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THE GROWTH AND POST HARVEST PERFORMANCES OF DIFFERENT SPECIES OF OYSTER MUSHROOM (*Pleurotus* sp.) CULTIVATED ON SAWDUST AND OIL PALM FROND

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ABSTRACT

Oyster mushrooms (*Pleurotus* sp.) have more than 1000 species worldwide such as grey (*Pleurotus sajor-caju*), yellow (*P. citrinopealatus*), pink (*P. flabellatus*) and white (*P. florida*) which are cultivated on various agricultural wastes. In this study, the growth performance, yield and postharvest quality of different species of oyster mushroom cultivated on sawdust and oil palm frond (OPF) were determined. Sawdust and OPF in combination with rice bran and calcium carbonate in 100:10:1 ratio respectively was used as substrates. The growth performance in terms of mycelium growth, days for mycelium to fill up the bag, pinhead emergence and fruiting body formation were measured. The postharvest qualities studied involved color, texture, moisture, ash, protein and crude fiber contents. Yellow oyster mushroom on OPF took the shortest time for mycelium growth, mycelium fill up the bag, pinhead emergence and fruiting body formation. However, oyster mushrooms cultivated on sawdust had higher biological efficiency (29.34 to 60.76%) as compared to on OPF (21.49 to 45.08%). White oyster mushroom had the highest biological efficiency followed by yellow, grey and pink. Meanwhile, grey oyster mushroom showed darker color compared to other oyster mushroom species. OPF used as substrates provide brighter yellow and pink color in yellow and pink oyster mushrooms respectively and greater in firmness especially for pink oyster mushroom. There was no significant difference ($P>0.05$) found in chemical properties of different oyster mushroom species cultivated on sawdust and OPF. In conclusion, oyster mushrooms cultivated on sawdust produced better yield even though OPF gave better growth performance and physical properties of color and firmness.

Key words: Oyster Mushrooms (*Pleurotus* sp.), oil palm frond, growth performance, postharvest quality

INTRODUCTION

Over 1000 species of the oyster mushroom have been described throughout the world, in more than 25 related genera; only about 50 valid species are recognized in the genus *Pleurotus* (Guzman, 2000). This valid species include *Pleurotus sajor-caju* (Fries) Sing. (grey oyster mushroom or phoenix-tail mushroom), *Pleurotus cystidious* O.K. Miller (abalone mushroom), *Pleurotus ostreatus* var. *florida nom. prov.* Eger (white oyster mushroom), *Pleurotus citrinopileatus* Sing. (yellow oyster mushroom), *Pleurotus flabellatus* (Berk. and Br.) Sacc (pink oyster mushroom) and *Pleurotus sapidus* (Schulzer) Kalchbremer (black oyster mushroom) (Chang and Miles, 2004). They grow occasionally on dying trunks of deciduous or coniferous woods or naturally in the temperate and tropical forest on dead and decaying wooden logs. Besides, they may also grow on decaying organic matter. Oyster mushrooms contain high protein content ranging between 1.6 to 2.5% and mineral salts required for the human body. They also rich in Vitamin C, B complex and niacin contents approximately ten times higher than any other vegetables (Randive, 2012).

The different species of oyster mushrooms were successfully cultivated on different lignocellulosic by-products from agriculture or forestry and found to be good growing substrates (Martinez-Carrera, 1998). In the present study, sawdust and oil palm frond (OPF) were used as substrates for the cultivation of different species of oyster mushrooms (*Pleurotus* sp.). The comparison in term of growth performance, yield and physico-chemical properties among different species of oyster mushrooms which were grey oyster mushroom (*Pleurotus sajor-caju*), yellow oyster mushroom (*Pleurotus citrinopileatus*),

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pink oyster mushroom (*Pleurotus flabellatus*) and white oyster mushroom (*Pleurotus florida*), cultivated on sawdust and OPF were observed.

MATERIALS AND METHODS

Agricultural waste of oil palm fronds were collected, and dried. The fronds were then chipped to small pieces. Sawdust and OPF was mixed with rice bran, calcium carbonate in the ratio of 100:10:1 and water was later added to moisten the mixture. The mixed medium was then filled into polypropylene bags (29 x 46 cm) about 500 gm in each bag. The bags were tied up and closed into cylindrical shape using necks and lids and sterilized at 121°C for 30 min using autoclave. After sterilization the bags were cooled overnight and ready to be inoculated with different cultures of oyster mushroom species. The inoculated bags were incubated (spawn running) at 28-30°C in the dark room (5% light) until mycelia has completely covered the bags. After completion of spawn running (mycelium travel down the bag), the bags were transferred into a mushroom house where the environment inside the mushroom house was maintained at 28-30°C; 80-90% relative humidity (RH) and about 30% light. The bags were unfolded at the upper parts for cropping. Water was sprayed on the floor regularly to maintain the relative humidity up to the desired level in the form of fine mist with the help of a nozzle.

The mycelium growth rate at 5 day intervals and the number of days for mycelium to fill up the bag, pinhead emergence and fruiting body formation were also observed and recorded. Yield in terms of percentage biological efficiency was calculated as fresh weight of harvested mushroom/weight of substrate x 100.

Physico-chemical analysis of color was done on the cap (pileus) of mushrooms using a Minolta Chroma Meter (Model CR 200 Trimulus Colour Analyser, Minolta camera Co. Ltd., Japan). The color measurements were carried out immediately after harvesting. The texture of fresh mushrooms was determined using the Texture Analyzer TA.XTplus (Stable Macro System) using P/2 stainless steel probe. The maximum positive values (firmness) were recorded. Meanwhile moisture content was determined by weighing an amount of mushroom in the crucible dish and dried to a constant weight at 105°C for 4-5 hr in an oven. Ash content was measured by incinerating an amount of mushroom in a muffle furnace for 6 hr at 550°C until a white residue of constant weight was obtained. Protein content in the mushroom was determined by using Kjeldahl method. The percentage of nitrogen was converted to protein by multiplying with the factor of 5.99. In addition, crude fiber content was determined by using Fibertec System 2021 FibreCap after chemical digestion and solubilization of other materials were performed.

RESULTS AND DISCUSSION

The mushroom bags were standardized to a 16 cm length. There were significant differences (P<0.05) in the mycelium growth of different species of oyster mushroom as shown in Fig. 1. The yellow oyster mushroom had significantly the fastest time for mycelium to reach 16 cm (25 to 30 days) compared to other species where grey oyster mushroom took the longest period (30 to 50 days). The fastest mycelium growth in yellow oyster mushroom might be due to its higher adaptability in different environment and its ability to grow wild in the forest such as in Kakamega forest where, it grown naturally on the dead logs and branches of indigenous trees (Musieba *et al*., 2012). Between the two substrates, mycelium on OPF tends to grow faster than on sawdust. OPF may possibly provide better growth condition for oyster mushroom than sawdust. However, Ahmed (1998) stated that the best substrates for cultivating oyster mushrooms are sawdust and sugarcane bagasse compared to other agricultural based substrates and Khan (2005) also reported that cotton waste had the least time for the spawn running of *Pleurotus* sp.

As shown in Table 1, there were significant differences (P<0.05) in the number of days for mycelium to fill-up the bag among different oyster mushroom species. The yellow oyster mushroom showed significantly (P<0.05) the fastest completion of spawn running followed by pink, white and grey oyster mushroom. The yellow oyster mushroom only took about 27 to 28 days, pink oyster mushroom took 31 to 34 days, white oyster mushroom took 30 to 43 days and grey oyster mushroom took 35 to 46 days for the mycelium to fill up the bag. Significantly shorter time (P<0.05) were also observed in the number of days mycelium filled up the bag for OPF as compared to sawdust. It might probably due to the different compositions of both substrates mainly in the amount of lignin, cellulose and hemicelluloses contents and also the differences in various kinds of polyphenolic substances in them as proposed by Wang (1982) where OPF was reported to have lower content of cellulose (Gohl, 1993). Musieba *et al*. (2012) also found that yellow oyster mushroom on sawdust took the longest period of spawn running as compared to bean straw, rice straw, sugarcane bagasse, wheat straw, banana leaves and maize cobs.

Meanwhile, for the number of days for pinhead emergence, grey oyster mushroom took a significantly longer period (57 to 95 days) compared

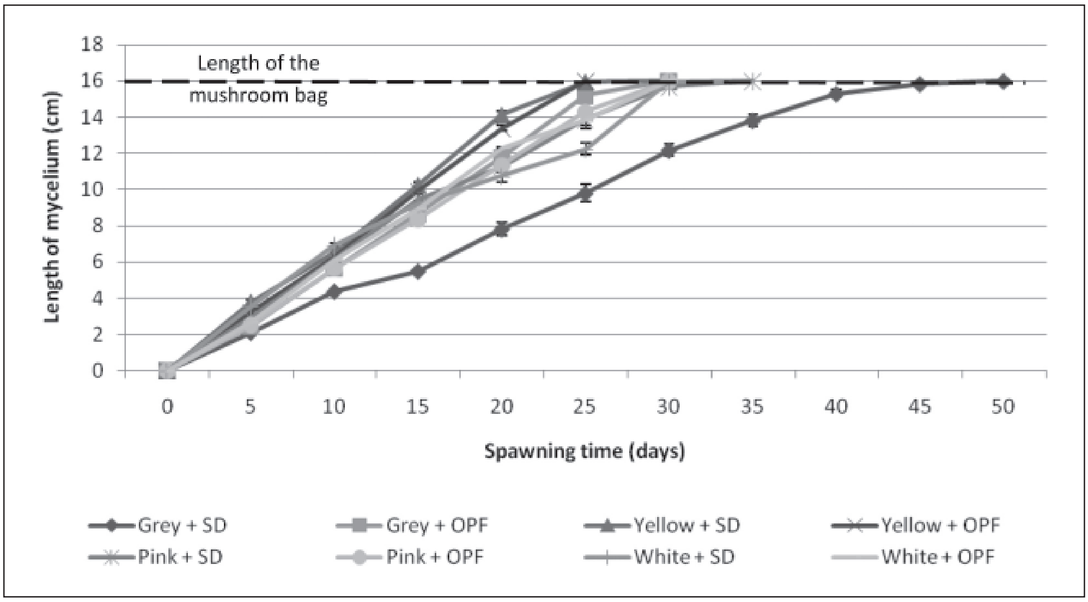

Fig. 1. The length of mycelium growth of different oyster mushroom species cultivated on sawdust and OPF. SD = sawdust; OPF = Oil Palm Frond

Table 1. The growth performance (days of mycelium filled up the bag, pinhead emergence and fruiting body formation) of different oyster mushroom species cultivated on sawdust and OPF

Oyster mushroom species	Growth performance (days)	
	Sawdust	OPF
Mycelium filled up the bag		
Grey	46.40 ± 3.65[Aa]	35.40 ± 1.14[Ba]
Yellow	27.80 ± 0.84[Ad]	27.20 ± 1.64[Bb]
Pink	34.20 ± 2.86[Ac]	31.60 ± 2.19[Bab]
White	42.80 ± 3.27[Ab]	29.60 ± 1.52[Bb]
Pinhead emergence		
Grey	56.60 ± 5.81[Ba]	95.00 ± 5.57[Aa]
Yellow	36.80 ± 9.39[Ac]	36.20 ± 6.30[Ac]
Pink	42.40 ± 5.86[Abc]	38.80 ± 3.03[Bbc]
White	49.40 ± 1.52[Ab]	45.40 ± 7.64[Ab]
Fruiting bodies formation		
Grey	59.20 ± 5.89[Ba]	97.00 ± 5.57[Aa]
Yellow	38.80 ± 9.39[Bc]	38.20 ± 6.30[Ac]
Pink	45.40 ± 5.86[Bbc]	40.80 ± 3.03[Abc]
White	52.40 ± 1.52[Bb]	48.20 ± 8.01[Ab]

Note : Values are means of 5 replicates. Mean (n=5) ± standard deviation
A-B : Values bearing the same superscript within the same row are not significantly different at 5% level ($P<0.05$)
a-d : Values bearing the same superscript within the same column are not significantly different at 5% level ($P<0.05$)

to other oyster mushrooms species (Table 1). White, pink and yellow oyster mushrooms took 45 to 49 days, 39 to 42 days and 36 to 37 days for pinhead emergence, respectively. Generally, oyster mushroom cultivated on sawdust took a shorter period (37 to 57 days) for pinhead emergence than on OPF (36 to 95 days). The longer period of pinhead emergence might be due to low humidity in the mushroom house. Other than that, the differences in the substrates composition also affect the timing for pinhead emergence in different oyster mushroom species where grey oyster mushroom took 20 to 25 days (Rangaswami *et al*., 1975) and 40 days (Khan *et al*., 1981) for pinhead emergence after inoculation.

There were also significant differences (P<0.05) in the number of days for fruiting bodies formation among different oyster mushroom species (Table 1). Grey oyster mushroom took significantly the longest time (59 to 97 days) for fruiting bodies formation compared to other oyster mushroom species (38 to 52 days). This may be due to its larger pileus size which required longer time to be harvested compared to yellow oyster mushroom which had relatively smaller pileus. Among two substrates, sawdust took shorter time (39 to 59 days) for fruiting bodies formation than OPF (38 to 97 days). Substrate having high quality of lignin and cellulose contents takes longer time to start pinning and fruit body formation (Oei, 2003). Mycelia growth is an initial step that provides suitable internal conditions for fruiting. Thus, the best mycelia growth becomes a crucial factor in mushroom cultivation (Pokhrel *et al*., 2009). Lignocellulosic material in mushroom substrate is proved to be the important factor in supporting the growth, maturity and fruiting of mushroom (Chang and Miles, 1988).

In Table 2, there were significant differences (P<0.05) in the yield of different oyster mushroom species. The highest biological efficiency was found in white oyster mushroom with 45.08 to 60.76% followed by yellow oyster mushroom with 43.29 to 53.23%, grey oyster mushroom with 30.57 to 39.21% and the least was pink oyster mushroom with 21.49 to 29.34%. Even though yellow oyster mushroom produced the most number of fruiting bodies than other species however white oyster mushroom produced larger size of fruiting bodies than yellow oyster mushroom. The thickness and diameter of the pileus also influenced the fruiting body weight (Ahmed *et al*., 2013). There were also significantly higher (P<0.05) biological efficiency of oyster mushrooms cultivated on sawdust (29.34 to 60.76%) than on OPF (21.49 to 45.08%). Sawdust might probably supply better nutrient for mushroom fruiting bodies than OPF. The addition of rice bran in the substrate could also be beneficial as a nutrient supplement and promoter to growth and yield of mushroom (Pokhrel *et al*., 2013). Mane *et al*. (2007) also reported that the addition of organic supplements such as groundnut oilseed cake, gram powder and rice bran not only affected growth parameters but also increased the yield of grey oyster mushroom.

Among all the oyster mushroom species, grey oyster mushroom had lower color L* value (Table 3) indicated darker color. Pink, yellow, and white oyster mushroom had lighter color with relatively higher color L* values. Between sawdust and OPF used, there was no significant difference (P>0.05) in term of lightness for all the oyster mushroom species. The pileus of oyster mushroom tends to become lighter (grey to brownish grey) under high temperature and high humidity. When placed under high temperature and low humidity, the pileus color becomes very light (light grey to white) (MushWorld, 2004). There were significant differences (P<0.05) in color a* values (redness) for different species of oyster mushroom as shown in Table 3. Grey oyster mushroom had the highest a* value whereas yellow oyster mushroom had the lowest value. There was no significant difference (P>0.05) found in color a* values between sawdust and OPF. The color a* value in pink oyster mushroom cultivated on OPF was more pinkish than on sawdust. For pink oyster mushroom cultivated on sawdust, the pinhead color was bright pink and started to fade when fruiting bodies began to mature. OPF might contribute to better retention in the intensity of red color in pink oyster mushroom. Expectedly, yellow oyster mushroom had the highest b* value (yellowness) compared to other species. Meanwhile, there were also significantly higher (P<0.05) color b* value of oyster mushroom cultivated on OPF than on sawdust. The use of OPF as substrates for yellow oyster mushroom may help to maintain the intensity of its yellow color.

Table 2. The yield (percentage biological efficiency) of different oyster mushroom species cultivated on sawdust and OPF

Oyster mushroom species	Biological efficiency (%)	
	Sawdust	OPF
Grey	39.21 ± 9.78^{Ab}	30.57 ± 12.12^{Bb}
Yellow	53.23 ± 8.42^{Aa}	43.29 ± 3.29^{Ba}
Pink	29.34 ± 7.91^{Ab}	21.49 ± 5.94^{Bb}
White	60.76 ± 22.68^{Aa}	45.08 ± 5.54^{Ba}

Note : Values are means of 5 replicates. Mean (n=5) ± standard deviation

A-B : Values bearing the same superscript within the same row are not significantly different at 5% level (P<0.05)

a-b : Values bearing the same superscript within the same column are not significantly different at 5% level (P<0.05)

Table 3. The physical properties (color L*, a* b* values and firmness) of different oyster mushroom species cultivated on sawdust and OPF

Oyster mushroom species	Physical properties	
	Sawdust	OPF
Color L* value		
Grey	62.87 ± 8.46^{Ac}	65.97 ± 6.29^{Ac}
Yellow	86.94 ± 4.25^{Aab}	86.60 ± 8.30^{Aab}
Pink	92.15 ± 0.79^{Aa}	90.13 ± 0.99^{Aa}
White	85.91 ± 1.93^{Ab}	87.05 ± 2.05^{Ab}
Color a* value		
Grey	5.66 ± 4.20^{Aa}	4.92 ± 2.34^{Aa}
Yellow	-4.40 ± 2.12^{Ac}	-6.59 ± 3.16^{Ac}
Pink	0.22 ± 0.73^{Ab}	3.92 ± 1.89^{Ab}
White	0.46 ± 0.21^{Ab}	0.37 ± 0.36^{Ab}
Color b* value		
Grey	13.93 ± 3.49^{Ab}	9.86 ± 1.50^{Bb}
Yellow	27.99 ± 6.79^{Ba}	39.81 ± 14.93^{Aa}
Pink	7.53 ± 1.74^{Bb}	10.73 ± 3.70^{Ab}
White	8.41 ± 0.79^{Bb}	9.20 ± 1.37^{Ab}
Firmness (g)		
Grey	100.96 ± 57.73^{Aa}	146.12 ± 43.43^{Aa}
Yellow	90.88 ± 27.71^{Ab}	43.08 ± 13.54^{Ab}
Pink	142.08 ± 42.27^{Aa}	154.13 ± 62.05^{Aa}
White	46.90 ± 6.82^{Ab}	64.26 ± 9.28^{Ab}

Note: Values are means of 5 replicates. Mean (n=5) ± standard deviation
A-B : Values bearing the same superscript within the same row are not significantly different at 5% level (P<0.05)
a-c : Values bearing the same superscript within the same column are not significantly different at 5% level (P<0.05)

Table 3 also shows the firmness of different oyster mushroom species cultivated on sawdust and OPF. Among different species, pink oyster mushroom had the firmest pileus which force range from 142.08 gm to 154.13 gm. This might be due to its larger pileus diameter and thicker pileus compared to other species. However, the used of sawdust and OPF gave no significant difference (P>0.05) in terms of firmness in all the species. The pink oyster mushroom may probably have the highest inferior quality among all the oyster mushroom species in terms of firmness as this quality is desirable because the fruit bodies do not break easily during packaging, thereby increasing their quality and shelf life (Shen and Royse, 2001). Mushrooms are accepted or rejected on the basis of their chemical and physical properties, especially the texture quality (Matser *et al*., 2000).

Table 4 shows the moisture content of different species of oyster mushroom cultivated on different substrates. There was no significant difference (P<0.05) found in the moisture content among different oyster mushroom species and between the two substrates. The moisture contents were in the range of 77.7 to 85.6%. Oyster mushroom contains very high moisture content of 80 to 90% when fresh and 5 to 20% when dried (Tisdale, 2004). This might be the reason for their short shelf life (Fasidi and Kadiri, 1993). There was also no significant difference (P>0.05) in ash content of different oyster mushroom species and substrates used. The ash content in different species of oyster mushroom ranges from 5.3 to 12% (based on dry weight). The different in the substrates used also had little effect on the ash contents even though Khan (2005) reported that ash content in oyster mushroom was around 10% and the highest content was obtained on grasses (19.1%) while the lowest was on sugarcane baggase. The ash content was also increased with time (Zhang *et al*., 2002).

Table 4 also shows that there was no significant difference (P>0.05) in protein content among different oyster mushroom species and between sawdust and OPF. The values obtained in this study were in the range of 6.76 to 8.09% (based on fresh weight). Oyster mushrooms are considered a good source of superior quality protein (Patil *et al*., 2010). Crisan and Sands (1978) found that protein content of mushrooms vary from flush to flush and they depends on the composition of the substrates used, size of pileus, harvesting time and species (Bano and Rajarathnam, 1982). Mushroom rank below animal meats but well above most other foods including milk in terms of the amount of crude protein (Chang, 1980).

Table 4. The chemical properties (moisture, ash, protein and fiber contents) of different oyster mushroom species cultivated on sawdust and OPF

Oyster mushroom species	Chemical properties (%)	
	Sawdust	OPF
Moisture content		
Grey	82.22 ± 1.07^{Aa}	81.03 ± 2.63^{Aa}
Yellow	80.45 ± 5.97^{Aa}	83.88 ± 1.78^{Aa}
Pink	83.23 ± 3.07^{Aa}	77.70 ± 6.85^{Aa}
White	85.76 ± 3.51^{Aa}	83.66 ± 3.00^{Aa}
Ash content		
Grey	0.66 ± 0.29^{Aa}	0.78 ± 0.10^{Aa}
Yellow	0.72 ± 0.20^{Aa}	0.58 ± 0.32^{Aa}
Pink	0.62 ± 0.07^{Aa}	0.86 ± 0.05^{Aa}
White	0.71 ± 0.09^{Aa}	0.75 ± 0.14^{Aa}
Protein content		
Grey	7.15 ± 0.20^{Aa}	7.96 ± 0.98^{Aa}
Yellow	7.16 ± 0.76^{Aa}	6.76 ± 0.49^{Aa}
Pink	8.09 ± 0.90^{Aa}	6.99 ± 1.10^{Aa}
White	7.66 ± 0.47^{Aa}	6.89 ± 0.52^{Aa}
Crude fiber content		
Grey	6.71 ± 0.75^{Aa}	7.45 ± 1.20^{Aa}
Yellow	7.71 ± 1.12^{Aa}	7.37 ± 0.78^{Aa}
Pink	7.59 ± 1.17^{Aa}	6.77 ± 1.02^{Aa}
White	6.69 ± 0.40^{Aa}	6.98 ± 0.87^{Aa}

Note : Values are means of 5 replicates. Mean (n=5) ± standard deviation
A : Values bearing the same superscript within the same row are not significantly different at 5% level (P<0.05)
a : Values bearing the same superscript within the same column are not significantly different at 5% level (P<0.05)

On the other hand, the amount of crude fiber in different oyster mushroom species and between different substrates used also showed no significant difference (P>0.05). Jain *et al*. (1988) also reported that the crude fiber content of grey oyster mushroom cultivated on three aquatic substrates varied within narrow limits of 11.7 to 17%. This study also suggested that the substrate does not influence the composition of grey oyster mushroom fruiting bodies. The fruiting bodies of oyster mushroom species contained polymeric substances, cellulose, hemicelluloses, lignin and crude fiber in the range of 28.5 to 41%, 13 to 39.3%, 14 to 20.2% and 14.1 to 20.2% respectively (Bisaria *et al*., 1987; Chang *et al*., 1981; Khanna *et al*., 1992; Ragunathan *et al*., 1996).

CONCLUSION

In conclusion, the best oyster mushroom species in terms of growth performance was yellow oyster mushroom when cultivated on OPF. In terms of yield, white oyster mushroom was the best among all species when cultivated on sawdust. For postharvest quality, grey oyster mushroom had darker color and yellow oyster mushroom had brighter yellow color when cultivated on OPF than on sawdust. Pink oyster mushroom had brighter pink color and firmer texture when cultivated on OPF than on sawdust. Meanwhile, there was no significant difference found in the chemical properties of different oyster mushroom species cultivated on sawdust and OPF.

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