MUSHROOM CULTIVATION: A BIOCONVERSION TECHNOLOGY FOR SUSTAINABLE AGRICULTURE IN HAMELMALO AGRICULTURAL COLLEGE, ERITREA

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ABSTRACT

'Mushroom' refers to the fruit body of saprophytic fungi which are rich in protein, minerals and vitamin-B complex. The current generation demands food that is low in calories, carbohydrates and fats and preferably high in vegetable proteins. If such a product also contains amount of vitamins and minerals and has a characteristic taste, it will be able to meet a growing demand, provided it is regularly available. Keeping the food security in mind, developing countries are cultivating mushrooms to meet the hunger of many people. In Eritrea, mushroom production is one of the budding industries to fetch economic revenues as well as providing nutritious food. Establishing this project and chosen the ones that can easily be cultivated in rural areas by using available agricultural wastes and with affordable technology. It is, therefore, the right time to start a 'unit on mushroom cultivation' in the campus of Hamelmalo Agricultural College, Eritrea with the objectives of transfer the technology to the rural farmers of the zoba; to create awareness with regard to the importance of mushrooms as food and to reuse different agricultural wastages as a substrate.

Key words: *Mushrooms; Bioconversion; Bio-efficiency; Mushroom Cultivation; Eritrea.*

I. INTRODUCTION:

The fruit bodies of fungi refer "Mushrooms" which are large enough to be seen with the naked eye. According to Chang and Miles, 2004, there are 2000 species showing various degrees of edibility out of 12,000 species that can be considered as mushrooms. About 35 mushroom species have been cultivated commercially and about 20 are cultivated on an industrial scale. A recent survey indicates that mushroom output of China has reached over 70% of the world total. In china, the production of *Agaricus bisporus* was around 330,000 metric tons in 1997 whereas; in Africa it was only 36,000 metric tons. Three types mushrooms (*Agaricus*, *Oyster* and *Shiitake*) are grown in Kenya and the prices of them are very high compared to that of other vegetables. The mushroom industry is Zimbabwe is dominated by many small-scale producers. In Eritrea, there are no large scale industries but it does cultivate mushrooms and has a great potential as an important producer in the future if it starts with the available and affordable infrastructure. One major advantage for the cultivation of mushrooms is the efficient re-use of agricultural wastes, residues such as cereal straw and chicken manure. A variety of waste materials have been applied for production of mushrooms, such as: paddy straw (Chang, 1965), oil palm pericarp waste (Graham and Yong, 1974), banana leaves and saw dust (Chua and Ho, 1973), cotton waste (Chang, 1974), sugarcane bagasse (Hu et al., 1973 and 1976) etc.

1.1 Present Status as Food and Medicine:

Mushrooms are rich in proteins (ranging from 3-7% in fresh and 25-40% in dry which is almost equal to that of corn, milk and legumes), essential amino acids (Lysine is low in most cereals but are abundant in mushrooms), low fat, low in sodium, high fiber, minerals and vitamin- C and -B complex (Riboflavin, Thiamin and Cyanocobalamin). Studies show that *Termitomite* sp. Mushrooms are good for brain and memory; *Volvariella volvaceae* for healing wounds; *Coprinus* sp. are helping the digest and decrease phlegm; *Agaricus* sp. are helping to increase breast milk; *Trimella fuciformis* good for sperm and semen productin; *Hericium erinacius* are healing wounds in intestine. *Lentinula edodes* for baby's cartilage; *Flammulina velutipes* helps in level healthy; *Agrocybe cylindraceae* keeps kidney and urine in good condition. The present generation demands food that is low in calories, carbohydrates and fats and preferably high in vegetable proteins. If such a product also contains amount of vitamins and minerals and has a characteristic taste, it will be able to meet a growing demand. Mushrooms have the double benefit of low sodium and more potassium and iron than most foods. Chitin is the primary structural material in mushrooms and has been shown to be of value as dietary fiber.

1.2 Importance of Mushroom Cultivation:

Around the world, enormous varieties of wild edible mushrooms are sold in many rural, suburban and international markets commanding according to Boa (2004) a minimum value of US$2 billion. In Nigeria, mushrooms are sold along rural roads during the rainy season (Okhuoya *et al*., 2010; Osemwegie *et al*., 2014). Environmental contamination can also be ameliorated by the application of mushroom mycelial technologies. The use of bioconversion processes to transform the polluting substances into valuable food stuffs. The spent substances can also be reutilized in order to eliminate pollution problems. This mushroom cultivation is used as a tool of healing soil called "*mycorestoration*" means, to repair or restore the weakened or damaged bio-systems of environments. To enact eco-forestry policy – *Mycoforestry*, to denature of toxic wastes –*Mycoremediation* and it will be used as a control management practice of insect pests called *Mycopesticides.* Mushroom cultivation fits in very well with sustainable farming and has several advantages, such as; it uses agricultural waste products; a high production per surface area can be obtained and after picking, the spent substrate is still a good soil conditioner.

Though partially accepted this mushroom production as a subset of agriculture, it is underexplored for economic benefits compared to other sects of agriculture in many African nations (Chelela *et al*., 2014). In spite of huge global market potential mushroom cultivation often neglected in agricultural policies (Sitta and Floriana, 2008; Nchuchuwe and Adejuwon, 2012). In Eritrea, it is one of the budding industries to fetch economic trend as well as providing nutritious food. Hence, the establishment of this pilot-project in Hamelmalo Agricultural College (HAC), that can easily be cultivated in the college campus by using available agricultural wastes and with affordable technology. It is the right time to establish a plant on 'mushroom cultivation' and make the farmers to aware about the importance of mushrooms as a food. It is, therefore, required to create awareness among growers and to meet the requirement of food. Any farmer or producer can afford this technology as a small-scale industry as well as export business to fetch more economy to the nation.

1.3 Growth Conditions for Mushroom Production:

As Peter et al., 2005 mentioned, the surroundings of the cultivating areas was cleaned with 0.5% formaldehyde from possible contamination from insects, moulds etc. The optimum temperature was maintained for the growth of the mycelium of the cultivated mushroom is 23° C to 26° C. The moisture content of compost at spawning was controlled at 65 to 70 percent with foggers, and the Relative humidity was maintained at 95%. Water is taken up in the largest quantity and carbon sources cellulose, hemicelluloses and lignin which are taken up from the substrate of compost. Nitrogen sources like proteins, amino acids and nucleic acids are found in manure.

II. METHODOLOGY

2.1 Study Area:

The Mushroom Cultivation Unit (Fig.1) was established in HAC, Zoba Anseba, Eritrea. Hamelmalo College is located at 15°53' N latitude and 38° 66' E longitude and an elevation of 1292 m above sea level and receives an average rainfall of 450 mm. The recorded a mean temperature is 20°C-35°C (MoA, 2003). As concerning as population, according to World Bank 2001, zoba anseba is having 5,702,000 and ranks fourth after Debub (10,148,000), Gash-Barka (7,548,000), Maekel (7,266,000). Mushroom production could be encouraged to complement the current inadequate agricultural turn out and improve food security in Eritrea.

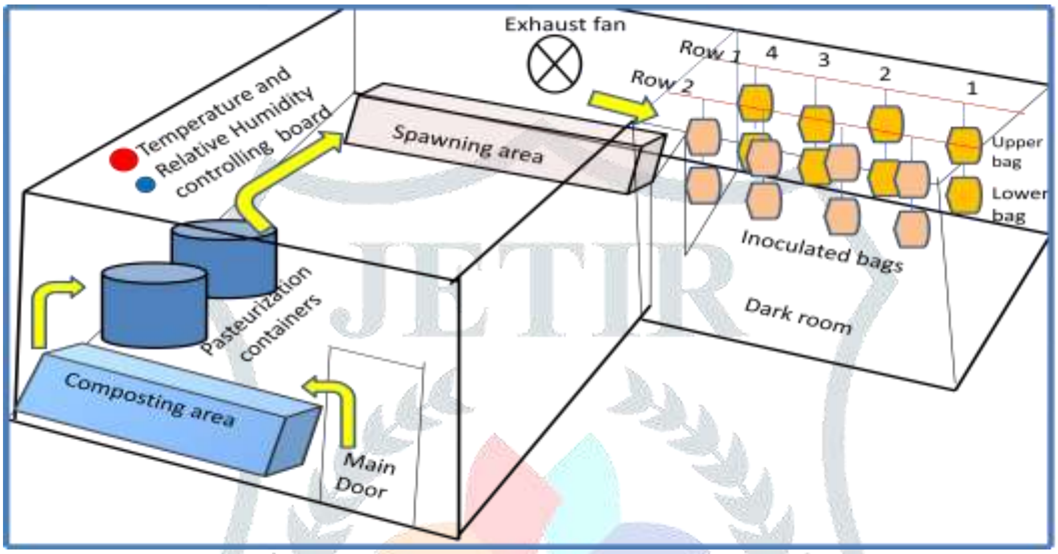


Figure 1. A Schematic Diagram of Mushroom Cultivation Room at Hamelmalo Agricultural College…

2.2 Methodology:

Spawn production, substrate/compost preparation, sterilization/pasteurization, spawning and incubation stages are major in mushroom production chain (Royse and Schisler, 1980; Wuest, 1983; Flegg *et al*., 1985; Oei, 2003; Mowday, 2008; Marshall and Nair, 2009; Roy *et al*., 2015).

2.3 Compost Preparation:

Composting is initiated by mixing and wetting the ingredients like wheat straw, sawdust, rice bran etc., as they are stacked in a rectangular pile with tight sides and a loose center. Nitrogen supplements (Chicken manure) spread over the top of the bulk ingredients and are thoroughly mixed. Once the pile is wetted and formed, aerobic fermentation (composting) commences as a result of the growth and reproduction of microorganisms. Heat, ammonia, and carbon dioxide are released as by-products during this process. These events result in a food source most suited for the growth of the mushroom to the exclusion of other fungi and bacteria. There must be adequate moisture, oxygen, nitrogen, and carbohydrates present throughout the process. Calcium carbonate ($CaCO_3$) is added to minimize the greasiness compost normally tends to have and it increases the flocculation of certain chemicals in the compost, and they adhere to straw or hay rather than filling the pores between the straws. Another benefit of this phenomenon is that air can infuse the pile more readily which is essential to the composting process.

Turning and watering are done at approximately 2-3 day intervals, but not unless the compost pile is hot (145° to 170°F). Turning provides the opportunity to water, aerate, and mix the ingredients, as well as to relocate the straw. Water addition is critical since too much will exclude oxygen by occupying the pore space, and too little can limit the growth of bacteria and fungi. As a general rule, water is added up to the point of leaching when the pile is formed. On the last turning water can be applied generously so that when the compost is tightly squeezed, water drips from it. There is a link between water, nutritive value, microbial activity, and temperature, and because it is a chain, when one condition is limiting for one factor, the whole chain will cease to function. Supplements are also added when the compost is turned, but they should be added early in the composting process.

By this the composting lasts from 6 to 14 days, depending on the nature of the material at the start and its characteristics at each turn. There is a strong ammonia odor associated with composting, which is usually complemented by a sweet, moldy smell. When compost temperatures are 155°F and higher, and ammonia is present, chemical changes occur which result in a food rather exclusively used by the mushrooms. As a by-product of the chemical changes, heat is released and the compost temperatures increase. Temperatures in the compost can reach 170° to 180°F during the second and third turnings when a desirable level of biological and chemical activity is occurring. At final, the compost should have a chocolate brown color, have soft, pliable straws, have moisture content of from 68 to 74 percent and have a strong smell of ammonia. When the moisture, temperature, color, and odor described have been reached the process of composting is completed (Fig. 2).

A B C

D E F

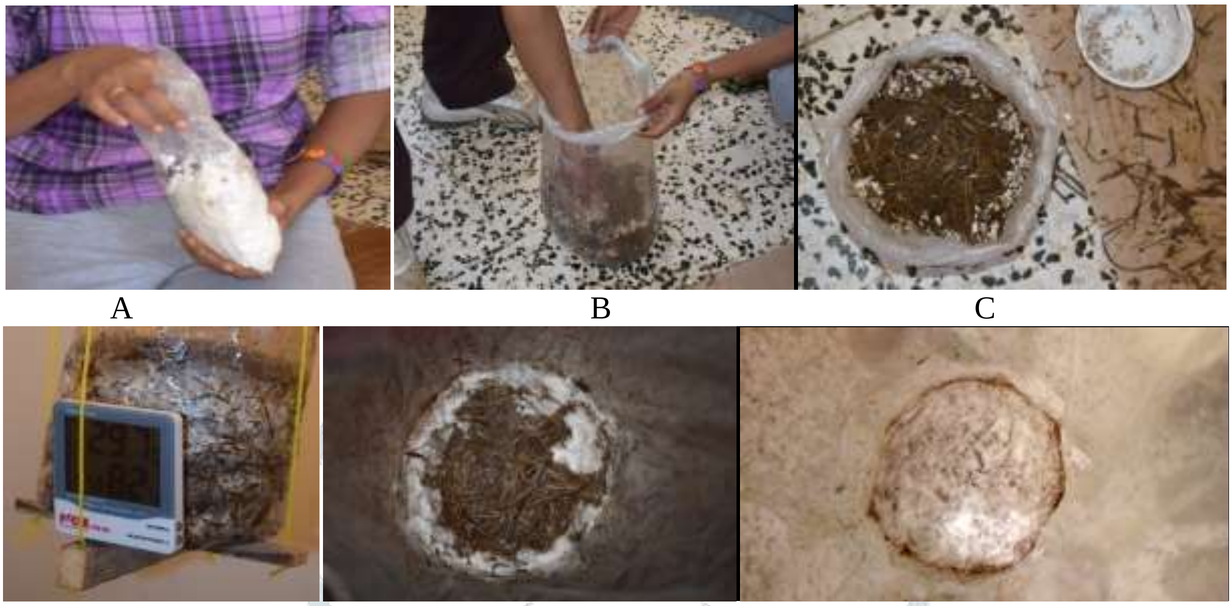
Figure 2. Substrates were stacked in a rectangular pile (A); Wetting with water (B); Mixing thoroughly (C); Adding calcium carbonate ($CaCO_3$) to minimize the greasiness (D); Kept in dark room for fermentation process (E); and Composted substrate after a week (F)

2.4 Pasteurization:

The compost is spread in metal drums which was prefixed the electric heater inside for sterilization the substrate. The substrate is made even by pressing lightly in the drums. A temperature of 55-60°C (131-140°F) is maintained but not more than 60°C (140°F) for 30 minutes to 1 hour. At the end of this pasteurization process the substrate was spawned.

2.5 Spawn Production and Spawning:

During the maturity, mushroom cap produces millions of spores (similar to the seeds of higher plants) on their gills which are lining the underside of the cap. The fungal mycelium can be propagated vegetatively on sterilized sorghum or paddy grains for spawn production. The grain is a substrate for the mycelium colonization with two weeks period. Once the spawn and supplement have been mixed throughout the compost, the compost temperature is maintained at 75-80°F and the relative humidity is kept high to minimize drying of the compost surface or the spawn. Under these conditions the spawn will grow - producing a thread-like network of mycelium and grows in all directions from a spawn grain, and eventually the mycelium from the different spawn grains fuses together, making a spawned bed of compost one biological entity. The spawn appears as a white to blue-white mass throughout the compost after fusion has occurred. As the spawn grows it generates heat, and if the compost temperature increases to above 80° to 85°F (Fig. 3).



A B C

D E F

Figure 3. Spawn (fungal mycelium grown on grains) (A); inoculation of spawn in a composted bag (B); three to four layers of spanning in the substrate (C); Maintaining the temperature and relative humidity (D); Growing hyphae on the surface of compost (E) and Fully grown mycelium on the compost after 2 weeks (F)

2.6 Casing:

For the equal formation of mushrooms ‘casing’ is applied as a top-dressing to the spawn-run on compost. The used material for casing is farm yard manure + loamy soil in 1:1 ratio. The most important functions of the casing layer are supplying water to the mycelium for growth and development and protecting the compost from drying.

2.7 Pinning:

After 18 days to 3 weeks, the fungal mycelium outgrowths on the casing the structures are called ‘pins’ which expanded and grown larger as buttons later formed as mushrooms. The harvesting mushrooms were completely grown up after 28 and keep on producing mushrooms until 42 days (Fig. 4).

A **B** **C** **D**

Figure 4. Pin heads on the casing surface (A); Premordia coming out of the bag (B); After 3 weeks the mushrooms are developed (C) and Completely opened caps after 28 days (D)

III. RESULTS

3.1 Harvesting:

After 4 weeks the premordia started coming up on both the surface and sides of the compost. Within 3 days the mushrooms were grown in proper size for harvesting. The stem of mushrooms were twisted and removed from the bag gently without damaging the substrate to avoid further contamination. The harvested mushroom were categorized in three parts i.e. larger (7.83cm to 10.20cm), medium (5.25cm to 7.43cm) and smaller (5.20cm to 2.29cm)) based on their cap size (Fig.5).

A **B** **C**

Figure 5. Harvesting mushrooms (A); categorized in different sizes (B) and Measuring (C)

3.2 Cost benefit ratio:

For one kilogram of substrate the first harvest gave 465 grams of mushrooms, second yield was 215 grams and the third 165 grams in the third flush. The bio-efficiency was calculated based on the following formula.

$$\text{Bio-efficiency} = \frac{\text{Weight of harvest}}{\text{Weight of dry substrate}} \times 100$$

The calculation used the weight of all mushrooms harvested from the substrate over multiple (three) flushes. In this project the bio-efficiency was 84.5%. The result is not up to the expected yields (>110%), it may be due to no other nutrients were added during the composting.

3.3 Mushroom Pathology:

After two weeks of period of time, it was observed that, a little bacterial growth and *Coprinus* spp. were noticed on the substrate. The moisture content (70-95%) is also one of the reasons for bacterial growth inside the mushrooms. A strong competitor *Coprinus* sp. fungi completes it life cycle with the straw mushroom, because *Coprinus* sp. are having the same growth requirements. Infestations by insect pests were the common pests found during the cultivation were mites, grubs, nematodes and earthworms. It was controlled by application of 0.5% formaldehyde.

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