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Selection of appropriate substrate for production of oyster mushroom (*Pleurotus ostreatus*)

Yohannes Besufekad*, Abraham Mekonnen, Bikila Girma, Robel Daniel, Getahun Tassema, Jale Melkamu, Malesu Asefa, Tsehaynesh Fikiru and Lalise Denboba

College of Natural and Computational Science, Department of Biotechnology, Wolkite University, Ethiopia.

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Mushroom production is an economically viable biotechnology process for conversion of various agro-industrial wastes into food. Mushroom, a fruiting body of macrofungi has been valued throughout the world as either food or medicine for more than three thousand years ago. The mushroom grows on a vast number of substrate and environment. Substrate compromises different agro-industrial residues that possess varied property for supporting the growth of mushroom. Though, the most appropriate composition of the substrate should be selected to obtain a better result. Hence, the study was conducted to select appropriate substrate for production of oyster mushroom and to identify the suitable combination from a selected substrate to get a high yield of oyster mushroom. The effects of different selected agro industrial residues on growth and bioconversion efficiency of oyster mushroom was determined. For this study, Oyster mushroom (*Pleurotus ostreatus*) were grown on different substrates namely cotton seed, enset waste, sawdust, and teff straw with different composition. The spawn was produced using three grains to know the performance of oyster mushroom. The main step used for oyster mushroom production includes preparation of culture media, spawn production, preparation of the substrate, fruiting, and harvesting. The highest bioconversion efficiency and yield were obtained from the combination of sawdust and teff straw. While the lowest yield and bioconversion efficacy was obtained from combination teff straw and enset waste.

Key words: Mushroom, oyster, spawn, substrate, waste.

INTRODUCTION

Mushroom production could be a possible option to alleviate poverty and improve the lifestyle of vulnerable people (Imtiaj and Rahman, 2008). The production is important for food shortage (Beetz and Kustudia, 2004; Tibuhwa, 2013), especially for low-income countries like Ethiopia. Food insecurity remains one of the world's biggest challenges; particularly, the problem is very severe in low and middle-income countries. Therefore, finding ways of improving food production in increasing population is paramount important. More than 2,000 species composed of 31 genera are identified to be edible over the world (Moore, 2005). Twelve species are commonly grown for food and/or medicinal purposes, across tropical and temperate zones. *P.* spp, commonly

*Corresponding author. E-mail: yohanbesufekad@gmail.com.

known as oyster mushrooms, are edible fungi cultivated worldwide especially in South East Asia, India, Europe and Africa. China produces 64% edible mushrooms in the world and 85% of all oyster mushrooms all over the world (*P.* spp.) is also produced in China (Chang, 1999). The three most commonly cultivated mushrooms are *Agaricus bisporus* (button mushroom), *P. ostreatus* (oyster mushroom) and *Lentinula edodes* (shiitake mushroom). Oyster mushrooms are the second largest commercially produced mushroom in the world (Sánchez, 2010; Mohamed et al., 2011) next to *A. bisporus*. Shorter growth time is required to oyster mushrooms in comparison to other edible mushrooms. It converts a high percentage of the substrates to fruiting bodies and hence increases profitability and low-cost cultivation technology (Baysal et al., 2003).

Mushrooms are highly valued for their rich characteristic flavor, potent nutritional properties and possess various types of dietary supplements. Mushrooms are low in calorific value but rank very high for their vitamins, minerals and protein contents (Beetz and Greer, 1999). The consumption of oyster mushrooms has an advantage of preventing as well as reducing diseases such as diabetes, heart disease, high blood cholesterol level, gastric cancer, hepatitis B, liver illness, kidney problems, hypertension, microbial infection, chronic fatigue syndrome and impaired immune response (Ooi, 2000).

Oyster mushrooms are known to contain therapeutic ingredients such as dietary fibers and phenolic compounds various bioactive compounds. Mushroom production is an appropriate technology for the management of agricultural and agro-industrial residues. Oyster mushrooms are saprophytes that decompose agricultural plant by-product as they have the ability to use cellulose, hemicelluloses, and lignin materials as a source of their nourishment. Mushroom cultivation provides an environmentally friendly and economical way of converting agricultural and forest wastes into nutritious food (Ragunathan et al., 1996). On the surface of the earth, around 200 billion tons per year of organic matter is produced through the photosynthetic process (Zhang, 2008). However, the majority of this organic matter is not directly edible by humans and animals in many cases, becomes a contaminated source of an environment.

Though, mushroom cultivation is a useful method to produce alternative food sources using different environmental wastes. Oyster mushroom is known for its ability to degrade lignocelluloses residues from agricultural fields and forests and convert them into protein-rich biomass (Rowel et al., 2000). Species of oyster-mushroom show good adaptability to a wide range of temperature, making it possible to grow this mushroom almost all year round without controlled climatic conditions (Chadha, 2001; Baysal et al., 2003). Many agricultural and industrial by-products are important in mushroom production including teff straw, coffee pulp, wood chips, and cotton waste has high cellulose, hemicellulose and lignin contents. Therefore, there is a limited study conducted on utilization efficiency of agricultural waste by the mushroom. Hence, this study was conducted to evaluate the growth, the economic feasibility of small scale production and yield (bioconversion efficiency) of oyster mushroom using locally available agro-industrial by-products.

Oyster mushroom production is a useful method of environmental waste management and waste disposal. The cultivation of oyster-mushroom adds value to the economy, environmental restoration and food security (provision) worldwide. Mushroom production is one of the strategies that can be used for poverty intervention and also for combating malnutrition. Therefore, this study provided to identify the best and appropriate composition of a substrate for production of oyster mushroom.

Providing food for rapidly growing world population and waste management belongs to major problems found in the world. The cultivation of oyster mushroom on agro-industrial residues is a prime factor for the conversion of low-value inedible wastes into a higher value commodity which can serve as food. Among bioconversion processes, mushroom cultivation is an appropriate technology for the management of agricultural and agro-industrial residues. The oyster mushrooms have gained popularity, because of their simplicity and low-cost cultivation technology. The cultivation of mushroom in a natural environment is limited by season and space. Hence, it necessitates the cultivation of mushroom in the controlled environment through maintaining appropriate growing condition as it is in the natural environment. One method of cultivation needed for selecting appropriate growing substrate composition. Hence, this study conducted to evaluate different types of a substrate for production of oyster mushroom.

MATERIALS AND METHODS

Study area

This study was conducted in Wolkite University, Department of Biotechnology laboratory. Wolkite is located in Southern Nation, Nationalities and Peoples Region (SNNPR) regional zone and the administrative center of the Gurage Zone. It found at 175 km distant from Addis Ababa, Ethiopia.

Study material

Oyster mushroom (*Pleurotus ostreatus*) was collected from small enterprise working on spawn production in Addis Ababa. A pure culture of oyster mushroom was maintained on potato dextrose agar and malt extract agar plates. Agro-industrial waste namely cottonseed, enset waste, bagasse, teff straw, and sawdust was collected from Gurage zone. In this study, we took five (5) different agro-industrial wastes as a substrate to know the combination appropriate for oyster mushroom production. The material used in this study includes the hood, plastic bag, autoclave, Petri dish, jar, aluminum foil, sprayer, bunsen burner, hot plate, incubator, metric ruler, measuring cylinder, electronics balance, glove, and cotton.

Figure 1. Preparation of culture media (Y. Chemical, Y1. Prepared media, Y2. Mycelia grow on prepared media).

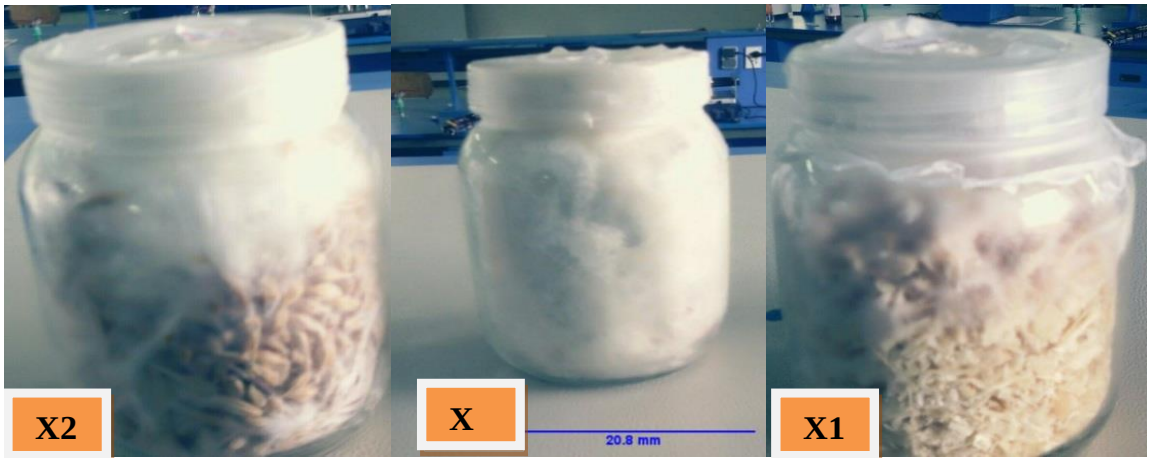

Figure 2. Spawn produced using three grains (X. Sorghum, X1. Bagasse, X2. Barley); Scale bar: 20.8 mm.

Experimental design and procedure

The experiment was laid down in CRD (completely randomized design) with four different substrate compositions in three different repeats. Then, collected data analyzed by SAS statistical analysis software.

Preparation of culture media

Pure cultures of oyster mushroom maintained on media prepared from potato dextrose agar (PDA), Malt extract agar (MEA), peptone and agar. 78 g of PDA, 60 g of malt extract agar, 30 g of Agar and 10 g of peptone was added to into 2 dm^3 of distilled water into a flask (Figure 1). Then it was placed on Bunsen burner to mix. The prepared media was placed on a hot plate to dissolve agar and then autoclaved at 121°C for 15 min. Fifteen milliliters (15 ml) of the medium dispensed into 9 cm diameter petri dishes. These were inoculated with the oyster mushroom cultures by using a spatula and incubated at 25°C.

Spawn production

Mushroom spawn is a medium that serves as the inoculum of the mushroom growth medium. Spawn was prepared by using barley, sorghum, and bagasse for comparison of the performance of oyster mushroom. Those two grains and bagasse washed and soaked in water overnight. The water was changed often to prevent fermentation. Once the grains have been prepared, they were boiled till it becomes soft but remain firm, then the water was drained and spread on a cheesecloth. Calcium carbonate (2%) was mixed with the grains. These grains were filled in half litter-size-empty bottles to three-fourths their capacity. These grains were sterilized in an autoclave for 15 minutes at 121°C temperature and 15 Pa (Pascal). Inoculation was carefully done in total aseptic conditions using pure culture or previously prepared grain spawn. After the inoculation, the bottles were incubated at 25°C temperature until mycelia fully cover the grains (Figure 2).

Substrate preparation and inoculation

The following substrates including sawdust, teff straw, and cottonseed waste, bagasse, enset waste were used for the study after soaked separately in water for moisture absorption. For the best results, substrates were mixed with wheat bran (10%) and gypsum (3%) supplement at a similar concentration (Figure 3).

Mixed substrates were placed in heat resistant polypropylene bags and sterilized in an autoclave at 121°C for 15 mins and allowed to cool at room temperature. After sterilization, each of experimental polypropylene bags was inoculated at the center of

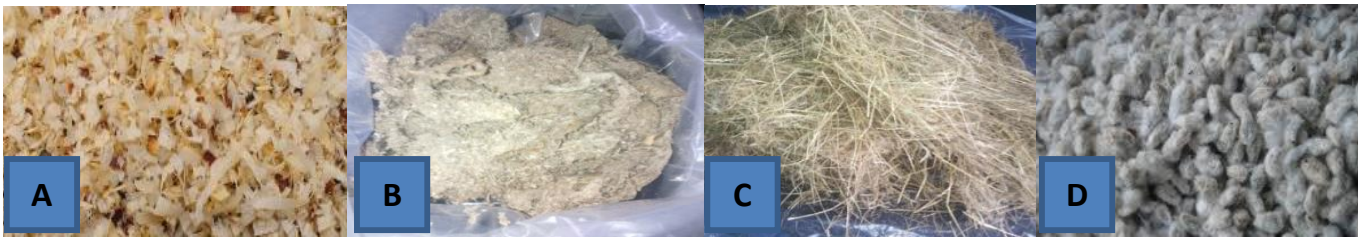

Figure 3. Different substrate used for Oyster mushroom cultivation (A. sawdust, B. enset waste, C. teff straw and D. cotton seed).

Figure 4. Fruiting bodies on combination of different substrate (T. sawdust+teff straw, T1. cotton seed+teff straw, T2. sawdust+enset waste, T3. Teff staw+enset waste); Scale bar: 6 mm.

the substrate with of pure culture of *P. ostreatus* under aseptic condition and bags tiled with wrap. They kept in dark room at 25 to 30°C and 90% relative humidity for 21 days.

Fruiting

When the mycelium has fully colonized the substrate, it can be able to produce fruiting bodies in response to a sudden change to the external physical environment, which first promoted the formation of initial fruiting bodies that later develop into fruiting bodies. The environmental changes that may trigger fruiting include changes in temperature, gas exchange, relative humidity, light and water availability within the compost. These induction factors also have an impact on the quality of the mushroom.

For *P.* Spp., decreasing the temperature from the spawn run temperature (25 to 27°C) to between 12°C and 18°C is the most common induction method used to stimulate fruiting. The primordial formed at the top of the bags and developed within 3 to 4 days and was ready to be collected (Figure 4). Under proper fruiting conditions, the additional flushes have occurred without any new inductions, but the flushes can be controlled by heating the blocks/bags followed by reducing the temperature.

Harvesting

The procedure for oyster mushroom harvesting involves grasping each mushroom stalk individually and twisting the mushroom until it is pulled out of the substrate. As the mushrooms begin fruiting, it is important to keep the humidity high (85 to 90% is recommended). As before, allow air to flush through the growing area prior to spraying (oyster mushrooms require a consistent source of fresh air). Temperatures can now be higher than for the initial pinning stage. The mushroom harvesting periods vary between different mushroom strains and usually range from 6 to 12 weeks and they can be harvested on a number of flushes. The determining factor in the number of flushes to be harvested and production time is substrate formulation together with the environmental conditions during cultivation. However, a period between the flushing of mushrooms named the resting stage, whereby the mushroom mycelia have to accumulate nutrients.

During this stage, contamination must be prevented to allow rapid mycelia growth. Harvesting of mushrooms can be carried out at different maturation stages depending on the mushroom species, market value and consumer preferences (Figure 5). Harvesting was carefully carried out before gills open in order to avoid a decreased market value and quality of mushroom.

Product evaluation

The bags were regularly disinfected using alcohol and hypochlorite to avoid contamination of substrates by unwanted microorganisms. When mycelia had fully covered the substrates bags, the bags were moved to another room for fructification. Bags were opened and regularly watered for fructification. After 27 days of inoculation and weights of the harvested mushroom was taken and recorded. The cap and stipe of the mushrooms were measured in cm using a metric ruler. Weight fruiting bodies of the mushroom were harvested in three different flushes.

Data collection

The data was collected from the result obtained. The growth and development of mushroom were monitored daily. The time (number of days) required from inoculation to completion of mycelium

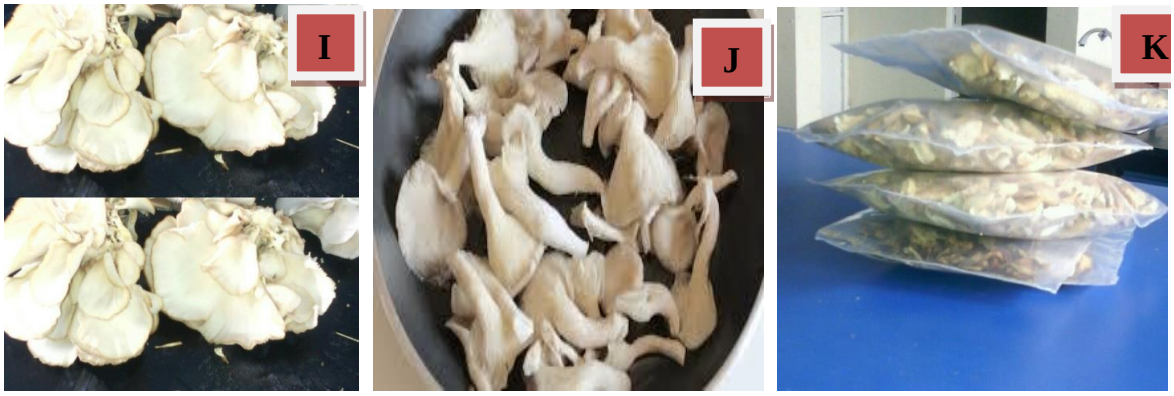

Figure 5. harvesting oyster mushroom produced on combination of selected substrate (I. harvested fresh oyster mushroom, J. Dry oyster mushroom, and K. packed oyster mushroom).

running, time elapsed between opening the plastic bags to pinhead formation and time required from opening the plastic bags to first-round harvesting were recorded. Growth parameters including stipe length (cm), cap diameter (cm), and ring diameter (cm) were recorded after each harvest. Yield parameters, such as a number of fruiting bodies per bunch, number of flushes and total fresh weight (g) of mushroom were also recorded at harvest time. Matured fruiting bodies were harvested by severing the base just above the surface of the substrate with a sharp blade. Two rounds of mushroom harvests were made across all substrate types in the course of the experiment. To evaluate the growth performance of mushroom on different substrates, yield and biological efficiency were calculated.

Data analysis

Analysis of variance

The analysis of variance (ANOVA) was carried out using statistical analysis system (SAS) version 9.2 software program using the Proc GLM procedure for completely randomized design (CRD) design (SAS Institute, 2008). The significant differences among substrate was presented by mean ± standard deviation (SD) at a level of $p<0.05$. The model used for CRD design was:

$$yij = \mu + \tau i + Eij$$

where, yij= the j^{th} observation of i^{th} treatment, μ=the overall mean, Ƭi= i^{th} effect (μi- μ) and Eij= the effect of j^{th} observation of i^{th} treatment, j=1…r, I=1…t.

Estimation of Bio-conversion efficiency (BE)

Weights of all fruiting bodies harvested from polypropylene bags were recorded as total yield of mushroom based on (Chang et al., 1993).

$$BE = \frac{FW}{DW} \times 100$$

where, BE = bio-conversion efficiency, FW = fresh weight of mushrooms harvested (g), DW= dry weight substrate (g). Yield performance and bio conversion efficiency of oyster mushroom on four kinds of substrates were calculated.

In this study, the collected data is analyzed by statistical analysis system (SAS) version 9.2 software program using the Proc GLM procedure for completely randomized design (CRD) design (SAS Institute, 2008).

RESULT

Production of spawn

After inoculation of spawn in prepared grains, the grains were fully covered by mycelia within 14 to 17 days. The mycelia coverage for sugarcane bagasse, sorghum and barley it takes 14, 16, 17 days, respectively as shown on Figure 6.

Analysis of variance for substrate

The analysis of variances for the studied growth parameters including stipe length (cm), cap diameter (cm), and ring diameter (cm) presented in Table 1. Also the yield parameters, such as a number of fruiting bodies per bunch, number of flushes and total fresh weight (g) and Dry weight (DW) of mushroom are indicated on Table 1.

The analysis of variance is highly significant for fresh weight, cape diameter and dry weight of mushroom at $p<0.001$ significance level. On the other hands, ring diameter and stipe length showed no significance level of ($p<5\%$). The parameters that showed high significance indicate that the source of variation for the cultivation of mushroom is varying among the type of substrate used in the experiment. The non-significance value of ring diameter and stipe length data indicated that the model used to evaluate this parameter is limited to show the difference by using different substrates.

Figure 6. Spawn production using three grains (A. sorghum, B. sugarcane bagasse and C. barley).

Table 1. Analysis of variances (ANOVA) with four treatments and three repeats.

Sources of variation	Degree of freedom	Mean square					
		FW	CD	RD	SL	NF	DW
Substrate	3	15603.35***	68.37***	0.52^{ns}	13.24^{ns}	1059.85*	1079.68***
Error	8	1150.96	2.44	0.94	6.03	142.75	119.52
CV		15.17	14.11	23.26	35.86	38.69	28.09
R^2		0.83	0.91	0.17	0.45	0.73	0.77

Where: *, **, ***significant at 5%, 1% and 0.1%, respectively; ns=non-significant at 5 % probability level, FW=fresh weight, CD= cape diameter, RD= ring diameter, SL= stipe length, NF=number of flush, and DW=dry weight, CV=coefficient of variation, R^2= coefficient of determination.

Table 2. Mean and standard deviation comparison of studied parameter on different substrate.

Substrate	Mean ± S.D					
	FW (g)	CD (cm)	RD (cm)	SL (cm)	NF (n)	DW (g)
Cotton + teff straw	279.02±20.95	17.88±0.42	3.78±0.18	6.45±2.01	20.44±5.01	43.51±17.89
Sawdust+teff straw	291.90±41.06	10.95±2.44	4.64±0.19	9.88±4.27	58.89±23.11	62.55±8.80
Sawdust+enset waste	172.54±26.05	7.82±1.26	4.40±1.64	5.95±1.28	24.50±1.8	31.89±8.68
Teffstraw+enset waste	151.08±42.42	7.69±1.42	3.86±0.99	5.1±0.33	19.66±2.90	17.68±2.22

SD=standard deviation, FW=fresh weight, CD=cape diameter, RD= ring diameter, SL=stipe length, DW=dry weight, g=gram, cm=centimeter, n=number for counting flush at each harvest.

Mean performance of substrate

The mean value of the growth and yield parameter are presented in Table 2. Oyster mushroom cultivated on a mixture of sawdust + teff straw recorded the highest fruit body weight followed by a mixture of cottonseed + teff straw; teff straw + enset waste and sawdust + enset waste. A maximum value of fresh weight is attained when we have used sawdust + teff straw and cottonseed + teff straw with a yield of 279.02 and 291.90 g, respectively. The least yield obtained from the combination of teff straw+ enset waste with a yield of 151.08 g.

Mushrooms growing on sawdust + teff straw had the highest cap diameter. The least stipe and ring diameter of the cultivated oyster mushroom was recorded in the combination of teff straw + enset waste. Oyster mushroom that grows on combination of cotton seed + teff straw and sawdust + teff straw has ring diameter 3.78 and 4.64 cm, respectively.

The response of substrate on yield parameter

The yield parameters have been determined mainly from growth parameter hence become the main criteria for the selection of substrate.

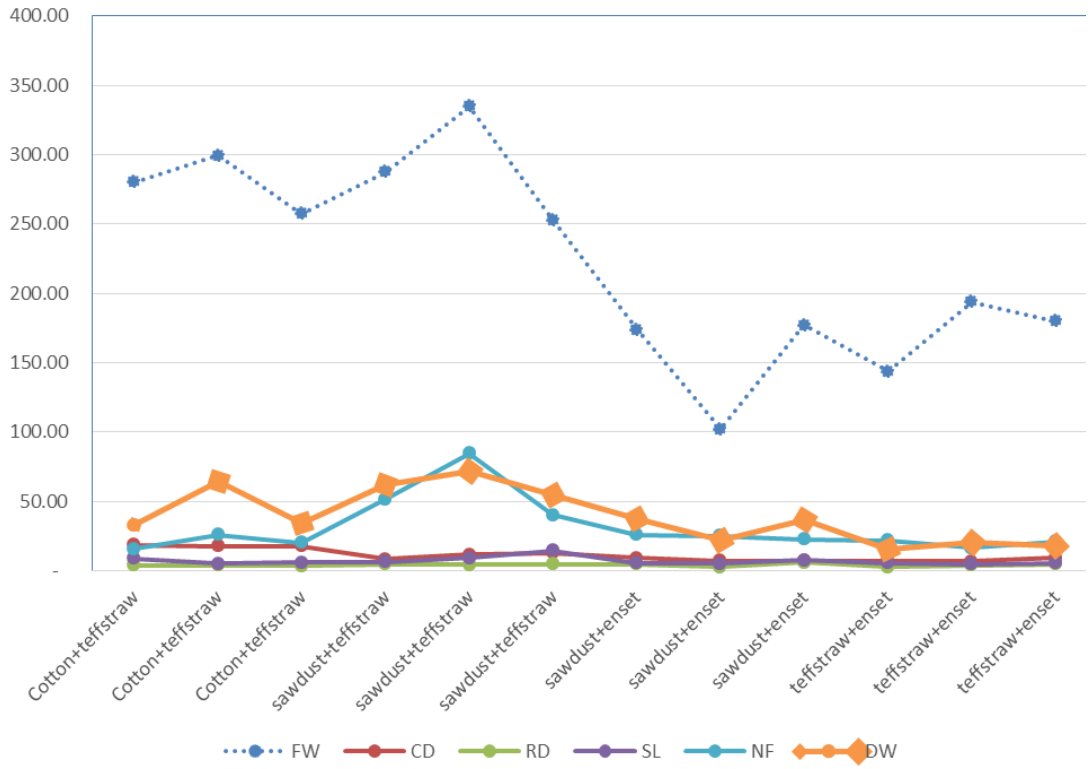

Figure 7. Response of different combination of substrate for production of Oyster mushroom.

The fresh yield of mushroom has declined as teff straw is substituted with enset waste as shown in Figure 7. In addition, a number of flush and dry weight has contributed to the yield performance of the substrate. Based on the result the highest fresh weight harvested when teff straw and sawdust used for a substrate.

Oyster mushroom grow on the combination of substrate

The growth of oyster mushroom on the combination of sawdust and teff straw is higher than the remaining three combinations of a substrate in these studies. Highest fresh weight of oyster mushroom was obtained from the combination of sawdust and teff straw. While the lowest of fresh weight recorded from the combination of teff straw and enset waste. Four different combinations of substrates are used for the production of oyster mushroom. This combination of substrate used for growth of oyster mushroom includes sawdust + teff straw, cotton seed + teff straw, sawdust + enset waste and teff straw + enset waste as shown on Figure 8.

Bioconversion efficiency of oyster mushroom

Mushroom bioconversion efficiency on different substrates mixtures having 45:45 and 90:10 WW main materials and additive wheat bran for three consecutive flushes are shown in Figure 8.

The mixtures of sawdust and teff straw reached their bioconversion efficiency of 73%, followed by 52% of teff straw + cottonseed, and 30% of sawdust + enset waste mixture. The lowest bioconversion efficiency is obtained 26.6% of teff straw + enset waste mixture (Figure 9).

Periods of oyster mushroom fruiting bodies maturation

The bags took 3 to 5 days from primordial formation to maturation of mushroom fruiting body. After 3 days, mushrooms became ready for picking. Duration for the maturation of fruiting bodies after primordial formation showed variations among different substrates and replicates (Figure 10).

DISCUSSION

Various grains such as sorghum, barley and bagasse are used for the production of spawn. Amongst these different grains used during the current investigation, oyster mushroom mycelia invasion took the minimum number of days (14) for spawn running on sugarcane

Figure 8. Oyster mushroom growing on different selected substrate (ST. Sawdust+teff straw, CT. cotton seed+teff straw,SE. sawdust+enset waste and TE. teff straw+enset waste).

bagasse followed by sorghum (16 days), barley (17 days). Similarity, Tsegaye and Tefera (2017) reported the production of spawn on sugarcane bagasse took the shortest time (14 days) compared to other grains sorghum and millet that took (16 to 17 days). The result further supported by (Rana et al., 2007) on oyster mushroom showed significantly rapid growth on different grains as compared to the rest of other mushroom species. Thus, sugarcane bagasse may be an appropriate source of carbon and energy for mycelia colonization and spawn production. The growth of Oyster mushroom (*P. ostreatus*) mycelia was relatively faster on a combination of sawdust + teff straw wastes as compared to the remaining three combinations.

The highest mycelium colonization, primordial initiation, fruiting bodies formation, and fresh weight were obtained from sawdust + teff straw with a yield of 730 g/kg. Previously, Tsegaye and Tefera (2017) reported highest fresh yield of mushroom (790 g/kg) harvested from a combination of cotton waste + coffee pulp which is closer to the current study. Adjapong et al. (2015) reported about 32.99 g of fruiting bodies of mushroom harvested per crop on maize husk.

Mushroom cultivation requires carbon, nitrogen and inorganic compounds as their nutritional sources, and main nutrients are carbon sources such as cellulose and lignin. Oyster mushrooms require less nitrogen and more carbon source. Thus, most organic matters containing cellulose, hemicellulose and lignin can be used as the mushroom substrate. The ability of oyster mushroom to grow successfully on the combination of sawdust and teff straw associated with the essential chemical composition of selected substrates is important for the growth of mushroom. Variations observed in the number of fruiting bodies produced may be associated with the physical nature of the substrates as well as the nature of the

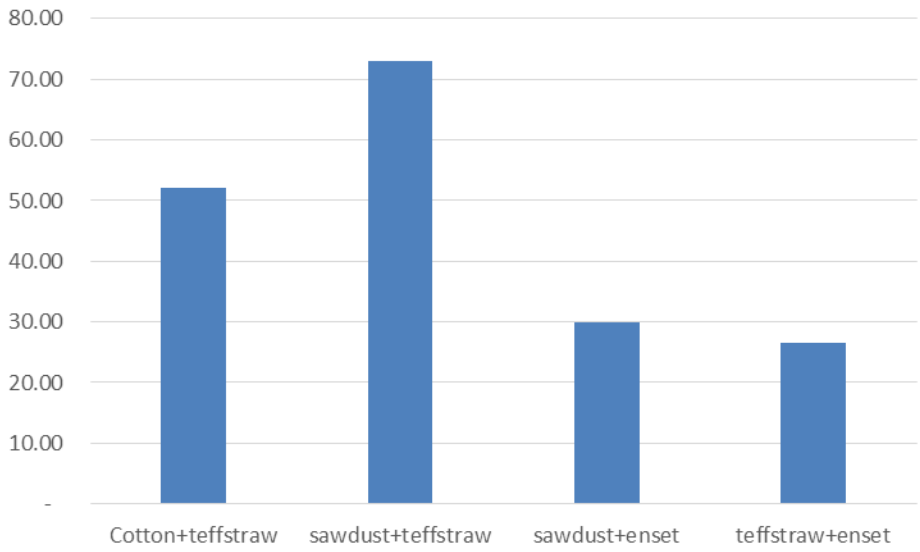

Figure 9. Bioconversion efficiency of oyster mushroom.

Figure 10. Progressive development of oyster mushroom on combination of different substrate (E. primordial formation, F. fruiting bodies, G. growth of fruiting bodies, H. matured oyster mushroom for harvest).

mushroom species. The number of fruit bodies recorded is related to their mycelia colonization.

In this study, data were collected on yield parameters and growth parameters. Yield parameter includes fresh weight (FW), number of flush and dry weight (DW). While the growth parameters are: cap diameter, stipe and ring diameter. The maximum value of fresh weight is obtained when we have used sawdust + teff straw and cotton seed + teff straw with a yield of 291.02 g and 279.90 g, respectively. While the least yield of fresh weight obtained from a combination of teff straw and enset waste with the yield of 151.08 g. The growth parameters such as ring diameter and stipe length showed the non-significance level at probability less than 5% ($p<5\%$). Parameters that showed non-significance do not indicate the source of variation for production of oyster mushroom. On the other hand, analysis of variance is highly significant for FW, CD and DW of oyster mushroom at $p<0.1\%$. The parameters that showed high significance indicates the source of variation for the cultivation of mushroom is vary among the type of substrate used in the experiment.

The highest mean value of growth and yield parameters are obtained from the combination of sawdust and teff straw. While the combination of teff straw and enset waste gives the lowest mean value of growth and yield parameters. In this study, four substrates such as teff straw, enset waste, sawdust, and cottonseed are used. The supplements used to enhance the growth of oyster mushroom are wheat bran and gypsum. Alcohol and bleach are chemicals used to control unwanted microorganism during oyster mushroom production. Continuous spraying of water is required during mycelia growth because it requires high humidity.

The bioconversion efficiency is calculated as fresh weight over the dry weight of substrate multiplied by one hundred. Highest bioconversion efficiency was obtained from the combination of sawdust and teff straw. This

indicates a high yield of oyster mushroom.

The mixtures of sawdust and teff straw reached their bioconversion efficiency of 73%, followed by 52% of teff straw + cottonseed, and 30% of sawdust + enset waste mixture. Previously, the biological efficiency of maize husk substrate was 39% (Adjapong et al., 2015). The lowest bioconversion efficiency is obtained 26.6% of teff straw + enset waste mixture.

Conclusion

Oyster mushroom production is the most important as a nutritional supplement and cash crop for the landless poor. Oyster mushrooms are high yielding, fast-growing crop. They are known to help lower cholesterol levels and are a great source of potassium, iron, and protein. Cultivation of edible oyster mushroom is a prime factor for the conversion of low-value inedible wastes into a higher value commodity which can serve as food material for humans as well as a source of the commercially important metabolites. Also, their spent can be used as cattle feed, fertilizer or landfills. Therefore, cultivation of oyster mushroom on agro-industrial residues provides multi-disciplinary advantages for the human being, animals as well as for the ecosystem. The highest yield (bioconversion efficiency) of oyster mushroom was obtained from the combination of sawdust and teff straw which are easily available substrates and large biomass exists in the country. The fresh mushroom biological efficiency was directly related to the nutritional composition of the substrate used for growing mushrooms. The observed differences in the substrates media may be due to the percentage composition of cellulose materials and essential chemicals and biomolecules that are important for the growth of oyster mushroom.

The highest values of yield parameters are obtained from the combination of sawdust and teff straw. While the lowest values of yield parameters are obtained from the combination of teff straw and enset waste. The analysis of variance is highly significant for fresh weight, cap diameter and dry weight of mushroom at probability less than 0.1%. This indicates the source of variation for the production of oyster mushroom is varying among the type of substrate used in the experiment. In this study, ring diameter and stipe length showed the non-significance level at probability less than 5%. Generally, in this study the combination of sawdust and teff straw is the best appropriate substrate for high yield production of oyster mushroom

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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