Effects of Processed Barley on Growth Performance and Ileal Digestibility of Growing Pigs

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ABSTRACT : Two experiments were conducted to evaluate the effects of processing of barley on the growth performance and ileal and fecal digestibility of growing pigs. In Exp. 1, a total of 20 cannulated pigs (10.80 kg BW) were allotted to four treatments. Treatments were coarse ground barley as a control (CON), finely ground barley (FINE), extruded barley (EXT) and enzyme supplemented coarse ground barley (ENZ). In Exp. 2, a total of 100 growing pigs (36.50 kg BW) were allocated to the same treatments in completely randomized block design based on sex and body weight. In the first trial, pigs fed extruded barley showed significantly higher crude protein digestibility over pigs fed finely ground barley ($p < 0.05$). Pigs fed finely ground barley generally showed lower nutrients digestibility. Extrusion and β-glucanase supplementation showed a trend to improve nutrients digestibility. However, fine grinding rather reduced nutrients digestibility. The similar trend was found in the digestibility of essential amino acids. Fine grinding of barley significantly reduced amino acids digestibility. Extrusion and enzyme supplementation were found to improve amino acids digestibility of barley in growing pigs. In the growth trial, pigs fed extruded barley grew significantly faster than any other processed barley fed pigs. And extrusion of barley significantly improved feed/gain of pigs ($p < 0.05$). Fine grinding of barley and enzyme supplementation did not improve growth performance of pigs.

In conclusion, fine grinding and enzyme supplementation does not appear to be an economical feed processing for growing pigs when barley is employed in the diets, while extrusion can be recommended as an effective feed processing technique for barley.
(**Key Words:** Pigs, Barley, Extrusion, Grinding, Performance, Enzyme)

INTRODUCTION

Swine producers and feed manufacturers who are oriented towards corn are sometimes unaware of the usefulness of barley. However, barley is an excellent feed source for swine, especially for finishing period. The protein content of barley is known to be intermediate to that of wheat and corn and similar to that of oats, generally low in lysine, isoleucine, threonine, tryptophan, and the sulfur containing amino acids (Patience and Thacker, 1989). Barley is intermediate to wheat and oats as an energy source for swine. The gross energy content of barley is similar to that of corn; but barley, because of its fibrous hull, is usually considered to have a feeding value of only 90% of corn when fed to non-ruminants. Its relatively high crude fiber content is one of the major reasons for the comparably low energy value (Patience and Thacker, 1989).

The performance of pigs fed barley-based diets is generally inferior to that of pigs fed wheat or corn. In comparison to corn, Hollis and Palmer (1971) suggested efficiencies of 89 and 87%, respectively for wheat and barley compared to corn in supporting weight gains in growing-finishing pigs.

Processing of barley can change the physical or chemical properties via mechanical, chemical and/or thermal treatments, and this can improve feed quality such as nutrient availability getting rid of toxins and microbial contamination. In addition to the processing of barley, supplementation of enzymes can be another way of enhancing its availability.

Han and Froseth (1993) and Goodman et al. (1993) reported improved utilization of energy when β-glucanase was added to barley-based diets for growing

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pigs and broilers, respectively. Investigations in broiler and chickens have established that supplementation with β-glucanase preparations can substantially improve the nutritive value of some barley-based diets (Newman and Newman, 1987) mainly by the breakdown of endosperm cell wall components, resulting in a more complete digestion of starch and protein in the small intestine. β-glucanase supplementation also significantly increased the ileal digestibility of starch from 92.6 to 94.3%, and of mixed-linked β-glucans, from 95.7 to 97.1% in pigs fed barley-based diet (Graham et al., 1989).

Many reports showed improvements by grinding to smaller sizes in corn (Hedde et al., 1985; Gieseman et al., 1990; Healy et al., 1994), sorghum (Healy, 1992; Owsley et al., 1981) and barley (Goodband and Hines, 1988) whereas Ohh et al. (1983) reported no improvements in growing performance of pig by reducing particle size of sorghum and Hale et al. (1979) found greater efficiency with coarsely ground than finely ground wheat. Confusion exists concerning the optimum particle size of swine diets because of broad classifications like fine, medium, and coarse are used to define particle size.

Hancock et al. (1992) examined the effects of extrusion of cereal grains and concluded that the extrusion technology offers promise in terms of improved nutritional value of cereal grains, provided that costs of process and equipment continue to decrease. Fadel et al (1988) extruded barley for finishing pigs and reported increased digestibilities of dry matter, energy, starch and nitrogen and the terminal ileum as 12, 12, 16 and 11%, respectively.

Thus, this experiment was conducted to investigate the effect of various feed processing of barley on the growth performance and ileal digestibility in growing pigs. The simple comparison among feed processing method and enzyme treatment were also made.

MATERIALS AND METHODS

Experiment 1

A total of 20 cannulated pigs (10.80 kg BW) were allotted to four treatments. Treatments were coarse (around 400 micrometer in particle size) ground barley as a control (CON), finely (around 200 micrometer in particle size) ground barley (FINE), extruded barley (EXT) and enzyme supplemented coarse ground barley (ENZ). Enzyme used in this study was a enzyme mixture (Fungal Xylanase 800,000 FXU, Fungal β-glucanase 75,000 FBG, Endogenous β-glucanase, 120,000 EGU and Pentosanase 2,500,000 PTU). Barley was a sole source of crude protein and chemical composition of the experimental diets are shown in table 1. Each pig was fitted with a simple T-Cannula located at the distal ileum approximately 7 cm from the ileocecal junction. After one day fasting, hipnodil and stresnil (Janssen Co. Belgium) anesthesia were administered via intravenous injection. The cannula and surgical procedure used in this study were made according to the method suggested by Walker et al. (1986). Following surgery, procain penicillin (2 ml) was administered before closing the incision site and injected daily for consecutive 5 d at a dose of 20,000 IU/kg body weight. Immediately following surgery, the pigs were transferred to individual metabolism crates (90-cm × 60-cm × 50-cm). Crates were equipped with woven plastic floor and automatic watering system. The room temperature was maintained at 32℃ for the first five days after surgery and 30℃ (±2) for the rest of the experiment. Pigs were fed on a *ad libitum* basis until they fully recuperated from the surgery. Then each pig was fed

Table 1. Formula and chemical composition of basal diet for metabolic trial

	% of the diet
Ingredients:	
Barely	63.82
Soybean oil	4.00
Lactose	18.00
Casein	6.00
Limestone	0.36
DCP (18%)	3.77
Salt	0.30
Vit. mixture[1]	2.50
Antibiotics[2]	1.00
Chromix oxide	0.25
Total	100.00
Chemical composition[3]:	
ME (kcal/kg)	3,058.73
Crude protein (%)	12.26
Lysine (%)	0.56
Methionine (%)	0.23

[1] Supplied per kilogram of 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; Riboflavin, 10,000 mg; Pantothenic calcium, 3,000 mg; Choline chloride, 30,000 mg; Niacin, 8,000 mg; Folacin, 200 mg; Vitamin B_{12}, 13 mg; Mn, 12,000 mg; Zn, 15,000 mg; Co, 100 mg; Cu, 500 mg; Fe, 4,000 mg; Folic acid, 40 mg; BHT, 5,000 mg; Co, 100 mg; sucrose to make 1 kg vit.-min. mixture.

[2] Supplied per kilogram of diet: Chlortetracycline, 110 mg; Sulfathiazole, 110 mg; penicillin, 55 mg.

[3] Calculated Value.

a restricted amount of experimental feed (about 5% of the BW/day) twice daily at 08:00 and 20:00 hour and had *ad libitum* access to water throughout the trial.

Ileal samples were collected continuously in vynyl bags between 08:00 h and 24:00 h at 2-h intervals on collection days. Collected samples were immediately frozen and stored at −20℃, freeze dried (Ilsin Eng. Co, Korea), ground with a 1 mm mesh Wiley mill, and used for chemical analysis. A fresh fecal sample was collected for 24 hours in pans placed under individual metabolic crate on the seventh and eighth day after five to six days of adaptation periods.

Experiment 2

A total of 100 growing pigs (36.50 kg BW) were allocated to the treatments in completely randomized block design based on sex and body weight. Treatments were the same as experiment 1, but diets were formulated to 18% crude protein. Barley was included at the rate of 25% of total ingredients. Pigs were housed in a concrete floored pen, with a feeder and a nipple waterer, and allowed *ad libitum* access to feed and water through whole experimental period.

Table 2. Formula and chemical composition of basal diet for growth trial

	% of diet
Ingredients:	
Corn	38.06
Barely	25.00
Soybean meal (44%)	26.34
Tricalcium phosphate	2.18
Salt	0.30
Vit. mixture[1]	0.20
Min. mixture[2]	0.23
Animal fat	5.32
Molasses	2.04
Choline chloride (25%)	0.14
CTC[3]	0.10
L-lysine	0.09
Total	100.00
Chemical composition[4]:	
ME (kcal/kg)	3,300
Crude protein	18.00
Lysine	1.00
Methionine + Cystine	0.60
Calcium	0.74
Phosphorus	0.70

[1] supplied per kg diet : 8,000 IU vitamin A, 2,500 IU vitamin D_3, 30 IU vitamin E, 3 mg vitamin K, 1.5 mg thiamin, 10 mg riboflavin, 2 mg vitamin B_6, 40 μg vitamin B_{12}, 30 mg pantothenic acid, 60 mg niacin, 0.1 mg biotin, 0.5 mg folic acid.

[2] supplied per kg diet : 200 mg Cu, 100 mg Fe, 150 mg Zn, 60 mg Mn, 1 mg I, 0.5 mg Co, 0.3 mg Se.

[3] supplied 100 mg chlorotetracycline per kg diet.

[4] Calculated Value.

Chemical analyses of the experimental diets and intestinal digesta were carried out according to the AOAC (1990) methods and Cr was measured by atomic absorption spectrophotometer (Shimadzu, AA625, Japan). Amino acid contents were determined following acid hydrolysis in 6N HCl at 110℃ for 16 hours (Mason, 1984), using an amino acid analyzer (LKB 4150 alpha, Pharmacia Instrument Co, England). Statistical analysis was carried out by comparing means according to Duncan's multiple range test (Duncan, 1955), using General Linear Model (GLM) Procedure of SAS (1985) package program.

RESULTS AND DISCUSSION

Experiment 1

Proximate nutrients digestibilities of growing pigs at the terminal ileum are shown in table 3. Pigs fed extruded barley showed significantly higher crude protein digestibility over pigs fed finely ground barley. Pigs fed finely ground barley generally showed lower nutrients digestibility. Hancock et al. (1992) reported that digestibilities of DM and N of cereals were increased by extrusion processing with barley responding the most (9 and 12% for DM and N digestibilities). Fadel et al. (1988) extruded barley for finishing pigs and reported increased digestibilities of dry matter, energy, starch and nitrogen at the terminal ileum as 12, 12, 16 and 11% respectively. The same trend was found in this experiment. However, fine grinding rather reduced nutrients digestibility. Confusion exists concerning the optimum particle size of swine diets because of broad classifications like fine, medium, and coarse are used to define particle size. Many reports showed improvements by grinding to smaller sizes in corn (Hedde et al., 1985; Gieseman et al., 1990; Healy et al., 1994), sorghum (Healy, 1992; Owsley et al., 1981) and barley (Goodband and Hines, 1988) whereas Ohh et al. (1983) reported no improvements in growing performance of pig by reducing particle size of sorghum and Hale et al. (1979) found greater efficiency with coarsely ground than finely ground wheat. Fine dietary particle sizes, pelleted diets based on coarser particle sizes and the substitution of fibrous foodstuffs for barley in barley based diets were shown by Potkins et al. (1989a)

Table 3. Effect of processed barley on the ileal digestibility of proximate nutrients of growing pigs (%, dry matter basis)

	Control	Extrusion	Fine Grinding	Glucanase	PSE[1]
Dry matter	81.91	81.31	74.85	80.23	1.28
Crude protein	73.95[ab]	81.82[a]	68.41[b]	71.77[ab]	2.49
Crude ash	58.10[ab]	61.89[a]	46.16[b]	57.34[ab]	2.19
Crude fat	91.87[a]	92.47[a]	90.87[a]	86.98[b]	0.74
Phosphorus	49.18	57.45	41.86	51.31	3.17

Contrasts	Ext. vs Others	Cont vs Glucanase	Coarse vs Fine
Dry matter	NS*	NS	NS
Crude protein	0.0427	NS	NS
Crude ash	NS	NS	NS
Crude fat	0.0697	NS	NS
Phosphorus	NS	NS	NS

[1] Pooled Standard Error.
[a,b] Means with different superscripts are different at $p < 0.05$.
* Not significant.

to affect the incidence and severity of lesions in the pars oesophagea of the stomach of the growing pig between about 20 kg and 90 kg liveweight. In subsequent experiments with pigs weighing about 30 kg of differing genotype, given a diet based on finely ground barley which was known to predispose to lesion formation, Potkins et al. (1989b) reported that lesions were found in some pigs at 10 to 11 weeks old but the incidence and severity increased progressively indicating development as quickly as one month after first giving the finely ground diet.

Table 4 summarized the amino acids digestibility of

Table 4. Effect of processed barley on the ileal digestibility of essential amino acids of growing pigs (%, dry matter basis)

	Control	Extrusion	Fine Grinding	Glucanase	PSE[1]
THR	81.54[a]	81.57[a]	66.14[b]	81.35[a]	2.18
VAL	64.26	72.68	64.50	69.32	1.72
MET	71.07[bc]	88.38[a]	63.49[c]	86.31[ab]	3.61
ILE	82.14[ab]	86.01[a]	75.94[b]	86.65[a]	1.74
LEU	81.61[ab]	87.25[a]	77.06[b]	85.16[a]	1.44
PHE	73.26[bc]	89.80[a]	65.28[c]	85.19[ab]	3.13
LYS	84.71[ab]	84.90[ab]	79.45[b]	86.31[a]	1.17
HIS	80.71[ab]	80.28[ab]	74.64[b]	83.82[a]	1.34
ARG	81.54[ab]	87.50[a]	72.83[b]	89.25[a]	2.52
Mean	77.87[ab]	84.26[a]	71.03[b]	83.71[a]	1.85

Contrasts	Ext. vs Others	Cont vs Glucanase	Coarse vs Fine
THR	NS*	NS	NS
VAL	NS	NS	NS
MET	0.0358	NS	0.0695
ILE	NS	NS	NS
LEU	0.0464	NS	NS
PHE	0.0087	NS	0.0683
LYS	NS	NS	NS
HIS	NS	NS	NS
ARG	NS	NS	NS
Mean	0.0570	NS	0.1615

[1] Pooled Standard Error.
[a,b] Means with different superscripts are different at $p < 0.05$.
* Not significant.

processed barely at the terminal ileum of growing pigs. The similar trend with proximate nutrients was found in the digestibility of essential amino acids. Fine grinding of barley significantly reduced amino acids digestibility. Extrusion and enzyme supplementation were found to improve amino acids digestibility of barley in growing pigs. Moughan and Smith (1987) examined the ileal digestibility of ground barley and reported that 74%, 75%, 77% as digestibilities of THR, LYS, HIS, respectively. Our data showed a little bit higher digestibility than the data of Moughan and Smith (1987).

Experiment 2

The growth performance of pigs fed differently processed barley diets are shown in table 5. Pigs fed extruded barley grew significantly faster than any other processed barley fed pigs. And extrusion of barley significantly improved feed/gain of pigs ($p < 0.05$). Fine grinding of barley and enzyme supplementation did not improve growth performance of pigs. With chickens, many reports suggested that enzyme treatments improved growth performance. In contrast to the chicken, pigs fed barley-based diets failed to demonstrate consistent improvement in performance with enzyme supplementation (Graham et al., 1986; Thacker et al., 1988).

Pigs are not affected by dietary gums such as β-glucan or pentosan (Honeyfield et al., 1983). In addition, it was reported that β-glucan is also highly digestible in the ileum of pigs (Graham et al., 1986), apparently more digestible than starch (Graham et al., 1989). Another possible reasone for no improvement caused by enzyme supplementation is the fact that barley was incorporated at the rate of only 25% of the experimental diet. And the pigs used in the growth trial of this study already grown up to over 35 kg, thus the digestive capacity might be already fully developed. The age of the pig may influence its response to enzyme supplementation. Similarly, the nutrients digestibility was improved in the metabolism trial of this study in which about 10 kg BW pigs were used, while no improvement was found in growth performance of pigs in the second growth trial in which about 35 kg BW pigs were used. Bedford et al. (1992) observed a significant improvement in rate of growth when the diet was supplemented with the β-glucanase with 26 days old piglets. Hancock et al. (1992) reported that marked improvements in growth efficiency and nutrient digestibility was found when extruded sorghum and extruded soybeans were fed to finishing pigs. They also reported 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. Digestibilities of DM and N were also increased on average by extrusion processing with barley responding the most (9 and 12% for DM and N digestibilities). They concluded that the extrusion technology offers promise in terms of improved nutritional value of cereal grains, provided that costs of process and equipment continue to decrease.

Many reports showed improvements by grinding to smaller sizes in corn (Hedde et al., 1985; Gieseman et al., 1990; Healy et al., 1994), sorghum (Healy, 1992; Owsley et al., 1981) and barley (Goodband and Hines, 1988) whereas Ohh et al. (1983) reported no improvements in growing performance of pig by reducing particle size of sorghum and Hale et al. (1979) found greater efficiency with coarsely ground than finely ground wheat.

In contrast to the result of this experiment, Lawrence

Table 5. Effects of processed barley on growth performance in growing pigs

	Control	Extrusion	Fine Grinding	Glucanase	PSE[1]
Initial Wt. (kg)	36.46	36.54	36.49	36.52	1.26
Final Wt. (kg)	57.44[ab]	58.86[a]	57.28[b]	57.02[b]	1.39
ADG (kg)	0.95[ab]	1.01[a]	0.93[b]	0.94[b]	0.01
ADFI (kg)	2.47	2.43	2.41	2.43	0.06
Feed/Gain	2.59[a]	2.39[b]	2.58[a]	2.57[a]	0.05

Contrasts	Ext. vs Others	Cont vs Glucanse	Coarse vs Fine
Final Wt.	0.0600	NS	NS
ADG	0.0730	NS	NS
ADFI	NS*	NS	NS
FG	0.0265	NS	NS

[1] Pooled Standard Error.

[a,b] Means with different superscripts are different at $p < 0.05$.

* Not significant.

et al. (1980) indicated that ground barley of fine particle size gave better responses than ground barley of coarse particle size. However, he did not find significant differences between pigs fed diets containing 850 g barley per kg prepared by either cold rolling or grinding through 1.56 mm or 4.68 mm screens.

Thus, based on the result of this experiment, extrusion appeared to be the most effective feed processing technique for the use of barley in growing pig diets. The use of enzyme for the growing pigs does not seem to be promising when small portion of barley is incorporated in the diets and fine grinding did not support better growth performance of growing pigs. However, enzyme supplementation improved amino acids digestibility of barley when fed as a major feed ingredient for growing pigs.

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