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RESEARCH PAPER

Nutritional Evaluation of Spent Mushroom Substrate of Fibrous Agricultural Residues at Different Phases of Mushroom Harvest

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ABSTRACT

Farming edible mushrooms with agricultural residues is a value-addition process to convert these materials, which are considered to be wasted for human consumption. It is considered one of the most efficient biological ways by which these residues can be recycled into value-added products for livestock feeding. In this present experiment cultivation of mushrooms was done in agricultural fibrous residue i.e. paddy straw. The nutritive value evaluation of paddy straw in terms of proximate analysis and fibre fraction was investigated during growth on different days of the harvest period of edible mushrooms *Pleurotus oestrateus* (oyster mushroom). The fibrous media act as a substrate for the growth of mushroom mycelia. This fibrous residue was evaluated at three different stages of mushroom harvest. Nutritional evaluation has been done for its proximate composition; fibre fraction and some major and trace mineral content. It was observed that crude protein (CP) and total ash content (%) of the paddy straw has been increased gradually before and after using it as the substrate for mushroom cultivation and were highest in the 2nd and 3rd harvests. However, fibre fraction in terms of ADF, NDF gradually decreases and is lowest in 3rd harvest. Crude protein content was increased by 8.16% and NDF content decreased by 57.30%. The mineral content of some major and trace mineral content increased up to 2nd and 3rd harvest periods. While assessment of the nutritional potential of mushroom spent substrate of paddy straw was highest in 2nd and 3rd harvest periods after that again decreasing trend may be the utilization of all the nutrients of the by-product for mycelial growth. Thus, the growth of mushroom mycelia in agricultural fibrous residue is a promising way to improve the nutritional value of the fibrous substrate by improving the CP content, mineral content and reducing the fibre content of agricultural by-products.

HIGHLIGHTS:

- Farming edible mushrooms with agricultural residues is considered one of the most efficient biological ways by which these residues can be recycled into value-added products for livestock feeding.
- The growth of mushroom mycelia in agricultural fibrous residue is a promising way to improve the nutritional value of the fibrous substrate by improving the CP content, mineral content and reducing the fibre content of agricultural by-products.

Keywords: Fibrous Agricultural by-products, spent mushroom straw, harvesting phases, nutritive value

Mushrooms are considered heterophytes which obtain their nutrients from various sources. Farming edible mushrooms with agricultural residues is a value-addition process to convert these materials, which are considered to be wasted for human

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consumption (Zhang *et al*. 2002). It is considered one of the most efficient biological ways by which these residues can be recycled (Zhang *et al*. 2002). Mushroom can be grown successfully on an ample variety of inexpensive fibrous substrates such as paddy straws which has a considerable cellulose component (Vetayasuporn, 2006; Mane *et al*. 2007). India, every year produced more than 70 million tons of paddy straws, and their disposals pose many problems (Rani *et al*. 2008). On the other hand, if one-fourth of the paddy straw burnt is utilized to grow edible mushrooms, approximately 319 million metric tons of it can be produced annually (Marimuthu and Krishnamoorthy 1991; Rani *et al*. 2008). It is considered an inexpensive substrate and utilization of it can be one of the best alternate solutions for feed shortage if the proper nutritive value of these spent mushroom straws can be evaluated for exploration of the best possible way for ruminant livestock feeding. Moreover, paddy straw is more fibrous with low nutritive value due to its strong lingo-cellulosic bond which makes it less palatable for ruminant species. *Pleurotus* species especially oyster mushroom is the fourth most important mushroom in the world (Rani *et al*. 2008). Cultivation of *Pleurotus* species is becoming popular throughout the world because of their ability to grow in a wide range of temperatures and on different lignocellulosic residues in a short cultivation time and their high nutritional value (Chahal 1989). The efficiency of mushroom species in producing food protein from agro-wastes lies in their extensive ability to secrete a variety of hydrolyzing and oxidizing enzymes that aid in the degradation of lignocellulosic wastes (Rai and Saxena 1990).

In the present study, an attempt has been made to use edible mushroom *Pleurotus oestrateus* species as potent biological agents for organic recycling of agricultural wastes like paddy straw and degradation of lingo-cellulosic waste at different stages of mushroom harvest and its potential in terms of nutritive value and mineral content for its possible use as ruminant feed.

MATERIALS AND METHODS

The work was conducted at the experimental shed of the Animal Nutrition Department, College of Veterinary Science, Assam Agricultural University, Khanapara, Assam.

Cultivation and harvesting of mushrooms

Cultivation of Oyster mushrooms was done in paddy straw as substrate (S) without using any chemicals for cultivation. The first step is the inoculation, for this mushroom spawn will be mixed with substrate material (Fibrous residue) and the growing medium is then placed into polybags in layers after full pressing with small holes or air filters in them for air exchange. The second step is the incubation of the bags in a properly ventilated room with a temperature of 18-25^{o}C, to incubate for the first phase of growth. For spawn growth, a 20-25 days time period was required for the full web of root-like threads of mycelium and colonise the growing substrate. The third phase is the fruiting phase, where the colonised spawn starts fruiting and maturation and harvesting of the mushroom fruiting body followed by collection of fermented spent mushroom substrate (SMS). Spent mushroom substrate (SMS) was collected at three different harvest periods of mushroom mycelia growth period i.e., the substrate (S) left after 1st harvest (20-25 days post inoculation) is categorised as S_1, then substrate (S) left after 2nd harvest (32 days post inoculation) and 3rd harvest (40 days post inoculation) as S_2 and S_3, respectively. The growth of mushroom mycelia in the substrate at different period was evaluated accordingly changes in the nutritive value of the spent substrate was analysed in the laboratory.

The spent mushroom substrate will be collected in three different periods of harvest are represented as follows:

- S_1 : Spent mushroom substrate, SMS obtained from 1st harvest i.e., 20-25 days)
- S_2 : Spent mushroom substrate, SMS obtained from 2nd harvest i.e., 32 days)
- S_3 : Spent mushroom substrate, SMS obtained from 3rd harvest i.e., 40 days)

To evaluate the proximate composition (%) i.e., CP (crude protein), EE (ether extract), Total ash, CF (crude fibre) method followed is as per the standard procedure of AOAC (2012), for fibre fraction i.e., NDF (Neutral detergent fibre), ADF (Acid detergent fibre) method followed was as per Van Soest *et*

al. (1967). For analysis of major minerals (Ca, P) and trace minerals i.e., Fe (iron), Cu (Copper), Zn (Zinc), Se (Selenium), and Mn (Manganese) etc. were estimated from 1g of mechanically ground and oven-dried samples at 175°C. Then it was digested with sulphuric acid and 40% nitric acid and was allowed to stand overnight at room temperature, before being analyzed for specific metals, using Atomic Absorption Spectrophotometer (AAS) Shimadzu –AA-65015 (Guzman and Jimenez, 1992).

The data collected from the study were subjected to statistical analysis using one-way ANOVA as per Snedecor and Cochran (1994) for meaningful and accurate comparison and interpretation.

RESULTS AND DISCUSSION

The chemical composition of spent mushroom straw (SMS) in terms of proximate composition and fibre fraction at three different stages of harvest has been presented in Table 1. The DM content of SMS significantly (P<0.01) reduces in the subsequent 2nd and 3rd harvests due to bio-decomposition and utilization of substrate for mycelia growth (Ab Rhaman *et al.* 2022). Among the experimental groups CP and total ash content at 2nd harvest (S_2) and 3rd harvest (S3) is significantly higher (P<0.01) than normal paddy straw. Mushrooms have a good source of protein (4.22g), carbohydrate (1.11g), fat (1.05g), ash (2.30g), and moisture (85.95) (Krishnamoorthy *et al.* 1998). This higher CP percentage might be due to the incorporation of nitrogenous substances during the growth of mycelial growth leading to an increase in fungal biomass during the subsequent fermentation process (Krishnaveni *et al.* 2014). The crude fibre (CF) content is lower than the normal paddy straw which might be due to the presence of cellular lignolytic enzymes (lignin peroxidise, manganese peroxidise) and cellulolytic enzyme (cellulose) that can be responsible for the breakdown of lignocellulosic bond during the fermentation process (Rani *et al*. 2008). The level of cell wall constituents (NDF%) and acid detergent fibre (ADF) percentage decreases gradually in the subsequent harvest due to the decrease in organic matter (OM) content during the fermentation process. There was also an increase in total ash content which signifies the accumulation of mineral matter in the subsequent harvest period (Mirunalini *et al.* 2012).

The mineral composition of the substrate also varies with different harvest periods and its concentration was higher in 2nd and 3rd harvests as depicted in Table 2. The mineral composition of spent mushroom paddy straw was higher compared to the normal paddy straw. There was significant variation in the major and trace mineral content among different phases of harvest. It has been observed that major minerals i.e., calcium (Ca) and phosphorus (P) as per cent basis significantly higher (P<0.01) in the 2nd and 3rd phases of harvest as compared to the 1st phase. The higher percentage of Ca and P might be due to the increased growth and coverage

Table 1: Comparative nutritional analysis of normal paddy straw and mushroom spent paddy straw at different stages of harvest

Attributes (%)	Rice straw without mushroom cultivation	Paddy straw as substrate			F Value
		1st harvest	2nd harvest	3rd harvest	
		S1	S2	S3	
Dry matter (DM)	85.20±0.35^{D}	46.80 ±0.29^{C}	41.30±0.44^{B}	39.40±0.26^{A}	3836.17**
Organic matter (OM)	81.60±0.49^{C}	80.20±0.64^{C}	76.90±0.64^{B}	72.10±0.90^{A}	37.78**
Crude protein (CP)	3.98±0.12^{A}	6.91±0.19^{B}	8.12±0.07^{C}	8.16±0.09^{C}	228.64**
Ether extract (EE)	1.16±0.06	1.34±0.09	1.12±0.05	1.27±0.09	1.58^{NS}
Crude fibre (CF)	32.56±0.58^{C}	22.43±0.26^{B}	20.28±0.55^{A}	19.94±0.48^{A}	147.959**
Total Ash	16.74±0.53^{A}	18.54±0.51^{B}	21.89±0.42^{C}	20.16±0.55^{B}	19.568**
Nitrogen-free extract (NFE)	40.10±0.48^{A}	49.65±0.38^{D}	47.64±0.34^{C}	46.00±0.42^{B}	99.948**
NDF (neutral detergent fibre)	66.37±0.94^{C}	62.05±0.77^{B}	58.03±1.01^{A}	57.30±0.85^{A}	21.350**
ADF (acid detergent fibre)	40.30±0.51^{A}	49.93±0.43^{C}	45.97±0.41^{B}	44.71±0.45^{B}	75.351**
ADL (Acid detergent lignin)	4.05±0.14^{C}	3.23±0.11^{B}	2.03±0.04^{A}	2.20±0.08^{A}	81.737**

***P<0.01; ^{NS}Non significant; Mean bearing different superscripts in a column differed significantly.*

Table 2: Evaluation of the mineral (Major and trace) composition of the normal paddy straw and paddy straw substrate at different phases of harvest

Attributes	Rice straw before mushroom cultivation	Paddy straw as substrate			F value
		1st harvest	2nd harvest	3rd harvest	
		S1	S2	S3	
Major mineral (%)					
Ca	1.25±0.09^{A}	2.98±0.12^{B}	3.99±0.12^{C}	4.04±0.04^{C}	166.10**
P	0.19±0.07^{A}	0.30±0.02^{A}	0.81±0.02^{C}	1.59±0.18^{D}	40.09**
Trace mineral (ppm)					
Fe	94.80±1.37^{A}	142.10±0.69^{B}	151.00±1.29^{C}	156.60±1.28^{D}	559.941**
Cu	2.23±0.10^{A}	9.69±0.69^{B}	33.11±0.35^{C}	34.57±0.45^{D}	1304.126**
Zn	40.30±0.51^{A}	103.30±3.71^{B}	122.60±1.40^{C}	128.50±0.94^{D}	385.343**
Se	1.60±0.14^{A}	7.06±0.17^{B}	9.86±0.72^{C}	10.07±0.79^{C}	51.385**
Mn	396.20±14.36^{A}	745.30±17.84^{B}	814.60±16.26^{C}	826.80±11.19^{C}	180.025**

***P<0.01; Mean bearing different superscripts in a column differed significantly.*

of mushroom mycelia over the entire substrate and their enzymatic product of degradation results in the incorporation of minerals as the end product of their metabolism. Similarly, trace mineral (in ppm) viz., Fe (iron), Cu (copper), Zn (zinc), Se (selenium) and Mn (manganese) content also increased significantly (P<0.01) in the 2nd and 3rd phase of harvest. Similar neutraceutical properties of *C. indica* mushroom have been reported by Mirunalini *et al.* (2012). The rich source of minerals found could be attributed to the composition of the substrate and the capability of the mushroom to use these components from the substrates (Krishnaveni *et al*. 2014; Roy *et al.* 2015). Demkova *et al*. (2021) reported that mushrooms can accrue heavy metals in a huge concentrations, such as mercury (Hg), lead (Pb) (Garcia *et al.* 2009), arsenic (As), cadmium (Cd) (Seyfferth *et al*. 2016), manganese (Mn), copper (Cu), iron (Fe) and zinc (Zn). Even though some of the heavy metals such as Zn, Fe, Mn and Cu are vital metals in mushroom fruit bodies, others, such as Hg, Pb, As and Cd elements, are reported as health hazards (Khani *et al*. 2017; Ab Rhaman *et al.* 2022).

CONCLUSION

Mushroom spent substrate of paddy straw has considerably high crude protein content (%) and low fibre fraction compared to the normal paddy straw due to fungal bioconversion of these fibrous residues transform it into the high nutritive content substrate and can have the potential to be used as a source of animal feed. It was found from this study that cultivation of mushrooms can increase the CP content of the agricultural waste and it increases to a maximum in the 2nd and 3rd harvest and gradually decreases due to decomposition. Thus, normal straw CP content can increase which has additional benefits for animal feeding and utilization of it as ruminant feed. Simultaneously, lower level fibre content and breakage of lignocellulosic bond enhances the availability of carbohydrates for utilization. Thus, this biotransformation of agro waste fibrous waste and high CP, mineral have the potential as livestock feed.

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