MUSHROOM CULTIVATION AND SELECTED POTENTIAL IMPACTS ON HUMAN LIFE: A REVIEW

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ABSTRACT

Edible/medicinal mushrooms are rich in dietary fibre, protein, carbohydrates and water, together with minerals and vitamins; they have low fat, calorie and a reasonable level of bioactive metabolites (phenolics, sterols and triterpenes). The cultivable species include Auricularia auricula-judae, Lentinula edodes, Agaricus bisporus, Volvariella volvacea, Pleurotus pulmonarius var. stechangii (P. sajor-caju), P. ostreatus, Flammulina velutipes, and Hypsizygus marmoreus. Studies on the bioactive constituents show their human health benefits: anti-hypertensive, anti-diabetic, anti-tumour, antioxidant, antimicrobial, hypocholesterolemic, hypoglycaemic and weight-reducing properties. Ganoderma lucidum mushroom, also called (reishi in Japan) or (lingzhi in China), has been used in traditional medicine for decades and gained attention in pharmaceutics. 'Reishi' represents spiritual potency and essence of immortality, ("herb of spiritual potency," a symbol of success, well-being, divine power, and longevity). The principles, significant potential impacts of mushroom growing and utilization on human and environmental health, have been expounded in this review.

Keywords: Mushroom Growing, Edible/Medicinal, Potential Impacts, and *Ganoderma* L*ucidum*.

INTRODUCTION

Mushrooms are edible or medicinal fungi with various scientific names under the family name, "*Agaricus*". Essentially, all fungi are eukaryotic and achlorophyllous and they exhibit a saprophytic mode of nutrition by absorbing nutrients from dead and decaying organic matter, since they have no xylem or phloem vessels, chloroplasts, leaves, flowers, stems or roots (Chang and Miles, 1992). However, what the seed is to the flowering plants, is what mushroom fruiting body is to the macrofungi, but they are neither plants nor animals (Chang and Haye, 1978). Mushrooms vary greatly in their size, colour, flavour, texture, shape, growth requirements, nutrients and mineral compositions, perishability and other properties (Kumar *et al*., 2013).

Mushrooms are very rich in major food nutrients and are considered an alternative source of high quality protein. They are an excellent source of carbohydrates, dietary fibre, unsaturated fatty acids, vitamins, selenium and other minerals ((Rashidi and Yang, 2016; Kadnikova *et al*., 2015).

Mushroom Farming or White Agricultural Revolution (WAR) (Agrodog) if embraced, can positively address the problems of poverty, disease, nutrition, food insecurity, communal clashes, as well as economic and climate change crises (Oyedepo, 2012).

A supportive diet with edible/medicinal mushrooms such as *Lentinula edodes* (shiitake), *Pleurotus* (oyster) and *Grifola frondosa* (maitake), can prevent human illnesses, including oxidative stress and enhancement of immunity (Wachtel-Galor *et al*., 2011). Their uses include, treatment of cancer patients, other immune system disorders and the reversing of the aging process. *Ganoderma lucidum* has been recognized as a medicinal mushroom of immortality (Wachtel-Galor *et al*., 2011). This current review was aimed at examining the principles of cultivation of edible/medicinal mushrooms and some of the potential impacts on human life.

The need for economic diversification and white agricultural revolution (mushroom farming) in Nigeria

It is, however, appalling to note that Nigeria since independence in 1960, (with a population of 45.2 million then), has grown to be the most populous country in Africa and ranked as the 7th most populous country in the world, with a current population estimate of 200, 705, 014 million as at 17th June, 2019, based on United Nations estimates. The figure accounts for about 2.6 % of the entire earth's population, and this means that about 1 out of every 43 inhabitants in the world, is a Nigerian. Projection by experts for 2050 is about 390 million people, when Nigeria is expected to be ranked as number 3 in the list of countries by population, next only to India and China (World Population Review, 2019). Many societal problems are traceable to uncontrolled population explosion (WHO, 2016).

In the same vein, the discovery of crude oil in the late 1950s in Oloibiri community in Bayelsa State Nigeria, was more or less the last straw that destroyed the Nigerian economic nerve. Before the discovery of crude oil (so-called black gold), Nigeria ran an agrarian economy, with the West boasting of cocoa and timber, the South palm produce, the North groundnut pyramid and East for plantain, yams and other root crops (Akinyetun, 2016). But, all these legacies were thrown to the wind after the discovery of crude oil, and ever since, oil has come to be the live wire of the Nigerian economy. Past and present governments have embarked on agricultural reform programmes, such as the Green Revolution, Operation Feed the Nation, Agricultural Transformation Agenda, etc.

A large varieties of mushrooms have been utilized in traditional medicine in many cultures for treating several health problems. The last decade witnessed a phenomenal increase in research on mushrooms with respect to their pharmaceutical potential, and many mushrooms are like mini-pharmaceutical factories that used for the production of several bioactive compounds having therapeutic potentials (Valverde *et al*., 2015; Alena *et al*., 2014).

The Greeks believed that mushrooms provided strength for warriors in battle, and the Romans took them as the "Food of the Gods." For centuries, the Chinese culture has treasured mushrooms as health food, an "elixir of life." Nowadays, mushrooms are popular valuable foods because they are low in calories, carbohydrates, fat, and sodium. Also, they are cholesterol-free. Besides, mushrooms are rich in important nutrients such as selenium, potassium, riboflavin, niacin, vitamin D, proteins, and fibre (Table 1). Many nutraceutical properties are described in mushrooms, such as prevention or treatment of Parkinson's and Alzheimer's diseases, hypertension, and of stroke. Mushrooms act as antimicrobial, immune –strengthening and cholesterol lowering agents, and they are important sources for biologically active compounds (Valverde *et al*., 2015).

Mushroom cultivation methods can involve a relatively simple farming activity, as with *Volvariella volvacea* and *Pleurotus pulmonarius* var. *stechangii (=P. sajor-caju)*, or a high-technology industry, as with *Agaricus bisporus*, *Flammulina velutipes*, and *Hypsizygus marmoreus*. Mushroom farming (WAR), if properly embraced in Nigeria, could serve as a catalyst to boost agricultural output and industrial revolution.

Even though Nigeria has the climatic requirements for the natural growth of mushrooms, most of our mushroom diversities are found in the wild, because intentional cultivation in Nigeria is still in its early stage of development.

Furthermore, with the growing demand for edible/medicinal mushrooms and for the fact that the initial capital outlay for beginning a commercial mushroom farm is not wearisome, it can become a sustainable source of income for the unemployed persons who are willing to give what it takes.

The Biology of Mushrooms

The term mushroom, is not a taxonomic name (Oyetayo, 2011). Mushroom is a distinctive fruiting body of a macroscopic fungus, which produces spores that can be either underground or above the ground and large enough to be seen with the unaided eye and can be picked by hand (Chang and Miles, 1992; Ukwuru *et al*., 2018).

They belong to the fungal kingdom, in the classes, **Ascomycetes** and/or **Basidiomycetes**. Fungi are eukaryotic, sessile organisms that are distantly related to plants, and more closely related to animals, but rather different from either of these groups (Stephenson, 2010; Chang and Haye, 1978). **Fig**. 1, is the structure of a typical straw mushroom showing the essential parts, such as the stem, annulus, volva and gills.

Health-promoting benefits of mushrooms

The consumption of fruits and vegetables is known to reduce the risks of many lifestyle-associated health conditions. Mushrooms appears to decrease the risk of obesity, diabetes, cardiovascular (heart) diseases and overall mortality, They also promote a healthy skin complexion and hair, energy level, brain function, bone strength and overall low weight (Oyetayo, 2011).

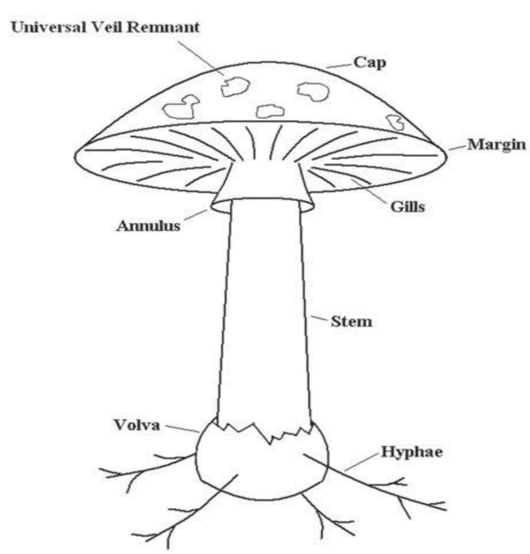

Fig. 1. Typical Mushroom Structure

Table 1. Proximate Composition of Shiitake, Portabella and Agaricus

Food nutrients	Per 19g Shiitake	Per 84g Portabella	*A. bisp.*	*A. bras.*
	g (w/w)	g (w/w)	g (w/w)	g (w/w)
Fat	0.09	0.29	1.8	2.8
CHO	1.29 (0.45 sugar)	3.25 (2.10 sugar)	89.1	75.8
Protein	0.43	1.77	3.0	13.3
Crude fibre	0.5	1.1	-	-
Ash	-	-	6.0	8.2
Energy (calories)	6.0	18	383.8	381

(Chang, 1999)

Key: CHO, carbohydrate; *A. bisp., Agaricus bisporus; A. bras., A. brasiliensis*

Requirements for Mushroom cultivation

Spawn (mushroom 'seed')

Oyster mushrooms can be obtained from the wild, and grown from the mycelia by tissue culture or spore print, and maintained on sorghum or millet grain as seed for cultivation (Chang, 1999).

This cereal grain culture, is called spawn and is used to seed the mushroom substrate. Most spawns are made with mycelia from a stored culture, rather than mycelia whose parent was a spore. This is because spores are likely to yield a new strain, and performance would be unpredictable (Chang and Haye, 1978). Spawn-making is a rather complex task and not feasible for the naive mushroom grower. Spawn of various oyster mushroom species may be purchased from commercial spawn makers who usually provide instructions for its use. Spawn frequently is shipped from the manufacturer to growers in the same aseptic containers used for spawn production. Inoculum for spawn production is frequently produced in polyethylene bags containing a microporous breather strip for gas exchange. Most commercial spawn production companies produce spawn only from inoculum that has met strict quality control standards. These standards include, verification of inoculum production performance before it is used to produce the spawn and insurance of the spawn's biological purity and vigour (Chang, 1999).

Culture conditions and maintenance

Before 1970, the cultivars used for commercial spawn production were maintained on various agar media or cereal grain with periodic sub-culturing. This method was reliable to some extent, but has the problem of periodic culture degeneration. In 1970, researchers successfully preserved and maintained the stability of spawn stocks of *A. bisporus* in liquid nitrogen. Several research reports on culture maintenance verified the suitability of cryogenic preservation, fundamentally changing the way spawn makers handled their cultures for commercial production (Chang, 1999). In practice, cryogenic preservation (Linde *et al*., 2018), is used to ensure the use of superior spawn-starter cultures. Many vials (perhaps as many as 200 to 300) containing spawn or mycelium from cultures of promising spawn lines are stored in liquid nitrogen. Following the successful testing of the spawn lines at both pilot plant and commercial testing facilities, the spawn maker can easily reproduce the superior lines many times during subsequent years (Chang, 1999).

Substrate preparation in bags

In the United States, the primary ingredients used for *Pleurotus* spp. production are chopped wheat straw (*Triticum aestivum* L) or cottonseed hulls (*Gossypium hirsutum* L) or mixtures of both. For production on wheat straw, the material is milled to a length of about 2 to 6 cm. Production of *Pleurotus* spp. on cottonseed hulls, has some advantages over straw-based production systems, in that, chopping of the hulls is not required. One of the most common substrate mixtures used on modern mushroom farms is 75 % cottonseed hulls, 24 % wheat straw, and 1 % ground limestone. This mixture of cottonseed hulls and wheat straw has a higher water holding capacity than cottonseed hulls alone. At Pennsylvania State's Mushroom Research Center (MRC), a large-scale capacity mounted feed mixer is used to simultaneously grind and mix the substrate materials as the moisture content is increased to about 67 – 69 % (Bhatti *et al*., 2007).

Pasteurization

In some commercial mushroom farms, ingredients are fed into revolving mixers. Water is then added to the desired level, and live steam is injected into the mixer, while in operation. In some cases, moistened and mixed substrate is filled into galvanized metal boxes with perforated floors. The substrate is pasteurized with aerated steam (65 ^{o}C; 1 h) by passing the steam-air mixture through the substrate from top to bottom. After pasteurization is completed, filtered air (HEPA filter, 99.9 percent efficiency) is passed through the substrate for cooling (approximately 1.5 hours) (Chang, 1999).

Spawning and spawn rate

Growers have sought, in the past, to optimize the amount of spawn used to inoculate their substrate. Increasing the amount of spawn used (1.5 up to 5 % of the wet weight of the substrate), may result in the yield increases of nearly 50 percent. Yield increases may be due to several factors. First, the increased level of nutrient available, and higher spawn rate, would provide more energy for mycelial growth and development. Second, more inoculum points available from increased spawn levels, would provide faster substrate ramification, thereby shortening the completion time of the production cycle. Finally, a more rapid spawn run, would reduce the time non-colonized substrate is exposed to competitors such as weed moulds and parasitic bacteria (Bhatti *et al*., 2007).

For increasing the levels of spawn used (up to 5 percent), there is a negative correlation between spawn rate and days to production. As the spawn rate increases, the number of days of production decreases. By using a spawn rate of 5 % of the wet substrate weight, it is possible to reduce the time to production by more than 7 days compared to a spawn rate of 1.25 %. Thus, growers could complete the crop cycle fast and minimize the exposure of the production substrate to pest infestations (Chang, 1999; Bhatti, 2007).

Substrate production in bottles

Bottle production of oyster mushrooms is most common in Japan, and it is also increasing in popularity in the United States. Substrate is filled into bottles contained in trays (usually 16 bottles per tray), sterilized and inoculated with *Pleurotus* spp. Upon completion of spawn run, bottle lids are removed and the surface of the substrate is scratched mechanically, while 1 to 2 mm of substrate surface containing the mycelia are removed. Scratching is required to stimulate the mycelia to produce mushroom primordia uniformly on the surface. After the mushrooms are harvested, they are weighed and packaged for shipment to market (Bhatti *et al*., 2007).

Production conditions

After spawning, the bags or bottles may be moved to a spawn run room where air temperature is maintained at 18 ± 2 ° C and the relative humidity is maintained at 95 to 98 % to minimize drying of the substrate surfaces. The first 12 to 21 days of spawn run, may be completed without artificial lighting. Spawn run in bags, usually requires less time (depending on the amount of spawn used) than spawn run in bottles. This is because spawn is thoroughly mixed in substrate contained in bags. For bottle production, the spawn is placed in a hole made in the center of the substrate contained in the bottle. So, mycelium must have enough time to reach the edges of the substrate before pinning is initiated. This difference may only be 3 to 4 days. At the end of the spawn run period, 4 hours of light may be provided daily by cool, white fluorescent bulbs. Light intensity, measured at various locations in the growing room, may range from 50 to 300 lux, and the lighting cycle is often controlled automatically. At the time of pinning, sufficient fresh air is introduced to lower CO_2 levels below 700 ppm (Chang, 1999; Mutema *et al*., 2019).

Postharvest handling

In recent years, the trend for specialty mushroom sales, has been toward the retail market. This trend is driven partly by an increased interest in specialty mushrooms and by the convenience that packaged products offered to the consumer. In some retail markets, only 10 percent of the customers buy 90 percent of the specialty types.

Oyster mushrooms typically, are packaged and sold at retail units of 100 grams (3.5 ounces). Often, oyster mushrooms and other specialty types are used to highlight the common cultivated mushroom that may be sold whole, sliced, or in bulk (Chang, 1999; Mutema *et al*., 2019).

Mycoremediation

The three main categories of bioremediation involving fungi, are biodegradation, biosorption and bioconversion. Each of these methods of bioremediation are important for reclaiming polluted land. In general, the process involves the introduction of a fungal species into contaminated soils followed by management of growth. Results can be seen within weeks or months and/or longer (Kamthan and Tiwari, 2017; Rhodes, 2014).

CONCLUSIONS

The cultivation of edible/medicinal mushrooms is achievable and this has rapidly increased globally in the last few decades. The trend predictably, will explode in the nearest future if the world is to mandatorily address the problems of food insecurity and malnutrition. The quest for alternative medicines, and ameliorating the problems of global economic crisis, environmental deterioration, waste accumulation and global climate change, can be handled, at least, to a reasonable extent, by embracing *Agrodoc*. Mushrooms are an incredible group of creatures with diverse metabolic potentials and enzymatic capability to help mankind achieve all these.

Both wild and cultivated mushrooms are produced on lignocellulosic materials, thereby converting non-edible, non-valuable, low-quality waste streams into high-quality products having food, health, feeds and economic values. Spent mushroom substrate (SMS), is usually considered a waste product, but with added economic value.

Conflicting Interests

The authors declare that there are no conflicting interests, considering the content of this review.

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