Sjournals
Scientific Journals
Agricultural Advances (2014) 3(7) 210-217
ISSN 2251-7820
doi: 10.14196/aa.v3i7.1539

Contents lists available at Sjournals

Agricultural Advances

Journal homepage: www.Sjournals.com

Original article

The effects of cultivation time, local organic substrates and their weight on smallholder urban oyster mushroom production in Zimbabwe

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ARTICLE INFO

Article history,
Received 01 June 2014
Accepted 29 June 2014
Available online 28 July 2014

Keywords,
Oyster mushroom
Cultivation time
Substrate
Urban smallholder
Zimbabwe

ABSTRACT

This study aimed at assessing the effect of cultivation time, local substrates and their weight on urban smallholder oyster mushroom production in Zimbabwe. The study was carried out in a low cost urban mushroom growing house and laid out in a randomized complete block design with each treatment replicated four times. Substrate type was highly significant ($p<0.01$) on days to fruiting, mean number of mushroom, mean mushroom weight and biological efficiency. Evaluation of different substrates for cultivation of oyster mushroom revealed that among the different substrates, wheat straw was superior which recorded minimum days to fruiting (16.62 days), maximum number of mushroom heads (106.25), maximum average yield per 3 months (4826.63g) and highest biological efficiency of 66.88%. Wheat straw accelerated the mushroom growing process having the lowest duration of days to fruiting. The mycelia completed colonization, primordium initiation and fruiting body formation were found within 16.62±0.69, 22.75±0.69, 26.88±0.69 and 31.00±0.69 days for wheat straw, hay, maize stalk and groundnut hulls, respectively. Wheat straw was found to have the highest biological efficiency (66.88±4.59) followed by hay (41.88±4.59), groundnut hull (40.00±4.59) and maize stalk

(39.88±4.59). However, the biological efficiency decreased with increase in substrate weight per bag, and substrate weight did not influence the days to fruiting.

1. Introduction

The cultivation of oyster mushroom and utilization have been on the increase in Zimbabwe especially due to their nutritional importance. This is despite that technology of artificial mushroom cultivation is a recent innovation, which stemmed from the realization that the incorporation of non-conventional crops in existing agricultural systems can help in improving the social as well as the economic status of small farmers (Ajonina and Tatah, 2012). Mushroom is an attractive crop to cultivate in smallholder urban setup for many reasons other than nutrition and income generation. The large amount of agricultural waste in urban areas and congenial climatic conditions provide tremendous scope for oyster mushroom cultivation. It enables smallholder urban farmers with limited land space to acquire substrate materials at low prices or even for free and to conserve our environment by recycling wastes. It is evidently clear that the cultivation of oyster mushroom by smallholder urban farmers has positive implications, such as they can be used to bridge the protein nutritional gap (Bilial et al., 2010) and income generation. On the other hand, mushroom productions in rural communities have alleviated poverty and improve the diversification of agricultural production (Godfrey et al., 2010).

Many studies on nutrient determination have revealed that mushrooms contain substantial amount of essential nutrients like protein, as high as 25.8% protein content as determined on dry wet basis (Olila et al., 2008). Mushroom are also a source of lipids, fibres, minerals, carbohydrates and contains an abundant amount of essential amino acids (Alam et al., 2008; Mallavadhani et al., 2006). It is an excellent source of thiamine, riboflavin, nicotinic acid, pyridoxine and ascorbic acid (Breene, 1990). In general edible mushroom are low in fat and calories, rich in vitamins B, D K and sometimes vitamin A and C (Caglarirmak, 2007) and contain more protein than any other food of plant origin (Bahl, 1998). Randive (2012) reported that oyster mushrooms are rich in Vitamin C, B complex, and mineral salts required by the human body. Oyster mushroom has no starch, low sugar content and high amount of fibre, hence it serves as the least fattening food (Osei, 1996).

As mushrooms are increasingly becoming an important component of diets worldwide and it is of paramount importance to choose appropriate substrates in a given place to grow them (Ajonina and Tatah, 2012). Mushroom substrate may be defined as a kind of lingo cellulose material which supports the growth, development and fruiting of mushroom (Chang and Miles, 1988). Substrate type is one of the major factors affecting the yield and quality of oyster mushroom (Chitamba et al., 2012). Most of all, oyster mushrooms (Pleurotus spp.) can utilize various kinds of substrate materials than any other mushrooms. The growth of diverse type of mushrooms require different type of substrates and availability of varied type of materials may dictate which type is used (Shah et al., 2004). Elsewhere, in a descending order of suitability of substrates bean, rice, finger millet and wheat straw were recommended for smallholder mushroom production (Kimenju et al., 2009). Substrates enriched by plant origin complements lead to a slow release of organic materials which could be taken up by the mycelium structures (Royse et al., 1991). Kumar et al., (2004) reported the successful cultivation of oyster mushroom on conventional substrates sufficiently available which are not utilized properly and productively. The purpose of this study was to assess the effects of cultivation time, local substrates and their weight on urban smallholder oyster mushroom production in Zimbabwe.

2. Materials and methods

2.1. Study area

Indoor propagation of mushrooms was carried out in the high density suburb of Lobengula West,Bulawayo in Zimbabwe. Bulawayo is situated on the south western part of Zimbabwe, 28:51E and 20:13S. Bulawayo experiences short dry winter followed by summer rains and receives average rainfall of 450 to 650mm.

2.2. Cultivation method

A room with brick wall measuring 4x4m was used for the indoor mushroom production .A knitted thatch grass mat was used for insulating the room to control the temperature and humidity. The bottom part of the walls were designed with aeration holes measuring 20x15cm .The holes were covered with mash wire forallowing air in and out of mushroom house. The flows were covered with 10cm thickness layer of river sand .The river sand was the cooling media within the mushroom growing house. Standard size bricks were put on top of the river sand layer. Mushroom grow bags were placed on top of the bricks during the growing period.

Grow bags were made of white polythene with a thickness of 75micron and 50cm diameter .The length was 100cm for 10kg weight substrate and 50cm for the 5kg weight substrate. The substrates used were initially dried and chopped to measure 5to 7cm for grass and 1.3to2cm for the legume(ground nut hulls in size .The process of bagging and spawning was done by feeding the bags with pasteurised substrate to a length of 10cm. The spawn was sprinkled over a shallow layer of substrate. The next layer of substrate was put and spawn sprinkled. The spawning process was repeated until thebag was filled up.The bag was then tied without living any air space .The bags perforated with a sharp pointed nail around the bags at a1.2cm distance from one hole to the other. Holes were punched to ensure adequate oxygen and carbon dioxide concentrations and gaseous exchange. The base of the bags was punched to make holes of 1.0 to 1. 2cm. Bottom holes were punched at intervals of 10cm to allow easy drainage of excess water.

2.3. Spawn run

After inoculationthe bags were incubated inthe growing house. The bags were covered with a black polythene plastic cover to control light, temperature and humidity. The bags were placed at distances of 25cm apart .During the spawn run stage, the grow bags were daily observed for contamination.

2.4. Mushroom management

Within the growing house, the temperatures and humidity were monitored using thermometer and hygrometer respectively. Humidity levels were controlled by continuous sprays of fine droplets of knapsack sprayer. The temperature were reduced by keeping walls and floor wet .A foot bath at the entrance of the growing room was kept with diluted Jik solution (disinfectant) was changed every two weeks to keep the environment highest hygiene levels. Mushrooms were covered with black polythene to initiate complete darkness within the grow bags. Holes were punched to ensure that the basidiocarps started to protrude out of the grow bags. Polythene covers were removed at three weeks to allow maximum light to speed up growth and improve shinny colour of mushroom basidiocaps when incubation period was over. A humid condition was maintained by spraying water using a knapsack sprayer on the walls and floors three times a day. Harvesting was done manually before the basidiocarps reached maturity .Basidiocarps were harvested at 10day intervals , their weight were recorded using a digital scale. The number of days to maturity were recorded. For every 4 harvests from each substrate an average was calculated. Basidiocarps were classified according to different standard grades namely; flats, caps and fully mature. Biological efficiency was calculated as number of basidiocarps harvested divided by expected yield per substrate multiplied by 100.

2.5. Data analysis

The data on different cultivation time, substrate type and weight were analyzed using the general linear model (GLM) procedure of SAS (1999). Means were separated using the Duncan comparison of means procedure. The following statistical model was used in the analysis:

$$Yijkl = \mu + Bi + Tj + Wk + eijkl$$

Where Yij is the dependent variable; μ is the overall mean; Bi is the cultivation time effect; Tj is the substrate type (Wheat straw, Hay, Maize stalk, Groundnut hull); Wk is the substrate weight (5kg vs 10kg) effect; eijkl is experimental error.

3. Results and discussion

The descriptive statistics, analysis of variance and the least squares means± SE for mushroom productive parameters are shown in Table 1, 2, 3, 4 and 5. In the present study wheat straw was found to be a good substrate for cultivation of oyster mushroom which is in agreement with the earlier reports (Kumar and Achal, 2008). Highest yield of oyster mushroom was observed on wheat straw and the next best option was maize stalk (Table

4). This varied production potential of different substrates might be due to the variations in their physical properties and nutritional composition. Substrate type was highly significant (p<0.01) on days to fruiting, mean number of mushroom, mean mushroom weight and biological efficiency. Wheat straw accelerated the mushroom growing process having the lowest duration of days to fruiting. The mycelia completed colonization, primordium initiation and fruiting body formation were found within 16.62±0.69, 22.75±0.69, 26.88±0.69 and 31.00±0.69 days for wheat straw, hay, maize stalk and groundnut hulls, respectively. Yang et al., (2013) observed that for both sterilized substrate and non-sterilized substrate, oyster mushroom on wheat basal substrate have faster mycelial growth rate, comparatively poor surface mycelial density, shorter total colonization period and days from bag opening to primordia formation, lower yield and biological efficiency and lower mushroom weight than that on cotton seed hull basal substrate. However, the addition of cotton seed hull to wheat straw substrate slowed spawn running, primordial development and fruit body formation.

Groundnut hull had the lowest had the least oyster mushroom yields which is contrary to observation by Poppe (1995) who reported that legume straws, mostly rich in N, was suitable as Pleurotus substrates. Maize stalk had the least biological efficiency of 39.88± 4.59, which was lower than maize straw biological efficiency of 52% for Pleurotus sajor- caju (Pani et al., 1997). Cereal straw has 0.5% total N, 38% cellulose, 15% lignin, C/N = 90 (Kaul et al., 1981), which suggest that basic substrate for oyster mushroom may need to b enriched with different additive to maximize production. Royse et al., (2004) suggested that physical processing of substrates material such as maize stalk through milling, may improve yield potential.

Table 1
Descriptive statistics for growth and productive parameters of Oyster Mushroom in Zimbabwe

Parameter	N	Mean	Standard Deviation	R-Square	CV%
Days to first fruiting (Dff)(days)	32	24.31	5.74	0.92	23.60
Mean number of mushroom (Mnm)	32	90.31	24.79	0.74	27.44
Average yield (Ay) (g)	32	3519.1	1517.04	0.79	43.11
Biological efficiency (BE%)	32	47.16	17.93	0.64	38.03
Cups	32	19.72	12.75	0.45	64.64
Mature	32	22.91	13.40	0.57	58.51
Flat	32	12.53	4.22	0.39	33.67
Spoiled	32	7.22	4.18	0.48	57.90

Table 2
Analysis of variance (mean squares) for growth and productive parameters of Oyster mushroom in Zimbabwe.

Source	Df	Dff	Mnm	Ay	BE%
Cultivation Time	3	9.791NS	1157.04**	48111921.95**	1597.84*
Substrate	3	300.875**	1474.880**	6272576.11**	4167.59**
Weight	1	1.125NS	3280.50**	21071409.03**	385.03NS
Substrate*Weight	3	2.708NS	989.25*	782592.36NS	269.34NS
Error	21	3.791	233.380	698607.42	169.01

*(P< 0.05), **(P<0.01), ns=non significant.

Table 3
Analysis of variance (mean squares) for growth and productive parameters of Oyster mushroom in Zimbabwe.

Source	Df	Spoiled	Cup	Mature	Flat
Cultivation time	3	155.34*	127.86ns	374.11*	119.34ns
Substrate	3	46.09ns	563.86*	634.11**	42.59ns
Weight	1	30.03ns	108.78ns	16.53ns	0.03ns
Substrate*Weight	3	26.09ns	25.95ns	44.86ns	52.59ns
Error	21	13.51	132.13	113.95	16.07

*(P< 0.05), **(P<0.01), ns=non significant.

Table 4

Least squares means and standard errors for growth and productive traits of Oyster mushroom in Zimbabwe.

Factor	N	Dff	Mnm	Yield	BE%
Substrate					
Wheat straw	8	16.62±0.69a	106.25±5.40a	4826.63±295.5a	66.88±4.59a
Hay	8	22.75±0.69b	87.50±5.40ab	3125.00±295.5b	41.88±4.59b
Maize stalk	8	26.88±0.69c	93.88±5.40ab	3250.00±295.5b	39.88±4.59b
Groundnut hulls	8	31.00±0.69d	73.65±5.40c	2875.00±295.5b	40.00±4.59b
Weight of substrate					
5 kg	16	24.50±0.49a	80.19±3.82a	2707.69±208.96a	50.63±4.59a
10 kg	16	24.13±0.49a	100.44±3.82b	4330.63±208.96b	43.69±4.59b
Cultivation time					
January to March	8	25.13±0.68a	97.00±5.40a	4321.87±295.5a	55.88±4.5a
April to May	8	23.63±0.68b	94.50±5.40a	3254.75±295.5b	44.75±4.5ab
June to August	8	23.13±0.68b	97.38±5.40a	3937.50±295.5bc	51.00±4.5a
September to December	8	25.38±0.68c	72.38±5.40b	2562.50±295.5d	37.00±4.5b

Means with different superscripts in the same column differ significantly ($p<0.05$).

Table 5

Least squares means and standard errors for growth and productive traits of Oyster mushroom in Zimbabwe.

Factor	N	Cups	Mature	Flat	Spoiled
Substrate					
Wheat straw	8	30.75±4.06a	33.88±3.78a	14.38±1.42a	9.25±1.29a
Hay	8	21.25±4.06ab	26.00±3.78ab	11.25±1.42a	6.75±1.29a
Maize stalk	8	15.50±4.06b	18.00±3.78bc	12.00±1.42a	6.75±1.29a
Groundnut hulls	8	11.37±4.06b	13.75±3.78c	12.50±1.42a	6.13±1.29a
Weight of substrate					
5 kg	16	21.56±4.59a	22.19±2.67a	12.50±1.00a	6.25±0.91a
10 kg	16	17.88±4.59a	23.63±2.67a	12.56±1.00a	8.19±0.91a
Cultivation time					
January to March	8	24.25±4.06a	25.00±3.78a	12.38±1.41a	10.38±1.29a
April to May	8	21.75±4.06a	28.25±3.78a	13.13±1.41a	4.75±1.29b
June to August	8	17.38±4.06a	25.50±3.78a	15.00±1.41ab	8.13±1.29ab
September to December	8	15.50±4.06a	12.88±3.78a	9.63±1.41b	5.63±1.29b

Means with different superscripts in the same column differ significantly ($p<0.05$).

The appreciable days to complete mycelium running of oyster mushroom on different substrates might be due to variation in their chemical composition and C: N ratio as reported by Bhatti et al. (1987) and Mondal et al (2010). The same author suggested the mixing of wheat straw with other organic material to improve mushroom production. Maximum yield (weight of fresh mushrooms harvested at maturity) was obtained on cottonseed hull/wheat straw substrate at a 3.75-5% spawn level and 6% S-41 supplement however, on switch grass substrate, increasing spawn levels and supplement levels stimulated yields in a linear fashion. Comparing rice straw with wheat straw, rice straw yielded about 10% more mushrooms than wheat straw under the same cultivation conditions (Zhang et al., 2002). However, this was depended on ground straw yielding higher mushroom growth rate and yield than the chopped straw. This means apart from the substrate type particle size had an effect on mushroom yield. Sainos et al., (2006) observed high activity of proteases and high content of intracellular protein in cultures grown on wheat straw. This suggests that the proteases are not secreted into the medium and that the protein is an important cellular reserve. On the contrary, cultures grown on wheat straw secreted laccases into the medium, which could be induced by this substrate. P. ostreatus grown on media prepared with a combination of wheat straw and wheat grain showed a high radial growth rate. Their results showed that cheaper and more productive mushroom spawn can be prepared by developing the mycelium on wheat straw and wheat-grain-based substrates. Using off-line thermochemolysis with tetramethylammonium hydroxide and solid-state (13)C NMR in

the molecular characterization of the undegraded wheat straw and the degraded samples Vane et al., (2001) observed that the degraded wheat straw samples had a lower proportion of syringyl- to guaiacyl-derived moieties and cinnamyl- to guaiacyl-derived moieties than the undegraded control. There were increases in both guaiacyl and syringyl acid to aldehyde ratios with composting time, which showed that side-chain oxidation has been mediated by P. ostreatus as a result there was a decrease in amorphous noncellulosic polysaccharides in relation to the crystalline cellulose upon degradation. These whole processes influence the growth of mushroom on the wheat straw.

Wheat straw was found to have the highest biological efficiency (66.88±4.59) followed by hay (41.88±4.59), groundnut hull (40.00±4.59) and maize stalk (39.88±4.59) (Table 4). However, the biological efficiency decreased with increase in substrate weight per bag and substrate weight did not influence the days to fruiting. Gitte et al., (2014) observed the biological efficiency of different substrate which ranged from 51.57 - 146.3 %. The highest biological efficiency 146.3% was observed in wheat straw. The next best in order was paddy straw- 132.4%. Whereas, soybean straw coconut coir pith and cotton waste performed 126.1%, 108.7 % and 92.07% biological efficiency, respectively. The range reported in the present study was within this range, although on the lower side. Wheat basal substrate had a faster mycelial growth rate, comparatively poor surface mycelial density, shorter total colonization period and days from bag opening to primordia formation, lower yield and biological efficiency than that on cotton seed hull basal substrate (Yang et al., 2013). Increasing the weight of different substrates can increase the total yield per season but reducing the biological efficiency . However, the time of cultivation shoed that may significantly influence mushroom yield and biological efficiency, but some undesirable characteristics, i.e. more spoiled mushroom in January to March. Obodai et al. (2003) reported a biological efficiency ranging from 61 to 0% for P. ostreatus. This could be due to the different substrate formulations and strain variations. However, the highest fruiting body number (36.33), fruiting body weight (31.17 g), yield (1039 g), and biological efficiency (207.8 %) belonged to wheat straw complemented by either wheat or rice bran (Mehrdad et al., 2011).

4. Conclusion

Utilization of agricultural waste in urban areas for production of oyster mushroom could be more economically and ecologically practical. There was momentous variation in average yield on different substrate weight. However, fewer substrate weight comparisons (5 kg= 270g/kg vs 10 kg =433g/kg) were made, which means there is need to assess the effects of more different substrate weights regimes on mushroom yield to ascertain the exact weight for optimal weight of production. This is because the average mushroom weight increased with increase in substrate weight. Groundnut hulls, gave the least yield, biological efficiency and mean number of mushroom which suggest it may not be a suitable substrate for oyster mushroom production. However, due to availability of groundnut hulls in urban setup, studies can further investigate the use of additives on groundnut hull. This study shows the prospects of oyster mushroom cultivation on wheat straw in Zimbabwe and suggests further study in controlled environment and use of additives for higher yield and production.

Acknowledgement

This articles was part of a study in fulfillment of the BSc Agriculture Management at Zimbabwe Open University by the second author.

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