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HIGH FIBER MEDIA AS THE MOST EFFICIENT SUBSTRATES FOR *PLEUROTUS FLORIDA* CULTURE

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Abstract - Implementation of agricultural residues for oyster mushroom culture has been accepted world-wide. In this study, we used wheat straw, barley straw, maize stem residue, and lawn residue as substrates coupled with wheat bran, rice bran and soybean powder as complements for the growth of *P. florida*. Wheat and barley straws which contained a high fiber and C/N ratio had the best growth period, fruiting body weight, yield, and biological efficiency. Assessment of substrate and complement combinations indicated that the lowest growth period was obtained from barley straw enriched with rice bran (24.67 day). 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. In conclusion, the highest fruiting body weight, yield, and biological efficiency was achieved by implementation of composts in which high fiber substrates and complements were combined.

Key words: Oyster mushroom, wheat straw, barley straw, high fiber

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INTRODUCTION

Oyster mushroom production technology under controlled conditions has been extensively developed, especially via the recycling of agricultural waste. It has been widely accepted in rural systems mainly due to its simple and cheap procedure requirements (Soto-Cruz et al., 1999).

Most *Pleurotus* species can grow on lingo-cellulose materials such as rotten wood, wood chips, and agricultural postharvest residues because they have high saprophyte characteristics (Straatsma et al., 2000; Stamets, 2000). In tropical and subtropical regions, a high amount of lingo-celluloses from agricultural wastes are inappropriately buried or burned in farms. Recycling of these unfavorable materials through mushroom culture can increase agricultural efficiency and enhance the degradation processes of lingo-cellulose sources (Obodai et al., 2003).

There are various numbers of parameters affecting the growth and performance of oyster mushroom including substrate source, substrate quality, spawn, strain, compost, and complement (Royse et al. 2004; Jafarpour et al., 2010). A high content of protein and nitrogen source has been reported to be effective in shortening the growth period and increasing both the yield and biological efficiency (Peksen and Yakupoglu, 2009; Adebayo et al., 2009; Fanadzo et al., 2010; Jafarpour et al., 2010). In contrast, a high nitrogen content of substrates was considered an obstacle for mushroom culture because since it raised media temperature and subsequently postponed the mycelium run (Gurjar and Doshi, 1995; Royse and Schisler, 1986).

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). Our previous study indicated that the enrichment of sugar beet pulp, palm fiber, and boll complemented with wheat bran, rice bran, carrot pulp, and soya cake powder improved the growth characteristics of *P. ostreatus* (Jafarpour et al., 2010).

This study was aimed at assessing the effect of substrates and complements with different fiber and nitrogen contents, on the growth performance of *P. florida*.

MATERIALS AND METHODS

Agricultural residues, including wheat straw, barley straw, maize stem residue, and lawn residue, were used as substrates while wheat bran, rice bran, soybean powder, and a mixture of soybean powder and rice bran (1:1 w/w) were considered as complement groups. Substrates with no complement were designated as the control for complement groups. The chemical compositions of all substrates and complements were analyzed prior to the experiments (Table 1).

The food complements were sterilized at 121ºC and 15 psi pressure for 1 h. Pasteurization of the substrates was conducted through water absorption for 1.5 h following tissue softening at 100ºC for 1.5 h (for more details, see Jafarpour et al., 2010). Fifty grams of organic complements and 80 g of spawns (based on 10 and 16% of substrate dry weight, respectively) were added to 500 g of substrates in each experimental unit (Zhang et al., 2002; Jafarpour et al., 2010). All environmental conditions in the culture hall were managed according to the growth requirements of Pleurotus as indicated in Table 2 (Stamets, 2000; Jafarpour et al., 2010).

The total growth period of *P. florida* was classified into three basic phases, including the spawn run phase or mycelium run/pin head stage, primary fruiting body, and complete fruiting body phases which were designated as MR/PH, PFB, and CFB, respectively. The total growth period, fruiting body number and weight, yield and biological efficiency were measured.

Data were analyzed using the general linear model (GLM) procedure in the SAS package. Mean comparisons for substrates and complements coupled with their combinations were conducted using Tukey's post-hoc and considering P-value <0.05 as significant level.

RESULTS

Growth period

The effect of the substrate on growth performance is presented in Table 3. The total growth period varied from 33.6 d (wheat straw) to 41.33 d (maize stem residue). The total period was partitioned into MR/PH, PFB, and CFB phases. Duration of MR/PH ranged from 27.93 d (barley straw) to 32.93 d (maize stem residue). The MR/PH phase was significantly shorter in barley straw and wheat straw than in either the maize stem residue or lawn residue ($P<0.05$). The differences between the substrates were not significant at the PFB step ($P<0.05$). However, there were significant variations among the different substrates at the CFB step. The longest and shortest CFB period was obtained in maize stem residue (5.93 d) and wheat straw (3.27 d), respectively.

Comparing complements as main effects (Table 4) showed that the total growth period was in the range of 33.17 d (rice bran) and 41.75 d (soybean powder and rice bran mix). The longest MR/PH and CFB periods pertained to the mixture of soybean powder and rice bran (34.42 d and 5.67 d, respectively), while the shortest mentioned stages belonged to the rice bran complement (26.5 d and 3.83 d, respectively). Interestingly, wheat bran had a significantly lower PFB duration than rice bran ($p<0.05$).

The combination effects of substrates and complements are shown in Table 5. The shortest and longest total growth periods were attributed to barley straw enriched by the mixture of soybean powder and rice bran (24.67 d) and maize stem residue enriched by rice bran (48.00 d), respectively.

Table 1. Chemical composition of substrates and food complements (Dry weight based)

Components (%)								
Protein*	**Ash**	**Fat**	**Food fiber**	**Carbohydrate****	**Carbon**	**Nitrogen**	**C/N**	**Substrate and complement**
9.06	11.10	1.60	36.95	41.29	30.60	1.45	21.10	Wheat straw
12.81	15.90	3.50	17.75	50.04	20.90	2.05	10.19	Chop maize
6.18	11.20	1.30	37.90	43.42	28.05	0.99	28.33	Barley straw
22.18	13.40	4.35	18.45	41.62	31.15	3.55	8.77	Lawn cut
13.12	4.75	4.10	11.80	66.23	21.15	2.10	10.07	Wheat bran
7.81	16.15	4.50	33.35	38.19	26.75	1.25	21.40	Rice bran
55.31	6.30	2.65	6.00	29.74	28.00	8.85	3.16	Soybean powder

* N × 6.25
** Lane & Eynon method

Table 2. Environmental conditions based on *P. florida* requirements

Fruiting body stage	Pin head stage	Spawn run phase	Parameters
16-20	10-16	21-24	Temperature (°C)
85-90	95-100	85-95	Relative humidity (%)
≤1000	≤1000	5000-20000	CO2 (ppm)
4-8	4-8	1	Air replacement
1000-2000	1000-2000	-	Light (Lux/day)

Table 3. Substrate effect on *P.florida* growth characteristics

Lawn cut	Barley straw	Chop maize	Wheat straw	Characteristics
38.47 ab	35.53 bc	41.33 a	33.6 c*	Growth period
32.27 a	27.93 b	32.93 a	27.86 b	M.R./P.H. stage
2.40 a	2.60 a	2.47 a	2.47 a	P.F.B. Stage
3.80 bc	4.73 b	5.93 a	3.27 c	C.F.B. stage
21.30 c	25.25 b	21.86 c	29.11 a	Fruiting body Weight
20.80 c	27.13 b	29.60 a	26.93 b	Fruiting body number
433.13 c	676.27 b	646.27 b	781.07 a	Yield
86.63 c	135.25 b	129.25 b	156.21 a	Biological efficiency

* Means with common letters in each row were not significantly different at $P \leq 0.05$

Fruiting body number and weight

The mean fruiting body number and body weight for substrates, complements, and their combinations are given in Tables 3, 4, and 6, respectively. The mean body number for the different substrate groups ranged from 20.80 (lawn residue) to 29.60 (maize stem residue). Tracking of the average body weight showed that the lawn residue had the lowest body weight while wheat straw had the highest (29.11).

For the complements' scenario, the average fruiting body number was in the range of 20.42 (control) and 28.75 (wheat bran). However, the average fruiting body weight varied from 23.17 (control) to 25.98 (rice bran). Even though application of wheat bran led to a significantly higher body number compared to rice bran, its corresponding body weight was noticeably lower than rice bran.

Comparison of the substrate and complement combinations indicated that the highest and low-

Table 4. Food complement effect on *P. florida* growth traits

Control	Soybean powder & rice bran	Soybean powder	Rice bran	Wheat bran	Characteristics
35.92 bc	41.75 a	35.92 bc	33.17 c	39.42 ab*	Growth period
29.25 bc	33.58 a	29.25 bc	26.50 c	32.67 ab	M.R./P.H. stage
2.50 a	2.50 a	2.33 a	2.83 a	2.25 a	P.F.B. Stage
4.08 b	5.67 a	4.33 b	3.83 b	4.25 b	C.F.B. stage
23.17 b	24.78 ab	24.70 ab	25.98 a	23.27 b	Fruiting body weight
20.42 c	28.25 ab	27.58 ab	25.58 b	28.75 a	Fruiting body number
461.92 b	699.83 a	687.58 a	670.17 a	651.42 a	Yield
92.38 b	139.97 a	137.52 a	134.03 a	130.28 a	Biological efficiency

* Means with common letters in each row are not significantly different at $P \leq 0.05$.

Table 5. Substrate and food complement combination effect on *P. florida* growth variables

Growth period	C.F.B. Stage	P.F.B. Stage	M.R./P.H. Stage	Complement	Substrate
35.33 cdef	3.67 f	2.33 a	29.33 bcde*	Wheat bran	Wheat straw
29.33 de	3.00 c	2.67 a	23.67 ef	Rice bran	
33.00 cde	2.33 c	2.33 a	28.33 bcde	Soybean powder	
38.67 abcd	4.67 bc	2.33 a	31.67 abcde	Soybean powder & Rice bran	
31.67 cde	2.67 c	2.67 a	26.33 def	Control	
45.00 ab	3.00 c	2.33 a	39.67 a	Wheat bran	Chop maize
40.33 abc	5.33 bcd	2.33 a	32.67 abcde	Rice bran	
41.00 abc	8.33 a	2.33 a	30.33 abcde	Soybean powder	
48.00 a	7.67 ab	2.67 a	37.67 ab	Soybean powder & rice bran	
32.33 cde	5.33 abc	2.67 a	24.33 def	Control	
36.67 bcd	5.67 abc	2.00 a	28.00 cde	Wheat bran	Barley straw
24.67 e	3.33 c	3.67 a	17.67 f	Rice bran	
38.00 abcd	4.00 c	2.67 a	31.33 abcde	Soybean powder	
39.67 abc	5.00 abc	2.33 a	32.33 abcde	Soybean powder & rice bran	
38.67 abcd	5.67 abc	2.33 a	30.33 abcde	Control	
40.67 abc	4.67 bc	2.33 a	33.67 abcd	Wheat bran	Lawn cut
38.33 abcd	3.67 c	2.67 a	32.00 abcde	Rice bran	
31.67 cde	2.67 c	2.00 a	27.00 cdef	Soybean powder	
40.67 abc	5.33 abc	2.67 a	32.67 abcde	Soybean powder & rice bran	
41.00 abc	2.67 c	2.33 a	36.00 abc	Control	

* Means with common letters in each column are not significantly different at $P \leq 0.05$.

est fruiting body numbers were attributed to wheat straw and rice bran (36.33) and lawn residue with no complement (12.33), respectively. However, the maximum (31.17) and minimum (18.63) fruiting body weights were produced in wheat straw complemented with wheat bran and lawn residue complemented by soybean powder, respectively.

Table 6. Substrate and food complement combination effect on *P. florida* production traits

Biological efficiency	Yield*	Fruiting body weight	Fruiting body number	Complement	Substrate
137.27 ^{cdef}	686.33 ^{cdef}	31.17 ^{a}	22.00 ^{efgh}**	Wheat bran	Wheat straw
207.80 ^{a}	1039.00 ^{a}	28.63 ^{abcd}	36.33 ^{a}	Rice bran	
151.80 ^{bcd}	759.00 ^{bcd}	27.83 ^{abcde}	27.33 ^{bcdefg}	Soybean powder	
177.53 ^{b}	887.67 ^{b}	30.03 ^{ab}	29.67 ^{abcd}	Soybean powder & rice bran	
106.67 ^{ghi}	533.33 ^{jhi}	27.87 ^{abcde}	19.33 ^{h}	Control	
134.20 ^{defg}	671.00 ^{defg}	20.07 ^{f}	33.67 ^{ab}	Wheat bran	Chop maize
114.00 ^{fgh}	570.00 ^{fgh}	22.83 ^{def}	25.00 ^{cdefgh}	Rice bran	
149.67 ^{bcd}	748.33 ^{bcd}	23.90 ^{bcdef}	31.33 ^{abc}	Soybean powder	
156.40 ^{bcd}	782.00 ^{bcd}	23.60 ^{cdef}	33.67 ^{ab}	Soybean powder & rice bran	
92.00 ^{hi}	460.00 ^{hi}	18.90 ^{f}	24.33 ^{cdefgh}	Control	
146.13 ^{cde}	730.67 ^{cde}	23.10 ^{def}	31.67 ^{abc}	Wheat bran	Barley straw
118.20 ^{efgh}	591.00 ^{efgh}	29.57 ^{abc}	20.00 ^{gh}	Rice bran	
164.20 ^{bc}	821.00 ^{bc}	28.43 ^{abcd}	29.00 ^{bcde}	Soybean powder	
136.40 ^{cdef}	682.00 ^{cdef}	23.243 ^{cdef}	29.33 ^{abcde}	Soybean powder & rice bran	
111.33 ^{fghi}	556.67 ^{fghi}	21.170 ^{ef}	25.67 ^{cdefgh}	Control	
103.53 ^{hi}	517.67 ^{hi}	18.73 ^{f}	27.67 ^{bcdef}	Wheat bran	Lawn cut
96.13 ^{hi}	480.67 ^{hi}	22.90 ^{def}	21.00 ^{fgh}	Rice bran	
84.40 ^{ij}	422.22 ^{i}	18.63 ^{f}	22.67 ^{defgh}	Soybean powder	
89.53 ^{hi}	447.67 ^{hi}	22.03 ^{ef}	20.33 ^{fgh}	Soybean powder & rice bran	
59.53 ^{j}	297.67 ^{j}	24.20 ^{bcdef}	12.33 ^{i}	Control	

* g per 500g substrate dry weight basis
** Means with common letters in each column are not significantly different at $P \leq 0.05$.

Yield and biological efficiency

The highest and lowest rates of both yield and biological efficiency were observed in wheat straw (781.07g and 156.21) and lawn residue (433.13g and 86.63), respectively. There were no significant differences between wheat bran, rice bran, soybean powder, and soybean powder plus rice bran, although all the complements had significantly higher yield and biological efficiency than the control group.

Assessment of the substrate and complement combinations showed that the mixture of wheat straw and rice bran led to a significantly higher yield and biological efficiency (1039.00 and 207.80, respectively) than the other combinations ($P<0.05$). On the other hand, the lawn residue without complement had a notably lower yield and biological efficiency (297.67 and 59.53, respectively) than other combinations ($P<0.05$).

DISCUSSION

In this study, we estimated the growth period at three stages, including mycelium run/pin head (MR/PH), primary fruit body (PFB), and complete fruit body (CFB), along with the total growth period as a whole index. Wheat and barley straws reduced the total growth period to 4.8-5 weeks. On the other hand, maize stem residue and lawn residue induced the growth period to 5.5 -5.9 weeks. Variation in the total growth period was attributable to changes in MR/PH and CFB stages in which barley and wheat straws had a significantly shorter period than either the maize stem residue or the lawn residue.

The highest fruiting body weight was also reached when wheat straw was used as a substrate though its fruiting body number was not the highest among of all of the examined substrates. Interestingly, wheat straw also maximized the yield and biological efficiency. This trend was observed in the growth period, fruiting body number, yield and biological efficiency for barley straw as well. Rice bran, which had the highest C/N ratio among all the complements, showed the shortest growth period and the highest fruiting body weight. However, application of soybean powder and wheat bran with high protein and low C/N ratio caused a long growth period and low fruiting body weight. Application of nitrogen sources has been quite controversial with regard to the effect on the increase in yield and biological efficiency in some studies (Gurjar and Doshi, 1995; Royse and Schisler, 1986; Paksen and Yakupoglu, 2009; Adebayo et al., 2009; Fanadzo et al., 2010; Jafarpour et al., 2010). Temperature rise and species differences were considered as the main reasons for this discrepancy in different reports (Gurjar and Doshi, 1995). In our study, the increase in the nitrogen content of the substrates was associated with a longer MR/PH stage. A high fiber content and C/N ratio could enhance the digestibility of the lingo-cellulose content, followed by high availability of cellulose materials as mushroom nutrients. In this issue, nitrogen might be in the bound form which needs more time to be delivered to the mushroom's mycelia (Fanadzo et al., 2010). In addition, it has been hypothesized that mushrooms have the ability to absorb and fix atmospheric nitrogen so that their requirements in nitrogen would be compensated (Bisaira et al., 1987).

The mixture of wheat straw and rice bran led to the highest yield and biological efficiency among all combinations. Interestingly, rice bran as a complement also had low levels of proteins and high levels of fiber. Our results on *P. florida* indicate that substrates and complements with a high fiber content and C/N ratio decreased the total growth period and MR/PH stage while increasing the yield and biological efficiency.

CONCLUSION

We assessed the implication of different substrates and complements on the growth period, fruiting body weight, yield, and biological efficiency of *Pleurotus florida*. The shortest growth period, mycelium run, and pin head stages were obtained from the media with high fiber and C/N ratio, whilst mushroom production on a high protein content material extended the total growth period in its compartments. Moreover, the highest fruiting body weight, yield, and biological efficiency were achieved by the implementation of substrates and complements containing high fiber and C/N ratios.

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