INTRODUCTION

Edible mushrooms, or wild edible fungi, have been collected and consumed by people for thousands of years. It has been estimated that over 70,000 species of fungi are found and of which about 2000 species (31 genera) are regarded as prime edible mushrooms (Moore, 2005). The archaeological record revealed edible species associated with people living 13000 years ago in Chile (Rojas and Mansur, 1995). Edible fungi were collected from forests in ancient Greek and Roman times and highly valued, though more by high-ranking people than by peasants (Buller, 1914). Some mushrooms contain compounds, which can make a contribution to the general health of man (Elliot, 1997).

Wild mushrooms are seasonal, and a particular mushroom may disappear from the initial place of collection for a number of years, appearing in another place beyond reach (Harding, 1996; Laessoe, 1998). Russula sp. (gilled mushroom) and Pycnoporus cinnabarinus (polypore) are wild mushrooms. Their fruit bodies were screened and found to possess antibacterial properties in previous work (Fajana et al., 1999). As mushrooms are widely distributed all over the world, some of them have been used in traditional medicine as anti-inflammatory, analgesics, hemostatic, diuretic, nourishment, antibehic and antitumour agents (Koyama et al., 1997). Most of the medicinal extracts from mushrooms are different forms of polysaccharides and all of them are strengtheners of the immune system with little or no side effects (Oei, 1991, 1996; Gao et al., 1997). For example, a sizofiran, antitumour polysaccharide extracted from the culture broth of Schizophyllum commune is an effective immunotherapeutic agent for cervical carcinoma because it stimulates a rapid recovery of the immunological status.
impairied by radiotherapy (Miyazaki et al., 1995).

Most of the cultivated mushrooms are saprophytic; they feed on organic matter which has already been manufactured by plants or animals. In nature they grow on fallen leaves, animal droppings and stumps of dead wood (Bilgrami and Verma, 1978). The cultivation of edible mushrooms offers one of the most feasible and economic method for the bioconversion of agro-lignocellulosic wastes (Bano et al., 1993; Cohen et al., 2002). The technology can also limit air pollution associated with burning agricultural wastes as well as to decrease environmental pollution due to unutilized agricultural wastes. Mushroom production can convert the huge lingo-cellulosic waste materials into a wide diversity of products (edible or medicinal food, feed and fertilizers), protecting and regenerating the environment. In addition, the mushroom production can generate equitable economic growth that has already had an impact at national and regional levels. This impact is expected to continue increasing and expanding in the future, because more than 70 % of agricultural and forest materials are non-productive and have been wasted in the processing. The mushroom conversion has been named the «non-green revolution» (Chang, 1999; Chang, 2005). The mushroom cultivation is a highly efficient method of disposing of agricultural residues as well as producing nutritious food (Chang et al., 1998).

Edible mushrooms like Pleurotus are known to be among the largest of fungi (Onuoha, 2007). Pleurotus ostreatus (Oyster fungus) (P. ostreatus) is an edible mushroom having excellent favour and taste (Shah et al., 2004). Pleurotus spp., commonly known as oyster fungus, is a common primary decomposer of wood and vegetal residues (Zadrzazli and Kurtzman, 1982). It can be naturally found in tropical and subtropical rainforests, and can be artificially cultivated (Maziero et al., 1992). Appreciated because of its delicious taste, this fungus has high quantities of proteins, carbohydrates, minerals (calcium, phosphorus, iron) and vitamins (thiamin, riboflavin and niacin) as well as low fat (Sturion and Oetterer, 1995; Justo et al., 1998; Manzi et al., 1999). Edible mushrooms and their constitutive active compounds have been described to have beneficial effects on hyperglycemia and hypercholesterolemia (Cheung, 1996; Lo et al., 2005).

Mushrooms with their flavor, texture, nutritional value and high productivity per unit area have been identified as an excellent food source to alleviate malnutrition in developing countries (Eswaran and Ramabadran, 2000). P. ostreatus are rich source of proteins, minerals and vitamins (Caglarirmak, 2007). Apart from food value, its medicinal value for diabetics and in cancer therapy has been emphasized (Sivrikaya et al., 2002). Pleurotus species contain high potassium to sodium ratio, which makes mushrooms an ideal food for patients suffering from hypertension and heart diseases. The practice of mushroom cultivation not only produces medicinal and nutritious food but also improves the straw quality. This takes place by reducing lignin, cellulose, hemicelluloses, tannin and crude fiber content of straw making it ideal for animal feed (Ortega et al., 1992).

Mushrooms cultivation requires carbon, nitrogen and inorganic compounds as their nutritional sources and the main nutrients are carbon sources such as cellulose, hemicellulose and lignin. Oyster mushrooms require less nitrogen and more carbon source. Thus, most organic matters containing cellulose, hemicellulose and lignin can be used as mushroom substrate i.e. rice and wheat straw, cottonseed hulls, corn cob, sugarcane bagasse, sawdust, waste paper, leaves, and so on. Mushrooms are reported to be easily grown on different lignocelluloses wastes such as banana leaves, cereal straw, paper wastes, sawdust and poultry droppings (Fasidi and Kadiri, 1993; Onuoha, 2007; Shah et al., 2004).

The oyster mushroom is grown under natural conditions on living trees as parasite or dead branches of trees as saprophyte and primary decomposer. The chemical composition of the fresh fruiting bodies of oyster mushroom, *Pleurotus ostreatus* indicates a large quantity of moisture (90.8%), whereas fresh as well as dry oyster mushrooms are rich in proteins (30.4%), fat (2.2%), carbohydrates (57.6%), fiber (8.7%) and ash (9.8%) with 345 K (cal) energy value on 100 g dry weight basis; while vitamins such as thiamin (4.8 mg), riboflavin (4.7 mg) and niacin (108.7 mg), minerals like calcium (98 mg), phosphorus (476 mg), ferrous (8.5 mg) and sodium (61 mg) on 100 g dry weight basis, are also found present (Pandey and Ghosh, 1996). Rambelli and Menini (1985) reported that this mushroom is reputed to be antitumoural because of its chemical composition. Oyster mushrooms are known to bear therapeutic ingredients such as dietary fibres (chitins and chitosans) and phenolic compounds (Kurtzman, 2005; Gregori et al., 2007; Moharram et al., 2008; Neyrinck et al., 2009). Various bioactive compounds isolated from *P. ostreatus* culture extracts of Ethiopian higher fungi showed other biological properties such as antiprotzoal, anthelmintic, phytotoxic and brine shrimp lethality activities (Dagne and Abate, 1995). Also Inchausti et al. (1997) investigated Leishmanicidal and Trypanocidal activity of the extracts and secondary metabolites of some Basidiomycetes.

Teff (*Eragrostis Tef*) is an intriguing grain, ancient, minute in size, and packed with nutrition. Teff is believed to have originated in Ethiopia between 4000 and 1000 before Christ (BC). The word teff is thought to have been derived from the Amharic word teffa which means "lost," due to small size of the grain and how easily it is lost if dropped. Nowadays, teff represents the re-discovery of a crop used by ancient civilizations (Stallknecht et al., 1993). Most of the Ethiopian farmers use traditional landraces of teff and these are distributed...
all over the country (Seyfu, 1997). Recently, a lot of scientists of developing countries, trying to offer new products for consumers, and trying to satisfy their nutritional needs, they were wondered about the lack of anemia, osteoporosis, celiac disease and diabetes in the Ethiopia population. It is also well known, in a worldwide nutritional needs, they were wondered about the lack of products for consumers, and trying to satisfy the scientists of developing countries, trying to offer new all over the country (Seyfu, 1997). Recently, a lot of grain is threshed is used as fodder. Farmers highly value and not as forage crop. However, the straw after the grain is threshed is used as fodder. Farmers highly value the straw of teff and it is stored and used as a very important source of animal feed, especially during the dry season. Teff straw is called Ch'ed. Farmers feed teff straw preferentially to milking cows and working oxen (Refera, 2001). Agricultural and industrial by-products that are relatively cheaper are best sources for supplementation of animals on fibrous basal feeds (Fitwi and Tadesse, 2013).

Composting is a fertilizing mixture of partially decomposed organic matter from plant and animal origin (Piet et al., 1990). Composting is a solid-waste fermentation process, which exploits the phenomenon of microbial degradation and mineralization (Mckinley and Vestal, 1984). The main purpose of composting to a mushroom grower is to prepare a substrate in which the growth of mushroom is promoted to the practical exclusion of other microorganisms. Fermor et al. (1985) reported that a composted substrate improved mushroom fruit body yield but, reduced infestation by insects, fungi and bacteria pathogens. Microorganisms colonizing mushroom compost during composting process are regarded as active agents, which determine the chemical composition and mineralization thereby making it possible for mushroom growth (Fermor et al., 1985).

Cultivation of oyster mushroom (Pleurotus ostreatus) has increased tremendously throughout the world because of their abilities to grow at a wide range of temperature and utilizing various agro-based residues. Pleurotus species are efficient lignin degraders, which can grow on different agricultural wastes with broad adaptability to varied agro-climatic conditions (Jandiak and Goyal, 1995). Growing oyster mushrooms convert a high percentage of the lingo-cellulosic substrate to fruiting bodies increasing profitability. Of them, Pleurotus ostreatus demands few environmental controls, and their fruiting bodies are not often attacked by diseases and pests, and they can be cultivated in a simple and economic way (Kues and Liu, 2000). It requires a short growth time in comparison to other edible mushrooms. All this makes P. ostreatus cultivation an excellent alternative for production of mushrooms when compared to other mushrooms (Kausar, 1998). P. ostreatus grown on different substrates are nutritious with high protein, fiber, and low fat. Oyster mushroom can be grown on various substrates including paddy straw, maize stalks/cobs, vegetable and plant residues. Pleurotus ostreatus has a short production cycle requires little space and few infrastructures for its cultivation, it also has a good selling price, and in this part of the country there is a strong culture of mushroom consumption all of which makes it a good option to improve the living conditions of Ethiopia’s people.

The mushroom consumption habit and cultivation practice of people in Ethiopia has not been well documented so far though it is believed that many part of the country is suitable for mushroom cultivation. Mushroom cultivation is a useful method of environmental waste management and waste disposal. Many agricultural and industrial by-products can find uses in mushroom production. Teff straw has high cellulose, hemi-cellulose and lignin contents, and their low protein content and digestibility. Therefore, the present study was focused to evaluate the growth and yield of Pleurotus ostreatus on Teff straw at Dilla University, Ethiopia.

MATERIALS AND METHODS

Pure culture collection and maintain

Pleurotus ostreatus was obtained from Mycology Laboratory, Department of Biology from Addis Ababa University. The pure culture of Pleurotus ostreatus was inoculated onto Malt extract agar. The pure culture was maintained on Malt extract agar slants at -4°C for one month, then sub-culturing subsequently after one month transferred (inoculated) onto fresh slant of Malt extract agar.

Substrate Collection

Teff straw used as substrate for composting was collected around Dilla town from 2013 October -2014 April (figure 1). Other nutrient supplement such as wheat bran and pH adjustment of Wood ash was obtained from the Dilla town. Beside this Cow dung and Chicken manure was obtained from Allege Research centre.

Compost preparation

The compost was prepared by outdoor single-phase solid-waste fermentation (Nair and Price, 1991). In order to prepare, aerobic composted substrate, about 80% of Teff straw was chopped manually into small pieces through using hammer mill as indicated figure 2. After chopping, mixing the chopped Teff straw with Wood ash, Wheat bran, Cow dung and Chicken manure, then the water was added until moisture content was between 40-60%. This is usually being determined by the 'rule of
![Figure 1. Teff straw](image1.jpg)

![Figure 2. A, chopping of Teff straw into small pieces; B, Composting area](image2.jpg)

thumb’ method (Buswell, 1984). Then supplement with 20% of three different supplements on 80 % of Teff straw as follows:-

Substrate A. 10% Chicken manure, 8% Wheat bran and 2% wood ash
Substrate B. 10% Cow dung, 8% Wheat bran and 2% wood ash
Substrate B. 18% Wheat bran and 2% wood ash
Substrate C. 18% Cow dung and 2% wood ash
Substrate D. 18% Chicken manure and 2% wood ash

on dry weight basis with some Modification of (Dawi t, 1998). The substrates were then added into hole of about 1.5 m wide, 1.5 m high and 1.5 m long which was under shadow area at Dilla University. This was covered with banana leaves and left for 2 weeks with turning and restacking every 3-4 days to produce homogenous compost.

**Spawn production**

Spawn is the vigorous mycelia growth of a single fungus on a chosen substrate material (liquid media, grains, saw dust substrate, wooden sticks (Jiskani, 2000). Sorghum was used for mother spawn. About 20 kg of sorghum was washed and dead floating removed then soaked overnight in 15L water and rinsed three times in distilled water. The excess water was drained off and 20% wheat bran, 12% gypsum (CaSO₄. 2H₂O), and 3% limes (CaCO₃) were added as shown in figure 3. The ingredients were thoroughly mixed; moisture was maintained at the level of 55 %, and distributed equally in to 500 ml glass bottle at the rate 370.66 g seed per bottles and autoclaved for 121°C to 1 hour. After cooling, each bottle was inoculated with 7 days old culture which grown on Malt extract agar and incubated
for 25 days at 25°C until the substrate fully colonized; at ten days interval mycelia invasion and contamination were recorded.

Sterilization of substrates and cultivation of mushrooms

After two weeks of composting, these substrates were distributed equally into plastic bags of 40x60 cm size at the rate of 3.5 kg substrate in triplicates and sterilized for three hours in barrel by fire. After cooling; they were inoculated with the spawn (one glass bottle per bag) and mixed thoroughly to facilitate rapid and uniform mycelia growth. The mouth of the bags was tied using a cotton plug and thread and holes were made over the polythene bags for aeration. Then, they were incubated in the dark at 27°C and mycelia development in the bag was observed and noted within 5 days.

Cultivation conditions

The bags were subsequently placed, long side down, into a spawn running room at 20 - 23°C in the dark and 65 - 70% relative humidity until completion of spawn running. After completion of spawn running the temperature and relative humidity was changed to 19 to 20°C and 80 - 90% RH, respectively. The bags were slit and the cut portions folded back. Water was sprayed for maintaining moisture up to the desired level in the form of fine mist from a nozzle.

Watering

Each cultivating bags were irrigated using tap water every morning and evening until 2 flushes of *Pleurotus ostreatus* fruiting bodies appears.
Harvesting of mushroom

The first primordia appear 2-4 days after scratching depending upon types of substrate, which were recorded. The harvesting date also varied depending upon types of substrate. Matured mushroom identified by curl margin of the cap was harvested by twisting to uproot from the base. Mushroom matured generally 48 hours after appearing the primordia. Data were recorded periodically during culture.

Statistical analysis

The data from the study were statistically analyzed. The data of actively mycelium growth during spawn making and formation of full morphology of Oyster mushroom and fruiting body were observed during cultivation on substrate. The data were expressed qualitatively in the form of figure.

RESULT AND DISCUSSION

Oyster mushroom (Pleurotus ostreatus) was cultured on malt extract agar for 7 days at 28°C and mycelium covered the plate. It was fully grow on plates as shown in figure 4. Healthy nutrition and diet are gaining importance, not only in the everyday life of human beings, but also in the treatment of chronic diseases. Medical practitioners of worldwide are recognizing that mushrooms are medicinal foods rich in nutrition (Stamets, 2005). Fauzia showed that mushrooms have higher nutritional values than fish or beef (Fauzia et al., 2003). Matila also suggested that a diet rich in mushrooms provides all the essential amino acids usually available in fruits and vegetables (Matila et al., 2002).

Spawn production

Sorghum is important crop for spawn production of oyster mushroom. Sorghum based spawn took 25 days to colonize the substrate completely as shown in figure 5. The moisture content of the sterile moist sorghum (55-60%) was found to be suitable for growth of mycelium of oyster mushroom.

Substrate sterilization and spawn inoculation

The substrate was sterilized by soaking into the boiled water for three hours in barrel. Mycelium running rate on the substrates was observed after 7 days inoculation of spawn (figure 6). Therefore, mycelium running was required high humidity and cultivation room should be dark. Pleurotus ostreatus commonly known as the oyster mushroom is one of the more commonly sought wild mushrooms, though it can also be cultivated on straw and other media. It has a high content of protein, fiber, carbohydrates, mineral such as iron, calcium, and phosphorus, vitamins (riboflavin, thiamine, ascorbic acid, and niacin), linoleic acid, and low concentrations of fat (Del Toro et al., 2006).

Primordial formation of oyster mushroom

The primordial formation and number of primordia per plastic bag (substrate) was affected by humidity, temperature and the substrate itself. The first primordia appear after 20 days after inoculation of spawn.
Figure 5. Spawn preparation on sorghum: A, inoculation of old culture (7 days) oyster mushroom on the sorghum; B, fully colonized sorghum by oyster mushroom mycelium after 25 days

Figure 6. Sterilization and inoculation spawn: A, sterilization of substrate; B, inoculation of oyster mushroom spawn on sterilized Teff straw substrate; C, mycelium colonization of the Teff straw

depending upon types of substrate. Beside of this the supplement such as wheat bran and manure also factor for either high or low number of primordial formation as indicated figure 7. Mushrooms cultivation also enables farmers to utilize organic substrates that would otherwise be regarded as waste products (wood, 1985;
Labuschagne et al., 2000). Edible mushrooms rank above all vegetables and legumes (except soybeans) in protein content and have significant levels of Vitamin B and C and are low in fat (stamets, 1993).

**Fruiting body production**

The effect of supplemented ingredients on Teff straw were investigated and found to influence the number of fruit body and size of fruit body. Fruiting body is the edible part of mushroom *Pleurotus ostreatus*. The fruiting body on the substrates that contains wheat bran and manure, the number and size of fruit body was high and larger when it was compare with alone substrate (Teff straw only). The harvesting date of mature fruit body was varied depending upon types of substrate. The mature fruit body became curl margin of the cap of oyster mushroom as shown in figure 8. Edible mushrooms are recommended by the FAO as food, contributing to the protein nutrition of developing countries dependent largely on cereals with it became a new and alternative demand for poultry and animal protein in fresh mushrooms. In general mushrooms are highly nutritious, their taste and delightful aroma makes them one of the delicious preferred foods in restaurants throughout the world (Chang and Mshignei, 2000). The high nutritional value of mushrooms is due to the presence of 8 essential amino-acids, polyunsaturated fatty acids (linoleic and arachidonic acids) and reduced quantities of saturated fatty acids (Fortes et al., 2006).
CONCLUSION

Mushroom cultivation needs knowledge as well as experience for growing fungi on agricultural solid waste materials that are not directly consumed by human beings. Oyster mushrooms can be converted this waste into protein, amino acid and vitamin rich food. Commercial production of oyster mushrooms is largely determined by the availability and utilization of cheap solid waste products, which are agricultural and industrial waste that are the most promising substrates for cultivation. Therefore, this study was also the baseline
information to cultivate mushrooms other edible mushrooms on this substrate as well as on the other substrate, as the result solve the food supply scarcity and quality and also remove solid pollutant from the environment.

ACKNOWLEDGEMENTS

The authors greatly acknowledge the Departments of Biology, College of Natural, and Computational Sciences of Dilla University for the kind assistance in providing the laboratory facilities and all the required consumables and equipment during the whole period of this research work.

REFERENCES


