Effects of Extrusion Condition of Barley on the Growth and Nutrient Utilization in Growing Pigs*

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ABSTRACT : To study the effects of different extrusion conditions of barley on growth performance, nutrient digestibility and nutrient excretion in feces, a total of 150 growing pigs (Landrace×Duroc×Large White; average 24.4 kg body weight) were allotted to five treatments, in a completely randomized block design. The experimental diets were based on corn-soybean and 30% of barley was included in each diet; barley was the only extruded ingredient. The treatments were 1) no extrusion (Control); 2) extrusion at 100℃ without preconditioning (ENLT); 3) extrusion at 150℃ without preconditioning (ENHT); 4) extrusion at 100℃ with preconditioning (ECLT); 5) extrusion at 150℃ with preconditioning (ECHT). Temperature in the barrel was controlled within ±5℃ by feed rate with the addition of water at the rate of 3 ℓ per min. in the extruder for each treatment. For the 6 week experimental period, extrusion of barley improved the average daily gain (ADG) and digestibilities of dry matter, crude protein and gross energy in growing pigs. As compared to control, significant improvements in ADG ($p<0.05$) were shown in the groups of feeding extruded barley at high temperature (ENHT and ECHT). There were also significant differences in the digestibilities of DM, CP and P between extrusion temperatures. Barley extruded at high temperature gave better digestibilities of DM, CP and GE than barley extruded at low temperature. Extruded barley diet groups showed significantly ($p<0.05$) lower excretions of DM, nitrogen (N) and P per kg gain as compared to the ground barley group. DM, N and P excretion per kg gain were also significantly lower in pigs fed barley extruded at 150℃ than at 100℃. In conclusion, extrusion considerably improved the nutritive value of barley and it appeared that temperature is the most important variable. *(Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 5 : 783-787)*

Key Words : Extrusion Conditioning, Barley, Growth Performance, Nutrient Digestibility, Growing Pigs

INTRODUCTION

Barley bas been reported to have a lower content of metabolizable energy for swine than corn or other cereals, though its gross energy is similar to corn (NRC, 1988). However, barley seems to be an excellent feedstuff for swine when used with the proper balancing of essential nutrients (Han et al., 1975; Froseth, 1984), or with proper processing (Chu et al., 1998; Chung et al., 1998). Han et al. (1975) reported that a ration based on barley, when adjusted to be of isocaloric value (ME) with animal fat, was of similar or better feeding value than a ration based on wheat or corn for growing-finishing swine. Attempts to improve the feeding value of barley by fine grinding (Chu et al., 1998), enzyme supplementation (Oldfield, 1960; Just et al., 1983; Graham et al., 1988, 1989; Li et al., 1996a,b; Chu et al., 1998) or steam pressure processing (Hintz and Garret, 1967) have not been satisfactory.

On the other hand, extrusion of barley tended to improve nutrient digestibility (Fadel et al., 1988; Chu et al., 1998) and growth performance (Chung et al., 1998; Chu et al., 1998) in growing-finishing or growing pigs. Extrusion conditions can also alter nutritional value, variables including the degree of cooking, preconditioning and temperature are important to the feed processing (Litjens and van der Peol, 1991; Chae et al., 1997; Thomas et al., 1997). Addition of heat and water by conditioning will alter components like starch and protein in the feed (Thomas and Van der Poel, 1996). Increased moisture during extrusion is also related to the friction, shearing, and temperature in the extruder (Hancock, 1992). Chiang and Johnson (1977) reported that gelatinization of wheat starch increased as extrusion temperature was increased from 65 to 110℃. Gomez and Aguilera (1984) also demonstrated improved gelatinization of corn starch with reduced moisture contents.

Information is limited on the effect of feeding barley extruded with different condition on pig performance. The objective of this study was to evaluate the effects of extrusion conditions of barley on nutrient digestibility, growth performance and nutrient excretion in manure of growing pigs.

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MATERIALS AND METHODS

A total of 150 growing pigs (Landrace×Duroc× Large White; average 24.4 kg body weight) were allotted to five treatments on the basis of sex and body weight, in a completely randomized block design.

Barley was ground with a hammer mill (Champion®, 6 mm screen), and extruded with a semi-moist type extruder (Millbank®, single screw, New Zealand) according to the conditions for each treatment. The treatments for barley extrusion were 1) no extrusion (Control); 2) extrusion at 100℃ without preconditioning (ENLT); 3) extrusion at 150℃ without preconditioning (ENHT); 4) extrusion at 100℃ with preconditioning (ECLT); 5) extrusion at 150℃ with preconditioning (ECHT). As the first variable, temperature in the last barrel was controlled within ±5℃ by feed rate in the extruder with 15 psi of steam pressure and 65℃ of inlet temperature. Water was evenly added at the rate of 3 ℓ/min. in the first barrel of the extruder for each treatment. Experimental diets were formulated to contain 18% crude protein and 30% barley as shown in table 1, and extruded barley was substituted with ground barley on a weight basis.

Table 1. Formula and chemical composition of experiment diet

Ingredient (%)	% inclusion
Corn	36.88
Barley	30.00
Soybean Meal (44%)	25.08
Animal fat	4.62
Tri-Calcium Phosphate	1.34
Limestone	0.70
L-Lysine · HCL	0.20
DL-Methionine	0.15
Threonine	0.07
Vit.-mix.[1]	0.25
Min.-mix.[2]	0.20
Antibiotics[3]	0.20
Salt	0.30
Total	100.00
Chemical composition[4]	
Metabolizable Energy (kcal/kg)	3,340
Crude Protein (%)	18.00
Lysine (%)	1.10
Methionine+Cystine (%)	0.72
Calcium (%)	0.80
Phosphorus (%)	0.70

[1] Supplied per kg diet : Vitamin A, 2,000,000 IU; Vitamin D_3, 400,000 IU; Vitamin E, 250 IU; Vitamin K_3, 200 mg; Vitamin B_1, 20 mg; Vitamin B_2, 700 mg; Pantothenic acid, 3,000 mg; Choline chloride, 30,000 mg; Niacin, 8,000 mg; Folacin, 200mg; Vitamin B_{12}, 13 mg.

[2] Supplied per kg mixture : Mn, 12,000 mg; Zn, 15,000 mg; Co, 100 mg; Cu, 500 mg; Fe 4,000 mg; BHT, 5,000 mg; Folic acid, 400mg.

[3] A mixture of Olaquindox and Chlortetracycline (0.1% respectively).

[4] Calculated value.

Pigs were housed in 2.5×1.5㎡ pens with concrete floor and were allowed ad libitum access to water and feeds during the whole feeding trial. Pigs and feed remaineders were weighed biweekly to determine average daily gain (ADG), average daily feed intake (ADFI) and feed conversion (F/G).

A metabolic trial was performed using the total fecal collection method during the experimental period. Four pigs/treatment (average body weight: 26kg) were housed in individual metabolic cages, and had 4 days of adjustment period followed by 3 days collection period. Collected excreta were pooled, dried in an air forced drying oven (60℃, 72 hrs) and ground with a Wiley mill (1 mm sieve) for further chemical analyses.

Proximate nutrients in diets and feces were analyzed by the methods of AOAC (1990), and gross energy was measured by an adiabatic bomb calorimeter (Model 1241, Parr Instrument Co., Molin, IL).

Statistical analysis was carried out by comparing means according to Duncan's multiple range test (Duncan, 1955) using the General Linear Model (GLM) procedure of SAS (1985). Treatment served as a main effect. Contrasts were made as follows : control vs. extruded, low temperature vs. high temperature, and non-conditioning vs. conditioning.

RESULTS

Effects of extruding barley with different extrusion conditions (preconditioning and temperature) on growth performance in growing pigs are presented in table 2. In the 6 week experimental period, pigs fed extruded barley showed a higher ADG than those pigs fed ground barley. Pigs fed barley extruded at high temperature (150℃, ENHT and ECHT) grew significantly faster ($p<0.05$) and had a higher ADFI ($p<0.10$), but similar F/G, compared to those fed barley extruded at low temperature (100℃, ENLT and ECLT). Preconditioning did not affect ADG, ADFI and F/G.

Nutrient digestibilities of the experimental diets are presented in table 3. Pigs fed the extruded barley exhibited higher digestibilities of dry matter (DM), gross energy (GE), and crude protein (CP) as compared to those fed ground barley. Extrusion significantly improved the digestibilities of DM ($p<0.05$), CP ($p<0.05$) and GE ($p<0.10$). As shown in table 3, there were also significant differences in the digestibilities of DM, CP and P between extrusion temperature, resulting in higher digestibilities of DM, CP, C. ash and P of barely extruded at high temperature (150℃). Like growth performance of the

Table 2. Effect of extruded barley on growth performance of growing pigs

Treatment	Control	ENLT	ENHT	ECLT	ECHT	PSE[1]
Initial BW (kg)	24.04	24.05	24.07	24.05	24.04	0.44
Final BW (kg)	58.24	59.36	60.84	60.09	60.97	0.66
ADG (g)	814[b]	841[ab]	878[a]	858[ab]	879[a]	9.57
ADFI (g)	1844	1907	1988	1957	1972	23.39
F/G	2.27	2.27	2.26	2.28	2.24	0.01

Contrast	ADG	ADFI	F/G
Con. vs Ext.	NS[2]	NS	NS
ELT vs EHT	0.0559	0.0700	NS
ENC vs EC	NS	NS	NS

[1] Pooled standard error. [2] Not significant. [a,b,c] Means with different superscript in the same row differ ($p<0.05$).
Control: no extrusion; ENLT: extrusion, no steam conditioning, barrel temp. 100℃; ENHT: extrusion, no steam conditioning, barrel temp. 150℃; ECLT: extrusion, steam conditioning 3 ℓ/min, barrel temp. 100℃; ECHT: extrusion, steam conditioning 3 ℓ/min, barrel temp. 150℃.

Table 3. Effect of extruded barley on nutrients digestibilities of growing pigs

Treatment	Control	ENLT	ENHT	ECLT	ECHT	PSE[1]
DM (%)	85.0[b]	84.6[b]	87.3[ab]	86.4[ab]	88.6[a]	0.53
C. ash (%)	58.9[b]	60.8[ab]	68.2[ab]	69.0[a]	70.1[a]	1.69
CP (%)	84.6[c]	85.7[bc]	87.8[ab]	87.3[abc]	89.1[a]	0.51
C. fat (%)	78.5	80.4	79.3	80.4	79.3	1.91
GE (%)	85.6[b]	86.5[ab]	88.5[ab]	87.2[ab]	89.4[a]	0.53
P (%)	59.4[b]	62.0[ab]	67.1[ab]	70.0[a]	70.2[a]	1.56

Contrast	DM	C. ash	CP	C. fat	GE	P
Con. vs Ext.	0.0343	NS[2]	0.0247	NS	0.0628	NS
ELT vs EHT	0.0764	0.0186	0.0264	NS	NS	0.0205
ENC vs EC	NS	NS	NS	NS	NS	NS

[1] Pooled standard error. [2] Not significant [a,b,c] Means with different superscript in the same row differ ($p<0.05$).

Table 4. Effect of extruded barley on nutrients excretion in growing pigs (g/1,000 g weight gain)

Treatment	Control	ENLT	ENHT	ECLT	ECHT	PSE[1]
DM	201.5[a]	162.3[b]	149.2[b]	157.1[b]	148.9[b]	6.17
N	6.9[a]	5.6[b]	5.2[b]	5.5[b]	5.3[b]	0.19
P	4.4[a]	3.5[b]	3.1[bc]	3.1[bc]	2.8[c]	0.15

Contrast	DM	N	P
Con vs Ext.	NS[2]	NS	0.0085
ELT vs EHT	0.0252	0.0150	0.0008
ENC vs EC	NS	0.0228	0.0479

[1] Pooled standard error. [2] Not significant. [a,b,c] Means with different superscript in the same row differ ($p<0.05$).

pigs, however, nutrient digestibility was not affected by preconditioning during extrusion.

Nutrient excretion per kg gain is presented in table 4. Extruded barley diet groups showed significantly ($p<0.05$) lower excretions of DM, nitrogen (N) and P per kg gain as compared to the ground barley group. DM, N and P excretion per kg gain were also significantly lower ($p<0.05$) in pigs fed barley extruded at 150℃ than at 100℃. N and P excretions were significantly reduced by the barley extruded with preconditioning as compared to without preconditioning.

DISCUSSION

Growth rate, nutrient digestibility and the reduction in nutrient excretion in feces were improved by extrusion of barley. The improvements in growth rate and nutrient digestibility of pigs fed extruded barley were in agreement with previous reports (Fadel et al., 1988; Chung et al., 1998; Chu et al., 1998). Chung et al. (1998) reported that pigs fed extruded barley showed better ADG and digestibilities of DM, GE, CP and P than pigs fed ground barley, and Chu et al. (1998) also reported that pigs fed extruded barley grew faster and better F/G than those fed ground barley. Unlike the result of Chu et al. (1998), in this experiment, F/G was not improved when barley was extruded. Also the results obtained in this experiment are not consistent with those reported by Hancock et al. (1992). They observed that extrusion of cereal grains did not affect ADG but increased efficiency of gain by 4, 9, 6 and 3% for corn, sorghum, wheat and barley.

The improvement in ADG appeared to be due mainly to the increased feed consumption and improved nutrient digestibility of pigs fed extruded barley. The reduction is in agreement with the findings of Darroch et al. (1997), who reported that extrusion of hulless barley reduced fecal DM output by 25.6% and 47.4% when compared to raw ground hulless barley and hulled barley, respectively.

Barley is lower in energy and higher in fiber and protein content than corn and averages 6.0% fiber due to the hull surrounding the seed. The major nutrients in barley, starch and protein, are also enclosed within endosperm cell walls consisting mainly of mixed-linked (1-3), (1-4)-β-D-glucans and arabinoxylans (Aman and Graham, 1987). So, processing is indispensible in young animals for maximum utilization of barley. It appeared that fine grinding itself was not enough for efficient use of barley in growing pigs (Chu et al., 1998). Heat treatments such as extrusion (Fadel et al, 1988) and pelleting (Graham et al, 1989) could increase solubility of mixed-linked β-glucans and thus may improve absorption of nutrients in the small intestine. Berglund et al. (1994) also reported that extrusion resulted in increased soluble fiber content in barleys.

It was shown that the extrusion temperature is more important than conditioning. The extrusion temperature of 100℃ for barley seemed to be too low with regard to growth performance and nutrient digestibility in growing pigs. Chiang and Johnson (1977) reported that gelatinization of wheat starch increased as extrusion temperature was increased from 65 to 110℃, but only when the starch was preconditioned from 18 to 27% moisture.

In addition, preconditioning will increase production capacity and simultaneously affects the physical, nutritional and hygienic quality of the produced feed (Skoch et al., 1981), but raising moisture content of the extruded materials resulted in decreased friction, shearing and extrusion temperature (Hancock, 1992). Though researchers previously suggested that preconditioning could result in improved quality of feeds (Litjens and van der Poel, 1991; Chae et al., 1997; Thomas et al., 1997), in this experiment the importance of preconditioning during extrusion was small for the production traits. For the extrusion of corn and soybean meal, Chae et al. (1997) reported that proper extrusion condition was the combination of preconditions and water input that resulted in the greatest ileal digestibility of nutrients and growth performances in weaned pigs. Chae et al. (1997) found that gelatinization of corn as well as digestibilities of GE and CP were maximized at 150℃. Hancock (1992) also suggested that a compromise with pre-extrusion moisture concentrations of 18 to 25% and extrusion temperatures of 120 to 170℃ seemed to result in a high degree of gelatinization and minimal protein damage in cereal grains.

Conclusively, extrusion considerably improved the nutritive value of barley and it appeared that temperature is the most important variables.

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