Influence of Microbial Inoculants on Feeding Value of Spent Lentinula edodes Substrate

Yunfu Gu, Min Yi, Jianzhou Chen and Xiaoping Zhang

Department of Microbiology, College of Resource and Environment Science,
Sichuan Agricultural University, Chengdu 611130, China

Received 2012-08-01, Revised 2012-08-22; Accepted 2012-09-19

ABSTRACT

Sawdust-based Spent Lentinula Edodes Substrate (SLES) is an important agricultural waste resource for its’ huge production amount, on the other hand, it is hard to recycling because of the low digestibility. For the purpose of recycling the SLES, a study was conducted to improve the feeding values of SLES via microbial inoculation. The SLES was ensiled with 0.5% (v/w) Lactic Acid Bacteria (LAB, Lactobacillus plantarum) or 0.5% (v/w) yeast (Saccharomyces cerevisiae) for 15 days. Four treatments were made included 100% SLES (control), 99% SLES +0.5% LAB (T1), 99% SLES +0.5% yeast (T2) and 99% SLES +0.5% LAB +0.5% yeast (T3). Compared with the raw SLES (not fermentation), 100% SLES (control) after ensiling showed higher (p<0.05) pH (5.47) and lower lactic acid production. The addition of microbe to the SLES improved most of the physical parameters, fermentation parameters and microbial populations compared to the control experiments. On the other hand, microbial-blending to SLES decreased most of the chemical parameters except for the Crude Protein (CP). Compared to the raw, ensile fermentation would increase the amino acids and microbial inoculants to the SLES could increase the total amount of amino acids further and the most abundant component of essential-amino acid and non-essential amino acid were valine and glutamate, respectively. Among the four ensile treatments, the impact of the addition of 0.5% LAB and 0.5% yeast (T3) on the SLES storage and feeding value was the greatest one (p<0.05). In conclusion: Microbial inoculation improved ensiling and feeding values of SLES.

Keywords: Spent Lentinula Edodes Substrate, Feeding Value, Microbe Inoculation, Ensiling

1. INTRODUCTION

Lentinula edodes (Berk.) Sing. was first cultivated 800 years ago in China. It ranks second next to the button mushroom in the world production of mushrooms. Since the late 1980’s, China has become the largest producer of L. edodes (1.68×10^10 kg of dried product in 2007). About 5 kg of Spent Mushroom Substrate (SMS) is produced for each kilogram of mushrooms (Williams et al., 2001), so the SMS production in China is huge. Spent Lentinula Edodes Substrate (SLES), an important agricultural waste and major subgroup of SMS, composed of a substrate mixture of sawdust, wheat bran, corn flour, calcium phosphate and residues of inorganic nutrients and pesticides. The total production of SLES was approximately 8.40×10^10 kg in 2007. Recently, there has been increasing public concern on the effects of SMS disposal on the environment. According to recycling methods, SMS might be used for animal feed because of nutritional values in it. SMS contains several bioactive compounds such as polysaccharides and proteins formed during mushroom growth, therefore it could be a potentially value-added product. Previous researchers have proved that SMS could be used as animal feed resource (Zhang et al., 1995; Suzuki et al., 1995; Adamovic et al., 1998; Kakkar and Dhanda, 1998; Bae et al., 2006; Kim et al., 2007). However, as the digestibility of sawdust-based SMS like SLES is much lower than that of cotton/straw based SMS, the sawdust-based SMS should be further processed and improved nutritionally before feeding. Furthermore, SMS is hard to store due to it is wet and putrefactive.
Biotransformation during microbial ensiling processes can prevent the SMS from putrefaction and also preserve and convert it into economically useful feedstuffs. Direct-fed microbial including yeast and LAB in animal diets have been proved to be beneficial to animal performance (Krehbiel et al., 2003) and yeast may have positive effect on the growth of LAB because of facultative anaerobic (Yang et al., 2006). Microbial inoculation was also proved efficacious in improving ensiling characteristics of straws (Gao et al., 2008), yeast and LAB were also widely used in bioconversion of agricultural organic wastes like cotton waste, straws and corn cobs (Xu et al., 2007; 2010; Chu et al., 2012), while little is known about the impact of yeast and LAB on ensiling characteristics of SLES. Therefore, the objective of this study was to evaluate the impacts of yeast and LAB inoculants on the ensiling and feeding values of sawdust-based SLES.

2. MATERIALS AND METHODS

2.1. Fermentation of the SLES

Spent L. edodes substrate (SLES) was collected from a local L. edodes farmland in Ya’an city, Sichuan province, China. The original mushroom substrate was composed of sawdust (80%), wheat bran (17%), sugar (0.55 %), CaCO₃ (1 %), plaster powder (1.45%) on a dry basis. The SLES was air-dried and ground to pass through a 1 mm screen and water was added to make the total humidity be 65%. And then the mixture was treated as following: CK: control, no microbial inoculants (100% SLES); T1: 99.5% SLES + 0.5% (v/w) LAB; T2: 99.5% SLES + 0.5% (v/w) yeast inoculums; T3: 99% SLES + 0.5% (v/w) LAB + 0.5% (v/w) yeast inoculums. Each SMS treatment (approximately 2.5 kg) was sealed in a polyethylene bag (1600×1200×0.1 mm, Tuntian, Beijing, China) which were placed in 2 kg airtight plastic containers and ensiled at room temperature for 15d.

For the microbial inoculants, the yeast (Sacchromyces cerevisiae) was grown on YM (Invitrogen) broth at 30°C for 24 h and LAB (Lactobacillus plantarum) was cultured on MRS (Invitrogen) broth at 37°C for 48 h. Yeasts were determined on MRS agar (Invitrogen Corporation, USA) incubated at 30°C for 48 h and LAB were also determined on Plate Count Agar (PCA, Invitrogen Corporation, USA) incubated at 30°C for 48 h. LAB inoculants on the ensiling and feeding values of sawdust-based SLES.

2.2. Physical and Fermentation Parameters

Physical properties of the ferments were observed for fungal growth and for fermentative odor and acidic odor. Five lab-trained evaluators observed the ferments subjectively by a casual observation method. Fungal growth was determined by and acidic odor was based on 5-point scales as follows: 1 = very bad, 2 = bad, 3 = moderate, 4 = good and 5 = very good. The pH was measured using a compound electrode (E-201-C, Shanghai Shengguang Instrument. Co. Ltd. Shanghai, China). Lactic acid was monitored following the method of Shirazinnejad and Ismail (2010).

2.3. Microbial Parameters

Microbial analyses of the samples (10 g of sample size) were conducted according to the methods of Horwitz (2005) as follows, total bacterial count was determined on Plate Count Agar (PCA, Invitrogen Corporation, USA) incubated at 30°C for 48 h. LAB were determined on MRS agar (Invitrogen Corporation, USA) incubated at 37°C for 24 h. Yeasts were determined on Yeast-Malt (YM) extract agar (Invitrogen Corporation, USA) incubated at 37°C for 48 h.

2.4. Chemical Analysis

Dry matter was analyzed by drying samples at 65°C for 48 h to constant weight. Crude ash was determined by heating samples at 600°C for 3 h. Ash free Neutral Detergent Fiber (NDF), acid detergent fiber ADF were determined according to the method of Vorlaphim et al. (2011). Hemicellulose was calculated as NDF-ADF. Water Soluble Carbohydrates (WSC) was analyzed by the method of Amini (2005). Ether Extract (EE) was determined by the AOAC method using petroleum ether for distillation instead of diethyl ether. Crude protein (CP, N×6.25) was determined by the AOAC method using petroleum ether for distillation instead of diethyl ether. Crude protein (CP, N×6.25) was determined by Horwitz (2005) methods and NH₃-N by the method of Fan et al. (2008). Amino acid was monitored by an automatic amino acid analyzer (Biochrom 30°, DKSH and England).

2.5. Statistical Analyses

All the statistical analyses were made by One-Way Analysis of Variance (ANOVA). General contrasts of means among treatments were raw vs. control; control vs. T1, T2 and T3; T1 vs. T2 and T3; T2 vs. T3. Significant differences were detected at p<0.05. All the data were analyzed by using the SPSS statistical software version 12.0 (SPSS Inc., Chicago).

3. RESULTS

3.1. Physical and Fermentation Parameters

The SLES was anaerobic fermented with yeast and LAB. Physical parameters of the ferments were analyzed subjectively by five trained evaluators and presented in Table 1. After 15 days of ensiling, SLES fermented with both yeast and LAB (T3) had a better fermentative odor score than the raw SLES and other three ferments and...
the acidic odor score in T3 was also the highest one among all the treatments. As a result, all the treatments had undergone a desirable fermentation, which was evident by favorable fermentative odor and acidic odor.

Different fermentation parameters changes were caused by inoculated different microbial to the SLES (Table 1). As different microbial was added to SLES, pH decreased while the lactic acid increased. And these parameters were most significantly affected by both yeast and LAB inoculation. Among all the treatments, the treatment of T3 gained the lowest pH value and the highest lactic acid content.

3.2. Microbial Parameters

Populations of total bacteria, LAB, yeast and mould in the SLES with different microbial inoculants are shown in Table 2. Ferment SLES with single microbial (e.g., yeast, LAB) increased populations of total bacteria, LAB and yeast but decreased the population of mould present. All microbial populations except mould were the highest in T3 treatment which showed the most favorable microbial parameters.

3.3. Chemical Analyses

The chemical compositions of SLES with different fermentation treatments are presented in Table 3. Compared with the raw SLES, most of the ensiling treatment increased the amount of Water Soluble Carbohydrates (WSC) except of T3 (which content was 2.58%). Compared to the CK, SLES fermented with yeast and LAB resulted in lower fiber content (NDF, ADF and Hemicellulose) but higher crude protein. The lowest content of crude protein is only 7.43% which emerged in single microorganism fermentation and the content of crude protein in CK slightly higher than single microorganism, while the highest one is 11.2% in the treatment with both yeast and LAB fermentation. The contents of dry matter, crude ash and ether extract were not significantly different among all the four treatments.

The composition and amount of amino acids varied among different fermentation treatments (Table 4). Compared to the raw (not fermentation) SLES, any ensile fermentation treatments would increase the amino acids and microbial inoculants to the SLES could increase the total amount of amino acids further. Compared to the CK, microbial inoculants influenced the amino acids composition and amount variously. The total amount of amino acids in T1 was 5.08 g 100−1 g of dry SLES, which were 4.71 and 6.09 in T2 and T3 treatments, respectively. The most abundant component of essential-amino acid and non-essential amino acid were valine and glutamate in all treatments. Treatment T3 contained 0.52 g valine 100−1 g of dry SLES, while treatment CK, T1 and T2 contained 0.45, 0.47 and 0.47 g valine 100−1 g of SLES, respectively. The highest amount of glutamate appeared in T3 treatment was 0.82 g 1001 g of dry SLES, while the least amount was in T2 in which 0.71 g 100−1 g of dry SLES was detected. The essential-amino acid methionine in CK and non-essential amino acid tyrosine in T1 had the lowest amount of 0.17 and 0.01 g 100−1 g of dry SLES, respectively. Additionally, another major component of non-essential amino acid, aspartic, ranged from 0.59 g to 0.79 g/100 g of dry SLES.

Table 1. Physical, fermentation parameters of SLES after fermentation a

| Items                      | Raw | CK b | T1 c | T2 d | T3 e | SE f |
|----------------------------|-----|------|------|------|------|------|
| Fermentation odor          | 2.920 | 3.850 | 4.170 | 4.260 | 4.650 | 0.24 a,b,def |
| Acidic odor                | 2.520 | 2.510 | 2.800 | 3.100 | 3.500 | 0.07 b,f |
| pH                        | 5.570 | 5.420 | 4.800 | 4.600 | 4.100 | 0.12 b,ef |
| Lactic acid (%)            | 0.032 | 0.038 | 0.211 | 0.181 | 0.375 | 0.01 b,ef |

a Based on 5-point scales, 5: very good, 1: Very bad. b, c, d, e CK= control, 100% SLES, T1= 99.5% SLES + 0.5% (v/w) LAB, T2= 99.5% SLES + 0.5% (v/w) yeast inoculums, T3= 99% SLES + 0.5% (v/w) LAB + 0.5% (v/w) yeast. SE = Standard error. f Raw differs from control (p<0.05). g Control differs from T1, T2 and T3 (p<0.05). h T1 differs from T2 and T3 (p<0.05). i T2 differs from T3 (p<0.05)

Table 2. Microbial populations of the SLES under different fermentation treatments a

| Items      | Raw b | CK c | T1 c | T2 c | T3 c | SE c |
|------------|-------|------|------|------|------|------|
| Lactobacillus | 2.36 | 5.74 | 7.53 | 5.66 | 8.39 | 0.08 b,e,g |
| Yeast      | 2.33 | 5.55 | 5.58 | 7.51 | 8.56 | 0.05 b,g |
| Mould      | 3.76 | 5.92 | 3.71 | 3.32 | 2.73 | 0.04 b,e,f,g |
| Bacteria   | 4.66 | 7.38 | 8.81 | 7.54 | 8.72 | 0.06 b,e,g |

a Wet basis. b, c log10 CFU/g: Colony-forming unit per gram of wet samples. d CK= control, 100% SLES, T1= 99.5% SLES + 0.5% (v/w) LAB, T2= 99.5% SLES + 0.5% (v/w) yeast inoculums, T3= 99% SLES + 0.5% (v/w) LAB + 0.5% (v/w) yeast. SE = Standard error. e Raw differs from control (p<0.05). f Control differs from T1, T2 and T3 (p<0.05). g T1 differs from T2 and T3 (p<0.05). h T2 differs from T3 (p<0.05)
Table 3. Chemical composition in SLES with different fermentation treatments

| Items                              | Raw  | CK   | T1   | T2   | T3   | SE   |
|------------------------------------|------|------|------|------|------|------|
| Neutral detergent fiber (%)        | 65.6 | 65.1 | 63.9 | 63.4 | 60.8 | 1.30 |
| Acid detergent fiber (%)           | 62.2 | 62.4 | 61.5 | 61.8 | 59.3 | 1.05 |
| Hemicellulose (%)                  | 3.4  | 2.76 | 2.43 | 1.64 | 1.50 | 0.48 |
| Dry matter (%)                     | 37.5 | 37.3 | 37.2 | 37.4 | 37.4 | 0.41 |
| Crude ash (%)                      | 10.7 | 10.6 | 10.4 | 10.3 | 10.3 | 0.22 |
| Crude protein (%)                  | 6.84 | 8.96 | 7.43 | 7.43 | 11.2 | 0.29 |
| Water soluble carbohydrate (%)     | 3.14 | 5.27 | 4.31 | 4.45 | 2.58 | 0.27 |
| Ether extract (%)                  | 1.64 | 1.63 | 1.61 | 1.61 | 1.62 | 0.03 |
| NH₃-N (ppm)                        | 234  | 442  | 452.0| 451.0| 398  | 9.37 |

* Dry basis. CK = Control, 100% SLES, T1 = 99.5% SLES + 0.5% (v/w) LAB, T2 = 99.5% SLES + 0.5% (v/w) yeast inoculums, T3 = 99% SLES + 0.5% (v/w) LAB + 0.5% (v/w) yeast. SE = Standard error.

Table 4. The amino-acid concentration of the SLES under different treatments (g 100⁻¹ g DM⁻¹)

| Amino acid                        | Raw  | CK   | T1   | T2   | T3   | SE   |
|-----------------------------------|------|------|------|------|------|------|
| Threonine                         | 0.242| 0.295| 0.302| 0.295| 0.364| 0.03 |
| Valine                            | 0.390| 0.454| 0.473| 0.478| 0.522| 0.02 |
| Methionine                        | 0.141| 0.182| 0.184| 0.175| 0.234| 0.01 |
| Isoleucine                        | 0.150| 0.183| 0.195| 0.172| 0.405| 0.01 |
| Leucine                           | 0.230| 0.293| 0.306| 0.284| 0.236| 0.02 |
| Phenylationine                    | 0.170| 0.174| 0.172| 0.184| 0.242| 0.01 |
| Lysine                            | 0.173| 0.194| 0.215| 0.195| 0.324| 0.02 |
| Total essential amino acids       | 1.490| 1.780| 1.850| 1.780| 2.330|      |
| Aspartic                          | 0.502| 0.610| 0.635| 0.596| 0.794| 0.02 |
| Glutamate                         | 0.670| 0.711| 0.774| 0.722| 0.825| 0.02 |
| Alanine                           | 0.280| 0.295| 0.343| 0.316| 0.406| 0.01 |
| Glycine                           | 0.264| 0.314| 0.375| 0.314| 0.425| 0.01 |
| Serine                            | 0.282| 0.324| 0.342| 0.334| 0.403| 0.02 |
| Prolinamide                       | 0.241| 0.252| 0.294| 0.264| 0.325| 0.02 |
| Tyrosine                          | 0.091| 0.094| 0.099| 0.104| 0.146| 0.01 |
| Arginine                          | 0.220| 0.245| 0.235| 0.247| 0.245| 0.02 |
| Histidine                         | 0.060| 0.088| 0.146| 0.084| 0.172| 0.00 |
| L-cysteine                        | 0.030| 0.059| 0.053| 0.050| 0.095| 0.00 |
| Total non-essential amino acids   | 2.640| 2.990| 3.300| 3.030| 3.840|      |
| Total amino acids                 | 4.130| 4.770| 5.150| 4.810| 6.170|      |

* Dry matter. CK = Control, 100% SLES, T1 = 99.5% SLES + 0.5% (v/w) LAB, T2 = 99.5% SLES + 0.5% (v/w) yeast inoculums, T3 = 99% SLES + 0.5% (v/w) LAB + 0.5% (v/w) yeast. SE = Standard error. Raw differs from control (p<0.05). Control differs from T1, T2 and T3 (p<0.05). T1 differs from T2 and T3 (p<0.05). T2 differs from T3 (p<0.05).

4. DISCUSSION

Biotransformation is a possible way in recycling SMS. Studies showed microbial inoculants would contribute to the SMS digestibility and the well-preserved TMR silage (Kim et al., 2011). Winsen et al. (2001) reported that after feed fermentation, the important difference between the feed and fermented feed was found in low pH (pH<4.5). Low pH prevents overgrowth of putrefying contaminants. Similar to the previous studies, in our study, the addition of microbe to the SLES changed its physical and fermentation parameters differently. Fermentation of SLES with both yeast and LAB resulted in the lowest pH and highest scores of fermentation odor and acidic odor (p<0.05), which indicated desirable fermentation parameters. Chemical compositions of SMS were one of the main limiting factors for its digestibility. The component of SMS varied significantly among different sources (Adamovic et al., 1998; Okano et al., 2004; 2006), study the chemical composition of different SMS would contribute to better understand the digestion process of SMS. Okano et al. (2004; 2006) reported that NDF, hemicellulose, cellulose and lignin contents for sawdust or corncob meal-based SMS were in the ranges of 64.4-75.2%, 16.6-28.4%, 39.2-44.4% and 4.6-7.9% on Dry Matter (DM) basis. In this study, the levels of fiber components in SLES were similar to those in sawdust.
5. CONCLUSION

Impact of microbial inoculants on storage and feeding values of spent 
*Lentinula edodes* substrate were studied and the physical characteristic, 
fermentation parameters, microbial populations and chemical 
components of SLES were significantly affected via microbial 
inoculants. Amino acid amounts of SLES were 

improved through microbial inoculation especially with 
both yeast and LAB and the most abundant component of 
esential-amino acid and non-essential amino acid in 
all four ensiling treatments were valine and glutamate, 
respectively. Microbial inoculants increased the feed 
values which provided a prospect of utilizing the SLES 

and further studies should pay much attention to the 
impact of fermented SLES on animal performance.

6. ACKNOWLEDGEMENT

This study is financially supported by the Sichuan 
Agricultural University and Sichuan government.

7. REFERENCES

Adamovic, M., G. Grubi, I. Milenkovic, R. Jovanovi and 
R. Protic et al., 1998. The biodegradation of wheat 
straw by *Pleurotus ostreatus* mushrooms and its use 
in cattle feeding. Anim. Feed Sci. Technol., 71: 357-362. DOI: 10.1016/S0377-8401(97)00150-8

Amini, F., 2005. Soluble proteins, proline, carbohydrates 
and Na+/K+ changes in two tomato (*Lycopersicon esculentum* Mill.) cultivars under *in vitro* salt stress. 
Am. J. Biochem. Biotechnol., 1: 204-208. DOI: 10.3844/ajbbsp.2005.204.208

Bae, J.S., Y.I. Kim, S.H. Jung, Y.G. Oh and W.S. Kwak. 
2006. Evaluation on feed-nutritional value of spent 
mushroom (*Pleurotus ostreatus*, *Pleurotus eryngii*, 
*Flammulina velutipes* substrates as a roughage 
source for ruminants). J. Anim. Sci. Technol., 48: 
237-246.

Bisaria, R., M. Madan and P. Vasudevan, 1997. 
Utilisation of agro-residues as animal feed through 
bioconversion. Bioresour. Technol., 59: 5-8. DOI: 
10.1016/S0960-8524(96)00140-X

Chu, G.M., J.M. Yang, H.Y. Kim, C.H. Kim and Y.M. 
Song, 2012. Effects of fermented mushroom 
(*Flammulina velutipes*) by-product diets on growth 
performance and carcass traits in growing-fattening 
Berkshire pigs. Anim. Sci. J., 83: 55-62. DOI: 
10.1111/j.1740-0929.2011.00924.X

Fan, Z.Y., J.H. Chen, J.Z. Xiao and P. Zhao, 2008. 
Determination of ammonia-N in silage by flow 

injection analysis. J. Agric. Sci. Technol., 10: 98-100.

Gao, L., H. Yang, X. Wang, Z. Huang and M. Ishii et al., 
2008. Rice straw fermentation using lactic acid 
bacteria. Bioresour. Technol., 99: 2742-2748. DOI: 
10.1016/j.biortech.2007.07.001

Horwitz, W., 2005. Official Methods of Analysis of 
AOAC International. 18th Edn., AOAC 
International, Gaithersburg, ISBN-10: 0935587457.

Kakkar, V.K. and S. Dhandu, 1998. Comparative 
evaluation of wheat and paddy straws for mushroom 
production and feeding residual straws to ruminants. 
Bioresour. Technol., 66: 175-177. DOI: 10.1016/S0960-8524(97)00098-9
Kim, M.K., H.G. Lee, J.A. Park, S.K. Kang and Y.J. Choi, 2011. Recycling of fermented sawdust-based oyster mushroom spent substrate as a feed supplement for postweaning calves. Asian-Aust. J. Anim. Sci., 24: 493-499.

Kim, Y.I., J.S. Bae, S.H. Jung, M.H. Ahn and S.K. Kwak, 2007. Yield and physicochemical characteristics of spent mushroom (Pleurotus eryngii, Pleurotus ostreatus and A. velutipes) substrates according to mushroom species and cultivation types. J. Anim. Sci. Technol., 49: 79-88.

Krehbiel, C.R., S.R. Rust, G. Zhang and S.E. Gilliland, 2003. Bacterial direct-fed microbials in ruminant diets: Performance response and mode of action. J. Anim. Sci., 81: 120-132.

Kwak, W.S., S.H. Jung and Y.I. Kim, 2008. Broiler litter supplementation improves storage and feed-nutritional value of sawdust-based spent mushroom substrate. Bioresour. Technol., 99: 2947-2955. DOI: 10.1016/j.biortech.2007.06.021

Okano, K., E. Tenemura, S. Miki and S. Inatomi, 2006. Effects of incubation temperature and period on the digestibility of spent corncob meal substrate after cultivation of Pleurotus eryngii. Nihon Chikusan Gakkaiho., 77: 225-230.

Okano, K., R, Kitao and S. Miki, 2004. Changes in digestibility and cell wall constituents of corncob meal medium cultivated with Pleurotus eryngii and Pleurotus salmonoeostreaninus. Anim. Sci. J., 75: 551-557.

Shirazinejad, A. and N. Ismail, 2010. Effect of Lactate Treatments on Survival of Food-Borne Pathogens in Frozen Shrimp (Penaeus merguiensis). Am. J. Agric. Biol. Sci., 5: 242-246. DOI: 10.3844/ajabssp.2010.242.246

Suzuki, Y., K. Okano and S. Kato, 1995. Characteristics of white-rotted woody materials obtained from Shiitake mushroom (Lentinus edodes) and nameko mushroom (Pholiota nameko) cultivation with in vitro rumen fermentation. Anim. Feed Sci. Technol., 54: 227-236. DOI: 10.1016/0377-8401(95)00769-J

Vorlaphim, T., M. Phonvisay, J. Khotsakdee, K. Vasupen and S. Bureenok et al., 2011. Influence of dietary curcumin on rumen fermentation, macronutrient digestion and nitrogen balance in beef cattle. Am. J. Agric. Biol. Sci., 6: 7-11. DOI: 10.3844/ajabssp.2011.7.11

Wang, W.P., F. Wang and D.F. Chen, 2004. Effects of different culture composts on the amino acid content of lentinus edodes fruit-body. J. Anhui. Agric. Sci., 32: 948-949.

Williams, B.C., J.T. McMullan and S. McCahey, 2001. An initial assessment of spent mushroom compost as a potential energy feedstock. Bioresour. Technol., 79: 227-230. PMID: 11499576

Winsen, R.L.V., B.A. Urlings, L.J. Lipman, J.M. Snijders and D. Keuzenkamp et al., 2001. Effect of fermented feed on the microbial population of the gastrointestinal tracts of pigs. Applied Environ. Microbiol., 67: 3071-3076. PMID: 11425724, DOI: 10.1128/AEM.67.7.3071-3076.2001

Xu, C., Y. Cai, J. Zhang and H. Matsuyama, 2010. Feeding value of total mixed ration silage with spent mushroom substrate. Anim. Sci. J., 81: 194-198. PMID: 20438500

Xu, C.C., Y.M. Cai, J.G. Zhang and M. Ogawa, 2007. Fermentation quality and nutritive value of a total mixed ration silage containing coffee grounds at ten or twenty percent of dry matter. J. Anim. Sci., 85: 1024-1029. PMID: 17145973

Yang, S.Y., K.S. Ji, Y.H. Baik, W.S. Kwak and T.A. McCaskey, 2006. Lactic acid fermentation of food waste for swine feed. Bioresour. Technol., 97: 1858-1864. PMID: 16257200

Zhang, C.K., F. Gong and D.S. Li, 1995. A note on the utilization of spent mushroom composts in animal feeds. Bioresour. Technol., 52: 89-91.