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RESEARCH ARTICLE

THE NUTRITIONAL VALUE OF *PLEUROTUS OSTREATUS* (JACQ.:FR.) KUMM CULTIVATED ON DIFFERENT LIGNOCELLULOSIC AGRO-WASTES

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Abstract

Pleurotus ostreatus was cultivated on different agro wastes viz soybean straw, paddy straw, wheat straw alone or in combination of 1:1 ratio. Maximum yield of *P. ostreatus* was recorded on soybean straw. Maximum protein, fat, ash, P, K and Na content was recorded when *P. ostreatus* was cultivated on soybean straw alone whereas maximum Ca and Fe content was recorded when *P. ostreatus* was cultivated on combination of soybean and paddy straw. Amino acid profile showed *P. ostreatus* proteins are rich in glutamic acid, aspartic acid and lysine content whereas vitamin C and folic acid were also recorded. Biochemical changes take place in the substrates because of the mushroom growth. A decrease in cellulose, hemicellulose, crude fibre, carbohydrate lignin and tannin content was observed, while an increase in protein, ash and mineral content in spent straw was recorded.

Keywords: *Pleurotus ostreatus,* agricultural wastes, yield, nutrients

Introduction

Pleurotus species are popular and widely cultivated throughout the world mostly in Asia and Europe owing to their simple and low cost production technology and higher biological efficiency (Mane *et al.,* 2007). *Pleurotus* species are efficient lignin degraders which can grow on wide variety of agricultural wastes with broad adaptability to varied agro-climatic conditions (Jandaik & Goyal, 1995).

Pleurotus species are rich source of proteins, minerals (Ca, P, Fe, K and Na) and vitamin C, B-complex (thiamine, riboflavin, folic acid and niacin) (Çağlarırmak, 2007). They are consumed for their nutritive as well as medicinal values (Agrahar-Murugkar & Subbulakshmi, 2005). Mushroom protein is intermediate between that of animals and vegetables (Kurtzman, 1976) and is of superior quality because of the presence of all the essential amino acids (Purkayastha & Nayak, 1981). *Pleurotus* sp. contains high potassium to sodium ratio, which makes mushrooms an ideal

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food for patients suffering from hypertension and heart diseases. The practice of mushroom cultivation not only produces a nutritious food but also improves the straw quality. This takes place by reducing lignin, cellulose, hemi cellulose, tannin and crude fiber content of straw making it ideal for animal feed (Ortega *et al.,* 1992). The spent straw contains large quantity of N, P, K and can be used as manure (Maher 1991).

The objective of this work was to evaluate the yield potential and nutritive values of *P. ostreatus* as well as chemical composition of substrates and of the residues after cultivation on agricultural wastes available in plenty in this region. Although *Pleurotus* sp. can be easily cultivated on different agro wastes but yield potential vary with the substrate used. The area under soybean crop is increasing day by day in this part of India and a large quantity of biomass is produced after cultivation of soybean. Use of protein rich soybean agro-waste in combination with cereal agro-waste can help to increase the yield of *P. ostreatus.* Therefore, experiments were conducted to evaluate yield potential and nutritive value of *P. ostreatus* grown on paddy straw, wheat straw and soybean straw alone and in 1:1 combination.

Material and Methods

Strains of *Pleurotus ostreatus*. *P. ostreatus* strain was obtained from National Centre for Industrial Microbes (NCIM No. 1802), National Chemical Laboratory, Pune, India. The cultures were preserved on 2 % malt extract agar slants at 4º C. Subculturing was done after every 15 days.

Spawn Preparation. Spawn was prepared in polythene packets. Sorghum grains were boiled in water bath for 10-15 min in the ratio of 1:1 (Sorghum grains: water) and mixed with 4% (w/w) $CaCO_3$ and 2% (w/w) $CaSO_4$. Sorghum grains were then packed (250g) in polythene bags (of 200x300 mm. size) and sterilized in an autoclave at 121ºC for 30 min. After sterilization, the bags were inoculated with actively growing mycelium of the *P. ostreatus* from malt extract slants and incubated (at 27±2 ºC) for mycelial growth without any light for 10-15 days until the mycelium fully covered the grains.

Experimental details. Experiment was conducted in Randomized block design with five replications. Treatment of substrate namely paddy straw, wheat straw and soybean straw alone and in 1:1 combination was tested where ten polythene bags of one treatment were included in single replication. Yield data and other quality parameters were subjected to statistical analysis to find out level of significance following recommended procedures.

Cultivation of *P. ostreatus*. Soybean, paddy and wheat straw and their combination in 1:1 ratio were used as cultivation substrates following the method described earlier (Mane *et al.* 2007).

Yield and biological efficiency. Total weight of all the fruiting bodies harvested from all the three pickings were measured as total yield of mushroom. The biological efficiency (B.E. - yield of mushroom per kg substrate on dry wt. basis) was calculated by following the formula given by Chang *et al.,* (1981).

Proximate analysis – Analysis of moisture, protein, fat, crude fibre, total carbohydrates, ash of samples were done by standard methods (AOAC, 1995).

Lignin, cellulose, hemicellulose and tannin estimation. Estimation of lignin cellulose, hemicellulose and tannin was done by standard methods (AOAC, 1995).

Mineral Estimation. Calcium (Ca) in ashed samples was determined by atomic absorption spectrophotometry after mineralization by hydrochloric acid (M.F.A., 1982). Iron (Fe) in ashed samples was estimated using a 1, 10-phenanthroline spectrophotometric method (M.F.A., 1982). Sodium (Na) and Potassium (K) were extracted from dried samples by acids before being determined with an atomic absorption spectrophotometer (M.F.A. 1982). Phosphorus (P) was determined spectrophotometrically after treating the ashed sample solution with ammonium molybdate, metavanadate and nitric acid (Gujral *et al.,* 1987; M.F.A., 1982).

Vitamin estimation. Folic acid, thiamin (B1), riboflavin (B2), and niacin were estimated according to Kamman *et al.,* (1980). Vitamin C

was estimated by the 2,6- dichloro phenolindophenol titration method (AOAC,1995).

Amino acid Analysis. Amino acid composition of mushroom sample was determined by using a high performance liquid chromatography (HPLC) based amino acid analyser. ***Extraction:*** One gram of each dried and pulverised mushroom species was soaked in 20 ml of distilled water for 24 h and the resulting extract was filtered and kept in the refrigerator until when required for analysis. ***Amino acid analysis*:** The amino acid composition of each sample was determined using a high-performance liquid chromatograph (HPLC)-based amino acid analyzer (Agilent 1120 Compact LC) with single binary pump; Variable Wavelength Detector and the column used was ZORBAX Eclipse C18 with a detection wavelength 450 nm with the Ezchrom elite compact compliance software for data processing. The standards for different amino acids was procured from Himedia Mumbai and calibration chromatogram was established for 22 known amino acids (L-alanine, L-arginine, L-asparagine, L-aspartic acid, L-cysteine, L-cystine, L-glutamic acid, L-glutamine, glycine, L-histidine, trans-4-hydroxy-Lproline, L-isoleucine, L-leucine, L-lysine, L-methionine, L-phenylalanine, L-proline, L-serine, L-threonine, Ltryptophan, L-tyrosine, and L-valine). Thus, a 0.05 mmol standard solution of each of the standard amino acids was prepared by dissolving the corresponding acid in distilled water and then a mixture was constituted by mixing 1ml of each of the 22 standard amino acid solutions and this was later used to establish the standard chromatogram. The mobile phase consisted of a 10 mM aqueous sodium phosphate (pH 6.8) solution (buffer solution A) mixed with acetonitrile, running in a gradient, starting with a mixture consisting of 5% acetonitrile in the buffer solution, and ending with acetonitrile alone. The free amino acids in the standards and in the mushroom species were automatically derivatized by reacting with o-phthaldialdehyde under basic conditions to produce o-phthaldialdehyde derivatives in the reaction columns of the amino acid analyser. Two derivatization reagent solutions were prepared as follows: to 10 ml of 0.01 M sodium borate ($Na_2B_4O_7 \cdot 10H_2O$) buffer solution B (pH 9.1) were added 10 ml of *b* mercaptopropionic acid to make reagent solution I. Reagent solution II was prepared by mixing 10 ml of 0.01 M sodium borate ($Na_2B_4O_7 \cdot 10H_2O$) buffer solution B (pH 9.1) with 10 mg of o-phthaldialdehyde (OPA) dissolved in 3 ml of ethanol. Solutions I and II were filtered through 0.45 mm membrane filters before use. Following derivatization, the buffer solution A (mixed in acetonitrile in a 2:1 v/v ratio), containing the derivatized amino acids, was transferred into the HPLC for separation at a temperature of 45 °C, with 10 ml injection volume and a flow volume of 1.0 ml/min.

Result and Discussion

Yield Performance and Biological Efficiency of P. ostreatus

Effect of different substrates on the yield performance of mushroom varied significantly (Table 1). The first flush yielded 40%, followed by second flush of 35% and the rest in the third flush of the total yield of fruiting bodies. The yield of mushroom cultivated on different substrates ranged between 717.66 to 851.66 g /Kg dry straw. The maximum yield was recorded on soybean straw 851.66 g/Kg dry straw (85.16 % B.E.), followed by the yield on paddy straw 845.6 g/Kg dry straw (84.56 % B.E.). The mixture of soybean and paddy straw (816.99 g/kg dry straw) was at par with other but significantly higher than the yield recorded with the other substrates. The minimum yield was found on the mixture of wheat and paddy straw (71.76 % B.E.).

During the first picking maximum yield (g/kg of dry substrate) was recorded with paddy straw (405 g) which was significantly higher than all other substrate except for soybean straw (390 g). Minimum yield was recorded with wheat and paddy straw (290 g) as substrate.

Table 1. *Effect of different substrates on yield of Pleurotus ostreatus*

Substrates	Yield (g/kg dry straw)			Total	B.E. (%)
	1st picking	2nd picking	3rd picking		
Soybean straw	390.00	300.33	162.33	851.66	85.16
Paddy straw	405.00	328.00	112.66	845.66	84.56
Wheat straw	302.33	260.33	158.00	720.66	72.06
Soybean straw and Paddy straw	375.00	320.99	121.00	816.99	81.69
Soybean straw and wheat straw	330.66	270.00	176.00	776.66	77.66
Wheat straw and Paddy straw	290.00	242.00	185.66	717.66	71.76
S.E. ±	7.86	6.76	3.89	17.86	-
C.D. at 5 %	23.40	20.14	11.57	53.04	-

***** S.E. – Standard Error (±)
C.D. – Critical difference (p = 0.05)

In the second picking, the highest yield was recorded with paddy straw (328 g) which was significantly higher than all the other substrates tested, while minimum yield was recorded with wheat and paddy straw (242.00 g).

In the third and last picking, the maximum yield was recorded with wheat and paddy straw (185.66 g) which was at par with soybean and wheat straw (176.00 g) but significantly higher than all other substrates tested. The minimum yield was recorded with paddy straw (112.66 g). It was noticed that during the first two pickings, maximum yield recorded was with paddy straw and minimum was with wheat + paddy straw. The total yield was maximum in soybean straw (851.66 g) followed by paddy straw (845.66 g), although the difference was inconsistent.

Biological efficiency was used to express the yield of the fresh fruiting bodies per 100 g dry substrate (Chang *et al.,* 1981), the B.E. of the fruiting bodies of *P. ostreatus* when cultivated on various lignocellulosic waste is shown in Table 1. Soybean straw alone or in combination with paddy straw proved to be superior substrate followed by paddy straw and the least was recorded with wheat and paddy straw. Similar results with *P. sajor-caju,* where the superiority of soybean straw over paddy, wheat and sorghum straw in yield was reported (Mane *et al.,* 2007).

Proximate Composition of P. ostreatus

Different substrates affected the nutritional composition of mushroom (Table 2). Soybean straw showed maximum protein (24.66 %), fat (2.82 %) and ash (6.70 %) content. The protein content on dry weight basis varied from 20.33% to 24.66 %. It has been reported that not only the protein content of the substrate but also nature of protein in the substrate influences the protein content of the fruiting bodies (Wang *et al.,* 2001). The present results showed that protein content of *P. ostreatus* was significantly higher when grown on soybean straw than other substrate or their combination except for paddy straw alone or in combination. Similar results were reported for other *P. sajor caju* (Mane *et al.,* 2007).

The fat content on dry wt basis ranged between 2.56% to 2.82%. This range of fats is lower than that of earlier report (Wang *et al.,* 2001) and much depends on the nature of substrate.

The moisture content of *P. ostreatus* ranged from 88.51 % to 89.88 % confirming high moisture content of the fruiting bodies (Manzi *et al.,* 1999). The moisture content of *P. ostreatus* grown on different substrates was found to be significant which shows the moisture content is independent of substrate and is associated with mushroom species.

The mixture of wheat and paddy straw showed maximum moisture (89.88 %) and total carbohydrate (56.20 %) content in mushroom. Maximum ash content of *P. ostreatus* was recorded when grown on soybean straw (6.70 %) and was followed by soybean and paddy straw (6.42 %). The crude fibre (%) was maximum when *P. ostreatus* was grown on paddy straw (7.70%) followed by soybean and paddy straw (7.68 %) and minimum was recorded on soybean straw alone (7.15 %).

Table 2. *Effect of different substrates on proximate composition and mineral content of Pleurotus ostreatus*

Substrates	Moisture (%)	Protein (%)	Fat (%)	Crude Fiber (%)	Total carbohydrate (%)	Ash (%)	Ca (mg/ 100g)	P (mg/ 100g)	Fe (mg/ 100g)	Na (mg/ 100g)	K (mg/ 100g)	K/Na ratio
Soybean straw	88.54	24.66	2.82	7.15	53.20	6.70	300	1000	14.35	310	2320	7.48
Paddy straw	88.59	23.40	2.80	7.70	55.33	6.30	296	920	14.94	290	2260	7.79
Wheat straw	88.51	21.00	2.60	7.35	55.20	6.35	270	810	13.88	305	2100	6.88
Soybean straw and Paddy straw	89.37	23.00	2.70	7.68	50.50	6.42	330	870	15.62	295	2100	7.11
Soybean straw and wheat straw	89.34	21.10	2.56	7.40	52.00	6.15	260	910	14.20	260	2000	7.69
Wheat straw and Paddy straw	89.88	20.33	2.58	7.50	56.20	5.90	240	790	13.13	275	1900	6.90
S.E. ±	0.29	0.44	0.04	0.07	0.66	0.13	4.18	8.14	0.16	4.16	8.72	-
C.D. at 5 %	NS	1.30	0.11	0.22	1.96	0.38	12.45	24.25	0.47	12.39	25.90	-

S.E. – Standard Error (±)
C.D. – Critical difference (p = 0.05)

These results are in accordance with the values reported earlier by Sueli *et al.,* (2002), Syed *et al.,* (2009) for protein; Khydagi *et al.,* (1998) for fat and crude fibre content. Bonatti *et al.,* (2004) reported similar values for ash and moisture content and Akindahunsi & Oyetayo (2006) reported for total carbohydrate content in different *Pleurotus* species.

Mineral concentration of P. ostreatus

Minerals in the diet are essential for metabolic reactions, healthy bone formation, transmission of nerve impulses, regulation of water and salt balance (Kalac & Svoboda, 2000). The mineral content of *P. ostreatus* harvested varied with different substrates and their combinations (Table 2). Ca content of *P. ostreatus* ranged from 240 to 330 mg/100 g. The highest Ca content was reported when mushroom was cultivated on combination of soybean and paddy straw (330mg/100 g). The Ca content reported on combination of wheat and paddy straw (240mg/100 g) was least. Akindahunshi & Oyetayo (2006) reported the calcium content of *P. tuber-regium* as 2.9 mg/g in pileus and 1.2 ± 0.2 mg/g in stipe. Syed *et al*. (2009) reported similar results in *P. florida*.

The nutrient content of mushroom varies according to the substrate composition (Patrbansh & Madan, 1997). Phosphorus content of *P. ostreatus* ranged from 790 – 1000 mg/100g. Maximum phosphorus content of 1000 mg/100g was recorded on soybean straw. This was significantly higher than other and was followed by cultivation on Paddy straw (920 mg/100 g straw) while least was recoded with combination of wheat and paddy straw (790 mg/100 g straw). Since recommended daily intake (RDI) of P is 0.7g, *P. ostreatus* is high in P content, therefore can contribute to human nutrition as good source of Phosphorus (Çağlarırmak, 2007).

Sodium concentration of *P. ostreatus* varied significantly with different substrates. The highest sodium concentration was recorded on soybean straw (310 mg/100 g) and minimum was obtained on combination of Soybean and wheat straw (260 mg/100 g). The obtained value of sodium concentration coincides with earlier reports (Mattila *et al.,* 2001).

Potassium (K) content was higher compared to other minerals in *P. ostreatus*. The quantity of K was recorded from 1900 to 2320 mg/100g. The highest value was recorded when *P. ostreatus* was cultivated on soybean straw (2320 mg/100 g straw)

followed by the cultivation on paddy straw (2260 mg/100 g) and the least was recoded on the mixture of wheat and paddy straw (1900 mg/100 g). K content determined in this work was similar to previous studies (Manzi *et al.* 1999). Potassium content on different *Pleurotus* species ranges from 182 to 395 mg/100 mg RDI of Potassium is 3100 mg/day (Manzi *et al.* 1999). The presence of high potassium content over sodium in diet suggests the effectiveness against hypertension.

A balance between high K and low Na content in mushroom is obvious in the present study. Among the different substrates paddy straw show maximum K: Na ratio (7.79), followed by combination of soybean and wheat straw (7.69) while least ratio was recorded on wheat straw (6.88). Manzi *et al.*, (1999) and Mattila *et al.* (2001) also reported high K and Low Na concentration in mushroom fruiting body.

Fe content of *P. ostreatus* varied from 13.13 to 15.62 mg/100g when cultivated on different substrates. The mixture of soybean and paddy straw showed maximum Fe (15.62 mg/100g straw) content while minimum Fe was found on combination of wheat and paddy (13.13 mg/100g) straw. Similar variation in Fe content of *Pleurotus sp.* was also reported by Syed *et al.* (2009). Fe value of *P. ostreatus* grown on different substrates in the present work was similar that in earlier studies (Çağlarırmak, 2007; Kikuchi *et al.,* 1984).

Vitamin Concentration of P. ostreatus

The data in the Table 3 show vitamin content in fruit bodies of *P. ostreatus* cultivated on different agro-wastes. In present work, the mixture of soybean and wheat straw showed maximum folic acid (0.052 ± 0.02 mg/100g D.W.) whereas minimum of 0.033 ± 0.016 mg/100g D.W. was recorded when cultivated on combination of soybean and paddy straw. *P. ostreatus* is also a good source of the B vitamins, which helps in break down of protein, fat and carbohydrates. Çağlarırmak (2007) reported higher folic acid contents of *P. ostreatus* and *P.sajor caju* and are better source of folic acid whereas RDI of folic acid is 200 µg. Folic acid helps to protect against anaemia, diabetes and high blood pressure (Bobek *et al.*, 1991) and during pregnancy and feotus development (Çağlarırmak, 2007).

Table 3. *Vitamin content of Pleurotus ostreatus cultivated on different agricultural wastes*

Substrates	Folic acid (mg/100g)	Thiamin (B1) (mg/100g)	Riboflavin (B2) (mg/100g)	Niacin (mg/100g)	Vitamin C (mg/100g)
Soybean straw	0.045 ± 0.012	0.32 ± 1.2	0.54 ± 1.2	8.25 ± 0.12	15.21 ± 0.21
Paddy straw	0.038 ± 0.05	0.29 ± 1.8	0.65 ± 0.5	6.80 ± 0.25	12.52 ± 0.3
Wheat straw	0.048±0.03	0.33±0.6	0.68±0.8	9.13±0.7	15.80±0.8
Soybean straw and Paddy straw	0.033±0.016	0.35±0.4	0.59±0.7	8.29±0.8	13.26±1.2
Soybean straw and wheat straw	0.052±0.02	0.32±0.9	0.58±0.3	8.72±0.3	14.92±0.6
Wheat straw and Paddy straw	0.039±0.02	0.29±0.6	0.62±0.5	7.94±2.0	13.38±1.7

Thiamine (vitamin B1) is essential for neural functioning and carbohydrate metabolism and the deficiency results in beriberi. Thiamine values recorded in this work showed least variation in fruit bodies when cultivated on different agro-wastes. The mixture of wheat and paddy straw showed thiamine content of 0.29 ± 0.6 mg/100g (D.W.) while combination of soybean and paddy straw showed 0.35 ± 0.4 mg/100 g (D.W.) thiamine concentration in mushroom fruit bodies.

Riboflavin (vitamin B2) helps to keep healthy R.B.C. in blood. Wheat straw showed maximum (0.68 ± 0.8 mg/100g D.W.) riboflavin, whereas soybean straw showed (0.54 ± 1.2 mg/100g D.W.) the least concentration of riboflavin level in fruit bodies. Thiamine and riboflavin concentration of *Pleurotus* species in the earlier report are in the ranges of 0.004 - 0.08 and 0.04 - 0.3 mg/100g respectively (Furlani & Godoy, 2008).

Mushrooms are best sources of niacin, as it promotes healthy skin and ensure proper

functioning of digestive and nervous system. The maximum concentration of niacin was found (9.13 ± 0.7 mg/ 100g D.W.) in fruit bodies when cultivated on wheat straw, whereas, it was found minimum when cultivated on paddy straw alone (6.80 ± 0.25 mg/100g D.W.). The recorded values of niacin were similar to the previous studies (Breene, 1990).

Ascorbic acid was in the range of 12.52± 0.3 to 15.80±0.8 mg/ 100 g. In the present work maximum ascorbic acid in fruit bodies (15.30 ± 0.8 mg/100g D.W.) was recorded on wheat straw, whereas the least concentration of ascorbic acid 12.52 ± 0.3 mg/100g (D.W.) was recorded when grown on paddy straw alone. Bano (1976) reported 13.0 to 14.70 mg/100 g (D.W.) ascorbic acid in various mushroom species. The ascorbic acid reported in the present study is lower than the earlier study. However, no correlation can be drawn between the substrate - mushroom species relation.

Amino Acid Concentration of P. ostreatus

Table 4 shows the amino acid profile (mg/100g) of *P. ostreatus* when cultivated on different substrates. Of the total 19 types of amino acids estimated, the glutamic acid was 55-64 mg and aspartic acid was 29-45 mg while cystine (5.6–6 mg), methionine (3-5 mg) are in the least quantity. Kim *et al.* (2009) also reported maximum glutamic acid concentration (36.85±1.37) in *P. ostreatus*. Glutamic is one of the most abundant amino acids (18-36 mg) followed by leucine (23.5-37.0mg), threonine (24-32 mg), valine (24-30), arginine (20-32 mg). Earlier reports of Purkayastha & Nayak (1981); Mdachi *et al.*, (2004); showed that species of *Pleurotus* are rich in glutamic acid, aspartic acid, lysine, leucine, valine, arginine, threonine.

Table 4. *Amino acid profile of Pleurotus ostreatus cultivated on different agricultural wastes*

Sr.No	Amino acids	Soybean straw	Paddy straw	Wheat straw	Soybean straw and paddy straw	Soybean straw and wheat straw	Wheat straw and paddy straw
1	Alanine	25.1 ± 1.1	20.2 ± 0.4	28.3±1.0	20±2.6	23.7±0.2	18.5±1.5
2	Arginine	29.4 ± 0.4	22.2 ± 1.2	23.5±0.2	32.0±0.8	28.2±0.6	20.6±0.4
3	Aspartic acid	45.1 ± 2.0	38.7 ± 1.2	32.3±1.5	39.2±1.0	36.4±0.5	29.8±0.8
4	Cystine	5.6 ± 0.5	3.7 ± 0.3	6.0±0.6	3.9±1.2	3.2±0.3	3.5±0.2
5	Glutamic acid	64.2 ± 0.5	58.5 ± 0.2	56.8±0.2	63.1±1.8	59.0±2.0	55.7±3.2
6	Glycine	9.2 ± 1.5	9.5 ± 0.8	11.8±0.5	7.0±0.3	6.9±0.2	7.2±0.5
7	Histidine	15.9 ± 0.3	16.4 ± 0.6	19.2±0.3	12.2±2.6	15.8±0.5	13.0±1.0
8	Lysine	33.6 ± 2.1	36.2 ± 1.9	18.9±1.2	24.7±3.2	20.2±2.0	28.8±2.5
9	Methionine	4.3 ± 0.4	5.1 ± 0.5	3.6±0.4	4.9±0.3	3.9±0.7	3.2±0.6
10	Phenyl alanine	20.2 ± 0.3	16.5 ± 0.2	18.2±1.5	16.5±0.8	17.2±0.6	19.0±1.2
11	Proline	16.8 ± 0.3	13.8 ± 0.6	13.8±1.2	15.8±0.2	10.9±1.8	14.2±0.8
12	Serine	18.5 ± 0.8	16.3 ± 1.8	17.2±0.3	14.3±0.6	15.8±0.3	12.6±1.0
13	Threonine	32.5 ± 1.8	29.0 ± 1.5	26.3±1.2	28.0±1.6	28.5±2.2	24.8±1.4
14	Tryptophan	5.2 ± 0.8	6.9 ± 0.5	6.5±1.8	4.7±0.3	5.3±1.2	5.6±0.5
15	Tyrosine	12.3 ± 0.6	9.7 ± 1.2	9.2±0.4	11.0±0.8	10.5±1.7	8.6±0.3
16	Valine	30.1 ± 1.1	28.4 ± 2.5	25.0±1.9	27.5±0.4	28.7±0.9	24.2±0.8
17	Leucine	37.0 ± 1.6	35.2 ± 1.9	28.6±1.3	32.9±0.7	26.5±1.4	23.8±2.0
18	Isoleucine	21.5 ± 0.2	19.2 ± 0.4	18.5±1.4	18.0±2.1	14.6±1.3	16.0±0.5
19	Glutamine	5.6 ± 0.4	5.2 ± 0.5	6.2±0.3	5.3±1.0	4.6±0.8	4.8±0.3

(the above values are in mg/100g of fruiting body)

Biochemical analysis of raw straw and spent straw before and after growth of P. ostreatus

The data for biochemical content of different substrates used to cultivate *P. ostreatus* are presented in Table 5. Increase in protein and ash content and decrease in carbohydrate, crude fibre, cellulose, hemicellulose, lignin and tannin content of spent straw among the different substrates is obvious from the results. The maximum increase in protein content of the straw was recorded 4.10 to 14.00 % from the soybean straw. The maximum decrease in crude fibre (from 40.00 to 18.00 %) cellulose (36.20 to 16.00%) and lignin (from 26.32 to 9.96 %) were reported in the soybean straw.

Sueli *et al.* (2002) reported increase in protein, ash and decrease in crude fibre cellulose and lignin content of spent straw. In Paddy straw maximum decrease in tannin content (from 41.50 to 18.50%) was recorded while wheat straw showed maximum decrease in hemicelluloses content (from 22.80 to 10.00%) in spent straw. Similar results were reported earlier by Zadrazil & Dube (1992).

Mineral content of different substrates

The variation in mineral content in various substrate straws before and after cultivation was recorded (Table 6). The maximum increase in phosphorus content was recorded from 280 to 318 mg/ 100 g on soybean and paddy straw. The increase in iron content from 39.90 to 49.10 mg/ 100 g on soybean and wheat straw was recorded. The calcium content increased in wheat straw from 295 to 336 mg/ 100 g. The maximum increase in Potassium content was recorded in paddy straw (from 1990 to 2220 mg/ 100 g) while increased content of sodium was recorded in soybean straw from 350 to 365 mg/100 g.

P. ostreatrus cultivation on different substrates essentially needs understanding the methods of cultivation as well as the chemical composition of both substrate and fruiting body. This can be carried out in such a way that new formulations of lignocellulosic waste available in our region in plenty can be designed which does not affect the nutritional quality of the mushroom but improves it. This is obvious that minerals – micro and macro nutrients needed for the fruiting of the mushroom are similar to that of plants. Apart from P, K, Mg and S that are necessary nutrients for the fungal growth (Wang *et al*., 2001) many nutrients like Na, Mg and Ca are required for fruiting body is reported by Sueli *et al.,* (2002). K is available for the fungus usually in the form of Phosphate thus providing two essential minerals for metabolism (Miles and Chang, 1997). K is essential since it is a co-factor of several enzymatic reactions and is available in plenty in mushrooms (Chang *et al*., 1981; Wang *et al*., 2001). The widely studied micronutrients for the growth of many species of fungi are Fe, Zn, Al, Mn, Cu, Cr and Mo (Wang *et al*., 2001). Many are present beyond detectable limits in the substrate in binded form, making up co-enzyme, co-factor, activators of several enzymes (Miles and Chang, 1997). The mineral content of lignocellulosic biomass viz. Ca, Mg, P, Si, K are and others are usually in little quantity. The increase in protein content and Ca content of spent straw is because of decomposition of total carbohydrate, crude fibre, cellulose, hemicellulose which are utilized by the mushroom from the stage of inoculation. The increase in protein content of the spent straw is also because of the spread of mycelium in the substrate and secretion of extra cellular enzymes by the mushroom. Thus total carbohydrate, crude fibre, cellulose, hemicellulose, lignin, tannin decreases in the spent straw.

In the present study the analysis nutrients and minerals from *P. ostreatrus* based on substrates was determined for those substrates normally not used for to cultivate *P. ostreatrus.* The chemical composition of this strain for getting ideal yield and nutrition following cultivation on the substrate has been shown. There was an increase of mineral content in the degraded substrate since *P. ostreatrus* utilizes lignocellulosic constituent soon after inoculation on the substrate.

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Table 5. *Biochemical analysis of raw straw and spent straw after Pleurotus ostreatus growth of different substrates.*

Substrates	Protein (%)		Total Carbohydrate (%)		Crude fiber (%)		Ash (%)		Cellulose (%)		Hemi cellulose (%)		Lignin (%)		Tannin (%)	
	Straw	Spent straw	Straw	Spent straw	Straw	Spent Straw	Straw	Spent straw	Straw	Spent straw	Straw	Spent straw	Straw	Spent straw	Straw	Spent straw
Soybean straw	4.10	14.00	88.10	55.12	40.00	18.00	8.52	13.90	36.20	16.00	22.25	11.50	26.32	9.96	39.00	19.00
Paddy straw	2.80	7.80	86.30	48.10	35.12	18.25	8.45	12.60	36.10	19.46	19.00	11.60	23.15	12.10	41.50	18.50
Wheat straw	3.00	7.30	85.50	51.00	36.90	17.33	7.40	13.50	38.00	19.00	22.80	10.00	24.18	13.00	35.00	19.50
Soybean straw and Paddy straw	2.94	8.00	86.00	54.33	33.14	17.66	9.30	13.82	35.00	22.80	20.66	11.15	24.30	12.25	40.00	22.00
Soybean straw and wheat straw	2.82	8.25	85.30	50.50	38.12	20.33	10.90	14.33	32.30	18.50	23.00	12.60	22.80	12.90	36.50	23.00
Wheat straw and Paddy straw	2.70	7.60	84.70	52.20	34.20	18.00	8.85	13.00	32.10	18.33	19.20	10.25	23.38	12.00	38.60	24.00
S.E. ±	0.05	0.16	0.38	0.46	0.70	0.50	0.15	0.46	0.68	0.82	0.72	0.59	0.39	0.48	1.07	0.70
C.D. at 5%	0.14	0.47	1.13	1.37	2.08	1.49	0.44	1.37	2.02	2.44	2.14	1.75	1.16	1.43	3.18	2.11

S.E. – Standard Error (±)
C.D. – Critical difference (p = 0.05)

Table 6. *Effect of Pleurotus ostreatus growth on mineral content of different substrates*

Substrates	Phosphorus (mg/100g)		Iron (mg/100g)		Calcium (mg/100g)		Potassium (mg/100g)		Sodium (mg/100g)	
	Straw	Spent straw	Straw	Spent straw	Straw	Spent straw	Straw	Spent straw	Straw	Spent straw
Soybean straw	315	308	59.32	58.10	360	386	2350	2400	350	365
Paddy straw	252	275	4050	38.18	380	395	1990	2220	330	336
Wheat straw	246	255	41.90	41.20	295	336	2270	2200	370	382
Soybean straw and Paddy straw	280	318	43.35	42.10	338	350	2100	2270	362	365
Soybean straw and wheat straw	240	235	39.90	49.10	275	278	2350	2380	295	300
Wheat straw and Paddy straw	236	240	38.68	45.50	255	262	2280	2350	352	360
S.E. ±	6.40		1.29		8.12		8.90		7.19	
C.D. at 5%	19.07		3.84		24.19		26.52		21.42	

S.E. – Standard Error (±)
C.D. – Critical difference (p = 0.05)