Asian-Aust. J. Anim. Sci.
Vol. 24, No. 4 : 493 - 499
April 2011

www.ajas.info

Recycling of Fermented Sawdust-based Oyster Mushroom Spent Substrate as a Feed Supplement for Postweaning Calves*

Min-Kook Kim[a], Hong-Gu Lee[1,a], Jeong-Ah Park, Sang-Kee Kang and Yun-Jaie Choi**
Laboratory of Animal Cell Biotechnology, Department of Agricultural Biotechnology,
Seoul National University, Seoul 157-921, Korea

ABSTRACT : The objective of this study was to find the way to prolong the storage time of sawdust-based oyster mushroom (*Pleurotus osteratus*) spent substrate (OMSS) by fermenting with potential probiotic microorganisms to recycle the otherwise waste of mushroom farms. To this purpose, lactic acid bacteria (LAB) were screened to select the best lactic acid-producing strains. Three strains of LAB (*Lactobacillus plantarum* Lp1', *Pediococcus acidilacticii* Pa193, *L. plantarum* Lp2M) were selected and in mixture they lowered the pH of the fermented OMSS to 3.81. fOMSS (fermented sawdust-based oyster mushroom spent substrate) could be stored at room temperature for at least 17 days without any deterioration of feed quality based on the pH, smell, and color. In dry matter disappearance rate *in situ*, commercial TMR (total mixed ration), OMSS and OMMM (oyster mushroom mycelium mass) showed no significant differences between the samples after 6, 12 and 24 h incubation except for 48 h. Two separate field studies were performed to test the effects of fOMSS supplement on the growth performance of postweaning Holstein calves. Field trials included groups of animals feeding calf starter supplemented with: Control (no supplement), AB (colistin 0.08% and oxyneo 110/110 0.1%), fOMSS (10% fOMSS) and fConc (10% fermented concentrate) and DFM (direct-fed microbials, average 10^9 cfu for each of three LAB/d/head). Growth performance (average daily gain and feed efficiency) of the fOMSS supplement group was higher than that of AB followed by fConc and DFM even though there was no statistically significant difference. The Control group was lower than any other group. Various hematological values including IgG, IgA, RBC (red blood cell), hemoglobin, and hematocrit were measured every 10 days to check any unusual abnormality for all groups in trial I and II, and they were within a normal and safe range. Our results suggest that sawdust-based OMSS could be recycled after fermentation with three probiotic LAB strains as a feed supplement for post-weaning calves, and fOMSS has the beneficial effects of an alternative to antibiotics for a growth enhancer in dairy calves. (**Key Words :** Postweaning Holstein Calves, Fermentation, Sawdust-based Oyster mushroom Spent Substrate, Antibiotic Alternative, Growth Performance)

INTRODUCTION

Worldwide cultivation of *Pleurotus spp.* has greatly increased during the previous few decades (Chang, 1999; Royse, 2002). In Korea, total mushroom production was 158,642 M/T in 2008 of which oyster mushroom (*Pleurotus osteratus*) was 40,071 M/T. About 5kg of spent mushroom waste is produced for each kg of mushrooms (Williams et al., 2001). In 2008, approximately 200,000 M/T of oyster mushroom spent substrate (OMSS) was estimated to have been produced, some of which was fed to cows but most would have been discarded as a waste with significant disposal cost. Therefore, recycling of OMSS as animal feeds may benefit the farmers as well as having a resource recycling effect.

Oyster mushroom is cultivated by two different methods, a straw-based compost culture and a sawdust-based plastic bottle culture system. Spent straw compost could be directly fed to the ruminant animal or reprocessed by fermenting the compost supplemented with corn meal, soybean meal and wheat bran using *Aspergillus sp*. and yeast to improve the

* This research was supported by Technology Development Program for Technology Development Program for Agriculture and Forestry, Ministry for Food, Agriculture, Forestry and Fisheries, Republic of Korea (Project No. 610005031SB130) and by a graduate fellowship from the Brain Korea 21 project and the Research Institute for Agriculture and Life Sciences, Seoul National University.
** Corresponding Author : Yun-Jaie Choi. Tel: +82-2-880-4807, Fax: +82-2-875-7340, E-mail: cyjcow@snu.ac.kr
[1] Department of Animal Science and PNU-Special Animal Biotechnology Center, Pusan National University, Miryang, Gyeongnam 627-706, Republic of Korea.
[a] These authors contributed equally to this work.
Received September 17, 2010; Accepted December 8, 2010

nutritional value, especially the crude protein level (Zhang et al., 1995; Adamovic et al., 1998). Straw breakdown is achieved by the influence of *Pleurotus osteratus* digestive enzymes, particularly on cell wall components, cellulose and lignin, and these straws can be more easily digested by ruminants. However the sawdust-based OMSS was hard to recycle due to the low nutritional value and short storage time.

Previous studies have suggested the possibility of using oyster mushroom by-product as an animal feed (Adamovic et al., 1998). The conversion of straws with the oyster mushroom (*Pleurotus spp.*) increased its nutritional value and digestibility for ruminant feed (Silvana et al., 2006).

Probiotics are live microorganisms that act beneficially in humans and animals and include *Lactobacillus*, *Bifidobacterium*, and *Enterococcus* species (Isolauri et al., 2001). When OMSS is fermented with lactic acid bacteria (LAB) strains, it might be possible not only to prolong the storage period but to also improve the nutritional value. LAB fermentation of OMSS also provides lactic acid, probiotic LAB, and various glucans of oyster mushroom to the feeding animals which are all known as prebiotics and probiotics.

Therefore, the aims of this study were: i) to select the LAB strains for the fermentation of sawdust-based OMSS to prolong the storage time and to improve the feed value, ii) to evaluate the effects of fermented OMSS supplement in animal trials in post-weaning Holstein calves.

MATERIALS AND METHODS

Selection of lactic acid bacteria for the fermentation of OMSS (oyster mushroom spent substrate)

Lactic acid bacteria were cultivated using MRS broth at 37°C for 24 h, *Bacillus spp.* were cultured in Trypticase™ soy broth (TSB) supplemented with 0.5% yeast extract at 37°C overnight, and yeast was cultured in YPD broth at 30°C for 24 h, all with vigorous shaking.

Preliminary to determining the proper combination of microorganisms to lower the pH and thus to prolong the storage time of the sawdust-based OMSS, OMSS fermentation mixture was prepared by mixing 150 g wet weight of OMSS with 75 g each of rice bran, wheat bran and corn hull, 50 g of molasses (named Conc hereafter) and 75 g of tap water (total 500 g). This mixture was inoculated with various combinations of lactic acid bacteria (*Pediococcus acidilactia* CAM1, *Pediococcus acidilactia* Pa175 and *Lactobacillus plantarum* Lp177), yeast (*Saccharomyces boulardii* Sb796) and *Bacillus* (*B. polymyxa* T-1 and *B. subtilis* T-4) and incubated at 30°C (Table 1). The pH of the fermentation product was monitored at 3, 10 and 17 d after inoculation. Next, ca. 200 lactic acid bacteria were individually cultivated in 10 ml of MRS broth at 37°C for 24 h and 1.5 ml of culture was inoculated into 30 g of TMR (total mixed ration) mix containing 30% OMSS (w/w) in a 50 ml plastic tube and screened for pH-lowering ability after 2 d fermentation at 30°C. LAB strains which gave the lowest pH were selected and used for the fermentation of OMSS for animal trials.

In situ digestibility of sawdust-based OMSS

In situ digestibility of OMSS was tested. Samples were dried in an oven (60°C, 48 h) and then ground. Chemical composition of OMSS samples is listed in Table 2. The

Table 1. Experimental design for the selection of microbial inoculants for the fermentation of sawdust-based OMSS (oyster mushroom spent substrate)

Feedstuff (g)	Cont 1	Cont 2	T1	T2	T3	T4
Rice bran	-	75	75	75	75	75
Wheat bran	-	75	75	75	75	75
Corn hull	-	75	75	75	75	75
Molasses	-	50	50	50	50	50
Water	-	75	75	75	75	75
OMSS	500	150	150	150	150	150
Total wet weight	500	500	500	500	500	500
			---------- Inoculant mix (ml) ----------			
Lactic acid bacteria (CAM1, 175, Lp177)[1] 1.9×10^9/ml			25	12.5	8.3	
Yeast (Sb796)[2] 3.4×10^8/ml				12.5	8.3	
Bacillus (T-1, T-4)[3] 4.7×10^9/ml					8.3	25

[1] CAM1, 175: *Pediococcus acidilactia*; Lp177: *Lactobacillus plantarum*. [2] Sb796: *Saccharomyces boulardii*.
[3] T-1: *Bacillus polymyxa*; T-4: *Bacillus subtilis*.

Table 2. Chemical composition of TMR[1] and sawdust-based OMSS[2] on a DM basis

Variable (%)	*In situ*		
	TMR[1]	OMMM[2]	OMSS[3]
Moisture	54	84	72
Crude protein	15.8	22.0	15.4
Ether extract	7.8	1.0	0.4
Crude fiber	15.1	30.0	40.5
Ash	6.2	6.5	5.2
Ca	0.2	0.3	0.5
P	1.2	0.6	0.3
ADF[4]	18.3	33.8	49.4
NDF[5]	33.5	49.1	65.1

[1] TMR = Total mixed ration.
[2] OMMM = Oyster mushroom mycelium mass collected from the mushroom culture bottle neck.
[3] OMSS = Sawdust-based oyster mushroom spent substrate.
[4] ADF = Acid detergent fiber.
[5] NDF = Neutral detergent fiber.

powder samples (25 g each) of TMR (commercial total mixed ration for young calves as a digestibility control), OMSS and OMMM (Oyster mushroom mycelium mass collected from the bottle neck of the oyster mushroom cultivation container) were put into pre-weighed polyester nylon bags (8×15 cm) with an average pore size of 45 um. Nylon bags were incubated in the rumen through a cannula of a Holstein steer, weighing approximately 600 kg, and removed at 6, 12, 24 and 48 h after incubation. After removal, nylon bags were cooled in ice water, washed under running tap water by hand to remove rumen fluid, dried for 48 h at 60°C, and then weighed to determine residual DM. Digestibility is defined as *in situ* dry matter disappearance (ISDMD) (Figure 2).

Animals and *in vivo* experimental procedure

All animal-based procedures were in accordance with the "Guidelines for the Care and Use of Experimental Animals of Seoul National University", which were formulated from the "Declaration of Helsinki and Guiding Principles in the Care and Use of Animals".

Holstein male calves were approximately 4 to 5 d of age and, on arrival, were moved to individual plastic calf condo cages (1.5×2.5 m). Calves were fed milk replacer until weaning at 55 d of age and adapted to each experimental diet for 5 days. Experiments were started at 60 d of age and ended at 90 d of age, i.e. 30 days of post-weaning period. Calves were fed twice daily at 8 AM and 5 PM using plastic buckets. A bucket stand was attached at the front side of individual pens at 50 cm above the floor. Calf starter was offered at 2 kg/d. Chemical composition of diets is listed in Table 3. Water was provided free choice and changed twice daily. Bromegrass hay was fed at 200 g/d. Calf condo cages were cleaned throughout the study.

The animal experiment was conducted in two segments. The first study (Trial I, average temperature: 20.5°C, relative humidity: 73.8%) was conducted from June 1 through June 30, 2008 and the second one (Trial II, average temperature: 5.5°C, average relative humidity: 65.4%) from November 15 through December 14, 2008 under field conditions.

In Trial I calves were divided into three groups (AB as a control group, fMOSS and fConc) of 6 calves each, and in Trial II four groups (Control, AB, DFM, and fOMSS) of 8 calves each. Basal diet for the calves was commercial calf starter (Calf starter™, Seoul Feed Co., Ltd. Incheon, Korea). Test groups were fed the basal diet supplemented with: antibiotics of 0.08% colistin and 0.1% oxyneo110/110

Table 3. Chemical composition of experimental diets[1] fed to Holstein calves on a DM basis

Variable (%)	Trial I			Trial II			
	AB	fOMSS	fConc	Control	AB	DFM	fOMSS
Moisture	12.28	15.59	14.52	12.28	12.28	12.28	15.59
Crude Protein	16.52	15.92	15.73	16.52	16.52	16.52	15.92
Ether Extract	3.24	3.30	3.45	3.24	3.24	3.24	3.30
Crude Fiber	11.11	11.52	10.44	11.11	11.11	11.11	11.52
Ash	5.72	5.62	5.63	5.72	5.72	5.72	5.62
Ca	0.71	0.67	0.66	0.71	0.71	0.71	0.67
P	0.51	0.52	0.53	0.51	0.51	0.51	0.52
ADF[2)]	12.43	12.99	11.64	12.43	12.43	12.43	12.99
NDF[3)]	26.04	26.32	24.77	26.04	26.04	26.04	26.32
TDN[4)]	72.15	68.48	70.68	72.15	72.15	72.15	68.48

Control diet was commercial calf starter and test groups were supplemented with:
[1] AB (colistin 0.08% and oxyneo110/110 0.1%); fOMSS (10% fermented oyster mushroom spent substrate); fConc (10% fermented concentrates); DFM (direct-fed microbials; lactic acid bacteria mix used for the fermentation of fOMSS and fConc.
[2] ADF = Acid detergent fiber. [3] NDF = Neutral detergent fiber.
[4] TDN = Total digestible nutrients; calculated using the equation of NRC (2001).

(group AB), 10% fermented oyster mushroom spent culture (group fOMSS), or 10% fermented concentrate (group fConc). Group DFM (direct-fed microbials) was orally-administered daily with 10ml of lactic acid bacteria (LAB) mixture (10^{10}-10^{11} live cells each of *Lactobacillus plantarum* Lp1, *Pediococcus acidilacticii* Pa193 and *L. plantarum* Lp2M). The Control group was fed the basal diet with no supplement.

fOMSS was prepared by mixing 30% oyster mushroom spent substrate (OMSS) with the concentrates including 15% rice bran, 15% wheat bran, 15% corn hull, 10% molasses, 15% water and LAB mixture (10^{10}-10^{11} live cells each/kg of *Lactobacillus plantarum* Lp1, *Pediococcus acidilacticii* Pa193 and *L. plantarum* Lp2M), and fermenting for 2 days at 30°C. fConc was prepared by fermenting the above-mentioned concentrate with the same LABs.

Blood collection and analysis

Blood samples were collected at 3 h after morning feeding (8 AM) on 60, 75 and 90 d of calf age. Blood was sampled by puncture of the jugular vein using evacuated tubes (Vacutainer Systems; Preanalytical Solutions, USA) containing either no anticoagulant for serum separation or K2 EDTA for blood collection. Blood tubes were placed on ice immediately after collection and the collected blood was centrifuged at 3,000 rpm for 15 min at 4°C and plasma was stored at -74°C until it was assayed. Total serum IgG or IgA in samples were determined by ELISA kit (Enzyme-linked immunosorbent assay) using Nunc immuno-plates (MaxiSorb, Nunc Roskilde, Denmark) following the manufacturer's instructions. The values were read at 450 nm using an ELISA reader (GRL 1000, Generallabs diagnostics, USA). Blood containing K2 EDTA was collected for measurement of red blood cells (RBC), platelets, hematocrit and hemoglobin by automated hematology analyzer (Sysmex, XE-2100D, Japan).

Feed analysis

Samples of experimental diets were analyzed for DM (2 h at 135°C), ash (2 h at 600°C), and CP content using the AOAC method (1990) adapted for an automatic Kjeldhal distiller (Kjeltec Auto 1035 Analyzer, FOSS, Sweden). Ether extract was determined by the AOAC method using petroleum ether for distillation instead of diethyl ether, CF was determined (AOAC, 1990) utilizing a Fibertec (Fibertec 2010 Analyzer, FOSS, Sweden); NDF and ADF were determined by the method of van Soest et al. (1991). Ca content was determined utilizing an atomic absorption spectrophotometer (AAS, Verian SpectrAA 280, Australia), and P content was determined by UV spectrophotometer (Shimadzu spectrophotometer UV 1201, Japan) (AOAC, 1990).

Statistical analysis

Body weight (BW), average daily gain (ADG), average daily feed intake (ADFI), feed efficiency (FE), and *in situ* digestibility data were analyzed using the GLM (General Linear Model) procedure of SAS (Statistical Analysis System, V9.1, USA, 2002), and treatment means were compared using the LSD multiple range test.

RESULTS

Selection of lactic acid bacteria (LAB) for the fermentation of OMSS (oyster mushroom spent substrate)

Various combinations of DFMs (direct-fed microbials) were tested for pH-lowering capacity to increase the storage period of the sawdust-based OMSS. This TMR mix was inoculated with various combinations of LABs (*Pediococcus acidilactia* CAM1, *Pediococcus acidilactia* Pa175 and *Lactobacillus plantarum* Lp177), yeast (*Saccharomyces boulardii* Sb796) and *Bacilli* (*B. polymyxa* T-1 and *B. subtilis* T-4) and incubated at 30°C (Table 1). The pH was measured at 3, 10 and 17 d (Figure 1). Control 1, containing only OMSS, showed the highest pH (pH = 6.58) and Control 2, TMR containing OMSS and the concentrate mix (rice bran, wheat bran, corn hull and molasses) without DFM, showed higher pH than the DFM treatment groups. Among the treatment groups, T1 containing only LABs had the lowest pH (4.04) at 3 d and this low pH was maintained during the experimental period of 17 d (pH 4.25 at 17 d). Thus, the laboratory collection of

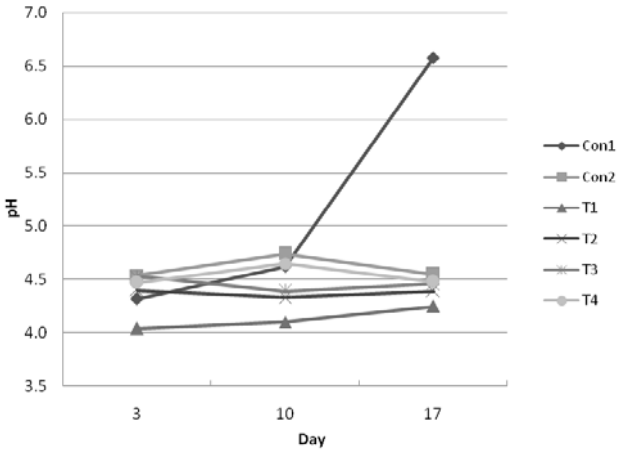

Figure 1. Acidification of fermented sawdust-based OMSS (oyster mushroom spent substrate). TMR mix was prepared by mixing OMSS with rice bran, wheat bran, corn hull, molasses and water, inoculated with various combinations of microbial culture mixtures, incubated at 30°C for 17 days and pH was measured at 3, 10 and 17 days after incubation. See Table 1 legend for group names.

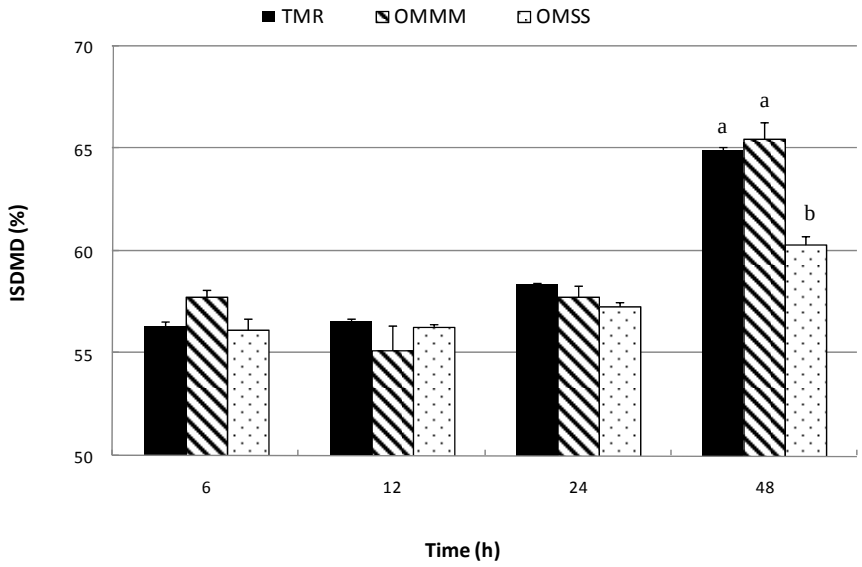

Figure 2. *In situ* digestibility of sawdust-based OMSS. *In situ* dry matter disappearance (ISDMD) was measured (see Material and Methods). Treatments were control (TMR), OMMM (Oyster mushroom mycelia mass), and sawdust-based OMSS (oyster mushroom spent substrate). Error bars represent standard error. [a, b] Means with different superscripts are different at $p<0.05$.

200 LAB strains were individually screened for their pH-lowering capacity in TMR mix containing 30% OMSS.

Lactobacillus plantarum Lp1', *Pediococcus acidilacticii* Pa193 and *L. plantarum* Lp2M gave the lowest pH value of 4.1-4.2 after 2 d fermentation. When these three LAB strains were combined to test the pH-lowering activity of OMSS-TMR mix, the resulting pH was 3.81 showing the synergistic activity (data not shown). Thus, these three LAB species were selected as DFMs (direct-fed microbials) and used for the OMSS fermentation as the inocula for the animal experiment.

In situ digestibility of sawdust-based OMSS

In situ digestibility of commercial TMR, OMSS and OMMM (oyster mushroom mycelia mass) was measured (Figure 2). There were no significant differences between the samples in dry matter disappearance rate after 6, 12 and 24 h incubation except for 48 h. *In situ* digestibility of OMSS was slightly lower at 48 h compared to TMR (control diets) and OMMM ($p<0.05$) (60.32±0.39, 64.91±0.19, 65.52±0.76%, respectively).

Effects of fOMSS supplement on animal performance (Trial 1)

Postweaned calves (average age = 60 d) were fed commercial calf starter with supplements of antibiotics (AB) (n = 6), fOMSS (n = 6) and fConc (n = 6) for a 30 d trial and the animal performance evaluated (Table 4). Feed intakes for the trial period averaged 2 kg/d. Initial BW of calves fed AB, fOMSS and fConc was similar (78.63, 72.53 and 72.63 kg, respectively). Final weight averaged 97.63 kg for calves fed AB, 93.16 kg for calves fed fOMSS and 92.00 kg for calves fed fConc. ADG (average daily gain) of the fOMSS group (0.68 kg) was higher than AB (0.63 kg) and fConc (0.64 kg) groups, though there was no statistically significant difference ($p = 0.74$). Likewise, FE (feed efficiency) of the fOMSS group was slightly better than the other groups, but without statistical significance ($p = 0.93$).

Table 4. Effects of fermented OMSS (oyster mushroom spent substrate) on the growth performance of weaned calves

Variable	Trial I			SE	p-value	Trial II				SE	p-value
	AB	fOMSS	fConc			Control	AB	DFM	fOMSS		
Calves (no.)	6	6	6			7	8	8	8		
Initial BW (kg)	78.63	72.53	72.63	1.49	0.24	65.54	66.55	68.15	70.25	0.84	0.49
Final BW (kg)	97.63	93.16	92.00	1.84	0.47	84.54	86.82	87.97	90.82	0.80	0.19
ADG (kg)	0.63	0.68	0.64	0.03	0.74	0.63	0.67	0.66	0.68	0.01	0.90
FE	0.317	0.344	0.323	0.01	0.93	0.317	0.338	0.330	0.343	0.005	0.90

Weaned calves were fed with commercial calf starter (control) supplemented with AB (colistin 0.08% and oxyneo110/110 0.1%); fOMSS (10% fermented oyster mushroom spent substrate); fConc (10% fermented concentrates); DFM (direct-fed microbials; lactic acid bacteria mix used for the fermentation of fOMSS and fConc.

ADG = Average daily gain; FE = Feed efficiency, expressed as kilogram of feed for kilogram of gain.

Effects of fOMSS supplement on animal performance (Trial 2)

To evaluate the practical efficacy of fermented OMSS as a feed additive and an antibiotic alternative, Trial II was designed to include Control (calf starter with no supplement, n = 7), AB (colistin 0.08% and oxyneo110/110 0.1%, n = 8), DFM (direct fed microbials, n = 8) and fOMSS (10% fOMSS, n = 8) groups (Table 4). One calf in the Control group died 15 d after the trial started due to bloating and it was excluded from the data collection. The ruminal bloat occurred suddenly and thus was difficult to predict under field conditions.

Trial II also started at d 60 of calf age and feed intakes for the 30 d trial averaged 2 kg/d. Initial BW of the test groups were similar: Control, AB, DFM and fOMSS groups weighed 65.54, 66.55, 68.15 and 70.25 kg, respectively. Average daily gain (ADG) of fOMSS was slightly higher than the other supplement groups. The Control group had lowest ADG supporting the growth-promoting activities of antibiotic and the other supplements, but there was no statistically significant difference between treatment groups ($p = 0.90$). Feed efficiency also was highest in fOMSS group followed by AB and DFM groups. Again the Control group showed the lowest FE compared to the other treatment groups, but without statistical significance.

The hematological values including IgG, IgA, RBC (red blood cell), hemoglobin, and hematocrit were measured every 10 d to check any unusual abnormality for all trial groups in trial I and II, and the values were within normal and safe range (data not shown; Knowles et al., 2000).

DISCUSSION

Selection of lactic acid bacteria (LAB) for the fermentation of OMSS (oyster mushroom spent substrate)

Oyster mushroom spent substrate, especially the sawdust-based ones, is problematic in recycling due to its low digestibility and short storage time. OMSS quickly deteriorated within a few days after harvest of mushrooms, especially in hot summer time. van Winsen et al. (2001) reported that after 2 d of feed fermentation, the important differences between the feed and the fermented feed were found in low pH ($pH<4.5$). Low pH prevents overgrowth of putrefying contaminants and also provides so-called probiotic LABs.

Fermentation of OMSS with lactic acid bacteria (LAB) lowered pH and acidic pH was maintained without much change during the 17 d of incubation (Figure 1). This fermented OMSS showed no symptoms of deterioration such as bad smell, change of color, and change of microbial flora (data not shown).

Effects of fOMSS supplement on animal performance

In situ digestibility of OMSS was compared with commercial TMR and mushroom mycelia mass (OMMM) and there was no difference among samples up to 24 h incubation (Figure 2). However, in the 48 h sample OMSS showed 5% lower digestibility compared to TMR and OMMM. This was expected because OMSS contains sawdust which has high NDF content making it difficult to digest. Even though OMMM has much higher crude fiber and NDF value compared to TMR (Table 2), *in situ* digestibility of OMMM was slightly higher than TMR, confirming the easily digestible nature of oyster mushroom mycelium.

To date research on mushroom spent substrate recycling has mainly concentrated on straw-based substrates, such as rice, wheat and maize straw, using both ruminants and monogastric animals. Diaz-Godinez et al. (2002) reported that sheep digested the spent maize straw better and more quickly than the untreated maize straw, which was due to damage of the lignocellulosic structure by mushroom enzymes. Zhang et al. (1995) reported that after fermentation by a yeast and a mold, the CP content of *Pleurotus osteratus* spent compost increased significantly from 24.1 to 32.3%. *In vitro* digestibility of the CP was also improved to 70% after the fermentation.

The general decline in growth performance for monogastric animals as the fiber content of feed increased has been reported previously. In finishing pigs, ADG and feed conversion ratio were similar on the control diet (0% of fermented OMSS) and 3% fOMSS group, but the growth performances were significantly lower in 5% and 7% fOMSS groups ($p<0.05$) (Song et al., 2007). Considering the developing rumen of young calves (d 60 of calf age), a 10% level of fOMSS (final OMSS content 3%) was supplemented in the animal trial using post-weaned calves.

In two animal trials, ADG and FE of the fOMSS group were higher than other groups including control and antibiotic, though without a statistically significant difference.

To evaluate the growth promoting activity of antibiotics, DFM and fOMSS, DFM and control group was included in trial II (Tables 3 and 4). In the second trial, ADG and FE of the fOMSS group were higher than those of control, AB and DFM groups, but with no significant difference. The oral administration of DFM also improved growth compared to the control group, however, it was lower than AB and fOMSS. These observations suggest that fOMSS has beneficial effects on the developing rumen of post-weaning calves, possibly resulting from the lactic acid, probiotic LAB and various mushroom glucans as well as the digestive enzymes produced by them.

CONCLUSIONS

Fermenting oyster mushroom spent substrate with selected lactic acid bacteria decreased the pH of OMSS, greatly prolonging the storage time. In two animal trials, fOMSS when supplemented to calf starter at 10% concentration improved the growth performance (ADG and FE) of the post-weaning calves compared to control and antibiotic groups, thus showing the potential of this strategy in recycling of sawdust-based OMSS. A further study is required to test the effects on the growth performance and meat quality of beef cattle by feeding fOMSS during the growing and finishing stages.

REFERENCES

Adamovic, M., G. Grubi, I. Milenkovic, R. Jovanovi, R. Proti, L. Sretenovi and L. J. Stoievi. 1998. The biodegradation of wheat strawby Pleurotus ostreatus mushrooms and its use in cattle feeding. Anim. Feed Sci. Technol. 71:357-362.

AOAC. 1990. Association of Official Analytical Chemists, Official Methods of Analysis 15th ed. AOAC, Arlington, VA.

Chang, S. T. 1999. World production of cultivated and medicinal mushrooms in 1997 with emphasis on *Lentinus edodes* (Berk) Sing, China. Int. J. Med. Mush. 1:291-300.

Diaz-Godinez, G. and C. Sanchez. 2002. *In situ* digestibility and nutritive value of maize straw generated after *Pleurotus ostreatus* cultivation. Can. J. Anim. Sci. 82:617-619.

Isolauri, E., Y. Sütas, P. Kankaanpää, H. Arvilommi and S. Salminen. 2001. Probiotics: effects on immunity. Am. J. Clin. Nutr. 73:444-450.

Knowles, T. G., J. E. Edwards, K. J. Bazeley, S. N. Brown, A. Butterworth and P. D. Warriss. 2000. Changes in the blood biochemical and haematological profile of neonatal calves with age. Vet. Rec. 147:593-598.

Royse, D. J. 2002. Influence of spawn rate and commercial delayed release nutrient levels on *Pleurotus cornucopiae* (oyster mushroom) yield, size and time to production. Appl. Microbiol. Biotechnol. 58:527-531.

SAS Institute. 2002. SAS/STAT release, Version 9.1. SAS Inst, Cary, NC.

Silvana, A., M. J. Pianzzola, M. Soubes and M. P. Cerdeiras. 2006. Biodegradation of agroindustrial wastes by *Pleurotus spp.* for its use as ruminant feed. Electron. J. Biotechnol. 9:215-220.

Song, Y. M., S. D. Lee, R. Chowdappa, H. Y. Kim, S. K. Jin and I. S. Kim. 2007. Effects of fermented oyster mushroom (*Pleurotus ostreats*) by-product supplementation on growth performance, blood parameters and meat quality in finishing berkshire pigs. Animal 1:301-307.

Van Soest, P. J., J. B. Robertson and B. A. Lewis. 1991. Symposium: carbohydrate methodology, metabolism, and nutritional implications in dairy cattle. J. Dairy Sci. 74:3583-3597.

van Winsen, R. L., B. A. P. Urlings, L. J. A. Lipman, J. M. A. Snijders, D. Keuzenkamp, J. H. M. Verhejden and F. van Knapen. 2001. Effect of fermented feed on the microbial population of the gastrointestinal tracts of pigs. Appl. Environ. Microbiol. 67:3071-3076.

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.

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.