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Growth, Yield, and Biological Efficiency of Oyster Mushroom *(Pleurotus ostreatus*) Grown on Different Substrate Mix Ratios

Asefa Keneni and Geda Kebede
Department of Biology, College of Natural and Computational Sciences, Ambo University, P. O. Box 19, Ambo, Ethiopia

Abstract

This study was undertaken in 2014 at Ambo University Department of Biology to assess growth, yield, yield parameters and biological efficiency of oyster mushroom (Pleurotus ostreatus). Four treatments T1 (10: 80: 10; teff straw: waste paper: cotton seed waste), T2 (20:60:20; teff straw, waste paper and cotton seed waste), T3 (30:40:30 Teff straw: waste paper: cotton seed waste) and T4 (33.3:33.3:33.3; Teff straw, waste paper and cotton seed waste) were evaluated in three replication using complete randomize block design. Results showed that T4 (33.3:33.3:33.3; Teff straw: waste paper : cotton seed waste) recorded the fastest mycelial extension followed by T3 (30:40:30 Teff straw: waste paper : cotton seed waste) while, T1 (10:80:10; teff straw: waste paper : cotton seed waste) exhibited the slowest mycelial extension on 7th and 14th days of incubation periods. T1 (10:80:10; teff straw: waste paper: cotton seed waste) took longer incubation periods from pinning to maturation while T4 took shorter periods from pinning to maturation in all flushes. Relatively highest and equal numbers of fruiting bodies were collected fromT1 (10:80:10; teff straw: waste paper: cotton seed waste), T2 (20:60:20; teff straw, waste paper and cotton seed waste) and T4 (33.3:33.3:33.3; Teff straw, waste paper and cotton seed waste), While T3 (30:40:30 Teff straw: waste paper: cotton seed waste) gave the least number of fruiting bodies. Pilus diameter was largest for T3 followed by T2 and T1 respectively. The stipe length of mushroom for all treatments did not varied significantly. The highest total fresh weight of matures and biological efficiency was recorded in T4 followed by T3 and the least on T1 (10:80:10; teff straw: waste paper: cotton seed waste). The result of this study showed the possibility of obtaining high yield and more biological efficiency by preparing equal proportion of teff straw, waste paper and cotton seed waste and hence recommend for further verification studies and scale up for commercial production of the oyster mushroom.

Keywords: Biological efficiency, growth, oyster mushroom, substrates, yield,

Introduction

Mushrooms have been recognized as important food items from ancient time and it have been cultivated for long period of time for their nutritional value and flavour especially in the far eastern countries. Their usage is being increased day by day for their significant role in human health, nutrition and degenerative disease control. The protein content of mushrooms is less than that of food from animal sources but much more than in most food from plant sources. They have low fat content, high fibre, contain all important minerals and essential amino acids with the exception of iron (Synyatsya *et al*., 2008; Daba *et al*., 2008)). It also

provides balanced diet compounds in sufficient quantities. In fact, mushrooms contain low saturated lipids, low calories and good vitamins and many mushrooms possess multi-functional medicinal properties (Daba *et al*., 2008; Beelman *et al*., 2003).

This low cost vegetable is not only packed with nutrients but also has properties to ward off cancer, HIV-1 AIDS and numerous other diseases (Beelman *et al*., 2003; Wasser 2002). It is an economic crop requiring low resources and area to cultivate, and can be grown throughout the world and all year round from plenty and low-cost materials that are easily found and available (Beetz and Kustudia, 2004). Besides, its cultivation is very much environmental friendly, capable of converting the lignocellulosic waste materials into food, feed and fertilizers (Hadar *et al.,* 1992; Jaradat, 2010).

Even though mushrooms could supplement nutritional needs of people for centuries during the rainy season, which is a period of grain scarcity, the mushroom eating habit among the majority of Ethiopian population is very low (Dawit, 1998), but mushroom consumption is a common practice among many ethnic groups of rural south and southwest Ethiopia than urban dwellers of the country. Moreover, older consumer's value mushrooms more than the young. Thus, reliable information on traditional use of wild mushrooms in Ethiopia is obtained from rural senior citizens. On the other hand, mushrooms are not highly valued in the central highlands of the country (Dawit Abate 2014). According to Teferi *et al*., (2013) wild mushrooms are mainly collected from the forest, uncultivated land and termite nests by almost all family members (children, women and men). However, none of the inhabitants were involved in cultivation of mushrooms due to lack of awareness on possibility of its cultivation. It has been reported that wild mushroom distribution has been on a sharp decline since the past two decades; implying an urgent need to initiate and create awareness among the inhabitants to adopt mushroom cultivation and conservation of this very important non-timber forest product in order to elevate the decreasing status of the mushroom (Teferi *et al*., 2013).

Mushrooms of *Pleurotus* spp. are commonly known as oyster mushrooms which occupy the second position among cultivated edible mushrooms worldwide due to their nutritional and medicinal values (Chang and Miles 2004; Mane *et al*., 2007; Upadhyay *et al*., 2008).The production of *Pleurotus* spp. offers one of the most potential and economic methods for the bioconversion of lignocellulosic waste produced by agriculture (Cohen *et al.,* 2002; Masarirambi *et al*., 2011; Rayse 2002). The environmental factor is very important for the production of oyster mushrooms. Various mushroom species are known to be sensitive to the climatic conditions (Singh *et al*.,

2003). The major environmental factors like temperature, humidity, fresh air and compact materials affect mushroom production and *Pleurotus spp*. grows in wide range of temperature (15-30^{0}C) which also varies from species to species (Uddin *et al*., 2011). A fairly good yield can be obtained up to 30^{0}C. Production of *P. fossulatus* prefers 20±1^{0}C but *P. ostreatus* prefers 21-35^{0}C and humidity of 65 to 100%; maximum growth of *P. ostreatus* was recorded at 25^{0}C, whereas *P. florida* gave the highest yield at 30^{0}C. *P. flabellatus* also have a similar temperature requirement (Sharma *et al*., 2013). Kong (2004) reported that *P. ostreatus*, *P. florida*, *P. sajor-caju* reached their optimum growth at 25^{0}C, while *P. cornucopiae* and *P. cystidiosus* reach their optimum growth at 25-35^{0}C temperature.

There are huge agricultural and other organic wastes (including teff, wheat and barley straw, sugar cane bagasse, wheat bran and husk, saw dust, coffee waste and food processing wastes) available in Ethiopia . Few of these wastes have been tested for their usability for the production of oyster mushroom under different environmental condition in Ethiopia. Birara *et al*., (2013) evaluated the bioconversion efficiency of invasive weed species (*Lantana camara*, *Prosopis juliflora*, *Parthenium hysterophorus*) and wheat straw as a substrate for oyster mushroom (*Pleurotus spp*) cultivation and reported that *Plerotus ostreatus* gave highest total yield of 840g Kg^{-1} and biological efficiency of 83.87% on *Parthernium hysterophorus*. They also reported that total yield had a positive correlation with biological efficiency and that the production utilization of the plant biomass for mushroom cultivation could contribute to alleviating ecological impact of invasive weed species while offering practical option to mitigating hunger and malnutrition in areas where the invasive weeds had become dominant. In their evaluation of eight locally available substrate composition; mixed mainly from three major substrates (saw dust, corn cobs and coffee bean husks), Beje *et al*., (2013) reported that the fastest mean value (0.69 cm /day) of mycelia extension was observed from SdZcCh (combination of saw dust of *Cordia africana* and *Pouteria adolfi-friederici*, corn cobs and coffee bean husks). However, they observed that the mycelia growth in coffee bean husks alone was completely ceased after 15 days of incubation and the highest (77.38%) biological efficiency was obtained from sdZcCh.

The competence of a given society could be measured based on the technical capability on efficient utilization of available resources. In Ethiopia agricultural residues are the major by products of agricultural processes which to some extent are used as feed for animals and a larger proportion of the wastes burned to clear the field for the next season. Burning of these huge wastes could increase the emission of green house gases which exacerbate degradation of the environment. Production of mushroom using theses wastes can have multipurpose effect: (1) it can

minimize the amount of organic wastes burned in the environment since these organic wastes can be converted in to mushroom biomass; (2) mushrooms are more efficient in converting organic wastes in to value added mushroom biomass than the animals and (3) the consumption of mushroom can alleviate malnutrition of an average Ethiopian and ensure food security since it is a healthier food source. Teff is the major staple food crop in Ethiopia with production majorly concentrated in high lands of the country and generate a significant amount of straw as major by product of the crop after the economic part is removed. Teff straw mixed with waste paper and cotton seed as substrate for mushroom production has not yet been tested in the Ethiopian mushroom research. The present study was therefore undertaken to assess the growth, yield and biological efficiency of oyster mushroom on substrates composed of different proportion of teff straw, waste paper and cotton seed waste mixed on dry weight basis.

Materials and Methods

Organism and culture conditions

The fungal strain, *Pleurotus ostreatus* (Oyster mushroom) was originally obtained from Mycology Laboratory, Department of Biology, Addis Ababa University, Addis Ababa, Ethiopia in 2014, and kept under refrigerated condition on potato-dextrose agar (PDA) slant. The pure culture of *Pleurotus ostreatus* was transferred on to potato dextrose agar (PDA) prepared in the laboratory using fresh potato 250 g; glucose (Dextrose) 20 g; agar 20 g and 0.2g of chloramphenicol in 1000 ml of water. The medium was poured into the Petri dishes and allowed to cool under aseptic condition in laminar flow chamber. The cooled and solidified medium was inoculated by 1 cm×1 cm agar block of the fungal strain and incubated at 25^0C. The growth of the culture and presence of contamination were visually inspected at three days interval.

Grain spawns production

The spawn (mushroom seed) of *Pleurotus ostreatus* was produced on yellow colored sorghum grain, wheat bran and calcium sulfate (gypsum) in the ratio of 88:10:2 respectively (Dawit, 1998). The required amount of sorghum grain was weighed and soaked over night in sufficient amount of water. The grains were washed and drained to remove the dead and floating seeds with excess of water. After removing the excess water from the grain, the required amount of wheat bran and gypsum ($CaSO_4$. $2H_2O$) were added and transferred to 1000 ml glass bottles (75% level) leaving a head space over the grain and autoclaved at 121°C temperature for 1h. After cooling, each bottle was inoculated with 20 agar blocks (1 cm × 1 cm) of 21day old mushroom culture from the Petri dish and incubated for three weeks at 28 ± 2^0C until the substrate were fully colonized and the

mycelia invasion and contamination were inspected at five days interval.

Collection of the substrate

The Teff straw and the Wheat bran were purchased from Ambo local market and wheat processing factory in Ambo respectively. Cotton seed waste and calcium carbonate were from Addis Ababa, Ethiopia, and the waste papers from different departments of Ambo University.

Treatments

Four treatments comprising different proportions of teff straw, waste paper and cotton seed waste (2000g) along with lime stone (Calcium Carbonate 20g and 200g wheat bran) on dry weight basis were used as shown in Table 1. The treatments were replicated three times and arranged in a complete randomized block design.

Table 1. The treatments showing the different substrate mix ratios

Treatments	Composition (g)/ratio of substrate materials			Total (g)
	Teff straw	Waste paper	Cotton seed waste	
Treatment One (T1) (10:80:10)	200	1600	200	2000
Treatment Two (T2) (20:60:20)	400	1200	400	2000
Treatment Three (T3) (30:40;30)	600	800	600	2000
Treatment Four (T4) (33.3:33.3:33.3)	667.5	667.5	667.5	2000

Preparation of the substrate

The required amount of Teff straw and cotton seed waste were separately soaked in sufficient amount of water over night. The waste paper was cut into small pieces of approximately 3-5 cm, weighed and soaked in sufficient amount of water immediately before use. Excess water present in the substrates was drained thoroughly and mixed with 10% wheat bran plus 1 % calcium carbonate and filled in sterilizable yellow color polyethylene bags. The substrates were autoclaved at 15Psi pressure at 121^0C for one hour. After sterilization the substrates were transferred to transparent polyethylene cultivation bags for easy mycelia growth supervision and presence of contamination. Each substrate (2,000 g) with 70% moisture was mixed with 10% spawn (dry weight/wet weight basis) and the inoculated polythene bags were then tightly tied with thread made of polyester/cotton. Pin holes were made through the bags (1/100 cm^2) for drainage and aeration. It was kept in a spawn running room at room temperature in the dark until primordia were formed. After primordial formation, large holes were made in the polythene bag to allow normal development of fruiting bodies. Bags were transferred to mushroom house under normal environmental conditions with a relative humidity maintained at 85-90%. The culture bags were moistened using tap water morning and evening until all flushes of *Pleurotus ostreatus* fruiting bodies were harvested. Adequate ventilation was provided to prevent increased CO_2

concentration in the room by opening the door and windows of the room for half an hour in the morning and in the evening.

Harvesting of mushrooms

Mushrooms were harvested before the fruiting body showed any splitting on the edges. The yield of mushrooms and different quality parameters such as days to first primordial initiation (DPI), number of effective fruiting bodies (NFB) and biological yield were measured and the biological efficiency (BE) determined using the following formula:

$$\text{Biological Efficiency} = \frac{\text{Weight of fresh fruiting bodies (g)}}{\text{Weight of dry substrate (g)}} \times 100$$

Data analysis

The one way analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS) software version 16.0 for windows was used to analyze the data. Where significant differences exist among treatments, means were compared using the least significant difference (LSD) method.

Results

Mycelia extension

There result showed significant ($P \leq 0.05$) differences in the mycelial extension of oyster mushroom grown on the different substrates. T4 (33.3:33.3:33.3; Teff straw, waste paper and cotton seed waste) showed the fastest mycelial extension followed by T3 (30:40:30 Teff straw: waste paper : cotton seed waste) while, T1(10:80:10; teff straw: waste paper : cotton seed waste) exhibited slowest mycelial extension on 7th and 14th days of incubation periods (Table 2). The days required for complete invasion of the substrates was significantly ($P \leq 0.05$) less for T4 (33.3:33.3:33.3; Teff straw, waste paper and cotton seed waste) and T3 when compared to T1 (10:80:10; teff straw: waste paper : cotton seed waste) (Table 2). Total days required to complete the production cycle was shortest for T4 (33.3:33.3:33.3; Teff straw, waste paper and cotton seed waste) followed by T3 (30:40:30 Teff straw: waste paper : cotton seed waste), while T1 took more days (26.5) (10:80:10; teff straw: waste paper : cotton seed waste).

Table 2. Mycelial extension and number of days for complete invasion on the different substrates measured on 7th and 14th day of incubation.

Treatment	Mycelial extension		Mean value	No. days for complete invasion	Total days for cycle
	7th day	14th day			
T1	1.8^{c}	5.6^{b}	0.26^{c}	26.5^{a}	105^{a}
T2	2.1^{b}	6.2^{a}	0.29^{b}	24.3^{a}	98^{b}
T3	2.3^{a}	6.4^{a}	0.31^{a}	23.2^{a}	93^{c}
T4	2.4^{a}	6.6^{a}	0.32^{a}	22 ^{a}	87^{d}

Growth rate of mushroom (Flushes)

Mean incubation periods of mushroom flushes showed highly significant differences (P≤0.05). T4 (33.3:33.3:33.3; Teff straw, waste paper and cotton seed waste) showed relatively shorter incubation periods though out all the flushes followed by T3 (30:40:30 Teff straw: waste paper : cotton seed waste). T1 (10:80:10; teff straw: waste paper : cotton seed waste) took relatively longer incubation periods through out all the flushes. T2 (20:60:20; teff straw, waste paper and cotton seed waste) took intermediate between the shortest and longest incubation periods through out the all flushes (Table 3).

Table3. The incubation period for the various treatments

Treatments	Incubation-1st flush	1st -2nd flush	2nd – 3rd flush	3rd – 4th flush
T1	45	22	20	18[a]
T2	42	21	19	16[b]
T3	40	20	18	15[b]
T4	35	19	17	15[b]
P≤0.05	NS	NS	NS	

Fig 1. Stages in the development of mushroom: (A) Pure plate culture of *P. ostreatus*; (B) oyster spawn ready for use; (C) the three substrate used for oyster mushroom production; (D) Primordial formation and elongation of pin heads on the production bag and (E) mature oyster mushroom ready for harvest.

Pinning to maturation time of oyster mushroom

The mean periods taken from pinning to maturation of each treatment showed slightly significant (P≤0.05) variation. T1 (10:80:10; teff straw: waste paper: cotton seed waste) relatively took longer periods from pinning to maturation while T4 (33.3:33.3:33.3; Teff straw, waste paper and cotton seed waste) took shorter time from pinning to maturation in all flushes as compared to other treatments. T3 (30:40:30 Teff straw: waste paper: cotton seed waste) and T2 (20:60:20; teff straw, waste paper and cotton seed waste) showed intermediate periods from pinning to maturation of the longest and shortest period throughout all the flushes (Table 4).

Table 4. Pinning to maturation time of the oyster mushroom

Treatments	1st flush	2nd flush	3rd flush	4th flush
T1	10	8[a]	8[a]	6
T2	9	8[a]	7[b]	6
T3	9	8[a]	7[b]	6
T4	8	7[b]	6[b]	5.5
P≤0.05	NS			NS

Yield of mushroom per flushes and total yield

In the first and second flushes all the treatments showed significant (P≤0.05) variation on the mean fresh weight of mushroom. No significant treatment variation was observed between T2, T3 and T4 in the third flush except T1 (10:80:10; teff straw: waste paper: cotton seed waste) which significantly differed from other treatments (Table 5). At fourth flushing, the significant variation was observed between T1 (10:80:10; teff straw: waste paper : cotton seed waste), T2 (20:60:20; teff straw, waste paper and cotton seed waste) and between T3. However, no variation was observed between T2 (20:60:20; teff straw, waste paper and cotton seed waste) and T4 (33.3:33.3:33.3; Teff straw, waste paper and cotton seed waste) (Table 5).

Table 5. Mean yield per flush for the different substrate mix ratio

Treatments	1st flush	2nd flush	3rd Flush	4th Flush	Total
T1	985[b]	219[d]	140[b]	100c	1444
T2	740[d]	370[b]	220[a]	130b	1460
T3	930[c]	285[c]	200[a]	190a	1605
T4	1000[a]	400[a]	200[a]	120b	1720

Number of bunches, mature and abort mushrooms

More number of bunches were recorded on T3 (30:40:30 Teff straw: waste paper : cotton seed waste) followed by T2 (20:60:20; teff straw, waste paper and cotton seed waste), while T1 (10:80:10; teff straw: waste paper : cotton seed waste) and T4 (33.3:33.3:33.3; Teff straw, waste paper and cotton seed waste) showed least and equal number of bunches. Relatively highest and equal numbers of fruiting bodies (matures) were collected fromT1 (10:80:10; teff straw: waste paper: cotton seed waste), T2 (20:60:20; teff straw, waste paper and cotton seed waste) and T4 (33.3:33.3:33.3; Teff straw, waste paper and cotton seed waste), While T3 gave the least number of fruiting bodies. Higher number of aborts were recorded with treatments T3(30:40:30 Teff straw: waste paper : cotton seed waste) followed by T2 (20:60:20; teff straw, waste paper and cotton seed waste) and the least number of aborts were recorded in T1 (10:80:10; teff straw: waste paper : cotton seed waste) (Figure 2).

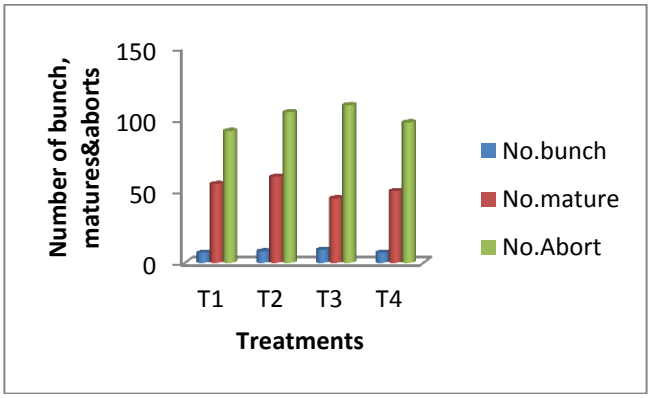

Fig 2. Number of bunches, matures and aborts in the mushroom production processes

Pilus diameter and Stipe length

Pilus diameter was found to be the largest from T3 (30:40:30 Teff straw: waste paper : cotton seed waste) followed by T2 (20:60:20; teff straw, waste paper and cotton seed waste), T1 (10:80:10; teff straw: waste paper : cotton seed waste) respectively. The pilus diameter was smallest for the sample collected from T4 (33.3:33.3:33.3; Teff straw, waste paper and cotton seed waste). The stipe length was not significantly different for all the treatments (Figure 3).

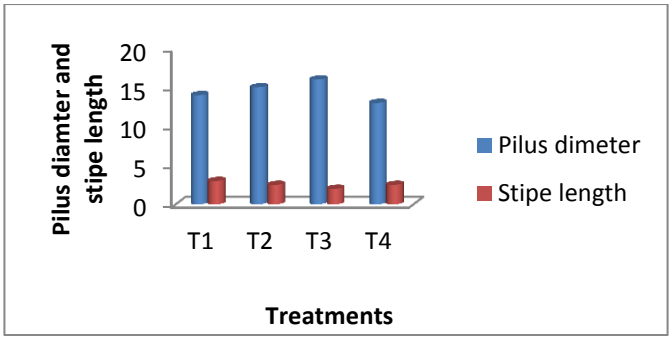

Fig 3. Pilus dimater and stipe length of harvested mushroom

Total yield and biological efficiency

The highest total fresh weight of matures was recorded in T4 (33.3:33.3:33.3; Teff straw, waste paper and cotton seed waste), followed by T3 (30:40:30 Teff straw: waste paper : cotton seed waste). The least total fresh weight was recorded in T1 (10:80:10; teff straw: waste paper: cotton seed waste) (Table 5). The effect of different treatments on biological efficiency of oyster mushroom showed significant ($P \leq 0.05$) differences. The highest biological efficiency was recorded with T4 (33.3:33.3:33.3; Teff straw, waste paper and cotton seed waste) followed by T3 (30:40:30 Teff straw: waste paper: cotton seed waste). The least was recorded with the treatment T1 (10:80:10; teff straw: waste paper: cotton seed waste) (Figure 4).

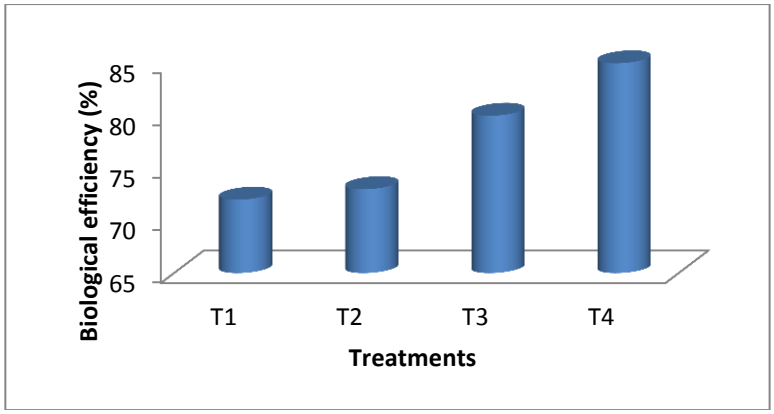

Fig 4. Biological efficiency of the different substrates

Discussion

The use of teff straw, waste paper and cotton seed mixed in different proportion as a substrate for the culture of oyster mushroom was not yet tested in Ethiopia. In this study equal proportion of the substrates T4 (33.3:33.3:33.3; Teff straw, waste paper and cotton seed waste) resulted in the fastest mycelial invasion (22 days) and another 13 days to first harvest, while T1 (10:80:10; teff straw: waste paper and cotton seed waste) took longer time (26.5 days) to complete mushroom mycelium colonization and 18.5 days to first harvest. Our observation is in line with that of Oseni *et al*. (2012) who reported a period of colonization to first harvest from 33 to 43 days on fermented saw dust supplemented with different proportions of wheat bran. These variations are mainly related to spawn rate, fungal species used and supplement added to the substrate (Mane *et al*., 2007).

The days to primordial formation after complete colonization of the substrate by the fungal strain showed significant variation. . T4 (33.3:33.3:33.3; Teff straw, waste paper and cotton seed waste), took only five days for initiation of primordial while T1 (10:80:10; teff straw: waste paper and cotton seed waste) took another 8.5 days. This was in line with results of Ashraf *et al.,* (2013) that recorded 3.73 to 5.13 days for primordial initiation after mycelia running.

The successive pinning to harvest duration in this study was shortened by at least a day in T4 (33.3:33.3:33.3; Teff straw, waste paper and cotton seed waste), T3 (30:40:30 Teff straw, waste paper and cotton seed waste) and T2 (20:60:20; teff straw, waste paper and cotton seed waste). The shortest mean duration of pinning to maturation was 8days in the 1st, 7 in the 2nd, 6 in 3rd and 5.5 in the 4th flushes. The longest mean duration of pinning to maturation was in T1 (10:80:10; teff straw: waste paper and cotton seed waste) with 10, in the 1st, 8 in the 2nd and 3rd flushes and 6 in the 4th flush. The duration as recorded in the present study was longer when compared with that of Beje *et al.,* (2013) who reported 3.3 as the shortest and 6.0 as the longest. Studies indicated that environmental factors affect the incubation periods of oyster mushroom. According to Zadrazil (1976) and Daba *et al*., (2008) they reported a longer period of incubation for oyster mushrooms at lower temperature and low relative humidity.

The yield (fresh weight) of the mushroom harvested from all the treatments in the first cycle was greater than the successive harvests which is in line with Ashraf *et al.,* (2013) who reported that different treatments vary in the amount of mushroom yield harvest at different flushes, and the subsequent decline in successive harvest. Number of bunches formed on different treatments were not significantly different. The number of fruiting

bodies collected from different treatments did not show variation except in T3 (30:40; 30 Teff straw, waste paper and cotton seed waste), that also recorded higher number of aborts (110) followed by T2 (20:60:20; teff straw, waste paper and cotton seed waste) (105) and T1 (10:80:10; teff straw: waste paper and cotton seed waste) (92). The higher number of fruiting bodies recorded in T3 might be due to the balanced proportion of the three substrates which induced maximum primordial formation from which some of them aborted. In the present study more number of bunches resulted in more number of fruiting bodies. This observation was in accordance with the results reported by Beje *et al*., (2013) who reported that substrates that gave higher yield also contained higher number of propagating fruit bodies per bunch and highest variability among treatments on the mean number of mature fruit bodies and aborts. In majority of the substrates, the number of pinhead abortions exceeded number of matures. Kimenju *et al*., (2009) reported that more than 50% of pinheads that emerged did not grow into marketable products. Beje *et al*., (2013) observed high rate of pinhead abortion from low-yield substrates such as cordial africana saw dust (sd1*C)* and *Zc*Ch (maize combined with mixed coffee bean husks). The largest (16 cm) pilus diameter was recorded in T3 (30: 40: 30; Teff straw, waste paper and cotton seed waste and the smallest (13cm) with T4 (33.3:33.3:33.3; Teff straw, waste paper and cotton seed waste); Oseni *et al*., (2012) reported the largest pilus diameter from sawdust substrate supplemented with 15% wheat bran (62.3 mm) and the smallest on sawdust substrate supplemented with 5% wheat bran (57.9 mm).

The stipe length for all treatments did not vary significantly (2.5–3.0 cm), which is in agreement with the results reported by Beje *et al*., (2013)(1.4–1.9 cm). Oseni *et al.,* (2012) observed stipe length of oyster mushrooms ranging from 39.4–59.5 mm on fermented sawdust substrate supplemented with different wheat bran levels and highest stipe length (59.5 mm) on substratum supplemented with 15% wheat bran. The total fresh weight of the mushroom was highest in T4 (33.3:33.3:33.3; Teff straw, waste paper and cotton seed waste) (1720 g) followed by T3 (30:40;30 Teff straw, waste paper and cotton seed waste (1605 g) and their biological efficiency of 85 and 80% respectively. In all the parameter tested T4 (33.3:33.3:33.3; Teff straw, waste paper and cotton seed waste) was found to be superior when compared to the rest, this could be due to the proportion of substrates that allows for optimization of bio-availability of the various nutrients contained in the mixture. Kimenju *et al*., (2009) reported that yields of mushroom in different substrates slightly declined from the first flush to the successive harvests. The crops of oyster mushroom were harvested in four flushes and the maximum yield was obtained in the first flush than the

2nd, 3rd and 4th flushes, respectively as observed by Oseni, *et al*. (2012).

Conclusion

Using organic waste as substrate for the production of edible mushroom based on this study finding may be considered as one waste recycling mechanism that will minimize the effect of organic wastes on the environment. Equal proportion of Teff straw, waste paper and cotton seed waste gave highest yield and 85% biological efficiency. This indicates that the lignocellulosic organic material contained in this organic waste was efficiently optimized and fully converted into nutrient rich oyster mushroom biomass. The future research direction should focus on developing a substrate that will give highest yield of mushroom by considering other agricultural wastes in order to obtain the best cocktail of oyster mushroom substrate.

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