African Journal of Biotechnology Vol. 11(37), pp. 8979-8985, 8 May, 2012
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB11.2525
ISSN 1684–5315 © 2012 Academic Journals

Full Length Research Paper

Performance of oyster mushroom (*Pleurotus ostreatus)* in different local agricultural waste materials

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Accepted 16 April, 2012

The present study was conducted to evaluate different substrates for establishment of yield performance of oyster mushroom (*Pleurotus ostreatus*). The substrates were prepared from single or mixture of different agricultural waste materials supplemented with lime and water as additive to each substrate. A total of eight substrates labeled 1 to 8 were prepared. Substrate 4, which is a mixture of palm kernel cake and maize cob, had the highest mycelia growth rate (80%), sprouted 15 days after inoculation and yielded the highest total fresh weight for a period of 10 harvests (2957.5 g). Substrate 3, a mixture of palm kernel cake and sawdust, had 78% mycelia growth rate, sprouted 16 days after inoculation and yielded 2535.7 g fresh mushroom. Substrate 2 is a mixture of maize straw and sawdust and had 75% mycelia growth rate, sprouted 17 days after inoculation and a total of 2207.4 g fresh weight. The mushroom grown in substrates 4, 3 and 2 produced bigger and firmer fruiting bodies, which differed significantly ($P < 0.05$) from the other substrates. Substrates 1 and 5 which had 50% mycelia growth rate, sprouted 31 and 33 days after inoculation and 1408.8 and 1092.6 g, respectively, were recorded after a period of 10 harvests. Substrate 4, 3 or 2 is therefore recommended for cultivation of oyster mushroom.

Key words: Oyster mushroom (*Pleurotus ostreatus*), mycelial growth, palm kernel cake (PKC), substrate, maturity.

INTRODUCTION

Oyster mushroom (*Pleurotus ostreatus*) is a common edible mushroom long cultivated in Asia. China is the world's largest edible mushroom producer (Dinghaun and Xiaoyong, 2004). Recently, oyster mushroom is cultivated around the world, especially in subtropical and temperate regions. It is a saprophyte that acts as a primary decomposer of woods especially deciduous trees, particularly beech (Phillips and Roger, 2006). Oyster mushroom can adapt better than other species of mushroom outside their place of origin (Chang and Miles, 2004). It can also be artificially cultivated on straw and other media. Huge quantities of lignocellulose agricultural residues are generated annually through agricultural and food processing industries (Buswell, 1991). Most of the agricultural residues such as rice bran, maize straw, maize cob, palm products and sawdust are wasted, while majority constitute environmental hazard. One of the best uses of these agricultural waste materials apart from using them to feed farm animals is to use them as growth media for mushroom production. Onokpise et al. (2007) reported that recycling waste and supplementation techniques in the production of mushrooms especially *Pleurotus* species that live on a wide range of substrates is beneficial to reduce pollution control.

Oyster mushroom is frequently consumed as soup, tea and pepper soup. It is medicinal because it contains statins such as lovastatin which reduce cholesterol levels (Gunde and Cimerman, 1995). The Food and Agricultural Organization (FAO) has recommended the use of mushrooms as a potential food source since mushrooms

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Table 1. Mixture of the materials and their weights.

Substrate	Maize straw (kg)	Maize cob (kg)	Palm kernel cake (kg)	Sawdust (kg)	Spent grain (kg)	Rice bran (kg)	Lime (kg)	Water (L)
1	7.5	0	0	0	0	2.0	0.2	40
2	7.5	0	0	2.0	0	0	0.2	40
3	0	0	7.5	2.0	0	0	0.2	40
4	0	2.0	7.5	0	0	0	0.2	40
5	0	0	0	7.5	2.0	0	0.2	40
6	9.5	0	0	0	0	0	0.2	40
7	0	9.5	0	0	0	0	0.2	40
8	0	0	0	9.5	0	0	0.2	40

have the capacity to convert agricultural wastes into rich protein foods (Chang and Hayes, 1978). They are also good sources of non-enzymatic antioxidant vitamins (Kumari and Achal, 2008).

Oyster mushrooms are a more valuable source of protein than either cattle or fish on dry weight basis, and are good source of almost all the essential amino acids when compared with most vegetables and fruits (Matila et al., 2002).

The use of local agricultural waste materials to grow mushroom will be of great benefit to farmers and the entire Nigerian population. Such waste materials can easily be obtained economically and locally, will provide eco-friendly and greener option to grow mushrooms. However, we need to look for the best mixture of the local agricultural waste materials to be used for oyster mushroom productions.

The successful implementation of mushroom farming techniques has the possibility of engaging thousands of farmers in mushroom production, thereby producing enough mushroom to feed millions of people in Nigeria.

Presently, cotton wastes and sawdust are the only agricultural wastes currently in use for production of substrates needed for mushroom growth (Danai et al., 1989). There is need to find other agricultural wastes to develop other substrates that can serve well than the already known substrate.

Palm kernel cake for instance can perform better than cotton wastes because they contain proteinaceous nutrients needed for mushroom growth (Kamarudin, 2006). Wastes from corn such as straw and cob are good sources of materials needed for producing substrates (Bassous et al., 1989). The objective of this study was to evaluate different mixtures of agricultural waste materials as substrates for oyster mushroom growth and yield performance.

MATERIALS AND METHODS

Agricultural waste materials used for the study include maize straw, maize cob, palm kernel cake, sawdust, spent grain and rice bran. These materials were collected fresh from the South East Zonal Biotechnology Centre and Department of Crop Science, University of Nigeria, Nsukka. The experiment was carried out at the Tissue Culture Laboratory of the South East Zonal Biotechnology Centre, University of Nigeria, Nsukka. The materials were sun-dried for one week before using. The dried maize straw and maize cobs were chopped while others were grounded. They were then mixed thoroughly with lime and water to produce eight substrates labeled substrates 1 to 8 (Table 1). Each substrate was replicated four times.

These mixtures were compressed by pressing down with bottle in transparent poly bags with length of 50 cm and width of 27 cm. They were kept for one day in a drum for fermentation to take place before steaming. The bags were then placed on wooden stands of 60 cm long inside two metal drums filled up to one-fifth (1/5) its volume with water such that the bags on the stands were 25 cm above the level of the water for steaming purpose. The bags were stem sterilized at the temperature of 100°C for 7 h and allowed to cool for 48 h before inoculation in aseptic environment in a laminar flow chamber at the laboratory of Crop Science Department, University of Nigeria, Nsukka. 25 g of oyster mushroom spawn collected from National Biotechnology Development Agency, Bioresources Development Centre, Odi, Bayelsa State, Nigeria, was introduced with inoculation hook into a hole created at each bag containing the substrate. The bags were transferred to an incubation room immediately after inoculation for mycelia growth. The bags were then opened after two weeks and left open for mushroom growth. The experiment was carried out once and there was no initial trial.

Data collection

Mycelial growth (%) was obtained by observing and measuring the rate of colour change in each substrate with measuring tape by placing the tape at the base of each substrate bag from where the change in colour starts to where it stopped. Days to first sprouting of mushrooms were recorded at sprouting. The number of first sprouted mushrooms was obtained by counting. The height of each mushroom at sprouting (cm) was obtained by measuring each mushroom with measuring tape from the base. Girth at sprouting (mm) was obtained by measuring the girth of the stipe at the base with a micrometer screw gauge. Diameter of cap at sprouting (cm) was obtained by measuring each cap with a meter rule. The number of caps at sprouting was obtained by counting. Days to maturity of first sprouted mushroom was obtained by recording the date at maturity. Height at maturity (cm) was obtained by measuring the height from the base with a meter rule at maturity. In addition, girth at maturity (mm) was obtained by measuring the girth of the

Table 2. Mycelial growth (%) and other characteristics of oyster mushroom grown in different substrates at sprouting.

Substrate	Days to first sprouting	Stipe height (cm) at sprouting	Stipe girth (mm) at sprouting	Number of sprouted mushroom	Diameter of cap at sprouting (cm)	Number of caps at sprouting	Mycelial growth (%)
1	31^{ab}	3.0^{ab}	5.3^{ab}	7^{b}	4.3^{a}	6^{a}	50^{b}
2	17^{b}	3.6^{ab}	6.5^{ab}	10^{ab}	4.5^{a}	5^{a}	75^{a}
3	16^{b}	4.8^{a}	9.0^{a}	14^{a}	4.9^{a}	6^{a}	78^{a}
4	15^{b}	6.5^{a}	9.4^{a}	15^{a}	5.9^{b}	6^{a}	80^{a}
5	33^{ab}	2.6^{ab}	5.0^{ab}	5^{bc}	4.3^{a}	4^{ab}	50^{b}
6	45^{a}	1.3^{b}	2.1^{b}	3^{c}	2.6^{c}	3^{ab}	35^{c}
7	46^{a}	1.2^{b}	1.7^{b}	4^{c}	2.7^{c}	3^{ab}	35^{c}
8	46^{a}	1.8^{b}	2.0^{b}	4^{c}	3^{c}	4^{ab}	20^{d}
LSD0.05	2.54	1.72	1.55	1.80	0.09	1.12	7.8^{4}
Standard error	0.89	0.60	0.19	0.63	0.06	0.39	2.75

Values with the same alphabet (s) along the vertical column are not significantly different (P > 0.05).

stipe at the base with a micrometer screw gauge, while diameter of cap at maturity was obtained by measuring each cap with a meter rule. The number of caps at maturity as well as number of mushrooms was obtained by counting. Finally the fresh weight (g) of harvested mushrooms was weighed immediately after each harvest.

Statistical analysis

The data were statistically analyzed using the statistical analysis system package (SAS). Means were separated by the least significant difference (LSD) at 5% significance level.

RESULTS

The results of the performance of oyster mushroom grown in the different agricultural waste materials are presented in Tables 2 to 4. Substrates 4, 3 and 2 differed significantly (P < 0.05) from substrates 1 and 5 in all the parameters collected. Substrates 1 and 5 also differed significantly (P < 0.05) from substrates 6, 7 and 8 in all the parameter collected. In addition, the results obtained reveal that substrates 4, 3 and 2 did not differ significantly (P > 0.05) among themselves. Substrates 1 and 5 varied but the differences were not significant (P > 0.05). Similarly, substrates 6, 7 and 8 varied but statistically the same.

Figure 1A shows the mycelial growth in all the substrates. The mean rate of mycelia growth was fastest in substrates 4, 3 and 2 (Table 2). The percentage mycelia growth rate was 80, 78 and 75%, respectively for substrates 4, 3 and 2 (Table 2). The average mycelial growth rate (50%) was observed in substrates 1 and 5, while low mycelia growth rate (less than 40%) was observed in substrates 6, 7 and 8, respectively. Furthermore, the results obtained from the different substrates with respect to days of first sprouting of the mushrooms after inoculation reveal that the mushrooms in substrates 4, 3 and 2 sprouted before the mushrooms in the other substrates. The mean number of days to first sprouting of the mushrooms in these substrates was 15, 16 and 17 days, respectively after inoculation. The incubation period for the inoculated mushroom spawn in substrate 4 was 14 days after inoculation, while those of substrates 3 and 2 were 15 and 16 days, respectively after inoculation. The first sprouted mushroom in substrates 4, 3 and 2 also matured faster than those of the other substrates. The sprouted mushrooms in these three substrates matured within 24 h of sprouting. The mean number of days to first sprouting of mushrooms in substrates 1 and 5 were 31 and 33 days, respectively after inoculation, while those of substrates 6, 7 and 8 were 45, 46 and 46 days, respectively after inoculation, an indication of poor performance level than those of the other substrates. Moreover, the mushrooms grown in substrates 1 and 5 matured 2 days (48 h) after sprouting, while those grown in substrate 6 matured 3 days after sprouting and those grown in substrates 7 and 8 matured 5 and 3 days, respectively after sprouting.The mean height of the first sprouted mushrooms in substrates 4, 3 and 2 were 6.5 cm, 4.8 cm and 3.6 cm, while those of substrates 1 and 5 were 3.0 cm and 2.6 cm and those of substrates 6, 7 and 8 were 1.3 cm, 1.2 cm and 1.8 cm respectively. The mean height of

Table 3. Characteristics of Oyster mushroom grown in different substrates at maturity.

Substrate	Days to maturity	Stipe height (cm) at maturity	Stipe girth (mm) at maturity	Number of mushrooms at maturity	Diameter of cap at maturity (cm)	Number of caps at maturity
1	33^{ab}	7.0^{b}	6.6^{bc}	7^{b}	9.5^{c}	6^{a}
2	18^{b}	6.9^{b}	12.6^{ab}	10^{ab}	12.0^{b}	5^{a}
3	17^{b}	9.5^{ab}	15.5^{a}	14^{a}	13.5^{ab}	6^{a}
4	16^{b}	12.5^{a}	14.6^{a}	15^{a}	16.0^{a}	6^{a}
5	35^{ab}	5.5^{b}	9.7^{b}	5^{bc}	7.4^{cd}	4^{b}
6	48^{a}	2.3^{c}	4.2^{c}	3^{c}	4.4^{d}	3^{b}
7	51^{a}	2.3^{c}	3.5^{c}	4^{c}	3.8^{d}	3^{b}
8	49^{a}	3.3^{c}	4.1^{c}	4^{c}	4.3^{d}	4^{b}
LSD 0.05	2.55	1.80	1.72	1.80	1.32	1.12
Standard error	0.89	0.63	0.60	0.63	0.46	0.39

Values with the same alphabet (s) along the vertical column are not significantly different (P > 0.05).

Table 4. Fresh weight (g) of Oyster mushroom in different substrates immediately after each harvest.

Substrate	First harvest	Second harvest	Third harvest	Fourth harvest	Fifth harvest	Sixth harvest	Seventh harvest	Eighth harvest	Nineth harvest	Tenth harvest	Total
1	153.5^{b}	154.0^{b}	154.2^{b}	165.0^{b}	172.5^{b}	170.1^{b}	169.5^{ab}	145.0^{bc}	95.0^{d}	30.0^{c}	1408.8^{b}
2	220.0^{ab}	224.0^{a}	229.1^{a}	250.3^{a}	270.2^{a}	270.5^{a}	251.0^{a}	200.1^{ab}	150.1^{c}	142.1^{b}	2207.4^{ab}
3	257^{a}	260.2^{a}	260.3^{a}	278.0^{a}	300.1^{a}	270.0^{a}	272.1^{a}	250.0^{a}	230.0^{b}	158^{b}	2535.7^{ab}
4	292^{a}	304.8^{a}	310.0^{a}	320.1^{a}	330.2^{a}	320.1^{a}	305.2^{a}	300.1^{a}	255^{a}	250^{a}	2957.5^{a}
5	136^{b}	132^{b}	140^{b}	140.0^{b}	150^{b}	139^{b}	100^{bc}	92.5^{c}	33.1^{c}	30.0^{c}	1092.6^{b}
6	82^{c}	80^{c}	82^{c}	70^{c}	60^{c}	52^{c}	32^{c}	20^{d}	0^{f}	0^{d}	478^{c}
7	83^{c}	79^{c}	80^{c}	80^{c}	65^{c}	52^{c}	29^{c}	20^{d}	0^{f}	0^{d}	488^{c}
8	100^{c}	95.1^{c}	100^{c}	101^{c}	90^{c}	72^{c}	40^{c}	30^{d}	25^{c}	0^{d}	653.1^{c}
LSD 0.05	68.2	75.5	78.2	80.8	78.5	72.0	65.9	51.2	21.5	19.9	350.0
Standard error	23.9	26.5	27.4	28.4	27.5	25.3	23.1	18.0	7.5	7.0	122.8

Values with the same alphabet (s) along the vertical column are not significantly different (P > 0.05).

the first sprouted mushroom in substrates 4, 3 and 2 at maturity were 12.5 cm, 9.5 cm and 6.9 cm. Generally, the highest growth rate was observed in substrate 4 (Figures 1C to E). Also, the widest girths (thickness of stipe) were obtained in the mushrooms grown in substrates 4, 3 and 2 at both first sprouting and maturity. The increase in thickness of stipe was recorded at maturity in the mushroom grown in substrates 3 and 4 with thickness of 15.5 and 14.6 mm, respectively. The least thickness of the fruiting body was recorded in substrates 6, 7 and 8. Though the same weight (25 g) and quantity of mushroom spawn was introduced into each substrate 5 kg per bag at inoculation, the largest number of mushroom at

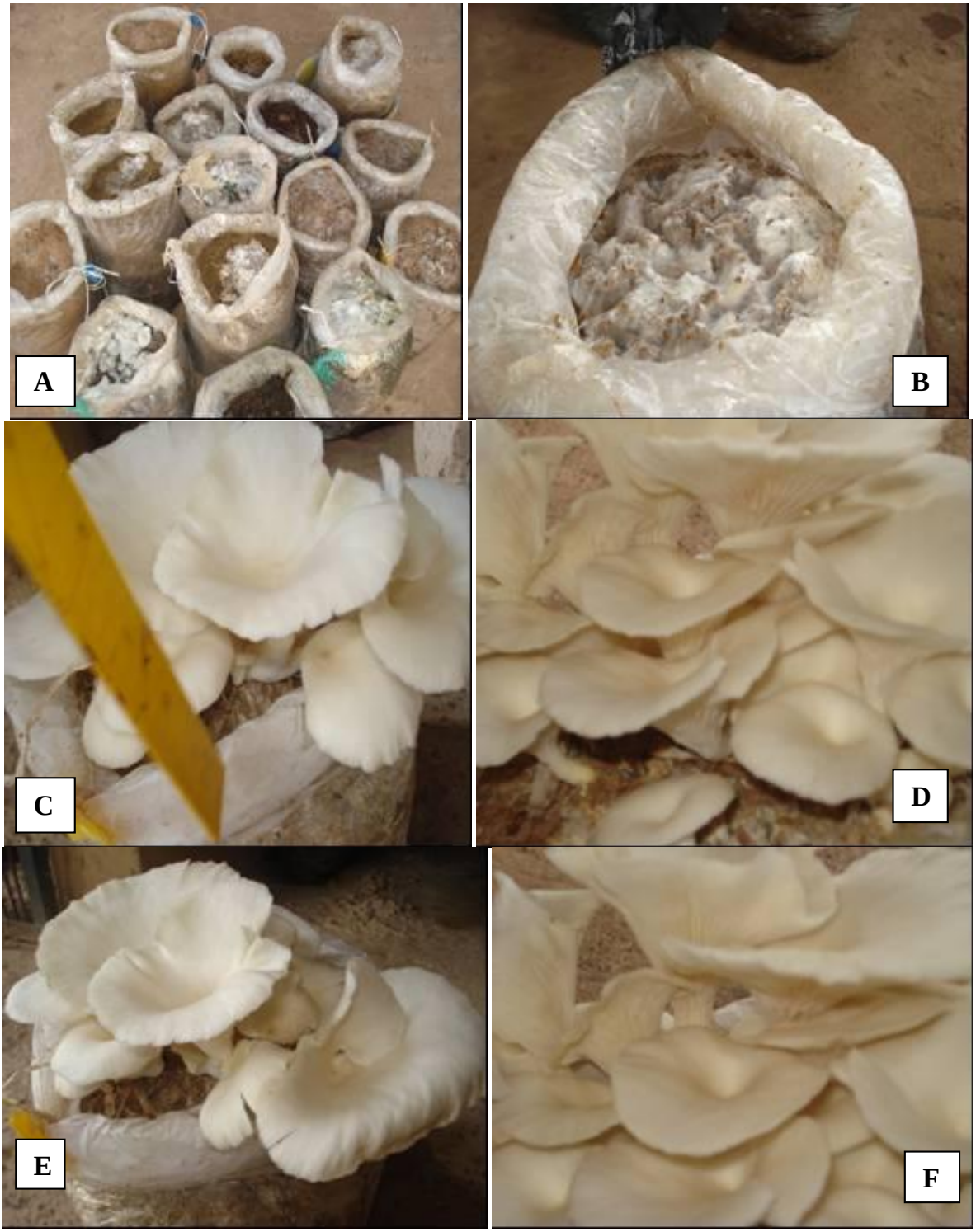

Figure 1. (A) Mycelia growth rate in different substrates. (B) Full colonization of mycelia ready for mushroom growth in substrate 4. (C to F) Morphological characteristics of oyster mushroom at maturity in substrate 4.

sprouting and at maturity were recorded in substrates 4, 3 and 2, indicative of their better performance level than the other substrates. Substrates 1 and 5 were intermediate with respect to number of sprouted and mature mushroom, while substrates 6, 7 and 8 were the poorest.

The results obtained also reveal that the diameter of caps of the mushrooms in substrates 4, 3 and 2 at maturity were more than those of the other substrates

(Tables 2 and 3). The least diameter of caps both at sprouting and maturity was obtained in substrates 6, 7 and 8. The total fresh weight of oyster mushroom harvested from substrates 4, 3 and 2 differed significantly ($P < 0.05$) from those of substrates 1 and 5, while those of substrates 1 and 5 differed significantly ($P < 0.05$) from those of substrates 6, 7 and 8. The total fresh weight of oyster mushroom obtained after 10 harvesting periods from substrates 4, 3 and 2 were more than those from the other substrates (Table 4). The harvested mushroom in substrates 6 and 7 stopped at eighth harvest, while in substrate 8 it stopped at ninth harvest, indicating that the nutrients in these substrates were exhausted before the end of the study.

DISSCUSSION

The fastest mycelia growth rate was observed in substrates 4 and 3. The palm kernel cake (PKC) present in substrates 4 and 3 may have contributed to the faster growth rate of mycelia observed in the substrates. This is in agreement with Somitra et al. (2007) that palm kernel cake is a local source of proteinaceous nutrients and supports mycelia and general mushroom growth. The mycelia growth rate in substrates 1 and 5 were observed to be average (50%), while those of substrates 6, 7 and 8 were poor (less than 40%). The results obtained from substrates 1 and 5 also suggest that waste materials from maize can be good sources of substrate preparation. The poor mycelia growth rate observed in substrates 6, 7 and 8 may be due to lack of proteinaceous materials in the substrates or due to other factors such as the structure or physical properties of the materials.

The results of the days to first sprouting of the mushrooms from the different substrates after inoculation reveals that the mushrooms in substrates 4, 3 and 2 sprouted before the mushrooms from the other substrates. The incubation period for the inoculated mushroom spawn in substrate 4 was 14 days after inoculation, while those of substrates 3 and 2 were 15 and 16 days, respectively after inoculation. The incubation periods of the inoculated mushroom spawn in the other substrates were far above the recommended incubation period of 14 days for oyster mushroom, an indication of poor performance of the substrates with respect to incubation period and days to first sprouting of the mushrooms. These differences in incubation periods could probably be related to structure of the materials which controls the temperature and moisture contents of the substrates (Sohi and Upadhyay, 1989). In addition, the highest height of mushrooms at maturity was recorded in substrate 4, while the least was from those grown in substrates 6 and 7. The reason for the poor growth of mushrooms observed in substrates 6 and 7 may be attributed to single agricultural waste materials used in preparing the substrates. Results further indicate that the widest girths were obtained in mushrooms grown in substrates 4, 3 and 2 at both first sprouting and maturity. Onokpise et al. (2007) established that palm kernel cake improves the thickness of fruiting bodies of mushroom species. This increase in thickness of the stipe was recorded at maturity in mushrooms grown in substrates 3 and 4.

The highest number of mushroom was recorded in substrates 4, 3 and 2 both at sprouting and maturity throughout the period of the study, an indication of better performance level than the other substrates. The least number of mushrooms were recorded in substrates 6, 7 and 8. However, the number of caps obtained in all the substrates was not the same. Substrates 1, 2, 3 and 4 differed significantly ($P < 0.05$) from substrates 5, 6, 7 and 8. The number of caps obtained in substrates 1, 2, 3 and 4 were more than those obtained in substrates 5, 6, 7 and 8 both at sprouting and maturity. The diameter of caps were approximately the same in all the substrates at sprouting but was not same at maturity. Substrates 4, 3 and 2 produced the highest diameter of cap at maturity. The diameter of cap in these substrates was 16, 13.5 and 12 cm, respectively at maturity. Gunde and Cinerman (1995) reported that oyster mushroom has a cap spanning diameter of 5 to 25 cm at maturity, and the results of this work are within the range they reported.The total fresh weights of oyster mushroom obtained from substrates 4, 3 and 2 after a period of 10 harvests were more than those obtained from the other substrates. The increase in fresh weight of oyster mushroom appeared to be dependent on the presence of either of the following in the substrates: palm kernel cake, maize cob, maize straw, rice bran and sawdust at the appropriate proportions. Oei (2003) reported that oyster mushroom performed better when cultivated in lignocelluloses rich waste materials like maize straw, sawdust, palm kernel cake and cotton waste. Harvesting of mushroom in substrates 6 and 7 stopped at eighth harvest, while in substrate 8, it stopped at the nint harvest, indicating that the nutrients in these substrates were exhausted before the end of the study. In conclusion, substrate 4, 3 or 2 that contained basically palm kernel cake or maize straw is therefore recommended for cultivation of oyster mushroom. They can easily be found economically and locally.

ACKNOWLEDGEMENTS

The authors are grateful to the UNESCO-HP PROJECT for funding the experiment and the Director of the South East Zonal Biotechnology Centre, University of Nigeria, Nsukka, Prof. C. E. A. Okezie for his effort in obtaining the fund. We are also grateful to the Head of Department of Crop Science, University of Nigeria, Nsukka, Prof. K. P. Baiyeri, for making the facilities of the Department

available for the work.

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