African Journal of Biotechnology Vol. 8 (4), pp. 662-666, 18 February, 2009
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2009 Academic Journals

Full Length Research Paper

Effect of using different lignocellulosic wastes for cultivation of *Pleurotus ostreatus* (Jacq.) P. Kumm. on mushroom yield, chemical composition and nutritional value

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Accepted 5 December, 2008

In this study, the mushroom yield, chemical composition and nutritional value of *Pleurotus ostreatus* (Jacq.) P. Kumm. cultivated in wheat stalk (WS), millet stalk (MS), soybean stalk (SS) and cotton stalk (CS) were determined. Fresh mushroom yield amounts (100 g of substrate, 70% moisture) obtained from WS, CS, MS and SS substrate media were 17.9, 14.3, 22.7 and 31.5 g, respectively. Samples of mushroom cultivated on different culture mediums were analysed for protein, energy, ash, fat, dietary fibre, carbohydrate, moisture, vitamins (thiamin, riboflavin, pyridoxin and niacin) and amino acid contents.

Key words: *Pleurotus ostreatus*, amino acid, chemical composition, nutritional value, lignocellulosic wastes.

INTRODUCTION

Pleurotus spp., commonly known as oyster fungus, is a common primary decomposer of wood and vegetal residues (Zadrazil and Kurtzman, 1982). It can be naturally found in tropical and subtropical rainforests, and can be artificially cultivated (Maziero et al., 1992). Appreciated because of its delicious taste, this fungus has high quantities of proteins, carbohydrates, minerals (calcium, phosphorus, iron) and vitamins (thiamin, riboflavin and niacin) as well as low fat (Sturion and Oetterer, 1995; Justo et al., 1998; Manzi et al., 1999).

For many reasons the fungi of the *Pleurotus* genus have been intensively studied in many different parts of the world; they have high gastronomic value. They are able to colonize and degrade a large variety of lignocellulosic residues, they require shorter growth time when compared to other edible mushrooms, they demand few environmental controls, their fruiting bodies are not very often attacked by diseases and pests and they can be cultivated in a simple and cheap way (Jwanny et al., 1995; Patrabansh and Madan, 1997). Previous research has shown great potential for using some lignocellulosic materials as raw material for the produc-tion of *Pleurotus ostreatus* (Pankow, 1984; Zadrazil, 1987; Gapinski and Ziombra, 1988). However, every kind of lignocellulosic substances is likely to be used as substrate for *Pleurotus* sp. cultivation, the main and co-substrate differ among countries and even regions on the basis of availability and cost (Oei, 1991; Balazs, 1995; Croan, 1999; Labuschagne et al., 2000).

Mushrooms are rich in protein, minerals, and vitamins, and they contain an abundance of essential amino acids (Sadler, 2003). Protein tends to be present in an easily digested form and on a dry weight basis mushroom normally ranges between 20 and 40% protein which is better than many legume sources like soybeans and peanuts, and protein-yielding vegetable foods (Chang and Buswell, 1996; Chang and Mshigeni, 2001). More-over, mushroom proteins contain all the essential amino acids needed in the human diet and are especially rich in lysine and leucine which lack in most staple cereal foods (Chang and Buswell, 1996; Sadler, 2003).

Several studies have been carried out on the chemical composition and nutritional quality of edible mushrooms from different countries, particularly on Spanish (Diéz and

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Alvarez, 2001), Italian (Manzi et al., 2001; Manzi et al., 2004), Turkish (Dundar et al., 2008), Indian (Agahar-Murugkar and Subbulakshmi, 2005; Longvah and Deosthale, 1998) and Nigerian (Aletor, 1995; Fasidi, 1996) species. Based on these explanations, the objective of this work was to determine the yield, chemical composition and nutritional value of *P. ostreatus* cultivated in wheat stalk (WS), millet stalk (MS), soybean stalk (SS) and cotton stalk (CS), that are usually burned or left in the field to rot in South-East Anatolia Region of Turkey.

MATERIALS AND METHODS

Wheat stalk (WS), CS, MS and SS used in this study for cultivation of *P. ostreatus* were agricultural lignocellulosic wastes obtained from Dicle University campus area. These materials were analysed for their carbon (C) and nitrogen (N) contents. The carbon content was calculated from the ash content of the substrate and the nitrogen content was determined by the Kjehldal method. Finally, the carbon/nitrogen (C/N) ratios of each raw material were calculated and shown in Table 1. Mycelium of *P. ostreatus* was obtained from Microbiology Laboratory of Science and Arts Faculty of Dicle University. The mushroom growing process was also accomplished in the Mushroom Culture Room of Science and Arts Faculty of Dicle University in which the temperature, ventilation and relative humidity could be controlled. Fresh mushroom yield amounts (100 g of substrate 70% moisture) were obtained from WS, CS, MS and SS substrate media were calculated. The fruiting bodies of *P. ostreatus* were collected after the first productive flow and dried in an oven at 60°C to constant weight and kept under refrigeration at 4°C. Samples of mushrooms were analysed for chemical composition (moisture, diatery fibre and ash) using the AOAC procedures (AOAC, 1995). Protein was determined following the method of Leco Manuel "Thermal conductivity" by the Kjeldahl. The nitrogen factor used for protein calculation was 4.17 (Nx4.17). Energy, fat and carbohydrate were determined by the method of Watt and Merill (1975), vitamins were analysed following the methods of Finglas and Faulks (1984) and Roche (1988). Amino acid components of muhrooms were determined by using the method of Phenomenex EZ Faast GC-FID Hydrolized Amino Acid Analysis Kit, Varian GC, CP-3800GC (Method of Hydrolise). These analyses were performed by the TUBITAK (The Scientific and Technical Research Council of Turkey) Food Institute of Marmara Research Centre.

Statistic analysis

The data obtained were analysed by ANOVA and tests of significance were caried out using Duncan's multiple range tests.

RESULTS AND DISCUSSION

As shown in Table 2, fresh mushroom yield amounts obtained from WS, CS, MS and SS substrate media were 17.9, 14.3, 22.7 and 31.5 g, respectively. When the highest yield was obtained from SS, the lowest yield was obtained from CS substrate medium.

Olivier (1990) mentioned that the highest yield can be obtained from the substrate which contains 0.7 - 0.9 % N in dried weight or the C/N ratio of the substrate should be 50 or higher than 50. According to Yildiz and Karakaplan (2003) different N and C/N ratio of the substrates used for the cultivation of *Pleurotus* spp. affect the yield performance of the mushroom. All of the commentary and findings of the authors (Olivier, 1990; Yildiz and Karakaplan, 2003; Dundar and Yildiz, 2009) are confirmed and supported our findings because as shown in Table 1; pure SS contains N at a highest level and the highest mushroom yield was obtained from SS, the second highest N level was in MS and MS gave the second highest yield, the third highest N level was in WS and we observed the third highest yield from WS, the lowest N level was in CS and the lowest mushroom yield was obtained from CS culture medium.

Table 1. Carbon (C) and nitrogen (N) analysis of lignocellulosic wastes materials used for *P. ostreatus* cultivation.

Material	C (%)	N (%)	C/N
Soybean stalk	38.96	0.54	72.14
Millet stalk	40.24	0.52	77.38
Wheat stalk	42.16	0.50	84.32
Cotton stalk	51.24	0.34	150.70

As shown in Table 2, using different substrates for the cultivation of *P. Ostreatus* had significant affect ($P \leq 0.05$) on mushroom yield. We obtained different yield amounts from varied substrate mediums. This result is in accordance with the view of the other researchers (Laborde et al., 1993; Sangwan and Saini, 1995; Ragunathan and Swaminathan, 2003) who mentioned that using varied substrate media for the cultivation of mushrooms causes different yield amount because of the biological and chemichal differences between the substrates medium and genotype of the cultured mushroom. Based on these statements the SS substrate medium is found as the most convenient culture medium for productivity of *P. ostreatus* in our study.

The protein contents of mushrooms depend on substrate medium as shown in Table 2. This result may be due to biological, chemical differences and the C/N ratio of growth media as indicated by other authors (Sangwan and Saini, 1995; Ragunathan and Swaminathan, 2003). The highest protein content of mushroom samples was found as 22.15 g when grown on SS substrate and the lowest was obtained as 14.06 g on MS culture medium. Moisture contents of *P. ostreatus* (g/100 g of dry weight) are not significally different among the mushrooms cultivated on different substrate media and also the carbohydrate contents of cultivated mushrooms showed no significant differences between substrates used. The carbohydrate contents obtained in this study are lower than those reported in the literature (Bonatti et al., 2004). In this study there is a significant difference ($P \leq 0.05$) among the ash contents. Bonatti et al. (2004) found 5.58 and 6.13 g of ash in *P. ostreatus* cultivated in banana

Table 2. Effect of different lignocellulosic wastes on mushroom yield, chemical composition and energetic value of *P.ostreatus*[a] (g/100g of dry weight) (mean ± SD ; *n* = 3).

Parameters	Millet stalk	Wheat stalk	Cotton stalk	Soybean stalk
Mushroom yield (g)	22.7d	17.9c	14.3b	31.5a
Energy (kcal/100 g)	242	243	247	255
Carbohydrate	39.40	37.87	39.94	36.07
Protein	14.06±0.18 d	17.10±0.53b	14.97±0.72c	22.15±0.14a
Fat	3.15±0.21a	2.59±0.12c	2.90±0.10b	2.45±0.05c
Dietary Fibre	31.32±0.12a	30.25±0.06b	29.80±0.04c	27.0±0.06d
Ash	4.71±0.04d	4.79±0.03c	4.60±0.01b	4.85±0.03a
Moisture	7.40±0.06a	7.38±0.03a	7.37±0.08a	7.40±0.06a

[a]Means with the different letters in the same column are significantly different ($P \leq 0.05$) by Duncan's multiple range test.

Table 3. Effect of different lignocellulosic wastes on amino acid content (mg/100 g) and composition of *P. ostreatus*[a] (mean ± SD ; *n* = 3).

Amino acids	Millet stalk	Wheat stalk	Cotton stalk	Soybean stalk
Alanin	10.87±0.13c	12.53±0.02b	12.60±0.05b	14.11±0.10a
Phenylalanine[e]	9.17±0.20d	11.0±0.09b	10.42±0.29c	13.64±0.19a
Glutamic acid	18.59±0.17c	25.31±0.26a	18.32±0.36c	20.71±0.14b
Lysine[e]	9.09±0.10d	11.28±0.06b	9.61±0.03c	11.80± 0.22a
Methionine[e]	2.98±0.10b	2.69±0.31c	2.08±0.02d	5.08±0.02a
Proline	7.41±0.17d	8.15±0.06c	9.33±0.16b	10.56±0.21a
Tyrosine[e]	5.74±0.07d	6.94±0.04b	6.35±0.19c	8.90±0.32a
Valine[e]	9.04±0.02d	10.51±0.05c	11.56±0.01b	13.58±0.02a
Histidine[e]	ND	ND	ND	ND
Aspartic acid	19.55±0.07d	22.53±0.44c	23.91±0.53b	41.31±0.28a
Glycine	9.38±0.04c	10.43±0.08b	11.41±0.05a	11.33±0.10a
Isoleucine[e]	9.17±0.05d	9.88±0.40b	12.30±0.29a	9.58±0.08c
Leucine	13.55±0.07c	16.36±0.09b	16.52±0.14b	20.47±0.18a
Serine	9.18±0.05b	7.91±0.02c	9.42±0.12a	7.85±0.06c
Threonine[e]	8.98±0.04d	9.43±0.02c	10.21±0.11b	10.92±0.01a
Hydrocy- L- proline	ND	ND	ND	ND

[a]Means with the different letters in the same column are significantly different ($P \leq 0.05$) by Duncan's multiple range test. ND: Not determined.
[e]Essential amino acids.

straw and rice straw, respectively, and these findings are higher than the values we found in this study. Dietary fibre content values obtained in this work (27.0 g at SS medium, 31.32 g at MS medium) are almost similar to those reported in the literature; 34.8% for *P. ostreatus* cultivated in wheat straw (Justo et al., 1999). In this study, the fat amount obtained are lower than the Bonatti et al. (2004) findings; 5.97 and 6.32 cultivated in banana and rice straw, respectively, and higher than the 1.8 g obtained by Shah et al. (1997). Table 2 shows that chemical composition of mushrooms cultivated in different culture media depends on growth medium and species. This result may have arisen from biological and chemical differences of substrate media.

The amino acid composition and content (mg in 100 g dried mushroom) are shown in Table 3. Sixteen amino acids were determined. The mushrooms cultivated on MS, WS, CS and SS substrates comprise the three principal amino acids at different amounts. In MS glutamic acid, aspartic acid and lysine amounts are 19.55, 18.59 and 9.09 mg, respectively. In WS their amounts are 25.31, 11.28 and 22.53 mg, in CS 18.32, 23.91 and 9.61 mg and in SS 20.71, 41.31 and 11.80 mg, respectively. In this study, the mushroom samples cultivated on different substrate media contain valine, leucine, isoleucine, threonine, methionine, phenylalanine, lysine and tyrosine essential amino acids. Apart from essential amino acids, considerable amounts of alanine, glycine, serine, proline, aspartic acid and glutamic acid also found in the mushroom. As shown in Table 3, different sub-

Table 4. Effect of different lignocellulosic wastes on vitamin contents of *P. ostreatus*[a] (mean ± SD ; *n* = 3).

Vitamins(mg/100 g)	Millet stalk	Wheat stalk	Cotton stalk	Soybean stalk
Thiamin	0.14±0.00b	0.12±0.01c	0.25±0.00a	0.07±0.00d
Riboflavin	0.15±0.00b	0.19±0.02a	0.21±0.03a	0.20±0.00a
Pyridoxin	0.23±0.01a	0.23±0.01a	0.21±0.02a	0.21±0.00a
Niacin	0.93±0.02b	0.67±0.00c	1.43±0.00a	0.59±0.00d

[a]Means with the different letters in the same column are significantly different ($P \leq 0.05$) by Duncan's multiple range test.

strates affects amino acid content significantly ($P \leq 0.05$) because of its biological and chemical differences. Each amino acid content generally changes due to the growth medium. Each amino acid content of the mushrooms which were cultivated on SS substrate mediums is generally higher than the other mushrooms cultivated on MS, WS, CS substrate media. The lowest amino acid content was generally found on MS substrate mediums. Additionaly, as shown in Table 3, the amino acid composition of the mushrooms cultivated on the diffrent substrates is not affected by different culture mediums. The mushrooms obtained from different substrates comprised the same amino acids. From the study we conclude that using different substrates for cultivation of *P. ostreatus* influences the amino acid content of each mushroom cultivated on different media but has no effect on amino acid composition as stated by Mendez et al. (2004). Amino acid compositions are similar to previous literatures (Crisan and Sands, 1978; Mendez et al., 2004). The amino acid composition of the mushroom was adequate according to the FAO/WHO/UNU (1985) adult human amino acid requirements. Under normal dietary conditions the amino acid profile of *P. ostreatus* studied confirms the high bilogical value of *P. ostreatus* protein.

Table 4 gives B complex vitamins of mushrooms cultivated on different substrate media. Thiamin, riboflavin niacin and pyridoxin levels exhibited variations in four different substrate media in the study. The growth medium had significant effect ($P \leq 0.05$) on vitamin contents of mushrooms. Thiamin (B_1) is a beriberi preventing factor and plays an important role in energy metabolism (Sencer, 1983; Demirci, 2006). The recommended daily intake (RDI) of thiamin is approximately 1.00 mg. Thiamin values found in this research were higher from those found in the literature (Mattila et al., 2001; Caglairmak, 2007). Riboflavin (B_2) findings are similar with the literature (Breene, 1990; Mattila et al., 2001; Caglairmak, 2007). RDI of this vitamin is 1–3 mg (Demirci, 2006) but requirement of B_2 varies according to daily calorie intake needs (Sencer, 1983). This means that *P. ostreatus* is a good source for B_2 requirement. Niacin is pellagra preventive factor and RDI of this vitamin is 6.6 mg for each 1000 calorie intake daily or 15–20 mg (Demirci, 2006; Sencer, 1983).

The niacin values found in this study were smaller than the literature (Caglairmak, 2007). And finally we can say the mushroom obtained from CS medium comprised the highest vitamin contents. As mentioned by Patrabansh and Madan (1999), the organic substance levels of mushrooms can be varied in a large scale by depending on some factor like growing conditions and using ingredients in compost. This statement closely supports our study findings.

In conclusion, as stated by Sturion and Oetterer (1995), the value differences of these organic subtances obtained from the study can be explained by using different cultivation substrate media for cultivation and the nutritional value of mushrooms can be greatly affected by the cultivation substrates. This statements clearly supports our investigation that almost all values obtained from the study showed significant statistical differences. Despite differences in the chemical composition of the mushrooms the overall nutritional potential of the mushrooms were quite good. Furthermore, the overall results indicated that the fruit bodies of the native mush-room studied has nutrient qualities similar to other cultiva-ted exotic edible mushrooms, and a higher protein con-tent than many cereals and vegetables. Additionaly, the agricultural wastes (WS, CS, MS and SS) used in this study for cultivation of *P. ostreatus* usually burned or left in the field to rot in our region, can effectively be use for the cultivation of *P. ostreatus*. This event will provide an economical gain to the region and protect the environment while providing a nutritious food source such as mushrooms and the SS substrate medium is found the most convenient medium for the cultivation of *P. Ostreatus* among the other culture media used in this study. Therefore we can recommend the SS substrate medium to mushroom cultivators for the cultivation of *P. Ostreatus*.

ACKNOWLEDGEMENT

The authors are grateful to TUBITAK (The Scientific and Technical Research Council of Turkey) Food Institute of Marmara Research Centre for chemical analyses of mushrooms.

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