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USE OF *Pleurotus pulmonarius* TO CHANGE THE NUTRITIONAL QUALITY OF WHEAT STRAW. I. EFFECT ON CHEMICAL COMPOSITION

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SUMMARY

The effect of *Pleurotus pulmonarius* on the chemical composition of wheat straw was evaluated. Wheat straw, treated and untreated with *P. pulmonarius*, was obtained from a commercial facility. Ten samples plastic bags of wheat straw used previously as substrate to culture edible fungus were collected at random. The negative control group consisted of the pasteurized wheat straw untreated with *P. pulmonarius*. All samples were analyzed to determine dry matter, organic matter, crude protein, neutral detergent fiber, acid detergent fiber, cellulose and hemicellulose

of each wheat straw. Data were analyzed by mean comparison using a t-Student test. No differences ($P>0.05$) between treatments were found for dry matter, crude protein and hemicellulose; however, straw treated with *P. pulmonarius* showed higher percentages ($P<0.05$) of organic matter, neutral and acid detergent fiber. It is concluded that growing *P. pulmonarius* in wheat straw improves the chemical composition of the straw by increasing its organic matter content and modifies the fiber structure, which increases the soluble carbohydrates content.

USO DE *Pleurotus pulmonarius* PARA CAMBIAR LA CALIDAD NUTRITIVA DE LA PAJA DE TRIGO. I. EFECTO EN LA COMPOSICIÓN QUÍMICA

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RESUMEN

Se midió el efecto en la composición química de la paja de trigo usada como sustrato en la producción de *Pleurotus pulmonarius*. Las pajas de trigo, tanto tratadas con *P. pulmonarius* como no tratadas, fueron obtenidas de una empresa comercial. Para obtener muestras representativas para el análisis químico se tomaron al azar diez bolsas de la paja usada como sustrato para cultivar el hongo. El grupo testigo consistió en las pajas esterilizadas sin tratamiento con *P. pulmonarius*. A todas las muestras se les determinó materia seca, materia orgánica, proteína cruda, fibra detergente neutro, fibra ácido detergente, celulosa y hemicelulosa. Los datos obtenidos fueron analizados

mediante una comparación de medias utilizando una prueba de t-Student. No se encontraron diferencias ($P>0.05$) para el porcentaje de materia seca, proteína cruda y hemicelulosa; sin embargo, se presentó un mayor ($P<0.05$) porcentaje de materia orgánica, fibra detergente neutro y ácido para la paja tratada en comparación con la no tratada. Se concluye que el crecimiento del *P. pulmonarius* en paja de trigo mejora la composición química de las pajas aumentando el contenido de materia orgánica y modifica la estructura de la fibra, con lo que se incrementa el contenido de carbohidratos solubles.

Introduction

Hunger is an imminent risk for humanity, suffered by two thirds of the world. Population growth is higher than food production capacity and the problem is enhanced by the energetic crisis and the continu-

ous environmental degradation. The continuous agro-industrial growth leads to a high production of solid byproducts, which in Mexico are estimated to be in excess of 50 million ton per year, mainly from crops such as corn, beans, rice, sorghum and barley (Padilla and Guzmán,

1997) that are burned and re-incorporated (as fertilizer) in the soil, or used as a base for paper, as fuel or composted. In low amounts it is also used for animal feeding (Guzmán *et al.*, 1987), however, they are low quality forages, high in fiber and low in crude protein and

vitamin, and deficient in minerals. Their byproducts are of low palatability. Nevertheless, some of them are rich in soluble carbohydrate content and may represent an important energy source for ruminants (Jung *et al.*, 1992; Karunanandaa *et al.*, 1995; Zadrazil, 1997).

KEYWORDS / Agricultural Byproducts / Chemical Composition / *Pleurotus* / Wheat straw /

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USO DE *Pleurotus pulmonarius* PARA MUDAR A QUALIDADE NUTRITIVA DA PALHA DE TRIGO. I. EFEITO NA COMPOSIÇÃO QUÍMICA

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RESUMO

Mede-se o efeito na composição química da palha de trigo usada como substrato na produção de *Pleurotus pulmonarius*. As palhas de trigo, tanto tratadas com *P. pulmonarius* como não tratadas, foram obtidas de uma empresa comercial. Para obter amostras representativas para a análise química se tomaram aleatoriamente dez sacolas da palha usada como substrato para cultivar o fungo. O grupo testemunha consistiu em palhas esterilizadas sem tratamento com *P. pulmonarius*. Determinou-se, em todas as amostras, matéria seca, matéria orgânica, proteína crua, fibra detergente neutro, fibra ácido detergente, celulose e hemicelulose. Os dados obtidos foram analisados mediante uma

comparação de médias utilizando uma prova de *t*. Não se encontraram diferenças ($P > 0,05$) para a porcentagem de matéria seca, proteína crua e hemicelulose; no entanto, se apresentou uma maior ($P < 0,05$) porcentagem de matéria orgânica, fibra detergente neutra e ácida para a palha tratada em comparação com a não tratada. Conclui-se que o crescimento do *P. pulmonarius* na palha de trigo melhora a composição química das palhas aumentando o conteúdo de matéria orgânica e modifica a estrutura da fibra, com o que se incrementa o conteúdo de carboidratos solúveis.

Crop residues are high in cellulose, hemicellulose and lignin, but low in pectin and silica. An important limiting factor in the use of the byproducts for animal feeding is their low digestibility, due mainly to non-polysaccharide components such as phenolic acids (Ortega *et al.*, 1986; Padilla and Guzmán, 1997). Lignin forms a ligno-cellulolic complex with some carbohydrates and proteins. This complex, specially the crystalline structure of cellulose in cell walls, is highly resistant to breakdown by enzymes, rumen microorganisms in the small intestine (Langar *et al.*, 1980; Henics, 1987). Lignin not only inhibits ruminal digestion of polysaccharides, but protects other highly digestible compounds (Hadar *et al.*, 1992; Karunanandaa *et al.*, 1995; Montañez *et al.*, 2004).

In order to increase the nutritional quality of straws and agricultural byproducts, different strategies have been used to disrupt the carbohydrates-lignin complex, facilitate the access of the cellulolytic microorganisms to the structural carbohydrates and improve the quality and nutritive value of straw (Langar *et al.*, 1980; Agosin *et al.*, 1986). Biological agents have been used to remove lignin and increase digestibility of low quality forages (Jung *et al.*, 1992; Karunanandaa and Varga, 1996; Montañez *et al.*, 2004). The basidiomycetes fungi have the capability to degrade lignin

in cell walls (Yamakawa *et al.*, 1992b); among these are white-rot fungi that are capable of decomposing and mineralizing cell components from plants, because during the colonization of the substrate by the fungi the easily digestible carbohydrates are converted into simpler sugars, a process known as fungus primary metabolism. The sugars are totally consumed by the fungus and then begins the secondary metabolism, which consists of the breakdown of structural carbohydrates and lignin from substrates by the extracellular enzymes like laccase, manganese peroxidase and peroxidase (Moyson and Verachtert, 1991; Karunanandaa *et al.*, 1995; Cohen *et al.*, 2002).

Because of the high annual production of agricultural residues and their low nutritional quality (Henics, 1987; Zadrzil, 1984) it is necessary to seek new techniques to increase their nutritive value, at low energetic cost and in an environmentally safe manner. The new byproducts should be recycled through animal feeding without affecting animal productive performance. The objective of this study was to evaluate the effect on chemical composition of wheat straw used as substrate in *Pleurotus pulmonarius* production.

Material and Methods

All samples were collected at a commercial facility that pro-

duces fungi in Jalisco, Mexico. The wheat straw that was used as substrate for growth of the edible fungus *Pleurotus pulmonarius* came from the southern region of Jalisco, Mexico. The wheat straw was pasteurized in water at 120°C for 45min and then cooled down to room temperature. The pasteurized substrate was manually packed in clear polyethylene bags at 10kg per bag and inoculated with 250g of a *P. pulmonarius* strain. Culture was carried out in an incubation room at 25-26°C for 60 days. The fruitbodies were harvested on days 52 and 53 after inoculation. Ten sample plastic bags of wheat straw used previously as substrate to culture edible fungus were collected at random. The negative control group consisted of the pasteurized wheat straw untreated with *P. pulmonarius*. Samples were transported to

the Animal Nutrition Laboratory of the Centro Universitario del Sur, Universidad de Guadalajara, in Ciudad Guzmán, Jalisco, Mexico. Samples were ground in a Willey mill using a 1mm screen, then analyzed for dry matter (DM), organic matter (OM), crude protein (CP) and ash. All determinations were based on the procedures described at AOAC (1985). Neutral detergent fiber and acid detergent fiber were determined according to the methodologies of Van Soest *et al.* (1991). All analyses were run by triplicate. The data were analyzed with the t-Student test (SAS, 1998).

Results and Discussion

The results of the chemical composition analysis of the untreated and treated wheat straws are shown in Table I.

TABLE I
PROXIMATE ANALYSIS AND CELL
WALL COMPONENTS IN UNTREATED AND
Pleurotus pulmonarius TREATED WHEAT STRAWS*

Component	NC ¹	TS ²
	%	
Dry matter	96.43 a	96.54 a
Organic matter	83.87 b	88.07 a
Crude protein	4.42 a	4.78 a
ADF	40.38 b	45.81 a
NDF	61.44 b	67.25 a
Hemicellulose	21.06 a	21.44 a
Lignin	11.45 b	8.50 a
Ash	16.13 a	11.93 b

* Dry matter basis. ¹ Negative control. ² Treated wheat straw with *Pleurotus pulmonarius*. Different literals in the same row differ ($P < 0.05$).

No difference was observed in dry matter ($P>0.05$). Similarly, Coronel and Martínez (1995) inoculated barley straw with *Pleurotus ostreatus*, and Escalona *et al.* (2001) inoculated *Pleurotus florida* on a mixture of molasses residues, sugarcane bagasse, and liquid residues. These authors did not find differences on dry matter. In contrast, Jung *et al.* (1992) using five basidiomycetes species of the white-rot on oat straw and alfalfa stems, reported dry matter reductions for all fungal species and substrates. Streeter *et al.* (1981, 1982) incubated *P. ostreatus* and the bacteria *Erwinia caratovora* on wheat straw, and reported higher dry matter decomposition for treated as compared with untreated straws. Kerem *et al.* (1992) using stems of cotton, and Tripathi and Yadav (1992), Ginterová and Lazarová (1987) and Kishan *et al.* (1990), using wheat straw treated with *P. oestreatus* found reductions in DM. Yamakawa *et al.* (1992a) also reported reductions of 23% in dry matter concentration of rice straw.

The present results show that the organic matter content was higher ($P<0.05$) and the ash content was lower ($P<0.05$) for *Pleurotus*-treated wheat straw. These results contrast with those reported by Langar *et al.* (1980), who showed that during *P. ostreatus* fructification on wheat straw, the organic matter and other cell wall components, with exception of lignin, were reduced after the fungus were removed. Ortega *et al.* (1986) and Escalona *et al.* (2001) reported that ash concentration increased 60 days after barley straws were incubated with *P. ostreatus*, possibly due to higher organic matter use by the fungus. A combination of 50% of wheat straw and 50% of cotton silage incubated with the same fungus resulted in lower organic matter for the combined straws (Silanikove *et al.*, 1988). In another study, *P. ostreatus* and *P. florida* cultivated on barley straw, resulted in higher organic mat-

ter digestibility for treated straw (Coronel and Martínez, 1995; Montañez *et al.*, 2004). Similarly, Karunanandaa *et al.* (1995) also reported losses of organic matter for rice straw treated with the white rot fungus and these losses happened mainly at the moment of fruit production.

No difference ($P>0.05$) was found in crude protein concentration. These results agree with those of Ortega *et al.* (1986), who recorded no change in crude protein when wheat straw was treated with *P. ostreatus* for 45 or 60 days. In contrast, Coronel and Martínez (1995) reported differences in crude protein between straw treated with *P. ostreatus* and *P. florida* and non-treated wheat straw, and concluded that the increment in crude protein resulted from the presence of stems and fruit bodies of fungi, left on the treated substrate after harvesting. In the same manner, for *P. ostreatus*-treated barley straw, Coronel and Ortega (1998) reported a higher nitrogen concentration, attributed to the fungus residues left after the harvesting process. Rao and Naik (1990) used *P. ostreatus* incubated on wheat straw to feed ruminants, and found that acid detergent fiber and crude protein increased for straw treated with *P. ostreatus*. They reported that some microorganisms associated with the fungus have the ability to fix nitrogen from the atmosphere, and this results in an increment of nitrogen content for the treated straws.

In the present study, neutral and acid detergent fiber contents were higher ($P<0.05$) for the fungus-treated straw. These results are in contrast with those reported by Coronel and Martínez (1995) and Aceves (1997), who did not find differences between wheat and barley straw treated with *P. oestreatus* and untreated straw for neutral detergent fiber; however, the acid detergent fiber increased, suggesting that *Pleurotus* used both fiber types as an energy source. Ortega *et al.* (1986)

observed a reduction in neutral detergent fiber concentration at 45 and 65 days after incubation of barley straw with *P. ostreatus*. Silanikove *et al.* (1988) used three substrates for *P. ostreatus* and observed that the combination of 50% of wheat straw and 50% of cotton silage resulted in a reduction in the lignin-carbohydrate complex concentration and increased acid detergent fiber; therefore, the substrate quality also increased. Based on these results it is possible that the changes of fiber components are influenced by the substrate used for the fungus incubation.

In the present study, ash increased ($P<0.05$), hemicellulose was unchanged ($P>0.05$) and lignin content decreased ($P<0.05$) on *Pleurotus*-treated wheat straw. These results agree with reports by Gintevorá and Lazarová (1987, 1988), who incubated *P. ostreatus* on wheat straw and observed that hemicelluloses and lignin were more degraded than cellulose. Hemicelluloses and lignin are two energetic compounds that are metabolized during the growth stage of the fungus, almost in the same ratio. In other studies, Moyson and Verachtart (1991) and Jung *et al.* (1992) observed that lignin was not the only component degraded during fungal growth, because the released energy during lignin breakdown is not enough for fungal growth; therefore, glucose, hemicellulose and cellulose are also used as energy sources for fungus growth. This situation depends on the species and strains of fungus used. This significant reduction of the lignin-carbohydrate complex may increase the soluble detergent fiber, improving its quality as foodstuff for animal feeding.

Conclusions

The growth of *Pleurotus pulmonarius* on wheat straw changes its chemical composition by increasing the organic matter content and modifying cell wall components, which

may improve the nutritional quality of agricultural byproducts. This process may allow using straw treated with *P. pulmonarius* for ruminant feeding.

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