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Effects of Substitution of Fermented King Mushroom By-Products Diet on the Growth Performance, Carcass Traits and Economics of Fattening Pigs

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ABSTRACT

This study was conducted to investigate the effects of fermented king oyster mushroom by-products diet (FMBD) on the growth performance, blood characteristics, and carcass traits of fattening pigs and its economics. The fermented diet mainly contained 40.0% king oyster mushroom (*Pleurotus eryngii*) by-products, 20.0% corn, 28.0% soybean meal, 0.1% supplemental probiotics and 0.08% cellulase. The mixed ingredients were fermented for 1 d at 37℃ followed by 9 d at room temperature, after which they were dried at 45℃ for 3 d. Pigs (n=96) were divided into eight heads per pen, four diet treatments and three replications. The basal diet (C) was substituted with 20% (T1), 50% (T2) and 80% (T3) FMBD. The concentration of crude protein (CP) was significantly higher ($p<0.05$) at the end of the fermentation period. The average daily gain (ADG) and feed efficiency were significantly lower ($p<0.05$) in T3 than C. Additionally, carcass grade was significantly better ($p<0.05$) in all treatments than C and the ratio of high carcass grade was higher. Although substitution of FMBD decreased growth performance, it improved carcass grade and decreased the feed cost of fattening pigs. Therefore, it was expected that the increase in the utilization ratio of FMBD will reduce the cost of animal production.

(**Key words :** Carcass grade, Fermented diet, Growth performance, King oyster mushroom by-products, Pigs)

INTRODUCTION

The production of mushroom by-products has recently increased because of the increasing mushroom industry in Korea, and the mushroom by-products produced more than 1.90 million ton per year (Kim et al., 2007). Accordingly, methods of recycling mushroom by-products are required. One potential method of recycling by-products is through use as an animal feedstuff. Media used for mushroom cultivation generally contain cotton waste, corn cob and rice straw with small amounts of rice bran, wheat bran, beet pulp, cotton seed hull, cotton seed meal and dried okara (Bae et al., 2006). These ingredients can also be used as animal feedstuff. Williams et al. (2001) reported that the media of mushroom cultivation had approximately 80% nutrients available because the mushrooms use only 20% of the nutrients. The spent media from king oyster mushrooms may also be used as animal feedstuff.

Mushroom by-products could easily be contaminated by fungi and bacteria owing to their chemical composition, which consists of high moisture, fiber and indigestible protein (Kim et al., 2007). Mushroom by-products begin to decompose and grow harmful fungi after 2 to 3 d and 1 wk after disposal, respectively, because of the high content of moisture and harmful microorganisms (Kwak et al., 2008). However, it may be possible to use the by-products from king oyster mushrooms as animal feedstuff if the capability of storage is improved.

Anaerobic fermentation using lactic acid bacteria improves the storability, palatability and nutrient value of feedstuff (Gao et al., 2008). Moreover, yeast helps the growth of lactic acid bacteria due to its ability to produce substrates such as lactic acid and organic acids (Yang et al., 2006). The fermentation of mushroom by-products by *Lactobacillus plantarium* and *Saccharomyces cerevisae* decreases the pH, while it increases the lactic acid concentration and the population of lactic acid bacteria and yeast (Kwak et al., 2009). Moreover, fermented diets improve gastrointestinal health and prevent clinical diseases via decreased gastric pH and enteric pathogens and increased gastric lactic acid

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concentration in pigs (Boesen et al., 2004). Therefore, the fermentation of by-products from king oyster mushrooms by lactic acid bacteria and yeast may improve storability and nutrient values.

Many researchers have used mushroom by-products as feed for ruminants (Bae et al., 2006; Kim et al., 2010) and chickens (Cheong et al., 2006). However, fermented king oyster mushroom by-products have not yet been investigated in pigs. Therefore, this study was conducted to investigate the effects of by-products from king oyster mushrooms (*Pleurotus eryngii*) applied as a fermented diet on the growth performance, blood characteristics and carcass traits and carcass grades of fattening pigs. Economic analysis was also calculated for the fermented king oyster mushroom by-products diet (FMBD) when compared with formula feed of fattening pigs.

MATERIALS AND METHODS

1. Processing and analysis of FMBD

The FMBD contained 40.0% king oyster mushroom by-products, 20.0% corn, 28.0% soybean meal, 9.82% rice bran, 1.0% corn oil and 1.0% sugar. The ingredients were simultaneously mixed and fermented in a fermenter (Bio-Rea; Tong yang, Seoul, Korea) supplemented with 0.1% probiotics and 0.08% cellulase at 37°C for 24 h. The probiotics contained approximately 3.0×10^7 colony forming unit (cfu) *Lactobacillus plantarium*, 2.0×10^7 cfu *Enterococcus faecium* and 2.0×10^7 thallus forming unit (tfu) *Saccharomyces cerevisae* per gram. The mixture was then transferred to anaerobic plastic containers, after which it was fermented at room temperature for 9 d and then dried at 45°C for 3 d.

Samples of FMBD were collected on the initial day (0 d) and at the end of the period (10 d) for determination of pH, proximate analysis and gross energy. The pH values were immediately measured at the time of sampling using a pH meter (Hanna HI 9025; Woonsocket, RI, USA) with an Orion 8163 glass electrode (Beverley, MA, USA). The proximate analysis was conducted according to the methods of AOAC methods (2000). Dry matter (DM) was determined by placing the samples in an air-forced dry oven at 130°C for 2 h, while crude protein (CP) was determined using the Kjeltec System (K-412/K-339 Buchi, Flawil, Switzerland) and ether extract (EE) was measured by the diethyl ether extraction method using an Extraction System (B-811 Buchi, Flawil, Switzerland). Crude fiber (CF) was determined by the filtration method using a Fiber Analyzer (Ankom A220; Mill tech, Seongnam, Korea). Ash was determined by heating the samples in an electric muffle furnace (KMF-500; Lab Corporation, Seoul, Korea) at 550°C and gross energy was determined using a bomb calorimeter (Parr 1266; Parr, IL, USA).

(1) Animals and diet

Pigs at the age of approximately 130 d with an average body weight (BW) of 74.28 ± 6.77 kg were used for this study. Animals (n = 96) were assigned to four dietary treatments based on BW and sex. Each of the four dietary treatments contained eight pigs (four barrows and four females) per pen and three replications (eight pigs × three replications × four diets). Animals were subjected to pre-feeding for 3 d, after which they were provided with free access to water and fed the experimental diet until they reached a BW of 110.52 ± 7.55 kg. All animals were cared for in accordance with the Guide for the Care and Use of Laboratory Animals (Animal Care Committee of Gyeongnam National University of Science and Technology).

The basal diet, which was used as a control (C), consisted of approximately 33.50% corn, 30.00% wheat and 12.50% soybean meal. For the treatments, the basal diet contained 20% (T1), 50% (T2) or 80% (T3) of FMBD. The chemical composition of the experimental diet is shown in Table 1. The pigs were fed the experimental diet for 52 d.

2. Sample collection and chemical analyses

The BW was measured at the initiation and end of this experiment. The amounts of the diet consumed were

Table 1. Chemical composition of experimental diets

Item	Treatments[1]			
	C	T1	T2	T3
Chemical composition[2], % as-fed basis				
Dry matter	87.49	86.99	86.25	85.50
Crude protein	15.50	15.42	15.31	15.19
Ether extract	6.41	5.37	3.81	2.25
Crude fiber	2.98	4.20	6.02	7.85
Ash	4.78	4.61	4.35	4.09

[1] The basal diet was substituted by fermented king oyster mushroom by-products diet: C, no substitution; T1, 20%; T2, 50% and T3, 80%.

[2] Analysed values.

recorded everyday at feeding time. The feed efficiency was calculated based on the average daily gain (ADG) and feed intake. At three hours after the end of the last feeding blood samples were collected from the jugular veins of 12 pigs selected at random in each treatment.

The plasma was obtained by centrifugation at 2,500 g for 30 min at 4°C and stored at −20°C for analyses. The chemical composition such as the concentration of creatine, aspirate transaminase (AST), alanine transaminase (ALT), lactate dehydrogenase (LDH), total cholesterol, high density lipoprotein-cholesterol (HDL-cholesterol) and low density lipoprotein-cholesterol (LDL-cholesterol) in the plasma were determined in a Blood Analyzer (Express Plus, Bayer, MA, USA). The cortisol concentration in plasma was determined using an Immulite (Diagnostic product Co., USA) method for chemiluminescent immuno-assay.

3. Carcass traits and carcass grades

The pigs weighed approximately 110 kg on average at the end of this experiment. All pigs were transported to a normal abattoir near the experimental station and slaughtered by stunning with electrical tongs (300 volts for 3 sec) 12 h after feed restriction. The shocked pigs were then exsanguinated while hanged. Carcasses were subsequently placed in a dehairer at 62°C for 5 min, after which remaining hair was removed using a knife and flame. Carcasses were then eviscerated, split and placed in a chiller set at 5°C for 12 h.

The percentage of dressing was calculated as the ratio of cold carcass weight to live weight. Backfat thickness was measured using the 10th rib at three-quarters distance along the *longissimus dorsi* toward the belly. Carcass grade in Korea is characterized by standards set by the Korea Institute for Animal Products Quality Evaluation (2009). Pork carcasses are graded both in quality and conformation terms. The quality of pork carcasses is graded as 1+, 1, 2 and 3 based on marbling, lean color and conditions of belly streaks. The conformation terms of pork carcasses are graded as A, B, C and D based on carcass weight, backfat thickness, balance, muscle and fat condition. Carcass grades in this study were expressed as 1 (extremely good), 2 (good), 3 (bad) and 4 (extremely bad) instead of 1+, 1, 2 and 3.

4. Economics of FMBD

The price of formula feed per kg was 630 Korean Won, while the prices of king oyster mushroom by-products, corn, soybean meal and rice bran per kg were 50, 290, 520 and 250 Korean Won, respectively. Based on these values, the price per kg of FMBD was calculated to be 292 Korean Won. This cost did not include basic costs such as labor, equipment, electricity and water because the experimental diets of all treatments were mixed in the animal farm. The feed cost was calculated based on feed intake of each treatment.

5. Statistical analyses

The data were analyzed in the General Linear Model (GLM) procedure of Statistical Analysis Systems (SAS; 1999) and the significance of differences among means was determined by Duncan's Multiple Range Test method (Duncan, 1955). A *p* value <0.05 was considered to indicate statistical significance.

RESULTS

1. Effects of fermentation period on the chemical composition of diet

Fermentation period affected the pH and chemical composition of FMBD (Table 2). The pH was significantly

Table 2. Effect of fermented priods on the pH and chemical composition of fermented king oyster mushroom by-products[1)]

Item	Fermented periods[2)]		SEM[3)]
	Initial	Finished	
pH	6.12	4.49*	0.04
Dry matter, % of as-fed basis	63.30	66.66	1.80
Chemical composition, % of M basis			
Crude protein	14.52	17.78*	0.84
Ether extract	1.93	1.43	0.28
Crude fiber	14.26	10.67*	1.63
Ash	4.94	4.61	0.20
Gross energy, kcal/kg	4,221.4	4,232.3	249.0

[1)] Mean of three diet samples analysed at the initial and end of fermentation days.

[2)] Fermented diets of the initial day (day 0) and last day (day 10) were analysed at 3 replications.

[3)] Standard error of the means.

* Significantly different from the initial fermented periods at p<0.05.

decreased ($p<0.05$) on the last day of fermentation (10 d) when compared with the initial day (0 d). The concentration of CP was significantly higher ($p<0.05$), while the CF concentration was significantly lower ($p<0.05$) at the end of fermentation than at the beginning of fermentation. However, the concentrations of DM, EE, ash and gross energy were not affected ($p>0.05$) by the fermentation process.

2. Growth performance

The substituted FMBD affected the growth performance and feed efficiency of fattening pigs (Table 3). The ADG was significantly lower ($p<0.05$) in T1 and T3, but the average daily feed intake (ADFI) was significantly higher ($p<0.05$) in T3 and the feed efficiency was significantly lower ($p<0.05$) in T3 than C. The ADFI and feed efficiency

Table 3. Effect of fermented king oyster mushroom by-products diet on the growth performance and feed efficiency of fattening pigs[1]

Item	Treatment[2]				SEM[3]
	C	T1	T2	T3	
Grow performance					
Initial body weight, kg	71.71	77.71	72.71	75.00	6.77
Final body weight, kg	112.37	110.71	109.71	109.29	7.55
Average daily gain, kg/day	0.782^{a}	0.638^{b}	0.711^{ab}	0.659^{b}	0.011
Feed intake					
Average daily feed intake, kg	2.17^{b}	2.06^{b}	2.36^{ab}	2.57^{a}	0.39
Feed efficiency, g/g	0.360^{a}	0.308^{a}	0.302^{a}	0.256^{b}	0.052

[1] Mean of 24 pigs for each treatment.
[2] The basal diet was substituted with fermented king oyster mushroom by-products diet: C, no substitution; T1, 20%; T2, 50% and T3, 80%.
[3] Standard error of the means.
[a,b] Values in the same row with different superscripts differ at p<0.05.

Table 4. The effects of fermented king oyster mushroom by-products diet on the chemical composition of plasma in fattening pigs[1]

Item	Treatment[2]				SEM[3]
	C	T1	T2	T3	
Plasma chemical composition					
Creatine, $10^3/mm^3$	1.30	1.24	1.35	1.20	0.09
AST[4], U/dL	52.33^{d}	66.40^{c}	81.50^{b}	105.00^{a}	4.28
ALT[5], U/dL	36.00^{a}	40.80^{ab}	41.50^{ab}	48.00^{a}	2.38
LDH[6], U/dL	2,614	2,844	2,853	2,921	109.3
Total cholesterol, mg/dL	104.60^{a}	93.20^{b}	92.25^{b}	93.33^{b}	2.64
HDL-cholesterol[7], mg/dL	40.83	40.24	39.48	42.33	2.65
LDL-cholesterol[8], mg/dL	58.00^{a}	50.08^{b}	48.98^{b}	50.50^{b}	2.85
Cortisol, mg/dL	5.08	5.12	5.56	4.83	0.31

[1] Mean of 12 pigs for each treatment.
[2] The basal diet was substituted with fermented king oyster mushroom by-products diet: C, no substitution; T1, 20%; T2, 50% and T3, 80%.
[3] Standard error of the means.
[4] Asparate transaminase.
[5] Alanine transaminase.
[6] Lactate dehydrogenase.
[7] High density lipoprotein-cholesterol.
[8] Low density lipoprotein-cholesterol.
[a,b,c,d] Values in the same row with different superscripts differ at p<0.05.

did not differ ($p>0.05$) among T1, T2 and C.

3. Plasma chemical composition

The effects of substituted FMBD on the blood corpuscles and plasma chemical composition are shown in Table 4. The concentration of creatine, LDH, HDL-cholesterol and cortisol were not affected ($p>0.05$), while AST concentration was significantly increased ($p<0.05$) as the amount of substituted FMBD increased. ALT concentration was significantly higher ($p<0.05$) in T3 than in C that of T1 and T2 did not differ ($p>0.05$) from C and T3. The concentrations of total cholesterol and LDL-cholesterol were significantly lower ($p<0.05$) in all treatments than in C did not differ ($p>0.05$) among treatments.

4. Carcass traits

The carcass characteristics and meat grade of pigs fed FMBD are shown in Table 5. The carcass weight and dressing did not differ ($p>0.05$) between C and the treatments. The backfat thickness was significantly higher ($p<0.05$) in T3 than in C, but did not differ ($p>0.05$) among T1, T2 and C. The carcass grade was significantly improved ($p<0.05$) in treatments when compared with C, and the carcass grade of T2 and T3 was significantly improved ($p<0.05$) relative to that of C and T1. The ratio of high grade (grade 1 and 2) was higher in treatments and increased as the amount of FMBD as a substitute of formula diet increased.

5. Economics

The economics of FMBD are shown in Table 6. The daily feed cost decreased by approximately 9.0%, 14.7% and 27.3% when the basic diet was substituted with 20%, 50% and 80% FMBD, respectively. The total feed cost per kg gain of body weight decreased by 6.4% and 14.0% in T2 and T3, respectively, while it increased by 12.0% of the feed cost per kg gain of body weight in T1.

DISCUSSION

The results of this experiment showed that the CP concentration increased at the end of the fermentation period, while the CF concentration was decreased relativeto the initial day of fermentation. Moreover, the surface color of FMBD changed from light brown at the beginning of the fermentation period to dark brown at the end of the period. These results indicated that the increase in CP concentration may be due to an increased population of lactic acid bacteria in FMBD at the end of the fermentation period. These findings are in accordance with those of a study conducted by Kim et al. (2008), who found that the CP concentration of mushroom by-products increased and the color changed from light brown to dark brown due to

Table 5. The effects of fermented king oyster mushroom by-products diet on the carcass traits and meat grades of fattening pigs[1]

Item	Treatment[2]				SEM[3]
	C	T1	T2	T3	
Carcass traits					
Carcass weight, kg	84.52	81.75	84.25	79.25	4.71
Dressing, %	75.22	74.51	76.43	73.35	3.03
Backfat thickness, mm	12.00^{b}	14.75^{b}	16.25^{ab}	17.33^{a}	1.60
Meat grade					
Carcass grade[4]	3.67^{a}	2.33^{b}	1.67^{c}	1.67^{c}	0.28
High grade rate[5], %	16.66	50.0	66.66	83.33	−

[1] Mean of 24 pigs for each treatment.
[2] The basal diet was substituted with fermented king oyster mushroom by-products diet: C, no substitution; T1, 20%; T2, 50% and T3, 80%.
[3] Standard error of the means.
[4] The carcass grades were assessed as: 1, extremely good; 2, good; 3, bad and 4, extremely bad (Standards of Korea Institute for Animal Products Quality Evaluation, 2009).
[5] The percentage of high grade rate was 1 plus 2 points of carcass grades.
[a,b,c] Values in the same row with different superscripts differ at $p<0.05$.

Table 6. The effects of fermented king oyster mushroom by-products diet on the feeding cost of fattening pigs[1]

Item	Treatment[2]			
	C	T1	T2	T3
Total feed intake, kg	105.1	107.1	122.5	133.8
Formula feed	105.1	85.7	61.3	26.8
Fermented diet	0.0	21.4	61.3	107.0
Feed cost, Korean Won	66,181.5	59,199.8	56,472.5	48,114.5
Formula feed	66,181.5	52,945.2	38,587.5	16,858.5
Fermented diet	0.0	6,254.6	17,885.0	31,255.7
Daily feed cost, Korean Won/day (Index, %)	1,272.7 (100.0)	1,138.4 (89.44)	1,086.0 (85.33)	925.0 (72.68)
Total BW gain, kg	40.6	33.2	37.0	34.3
Cost/kg gain of BW[2], Korean Won/kg (Index, %)	1,630.1 (100.0)	1,780.7 (109.24)	1,526.3 (93.63)	1,402.8 (86.05)

[1] Mean of 24 pigs for each treatment.

[2] The basal diet was substituted with fermented king oyster mushroom by-products diet: C, no substitution; T1, 20%; T2, 50% and T3, 80%.

[3] The values were calculated as total feed cost (Korea Won) divided by body weight gain (kg).

increased anaerobic fermentation days. The color changed because anaerobic fermentation easily degraded fermentable materials in mushroom by-products via microbial action and increased the ratio of non-biodegradable materials. Thus, the increased population of microorganisms increased the CP concentration and decreased the CF concentration in this experiment.

The pH at the end of fermentation period decreased to 4.49 in this experiment. Generally, the optimal pH for fermentation of diet is 4.0 to 5.0, but feed intake decreased when it was less than 4.0 and pathogenic bacteria occurred when it was higher than 5.0 (Lee et al., 2004). A low pH indicates improved storability and nutritional values of feed due to increased lactic acid or lactic acid bacteria and yeast. The results of this experiment indicated that the anaerobic fermentation improved the storability and nutritional value of king oyster mushroom by-products as a result of increased counts of lactic acid bacteria and decreased pH.

The substitution of 80% FMBD decreased the ADG and feed efficiency in this experiment. Song et al. (2007) reported that supplementation of diet with 7% fermented mushroom by-products decreased the ADG and feed efficiency in pigs. Kim et al. (2006) also reported that supplemental fermented persimmon shell diet influenced the growth performance via increased organic acids in finishing pigs. The ADG and feed efficiency were associated with reduced nutrient values of FMBD such as a low concentration of EE and high concentration of CF in the present study.

The substitution of FMBD increased the AST concentration and decreased the concentration of total cholesterol and LDL-cholesterol in plasma, which was in agreement with the results of a study investigating supplementation of the diet with oyster mushroom (Bobek et al., 1998; Cheung, 1998). Moreover, Song et al. (2007) reported that supplementation of the diet with 7% fermented mushroom by-products increased the total cholesterol and LDL-cholesterol in plasma. However, Chu et al. (2012) reported that substitution of the diet with fermented mushroom (*Flammulina velutipes*) by-products did not affect the blood characteristics of fattening pigs. We found no scientific literature describing the relationship between the FMBD and AST concentration of blood. The reason for this difference is unknown and further study is needed to draw conclusions about the effects of FMBD on the blood characteristics of pigs.

The substitution of 80% FMBD increased the backfat thickness in this experiment, which is in agreement with the results reported by Song et al. (2007), who found that supplementation of the diet with 7% fermented mushroom by-products increased the backfat thickness in pigs, but did not affect the carcass weight and dressing.

Supplementation with FMBD improved the carcass grade and increased the ratio of high carcass grade. Kang et al. (2010) reported that pork quality was affected by the ratio of carbohydrate to fat of fermented diet and Sasaki et al. (2007) reported that supplementation of fermented food co-product had affected pork quality. The carcass grade may be affected by values of nutrition or ME in fermented diet.

CONCLUSION

This study showed that substituted FMBD has improved the carcass grade and the ratio of high grade, while the growth performance was decreased in fattening pigs. This study also showed that the increased utilization ratio of FMBD reduced the cost of animal production. It was expected that the increase in utilization ratio of FMBD will reduce the cost of animal production. It is important to note that the use of by-products in animal industries is especially beneficial for countries that depend on imported feed ingredients.

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