhabitants, particularly in some less developed countries, still face, and will continue to face, three basic problems (Chang and Wasser, 2012) *i.e.* (a) inadequate food supplies, (b) diminishing quality of health, and (c) increasing environmental deterioration.

These three key underlying problems will affect the future wellbeing of humankind. The magnitude of these problems is set to increase as the world's population continues to grow. Inevitably, the amount of food and the level of medical care available to each individual will decrease, and global ecosystems will be subjected to intensified abuse.

Reducing Environmental Pollution through Bioconversion of Vast Quantities of Organic Wastes into Mushroom

Organic solid wastes are a kind of biomass, which are generated annually through the activities of the agricultural, forest and food processing industries. They consist mainly of three components: cellulose, hemicellulose, and lignin. The general term of these three main building blocks of plant fibre is known as lignocellulose (Chang, 1989). These are organic compounds composed of long chains of carbon and hydrogen, structurally similar to many organic pollutants. It is common knowledge that lignocellulosic wastes are available in abundance both in rural and urban areas. They have insignificant or less commercial value and certainly no food value, at least in their original form. When carelessly disposed of in the surrounding environment by dumping or burning, these wastes are bound to lead to environmental pollution and, consequently, lead to health hazards (Stamets, 2005).

These wastes can be converted into valuable resources through proper management, with their utilization leading to reduced environmental pollution and further economic growth. Lignocellulosic compounds are complex and insoluble. They can be treated by various chemical methods, for example, with dilute hydrochloric acid and calcium chloride to increase the digestibility and nutritional qualities, and even to form sugars to serve as carbon sources. However, these chemical methods are tedious and costly. Furthermore, treatments to eliminate adverse side effects of the chemicals are also very complex. In contrast, mushroom cultivation techniques have become significantly important in recent years to improve nutritional quality and to upgrade the economic value of the solid organic wastes. Mushroom, with other fungi, are only organisms that can synthesize and excrete the relevant hydrolytic and oxidative enzymes that enable them to degrade complex organic substrates into soluble substances, which can then be absorbed by the mushrooms for their nutrients (Chang and Miles, 2004).

Different species of mushroom have different abilities to utilize the substrates. This depends on the particular enzymes secreted by the individual mushroom. Examining the lingo-cellulolytic enzyme profiles of three important commercially cultivated mushroom exhibit varying abilities to utilize different lingo-cellulolytic as growth substrate (Buswell and Chang, 1994, Buswell, Cai, Chang, Peberdy, Fu, and Yu, 1996)

(a) *Lentinula edodes*, cultivated on highly lignified substrates, such as wood or sawdust, produces two extracellular enzymes (manganese peroxidase and laccase), which have been associated with lignin depolymerisation.

(b) Conversely, *Volvariella volvacea* prefers high-cellulose, low lignin-containing substrates, such as paddy straw and cotton wastes, which have relatively low-lignin content, and it produces a family of cellulolytic enzymes including at least five endoglucanases, five cellobihydralases, and two ß-glucosidases, but none of the recognized lignin-degrading enzymes.

(c) *Pleurotus pulmonarius* var. *stechangii* (an oyster mushroom) is the most adaptable of the three species and can be grown on a wide variety of agricultural waste materials of differing composition in terms of polysaccharide/lignin, because it can excrete both kinds of cellulose- and lignin-degrading enzymes.

Recycling of Organic Wastes into Mushrooms, Biogas, and Bio-Fertilizer

The ultimate aim in the applied aspects of any scientific endeavour is to integrate wherever possible the various disciplines of science as well as the technological processes, to maximize benefits accrued from such efforts. Combined production of mushroom, biogas, and bio-fertilizer from rural and urban organic wastes should be one of the aims of such integrated schemes that can eventually be put into profitable and beneficial operation. Even though people have been harvesting mushroom as food from wild sources from time immemorial, their nutritive value was not assessed, and their production under controlled conditions was, for the most part, not undertaken until recent decades. The lignocellulosic substrate, used for mushroom production after harvesting can be used as compost for soil conditioning or organic fertilizer.

It should be noted that this compost, besides being rich in nitrogenous material, contains partly degraded lignocellulosic components that, when combined with pure animal dung or human excrement in a biogas digester, yields not only biogas but also a good quality organic nitrogenous fertilizer in the form of sludge. The sludge from the biogas plant as a nitrogenous fertilizer is far more beneficial than the compost. Part of the biogas that is produced in the vicinity of the mushroom house can also be conveniently used for pasteurization of the mushroom bed material and maintenance of the optimal temperature in the house as well.

It is therefore suggested that an integrated approach in the production of mushroom, biogas, and bio-fertilizer should be considered as a feasible approach for rural and urban lignocellulosic waste utilization and disposal. Myco-restoration, one of the primary roles of mushrooms in the ecosystem is decomposition, which is performed by the mycelium. Mushroom mycelium can produce a group of complex extracellular enzymes, which can degrade and utilize the lignocellulosic wastes to reduce pollution. In this way, mushroom mycelia can also play a significant role in the restoration of damaged environments.

Stamets (2005) has coined a term, *myco-restoration*, which can be performed in four different ways: myco-filtration (using mycelia to filter toxic waste and microorganisms from water in soil film in the air), myco-forestry (using mycelia to restore forests), mycoremediation (a form of bioremediation using mycelia to decontaminate the area), and myco-pesticides (using mycelia to control insect pests). These methods represent the potential to create a clean ecosystem, where no damage will be left after fungal implementation, even if there are some toxic wastes. Bioremediation is a very important technique that involves the use of mushroom mycelia to remove or neutralize a wide variety of pollutants (Kulshreshtha, Mathur and Bhatnagar, 2013, Purnomo, Mori, Putra, and Kondo, 2013).

Economic and Social Impacts

It has been estimated (Pauli, 1996) that over 70% of agricultural and forest crop biomass produced is conceived as unusable materials and discarded as wastes/by-products that are not edible such as the extracted fibre constitutes only 2% of the sisal plant, and the remaining 98% is thrown away as waste; cane sugar represents a mere 17% of the weight of the biomass of the plant, while the remaining 83% is discarded as bagasse; extracted oil represents only 5% of the total biomass generated by palm coconut plantations, and 95% is waste; and trees are logged throughout the world, mainly to extract the cellulose in timber, which represents only about 30% of the biomass in the case of hardwood and a mere 20% in the case of softwoods. Additionally, billions of tonnes of sawdust, wood chip, coffee pulp, spent ground coffee, brewery spent grain, cotton seed hull, textile cotton waste, and cereal straw around the world are discarded as waste. The main disposal methods of these materials include burning on site, burying, and dumping at unplanned and uncontrolled landfills. Thereby, they may serve to pollute the environment. These lignocellulosic biomass waste materials can be served as potential raw substrates for cultivation of both edible and medicinal mushroom, which are beneficial to human welfare.

The following summarize the significance of mushroom in our drive towards alleviating poverty, enhancing human health, and arresting environmental degradation:

(a) Mushroom can convert lignocellulosic waste materials into a wide diversity of products such as food, dietary supplements, herbal medicines and cosmetics that have multi-beneficial effects to human beings (Chang and Buswell, 2003). In addition, mushroom cultivation can positively generate equitable economic growth.

(b) Mushrooms are relatively fast-growing organisms. Some tropical mushrooms can be harvested and consumed within 10 days after spawning. By the use of appropriate strains, mushrooms can be cultivated all year round. They can be cultivated using traditional farming techniques in rural areas, or by using highly industrialized technologies in urban and peri-urban communities.

(c) Mushroom cultivation can be labour intensive. Thus, the activity can generate new jobs, especially in tropical, less-developed countries.

(d) While land availability is usually a limiting factor for many types of primary production, mushroom cultivation requires relatively little land space. Actually, they can be stacked using shelf-like culture systems.

(e) Mushroom has been accepted as human food from time immemorial and can immediately supply additional protein to human food. Other sophisticated and unconventional sources of food protein, such as yeast, uni-algal cultures, and single-cell proteins, have relatively more complicated requirements and need to be processed before they can be consumed.

(f) Edible mushroom should be treated as healthy vegetables. After improving the cultivation techniques, they should be cultivated as widely and as cheaply as other common vegetables, which will thus be beneficial to the general public.

(g) In view of the pleasant flavour, high protein level, and tonic and medicinal values, mushrooms clearly represent one of the world's greatest untapped resources of nutritious and palatable food for our current generation and for future generations to come.

Major Steps for Mushroom Cultivation

Although the principles of cultivation are commonly similar for all mushroom, the practical approaches can be quite different for different species cultivated. The approaches have to be modified and adjusted according to the local climatic conditions, materials available for substrates, and varieties of the mushroom used. Mushroom cultivation is a complex business requiring precision. The major practical steps/segments of mushroom cultivation, as described by (Chang and Chiu, 1992) and (Chang and Mshigeni, 2013) are as follows:

Selection of an Acceptable Mushroom Species

It is important to determine if the particular species possesses organoleptic qualities acceptable to the indigenous population. The suitable substrates for cultivation should be plentiful, and environmental requirements for growth and fruiting should meet the growing conditions.

A Good-Quality Fruiting Culture

A "fruiting culture" is defined as a culture with the genetic capacity to form fruiting bodies under suitable growth conditions. The stock culture selected should be acceptable in terms of yield, flavour, texture, fruiting time, etc.

Robust Mushroom Spawn

A medium through which the mycelium of a fruiting culture has grown and which serves as the inoculum of "seed" for the substrate in mushroom cultivation, is called the "mushroom spawn." Failure to achieve a satisfactory harvest may often be traced to unsatisfactory spawn used. Consideration must also be given to the nature of the spawn substrate, since this influences rapidity of growth in the spawn medium, as well as the rate of mycelial growth and the filling of the beds following inoculation.

Preparation of Selective Substrate/Compost

Sterile substrate free from all competitive micro-organisms is the ideal medium for cultivating edible mushroom. Systems involving such strict hygiene are generally too costly and impractical to operate on a large scale. Substrates for cultivating edible mushrooms normally require varying degrees of pre-treatment to promote growth of the mushroom mycelia to the practical exclusion of other micro-organisms. The substrate must be rich in essential nutrients, in forms that are readily available to the mushroom and also free from toxic substances that inhibit the growth of the spawn. Moisture content, pH, and good gas exchange between the substrate and the surrounding environment are important physical factors to consider.

Care of Mycelial (Spawn) Running

Following composting, the substrate is placed in beds, where it is generally pasteurized by steam to kill off potential competitive microorganisms. After the compost has cooled, the spawn can either be sown over the bed surface, will be pressed down firmly against the substrate to ensure good contact, or they can be inserted 2 to 2.5 cm deep into the substrate. "*Spawn running*" is the phase during which mycelia grow from the spawn and permeate into the substrate. Good mycelial growth is an essential characteristic for mushroom production.

Fruiting/Mushroom Development

Under suitable environmental conditions, which may differ from those adopted for spawn running, natural germination occurs which is then followed by the production of fruiting bodies. The appearance of mushrooms normally occurs in rhythmic cycles called "flushes."

Harvesting Mushrooms Carefully

Harvesting is carried out at different maturation stages, depending upon the species, and upon consumer preferences and market value.

Conclusion

Presently there are many challenges for global human welfare involving inadequate regional food supplies, diminishing quality of health, and ongoing environmental deterioration. Therefore, utmost need to increase our knowledge and technology required for fair and effective global responses. Today, progress made in the fields of mushroom cultivation could provide tools to help reduce the burden of these issues or at least to aid in finding some reasonable solutions.

Mushroom can be used as food for a healthy state, containing pure refined products which can be used in the diet, serves as medicine for compromised health, and can be used as crude extract products in the form of dietary supplements (nutriceuticals). The multi-dimensional nature of the global mushroom industry, its role in addressing critical food shortages facing human kind, and their production, which has a positive contribution to environmental pollutions opens a new way for mushroom cultivation. Furthermore, mushroom production and distribution can serve as agents for promoting equitable economic growth in society. Mushroom are a unique group of fungi through which we can pilot a non-green revolution (white agricultural revolution) in less-developed countries and in the world at large. They demonstrate great potential for generating great environmental and socio-economic impacts in human welfare on local, national, and global levels.

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