Spent Wheat Straw Compost of *Agaricus bisporus* Mushroom as Ruminant Feed

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ABSTRACT : Spent compost wheat straw is an available by-product from edible mushroom production, which constitutes a potential pollutant and is cost effective for disposal. This study was conducted to determine the nutritive value as ruminant feed of spent wheat straw compost from *Agaricus bisporus* mushroom production. The compost was provided from a mushroom farm, the casing soil was removed from the whole compost, and then it was sun dried and sampled for chemical analysis. An experiment was conducted, in which four wheat straw-based diets comprising control (I), 10% spent straw (II), 20% spent straw (III) and 30% spent straw (IV) were tested in a cross-over design using 8 sheep. Dry matter intake (DMI) was 74.0, 73.8, 70.2 and 57.1 and organic matter intake (OMI) was 62.7, 63.4, 58.0 and 44.4 g per kg $BW^{0.75}$ for diets I, II, III and IV, respectively, which, were significantly ($p<0.05$) lower for diet IV. Digestible OMI was respectively 33.1, 32.6, 30.6 and, 20.2 g per kg $BW^{0.75}$ on the four diets which were significantly ($p<0.05$) different between the treatments. Inclusion of spent compost straw up to 20% of the diet did not affect the digestibility of DM, OM, CF, ADF and NDF, but the diet containing 30% compost straw had statistically ($p<0.05$) lower digestibilities. Nitrogen balance was also significantly ($p<0.05$) different between the treatments. ***(Asian-Aust. J. Anim. Sci. 2006. Vol 19, No. 6 : 845-851)***

Key Words : Wheat Straw Spent Compost, Mushroom, Nutritive Value

INTRODUCTION

For the past five decades, in many parts of the world, much interest has been evident in new techniques for bioconversion of lignocellulosic materials. In this regard, production of edible mushrooms has been industrially developed in more than 80 countries (Manning, 1985; Spencer, 1985). Total mushroom production worldwide has increased rapidly during the last 20 years. During the 1979 production year, the button mushroom, *Agaricus bisporus*, accounted for over 70% of the world's supply (Spencer, 1985). In Iran, the mushroom industry has expanded during the last two decades and currently more than 50,000 tons of mushroom compost is produced annually by aerobic fermentation systems (Riahi et al., 1998).

After growing and cropping of mushrooms more than two tons of spent wheat straw (SPWS) remains from each ton of mushroom harvested (Oei, 1991). This mass of SPWS, will become an increasing problem and disposal of the large volumes of material produced on a sizeable farm can present considerable environmental concerns from nitrate leaching into ground water to filling up landfills (Kleny and Wetzler, 1981). The compost is made by mixing wheat straw, animal manure, calcium and nitrogen supplements (Bakshi and Langar, 1991; Valmaseda et al., 1991; Riahi et al., 1998). This waste material can be rich in microorganisms and extra-cellular enzymes (Ball and Jackson, 1995) and contain relatively high levels of nitrogen, potassium, phosphorus, calcium and trace elements, notably iron and silicon, (Langar et al., 1980; Burton et al., 1994) that may be used as animal feed.

Nutritive value of wheat straw cultured with *Pleurotus* fungi has been reported by some researchers (Dehanda et al., 1996; Zadrazil, 1997; Jalc et al., 1998 and Fazaeli et al., 2002a, 2004a, b). According to Zadrazil (1997) the *in vitro* dry matter digestibility of wheat straw, cultured with *Pleurotus ostreatus*, after harvesting of mushrooms (spent straw) was increased by 4.4 to 8.9 percentage units. Calzada et al. (1987) found that during the solid-state fermentation of wheat straw by *P. sajor-caju* lignin content decreased significantly and *in vitro* digestibility was increased by 14.3 to 29.5 percent. Fazaeli et al. (2002a) reported that fungal treatment increased the digestibility of DM and OM by more than 10% units and resulted in a higher intake of DM, OM and DOM, when fed to cattle. Digestibility of the straw is dependent on the depolymerization of its structural carbohydrates. Enzymatic degradation of these macromolecules in the straw would result in degradation and increase the digestibility and availability of the carbohydrate (Giovannozzi et al., 1989; Fazaeli et al., 2004b). According to Langer et al. (1980) and Durrant et al. (1991) fungal cultivation resulted in considerable changes in the spent straw, remaining after mushroom harvesting, leading to increased crude protein and soluble cell wall content which might be more useful than the original straw when fed to ruminants. Inclusion of up to 25% spent wheat straw, obtained from cultivation of *Agaricus bisporos* mushroom, in the diet of buffalo, resulted in a similar nutrient digestibility but a lower dry mater intake, compared

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Table 1. Formulation and chemical composition of the experimental diets (DM basis)

Feedstuffs (%)	Diets			
	I	II	III	IV
IWS	67	58.7	50.5	42.8
SPWS	0.0	10.0	20.0	30.0
Alfalfa hay	13.3	13.3	13.3	13.3
Beet pulp	13.3	13.3	13.3	13.3
Cotton seed meal	5.3	3.7	2.1	0.0
Urea	0.5	0.35	0.2	0.0
Common salt	0.3	0.3	0.3	0.3
Vitamin mineral supplement	0.3	0.3	0.3	0.3
Total (%)	100	100	100	100
Chemical composition (%)				
OM	86.7	85.9	82.5	78.0
Ash	13.3	14.1	17.5	22.0
CP	7.4	7.3	7.6	7.5
CF	31.7	32.1	28.0	26.5
NDF	56.6	57.2	49.4	46.6
ADF	37.3	38.2	34.3	34.0

IWS = Initial wheat straw, SPWS = Spent wheat straw.
I = Diet without SPWS (control), II = Diet contained 10% SPWS.
II = Diet contained 20%, VI = Diet contained 30% SPWS.

to the control diet (Langer et al., 1982). Spent mushroom wheat straw could be more degradable in the rumen (Zadrazil, 1997). Based on recent and historical trends, it is expected that diversification of the mushroom industry will continue in many parts of the world. However, there is limited information regarding the nutritive value and utilization of mushroom spent wheat straw compost in animal nutrition. The aim of this experiment was to study the digestibility and voluntary intake of the spent *Agaricus bispuros* mushroom wheat straw, from the bag system of mushroom production used in Iran, in sheep feeding.

MATERIALS AND METHODS

Preparing of spent wheat straw

Compost of spent wheat straw (SPWS) was obtained from local mushroom production units (Ashtiyan area in central part of Iran). The compost had been made by mixing wheat straw (6,000 kg), poultry manure (3,500 kg), urea (100 kg) molasses (100 kg) and calcium sulfate (400 kg). *Agaricus bisporus* spawn had been inoculated at 200-250 g per square meter on the wheat straw based compost. After 8 weeks of incubation, when the mushroom production and harvesting was completed, the bags of compost were removed from the growing room and the top layer of soil casing was separated, then the spent straw was dried under the sun. The air-dried SPWS as well as the initial wheat straw was chopped into 3-6 cm lengths using an electric chopper machine and kept for the feeding trial. Three replicate samples of the SPWS and initial wheat straw were collected , ground through a 1 mm-screen laboratory mill and stored for chemical analyses.

In vivo experiment

A one week pre-test was conducted to understand the acceptability and voluntary intake of the SPWS by sheep. The main experiment was carried out in a 4×4 crossover design consisting of four treatments and four time periods, using 8 mature castrated male sheep weighing 38.5±2.8 kg. The sheep were kept in individual metabolism cages and allocated to four experimental diets:

Diet with 0.0% SPWS as control.
Diet with 10% SPWS.
Diet with 20% SPWS
Diet with 30% SPWS.

The diets were formulated (Table 1) to provide maintenance requirements of the experimental animals (NRC, 1985). All feedstuffs were mixed and offered *ad libitum* as a total mixed ration (TMR) at 08:00 and 16:30 h daily.

The experiment was completed in four periods. Each period lasted three weeks, two weeks for adaptation and one week for collection. Feed intake was recorded and samples of feeds and residues were collected during the collection period and frozen at -20°C until processed for analyses. Faeces from individual animals were collected every morning, and sampled after weighing. At the end of collection periods the samples of feeds and orts were dried at 65°C for 48 h and faeces were dried at 65°C for 96 h. The dried samples were ground through a Wiley mill with a 1-mm screen, and then the samples of each experimental feed from each animal were composited for analysis. Feed composites were corrected to a 100% DM basis by drying an aliquot at 100°C for 48 h. During the collection period, urine was collected and sampled for analyses and nitrogen balance estimation.

Chemical analysis

The samples of feed and faeces were dried and ground through a 1 mm screen hammer mill, then they were chemically analysed. The OM was obtained by ashing the samples at 500°C for 4h; CP was measured by Kjeltek method (N×6.25); CF and ADL were determined according to AOAC (1990). The NDF and ADF were determined using the methods of Van Soest et al. (1991).

Statistical analysis

Data obtained from the *in vivo* experiment were analysed by parametric statistics, including analyses of variance using GLM procedure of SAS software (1992). The following model was used to describe the nutrient intake and digestibilities:

Table 2. Chemical composition of wheat straw and spent wheat straw compost[1] (% of DM basis)

Composition	IWS	SPWS
OM	90.8^{a}	64.95^{b}
Ash	9.9^{b}	35.05^{a}
CF	42.9^{a}	17.8^{b}
CP	3.1^{b}	11.0^{a}
EE	0.89	1.26
NFE	43.2^{a}	34.9^{b}
NDF	78.2^{a}	27.8^{b}
ADF	53.8^{a}	21.0^{b}
ADL	9.5^{b}	20.8^{a}
CEL	42.3^{a}	7.0^{b}
HCEL	24.4^{a}	6.8^{b}
Ca	0.8^{b}	5.4^{a}
P	0.2^{b}	0.9^{a}

[1] The values are average of three replicates.
IWS = Initial wheat straw, SPWS = Spent wheat straw.
CEL = Cellulose, HCEL = Heme-cellulose.

$$Y_{ijk} = \mu + P_j + T_k + C_l + E_{ijk}$$

Y_{ijk} = Responses of animal i in treatment k of period j,
μ = Overall sample mean
P_j = Period j effect,
T_k = Treatment k effect,
C_l = Animal i effect,
E_{ijk} = Ordinary least squares residual error.

RESULTS

Chemical composition

Spent wheat straw contained considerably lower OM, CF, NFE, NDF, ADF, cellulose and hemi-cellulose than the initial wheat straw. However, concentration of ash, CP, ADL, Ca and P were much higher in SPWS comparing to the initial wheat straw (Table 2).

Voluntary intake and digestibility

The voluntary intake of DM and OM were not different when the SPWS was included at 10% of the diet but increasing the level of SPWS in the diet reduced DM and OM intake. However, the differences were significant ($p<0.05$) only on the 30% SPWS diet (Table 3). The intakes of digestible DM and OM were significantly ($p<0.05$) decreased when the animals received diet IV, which contained 30% SPWS. When the voluntary intake was based on the metabolic body weight (g/kg $BW^{0.75}$), the average intake of DM and OM significantly ($p<0.05$) decreased for diet IV, but, no significant differences were observed between the other diets. The intake of digestible dry matter (DDM) and digestible organic matter (DOM) were also significantly ($p<0.05$) lower on diet IV, compared to the other diets.

Inclusion of SPWS up to 20 kg/100 kg of the diet did not affect the digestibilities of DM, OM, CF, NDF and ADF, but the diet containing 30 kg/100 kg SPWS had significantly ($p<0.05$) decreased digestibilities of DM, OM, NDF and ADF. Digestibility of CP was significantly ($p<0.05$) decreased on diets III and IV, but the highest reduction of CP digestibility was observed on diet IV with 30 kg/100 kg SPWS.

Nitrogen balances

Results obtained from nitrogen balance measurements

Table 3. Average feed intake and digestibility from *in vivo* experiment

Items	Level of SPWS (%)				SEM
	0.0	10	20	30	
Intake (g/d/animal)					
DM	1,144^{a}	1,144^{a}	1,082^{ab}	883^{b}	123
OM	974^{a}	974^{a}	896^{ab}	680^{b}	104
DDM	556^{a}	541^{a}	510^{ab}	355^{b}	69
DOM	526^{a}	510^{a}	479^{ab}	309^{b}	77
Intake (g/kg $BW^{0.75}$)					
DM	74.0^{a}	73.8^{a}	70.2^{a}	57.1^{b}	8.6
OM	62.7^{a}	63.4^{a}	58.0^{ab}	44.4^{b}	6.7
DDM	36.2^{a}	34.5^{a}	32.6^{ab}	22.7^{b}	3.9
DOM	33.1^{a}	32.6$_{a}$	30.6^{ab}	20.2^{b}	4.2
Digestibility (g/100 g)					
DM	48.8^{a}	46.8^{a}	46.5^{a}	41.2^{b}	3.5
OM	52.8^{a}	51.3^{a}	52.7^{a}	45.5^{b}	3.1
CP	49.6^{a}	46.8^{a}	38.1^{b}	28.1^{c}	5.8
CF	49.7^{a}	48.9^{a}	49.7^{a}	46.2^{a}	1.8
ADF	41.8^{a}	41.7^{a}	40.6^{a}	34.6^{b}	3.7
NDF	46.7^{a}	47.5^{a}	47.0^{a}	42.9^{b}	2.4

Means with the different superscripts within a row are significantly ($p<0.05$) different.
SPWS = Spent wheat straw.
SEM = Standard error of mean.

Table 4. Nitrogen balance

Items	Level of SPWS (%)				SEM
	0.0	10	20	30	
N intake (g/d)	12.7[a]	12.3[a]	12.2[a]	9.6[b]	1.6
Faecal N excretion (g/d)	6.4[c]	7.4[ab]	7.6[a]	6.9[b]	0.6
Urine N excretion (g/d)	5.1[a]	3.6[b]	3.4[b]	3.3[b]	0.8
N retention (g/d)	1.24[b]	1.37[a]	1.31[ab]	-0.57[c]	0.3
N retention (g/100 g N)	10.5[b]	11.2[a]	10.7[ab]	0.00[c]	3.8

Means with the different superscripts within a row are significantly ($p<0.05$) different.
SPWS = Spent wheat straw.
SEM = Standard error of mean.

are presented in Table 4. There were significant ($p<0.05$) differences between treatments for nitrogen intake and excretion. Nitrogen intake was the lowest when the animals received 30 kg/100 kg SPWS diet, however no significant differences were observed between the other diets. Faecal nitrogen excretion was the lowest ($p<0.05$) when the animals received the control diet, but among the experimental diets, 30 kg/100 kg SPWS had the lowest N excretion. The excretion of urinary nitrogen was significantly ($p<0.05$) lower in all diets containing SPWS than the control diet, but no significant variation was observed between the diets which contained SPWS. The amount of nitrogen retention based on g/d/animal or percentage of nitrogen retained varied significantly ($p<0.05$) between the treatments. Inclusion of the SPWS at 10 kg/100 kg of the diet increased nitrogen retention, but a significantly ($p<0.05$) negative effect was observed on nitrogen retention when the SPWS was included in the diet at 30 kg/100 kg. However, the nitrogen balance was increased by including the SPWS at 10 kg/100 kg in the diet, but it was decreased on diet IV that contained 30 kg/100 kg SPWS.

DISCUSSION

Chemical composition

Results of chemical composition showed (Table 2) that the SPWS which remained from *Agaricus bisporus* cultivation contained a considerable amount of CP and is a rich source of Ca and P that could be used in the diet of ruminants. The relatively higher amount of CP in SPWS (11 vs. 3.1% in initial straw) could be the result of using nitrogenous fertilizers during the composting period and remaining fungal residues (Bakshi and Langar, 1991; Valmaseda et al., 1991; Riahi et al., 1998). Ball and Jackson, (1995) reported that this type of waste material could be rich in microorganisms and extra-cellular enzymes and contained relatively high levels of nitrogen, potassium, phosphorus, calcium and trace elements. The concentrations of CF, NDF and ADF were much lower in the SPWS comparing to the normal wheat straw. However, this waste material contained a low level of OM and its utilization is limited because of a very high level of ash content (35 g/100 g DM). The lower amount of ADF and NDF could be the result of decreased OM in the SPWS, which is similar to the results reported by the others (Quimio, 1988; Bakshi et al., 1991; Maeda et al., 1993). The high level of ash is due to the depletion and consumption of OM of straw by the fungi. Moreover, in the case of *Agaricus* production system, the straw is contaminated with soil, which is used as a top layer of the substrate for fungal cultivation. Although the soil was present at the surface and was separated from the straw before use, it was not possible to completely separate it from the straw. The ash content of SPWS has been reported from 38-53% (Langar et al., 1982; Bakshi, et al., 1991).

Voluntary intake

The response of animals to the experimental diets was different. Voluntary intakes were significantly ($p<0.05$) reduced when the animals received the 30% SPWS diet. Such a reduction in voluntary intake could be mostly as a result of higher content of ash in diet IV. As shown in Table 1, the ash content was 22.0% in diet IV whereas it was between 13.3 and 17.5% in the other diets. The high concentration of ash and acid insoluble ash that could accord with limiting minerals in feeds would have a negative effect on the voluntary feed intake (Crosbie and Rowe, 1988; Giovannozzi et al., 1989; Kakkar et al., 1990; Gerrits, 1994). According to Kakkar et al. (1990), who utilised mushroom harvested spent straw as feed for buffaloes, the voluntary intake decreased due to the relatively high content of ash (26.4%) in the diet. Tamong et al. (1992) reported that 15% of acid insoluble ash decreased the voluntary intake when they used azolla (*Azolla pinnata*) forage in goat feeding. In addition to the high concentration of ash, presence of inhibitor substances such as phenolic compounds in SPWS, produced as a result of lignocellulose degradation through solid state fermentation by fungi, could affect the voluntary intake negatively (Langar et al., 1980; Burton et al., 1993; Bonnen et al., 1994). Reports indicated that mushroom spent straw obtained from *Coprinus fimetarius* or *Pleurotus* fungi did not have such a limitation in intake when fed to ruminants (Walli et al., 1991; Fazaeli et al., 2002b). These types of fungi are cultured on cereal straws without using any soils and the remaining compost straw contained much lower ash than the spent straw from button mushrooms (Valmaseda et al., 1991; Zadrazil, 1997; Fazaeli et al., 2002a).

Digestibility

When the amount of SPWS was increased from 20 to 30 % of the diet, the nutrient digestibility was significantly ($p<0.05$) reduced Such a decrease in digestibility may be due to the high level of ash (22% of DM) in diet IV and may have contained a relatively high amount of silicon that limits digestibility and intake (Bakshi et al., 1985; Sharma et al., 1999). High lignin (Table 2) could be another factor that negatively affected the digestibilities (Bonnen et al., 1994; Ball et al., 1995). Undersander et al. (1987) found that digestibilities of roughage feeds could be extremely decreased when the acid insoluble ash and lignin contents increased. According to Tamong et al. (1992) digestibility of azolla decreased because of high levels of acid insoluble ash and lignin. Crosbie and Rowe (1988) found a negative relationship between digestibility and silicon or lignin content of oat hulls. Decreasing digestibility has been reported by Langar et al. (1982) and Bakshi et al. (1985), when they included *Agaricus* compost residues in the diet of buffaloes. These results are not in accordance with the results reported with spent wheat straw remaining from *Pleurotus* fungi. Zadrazil (1997) studied the nutritive value of wheat straw, cultured with *P. ostreatus*, after harvesting of mushrooms (spent straw) and noted that *in vitro* dry matter digestibility was increased. Calzada et al. (1987) found that during solid-state fermentation of wheat straw by *P. sajor-caju*, lignin content decreased significantly and *in vitro* digestibility was increased. Such differences are related to the substrates and system of composting which are different between the two types of mushroom (button and oyster) culturing.

The digestibility of CP significantly ($p<0.05$) decreased as the level of SPWS increased from 10 to 20 or 30% of the diets, which indicated that CP of the compost spent wheat straw remaining from *Agaricus bisporus* cultivation had lower digestibility than the other components. Some part of the nitrogen source in SPWS originates from mycelium and the mushroom fruit body, which may be partly complexed with chitin that would not be easily digestible. Yamakava et al. (1992) studied the intake and digestibility of rice straw treated with *P. ostreatus* and reported that *in vivo* dry matter digestibility of treated straw was decreased by sheep. Walli et al. (1991) treated wheat straw with *Coprinus fimetarius* fungus and fed it to Holstein male cattle. Results indicated that protein value was increased but no enhancement was found in the digestibility and TDN content. Marwaha et al. (1990) noted that the *in vivo* digestibility of DM, CP, CF and ADF were decreased in fungal (*Pleurotus sajor-caju*) treated wheat straw. The digestibility of fungal treated or spent straw remaining from mushroom production could be affected by the type and species of fungi, condition and aim of mushroom culturing.

Nitrogen balance

It is now well established that nitrogen retention depends on the intake of nitrogen, amount of fermentable energy source, urinary and faecal excretion. The experimental diets used in this study, contained similar amounts of nitrogen but the nitrogen retention was significantly ($p<0.05$) lower when the animals received the 30% SPWS diet. This reduction is due to low nitrogen consumption as a result of lower feed intake (Table 3). In addition, nitrogen retention depends on the fermentable carbohydrate of the diet (Sarwar et al., 2003). As shown in Table 2, ash content is very high in SPWS which could accord with lower fermentable carbohydrate concentration. Therefore, reduction of intake and decreasing of metabolism may have resulted in a negative nitrogen balance in diet IV which contained the highest amount of SPWS.

CONCLUSIONS

It can be concluded that *Agaricus bisporus* harvested spent wheat straw, obtained from a bag cultivation system, contained considerable amount of nitrogen and may be used as a ruminant feed. However, its utilisation in the diets of ruminants is limited because of high mineral content, which may reduce its acceptability and nutrient balances. This experiment showed that inclusion of spent compost straw up to 20 kg/100 kg of the diet could be equivalent to 16.5% of wheat straw, 3.2% of cotton seed meal and 0.3% of urea and did not affect the nutrient intake, digestibility and nitrogen balance.

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