Effects of Wet Feeding of Processed Diets on Performance, Morphological Changes in the Small Intestine and Nutrient Digestibility in Weaned Pigs**

J. S. Yang, J. H. Lee, T. G. Ko, T. B. Kim[1], B. J. Chae[2], Y. Y. Kim and In K. Han*
Department of Animal Science and Technology, College of Agriculture and Life Sciences
Seoul National University, Suwon 441-744, Korea

ABSTRACT : This study was conducted to evaluate the effects of different methods of feeding and processing of diets on performance, morphological changes in the small intestine and nutrient digestibility of young pigs. A total of 120 pigs (Youkshire×Landrace×Duroc; initial body weight of 5.83±0.67 kg) were randomly allotted into six treatments in a 2×3 factorial design. Treatments were 1) dry feeding with a mash diet (DM), 2) dry feeding with a pelleted diet (DP), 3) dry feeding with an expanded crumble diet (DEC), 4) wet feeding with a mash diet (WM), 5) wet feeding with a pelleted diet (WP), 6) wet feeding with an expanded crumble diet (WEC). Average daily gain (ADG) and average daily feed intake (ADFI) were not significantly (p>0.05) different among treatments. However, feed conversion ratio (FCR) was significantly improved when pigs fed a pelleted diet or an expanded crumble diet. Pigs fed an expanded crumble diet showed 9.2% and 17.3% improvement in ADG and FCR compared with those fed a mash diet. The morphological changes in the small intestine were examined at the termination (4 weeks after weaning) of the experiment. Differences in morphological changes of gastrointestinal tract were not significant among treatments. Though villus height was not significantly affected by feeding method or feed processing, the villus height of weaned pigs tended to be preserved by wet feeding. The use of a pelleted diet also helped to prevent the shortening of villus height. Pigs fed a WP diet maintained the highest villus height at all parts of the small intestine. There was no significant difference (p>0.05) in nutrient digestibility among treatments. However, nutrient digestibility for pigs fed a pelleted diet had a higher than that of pigs fed mash diets. Especially, pigs fed a WP diet digested 5.3% more P each day than those fed a DM diet. Compared with the mash diet, the expanded crumble diet decreased feed cost per kg weight gain by 15%. The net profit per pig was 79% higher in the expanded crumble diet pigs than in mash diet pigs. In conclusion, this study suggests that feeding processed diets to piglets can be more beneficial in terms of FCR and production cost. ***(Asian-Aust. J. Anim. Sci. 2001. Vol 14, No. 9 : 1308-1315)***

Key Words : Wet Feeding, Feed Processing, Growth Performance, Intestinal Morphology, Nutrient Digestibility, Weaned Pigs

INTRODUCTION

A major problem with weaning piglets at 3 weeks of age is the growth depression related to weaning. This "growth check" lasts from 7 to 14 days depending on managerial and environmental factors and is characterized by little or no weight gain and low feed intake accompanied frequently by diarrhea (Binder et al., 1978; DeUriarte and Zimmerman, 1978; Lecce et al., 1979).

At weaning, it is a general practice to abruptly shift nursing piglets from sow's milk to dry feed and water. In addition to this severe dietary change, other potential stresses are imposed, such as separation from mother, changes in environment, disruption in social order, etc. (Bayley and Carlson, 1970; Reklewski, 1972; Lecce et al., 1979).

It is generally accepted that wet feeding improves feed intake, growth, feed conversion and health of weaned pigs (Partridge and Gill, 1993). Cumby (1986) attributed the increased use of liquid feeding systems to these factors and to a reduction in cost resulting from the use of inexpensive wet by-products. Voluntary feed intake might be stimulated by wet feeding in a number of ways. Bigelow and Houpt (1988) reported that 75% of daily water intake occurred in conjunction with eating bouts in the young pig, while Barber et al. (1989) recorded a direct correlation between water intake and feed intake after weaning, suggesting that piglets prefer to eat their feed in the presence of water.

Feed processing can change the physical and chemical properties of feedstuffs. In addition, it can also improve the nutritional value of the feed through various mechanisms. Pelleting is extensively used in commercial swine feed production. Many researchers reported that pelleted diets improved ADG and nutrient digestibility (Skoch et al., 1983; Stark et al., 1993; Wondra et al., 1995). The expanding of a diet was also reported to improve growth rate and digestibility in young pigs (Boulduan et al., 1993; Ohh et al., 1996; Johnston and Hancock, 1999).

Effects of wet feeding and feed processing have been examined in many studies individually, but there were few

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* Address reprint request to In K. Han. Tel: +82-2-502-0757, Fax: +82-2-502-0758, E-mail: inkhan@kornet.net.
[1] Dodram B&F, #386 Naesong Ri, Keumwang Eub, Eumsung-Gun, Chungbuk 369-901, Korea.
[2] Division of Animal Resources, Kangwon National University, Chunchon 200-701, Korea.
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experiments that evaluated the effects of wet feeding and processing in combination. Therefore, this study was conducted to investigate wet feeding effects of processed diets on the performance, nutrient digestibility and morphological changes of the small intestine in weaned pigs.

MATERIALS AND METHODS

A total of 120 weaned pigs (Yorkshire×Landrace ×Duroc; average body weight 5.83±0.67 kg, 21 days of age) were used to evaluate the effects of different methods of feeding and processing of diets on performance, morphological changes in the small intestine and nutrient digestibility of young pigs. Pigs were grouped on the basis of body weight and gender, and were randomly allotted into 6 different treatments with 5 replications each treatment in a 2×3 factorial arrangement. Treatments were 1) dry feeding with a mash diet (DM), 2) dry feeding with a pelleted diet (DP), 3) dry feeding with an expanded crumble diet (DEC), 4) wet feeding with a mash diet (WM), 5) wet feeding with a pelleted diet (WP), 6) wet feeding with an expanded crumble diet (WEC).

Experimental diets were formulated to meet or exceed the nutrient requirements for young pigs recommended by NRC (1998) during the entire experiment period (table 1). Standard pellet and expanded crumble diets were processed by the following protocols. For standard pellet, corn grain was ground with a 3.5 mm diameter grinder (Hammer mill, BUHLER, Switzerland). Ground corn and other ingredients were processed in a conditioner for 8 seconds with 80°C, 2.5-3.0 kgf/cm^3 of steam pressure at 12.5Å. And then, they were agglomerated into large particles by pellet mill. The pellet mill (California Pellet Mill Co., USA) had a 3.2 mm screen size and 63 mm of die thickness, with 200 horse power. The pellet diet produced had 98.3 of pellet durability index, 627 g/l of specific gravity and 39.8 of α value that means degree of gelatinization.

For expanding (ALMEX, Netherlands), corn grain was ground with a 3.5 mm diameter grinder. Ground grain and other ingredients were processed in a conditioner for 9 seconds with 94°C, 4.0 kgf/cm^3 of steam pressure at 12.5Å. The barrel temperature of the expander was 140°C, with 350 horse power. After the expanding mill, the feeds were crumbled with an average particle size of 1-4 mm. The produced expanded crumble diet had 601 g/l of specific gravity and 42.1 of α value. α value of mash diet was 32.1. α value was improved by pelleting and expanding by 24 and 31%, respectively.

All the feeders used for this feeding trial were dry type, identical in appearance without compartments, and 4 piglets could consume diets simultaneously. For pigs in the wet feeding group, feeds were watered in a ratio of 1:2, fed sufficiently 4 times a day.

For convenient access to the water, nipple waterers with water cups were installed. For pigs in the dry feeding group, the same feeder and water nipple was used. The flow rate of water by nipple was 1.0 L/min.

Experimental diets and drinking water were provided *ad libitum*. Body weights and feed intakes were recorded every week until the experiment ended. Body weight gain was calculated by the difference between the initial body weight and final body weight. Feed conversion ratio was calculated by dividing the amount of feed consumed with the corresponded body weight gain. At the termination of the feeding trial, 3 pigs from each treatment were randomly selected and slaughtered for examining the morphological changes in the small intestine including villus height and crypt depth. The samples of the small intestine were obtained (≒4 cm in length) at distances of proportionately 0.25, 0.50 and 0.75 along the gut from the gastric pylorus to the ileo-caecal valve. These were fixed in neutral-buffered formalin and processed by the standard paraffin method. Sections (3-4 cm) were stained with haematoxylin and eosin, and examined under a light microscope. Measurements of villus hight and crypt depth were taken only from sections where the plane of section ran vertically from the tip of the villus to the base of an adjacent crypt. From each section, a calibrated eyepiece graticule was used to measure 10 of the tallest well oriented villi from tip to crypt mouth, and 10 associated crypts from crypt mouth to base (Hampson et al., 1988).

For the determination of nutrient digestibilities, the total fecal collection method was used. A total of 12 pigs (6 boars and 6 gilts) averaging 8 kg of body weight were housed in individual metabolic cages. After four days of adaptation period, total excreta were collected during three consecutive days. The amount of feed consumed and excreta produced were recorded daily. Collected excreta were pooled and dried in an air forced drying oven at 60°C for 72 hours and ground with 1 mm Wiley mill for chemical analyses. Analyses of proximate principles of the experimental diets and excreta were conducted according to the methods of AOAC (1990). Statistical analysis was carried out to compare means according to Duncan's multiple range test (Duncan, 1955), using General Linear Model (GLM) procedure of SAS (1985) package program.

RESULTS AND DISCUSSION

Performance

The performance of weaned pigs is presented in table 2. During phase I (0~14 days), pigs fed processed diets showed an improved (p=0.0006) feed conversion ratio (FCR) compared with pigs fed a mash diet, while FCR was

Table 1. Formula and chemical composition of the piglet diets

	Phase I		Phase II		
	Mash	Pellet & EC	Mash	Pellet	EC
Ingredients (%)					
Corn (extruded)	25.40	23.54	25.48	24.36	24.51
Wheat	-	-	20.00	20.00	20.00
Milk replacer[1]	8.80	8.80	9.15	9.15	9.15
Whey protein concentate	15.00	15.00	-	-	
Soybean meal (dehulled)	19.38	23.07	24.67	24.76	24.64
Soybean oil	5.23	5.00	-	-	-
Lard	-	-	4.26	4.29	4.26
Fish meal	6.00	4.00	4.00	4.00	4.00
Lactose	7.50	7.50	-	-	-
Dried porcine solubles	1.25	1.25	1.25	1.25	1.25
Limestone	0.45	0.67	0.70	0.70	0.70
Mono-calcium phosphate	1.10	1.25	1.25	1.25	1.25
Salt	-	-	0.20	0.20	0.20
Bakery by-product	9.00	9.00	8.00	9.00	9.00
L-Lysine- HCl (78%)	-	-	0.15	0.16	0.16
DL-Methionine (Liq., 88%)	0.14	0.17	0.14	0.13	0.13
Vitamin-mineral mixture[2]	0.35	0.35	0.35	0.35	0.35
Antibiotics[3]	0.30	0.30	0.30	0.30	0.30
Choline chloride (25%)	0.10	0.10	0.10	0.10	0.10
Total	100.00	100.00	100.00	100.00	100.00
Chemical composition[4]					
ME (kcal/kg)	3,500	3,498	3,378	3,383	3,380
Crude protein (%)	23.00	23.00	20.70	20.72	20.70
Lysine (%)	1.65	1.66	1.28	1.29	1.29
Methionine+cystine (%)	0.95	0.96	0.80	0.80	0.79
Calcium (%)	0.88	0.88	0.88	0.88	0.88
Phosphate (%)	0.77	0.77	0.77	0.77	0.77

[1] Composition : whey 89.3%, soy flour 10%, Al silicate 0.7%.

[2] Provided the following per kg of diet : Vitamin A, 3,300 IU; Vitamin D_3, 750 IU; Vitamin E, 15 mg; Vitamin K_3, 1.2 mg; Vitamin B_1, 0.38 mg; vitamin B_2, 2.64 mg; Niacin, 13.2 mg; Pantothenic acid, 9.75 mg; Pyridoxin, 0.66 mg, Choline 135 mg; Folic acid, 0.50 mg; Biotin 34.5 μg; Vitamin B_{12}, 13.5 μg; Cu, 135.6 mg; Zn, 85.2 mg; Se, 0.20 mg; Mn, 39 mg; Fe, 64 mg; 15.4 mg; I, 0.90 mg.

[3] Provided per kg diet : Olaquindox 50 mg, Avilamycin 40 mg.

[4] Calculated values.

improved by feeding an expanded crumble diet. Interaction between feeding methods and processing methods was shown (p=0.0471) in average daily gain (ADG). In phase II (15~28 days), there was no significant differences (p>0.05) in ADG and average daily feed intake (ADFI) among treatments. Feed conversion ratio (FCR) was significantly (p=0.042) improved in pigs fed processed diets compared with those fed a mash diet. Pigs fed an expanded crumble diet had 15% better FCR compared with those fed a mash diet.

For the overall period (0~28 days), ADG was not significantly different (p>0.05) among treatments. ADFI was increased by 6% in pigs fed mash diets compared with those fed processed diets, but there was no significant difference among processing methods. FCR was improved by feeding processed diets (p<0.01), regardless of feeding method.

Researchers have attributed the improved performance from pelleting to decreased feed wastage and increased nutrient digestibility (Ohh et al., 1996; Skoglund et al., 1997). Research conducted in Europe and the United States has shown that pelleted nursery diets increased ADG and FCR by 7 to 8%, respectively. In the present study, pigs fed a pelleted diet showed 7.4% and 12.5% improvement in ADG and FCR compared with those fed a mash diet. No difference between feeding methods (wet feeding vs dry feeding) was found in this study. However, Russell et al. (1996) reported that wet feeding increased dry matter intake and weight gain of piglets during the first 4 weeks post-weaning.

In several studies, it has been reported that feed processing (pelleting or expanding) improved the

Table 2. Effect of feeding and processing methods of diets on growth performance of weaned pigs[1]

Treatments	Dry			Wet			SE[2]
	Mash	Pelleted	Expanded crumble	Mash	Pelleted	Expanded crumble	
D 0-14							
ADG (g)	213[b]	262[a]	271[a]	264[ab]	235[ab]	241[ab]	6.98
ADFI (g)	290	278	285	309	279	270	6.61
FCR	1.36[a]	1.07[c]	1.05[c]	1.27[ab]	1.20[bc]	1.12[bc]	0.03
D 15-28							
ADG (g)	447	487	499	465	489	488	9.26
ADFI (g)	704	690	674	743	707	680	14.13
FCR	1.59[a]	1.42[ab]	1.36[b]	1.59[a]	1.45[ab]	1.40[b]	0.03
D 0-28							
ADG (g)	330	374	385	355	362	364	7.24
ADFI (g)	497	484	479	524	489	472	9.00
FCR	1.51[a]	1.29[c]	1.25[c]	1.47[ab]	1.36[bc]	1.30[c]	0.02

	Feeding methods	Processing methods	Interaction (P value)
Phase I (D 0-14)			
ADG (g)	0.4778	0.1496	0.0471
ADFI (g)	0.8698	0.1991	0.4501
FCR	0.3852	0.0006	0.1128
Phase II (D 15-28)			
ADG (g)	0.8717	0.2256	0.8150
ADFI (g)	0.4213	0.3443	0.8631
FCR	0.6189	0.0042	0.9411
Overall (D 0-28)			
ADG (g)	0.8396	0.1081	0.2858
ADFI (g)	0.5798	0.1568	0.6231
FCR	0.5085	0.0001	0.4230

[1] Average initial body weight of piglets was 5.83 kg and the final body weight was 15.96 kg through the 28-day growth trial.
[2] Pooled standard error, [a,b,c] Means with different superscript in the same row differ at $p<0.05$.

performance of young pigs (Bolduan et al., 1993; Ohh et al., 1996). Armstrong (1993) and Peisker (1994) demonstrated greater feed intake and faster growth when piglets (4-8 weeks of age) were fed an expanded crumble diet rather than unprocessed diets, and FCR was improved.

It has been suggested that the beneficial effect of expansion on feed intake could be due to inactivation of appetite suppressant ingredients and activation of natural flavors (Armstrong, 1993; Peisker, 1994). In the present study, pigs fed a WP or WEC diet showed a 9.7% or 10.3% improvement in ADG, respectively, compared with those fed a DM diet. Recently, Chae et al. (2000) conducted an experiment with extruded corn and sorghum in nursery pigs. The feed conversion of pigs fed extruded corn or sorghum was better than those fed the unextruded ones.

The present study showed that the performance of young pigs could be improved by feed processing rather than feeding methods. Piglets fed the processed diets showed better FCR by 15-20%. Meanwhile, this study suggests that a mash diet can be suitable for wet feeding, but processed diets are more suitable for dry feeding.

Morphological changes in the small intestine

The villus height and crypt depth at the three sites along the small intestine are given in table 3. Villus height and crypt depth were not significantly different among treatments. However, villus height of pigs fed a WP diet was increased by 14% or 7.5% compared with those fed a DM or DEC diet. Partridge et al. (1993) demonstrated that wet feeding was well accepted by young pigs and had been shown to enhance gut health and function by providing appropriate conditions for enzyme activity, digestion, nutrient absorption and microbial growth. In the present study, wet feeding of pelleted diets did not significantly affect morphological changes in the small intestine, but had a tendency to prevent the decrease in villus height and increase in crypt depth generally associated with weaning. Pluske et al. (1996) demonstrated that the regular feeding of a milk diet also prevented the decrease in villus height and increase in crypt depth. They also reported that piglets consuming a dry starter diet displayed villus atrophy, an increase in crypt depth, and a reduced concentration of mucosal protein.

Table 3. Effects of feeding and processing methods of diets on morphological changes in the small intestine of weaned pigs

Treatments	Dry			Wet			SE[1]
	Mash	Pelleted	Expanded crumble	Mash	Pelleted	Expanded crumble	
Villus height[2] (μ m)							
0.25	622	697	667	701	728	678	19.16
0.50	642	708	661	699	723	593	22.52
0.75	586	649	637	660	663	589	16.60
Crypt depth (μ m)							
0.25	317	404	350	342	347	343	10.33
0.50	318	368	320	349	344	357	11.31
0.75	245	326	322	241	300	328	13.66

	Feeding methods	Processing methods	Interaction (P value)
Villus height			
0.25	0.3845	0.6259	0.8172
0.50	0.9798	0.3498	0.5625
0.75	0.6081	0.3994	0.2116
Crypt depth			
0.25	0.5649	0.2440	0.3183
0.50	0.5472	0.7212	0.5207
0.75	0.7722	0.0616	0.8817

[1] Pooled standard error.

[2] Distances of proportionately 0.25, 0.50 and 0.75 along the gut from the gastic pylorus to the ileo-caecal valve.

As shown in table 3, the villus height of piglets was shorten by 5 to 10% through feeding a WEC diet. This result seems to be caused by less feed intake throughout the experimental period. Kelly et al. (1991) reported that villus length and crypt depth were positively related to feed intake. This relationship could indicate a stimulatory effect of feed intake on development of the wall of small intestine. Furthermore, Kelly et al. (1991) and Pluske et al. (1996) reported that pigs fed less feed showed villus atrophy and increased crypt depth at all sites along the small intestine compared with pigs fed a higher quantity feed. The small intestine of the early weaned pig undergoes major changes in villus architecture and reduction in specific enzyme activity during the immediate post weaning period (Gay, 1976; Armstrong and Clawson, 1980; Hampson and Kidder, 1986). The alterations in mucosal architecture resulted in reduced ability of villi to transport amino acids (Smith, 1984). The cumulative effect of these factors has been considered to result in a reduced digestive capacity in vivo and to explain the low feed intake frequently encountered during the post weaning period (Hampson, 1983). Reductions in mucosal mass and a depression of digestive enzyme capacity occur in malnourished or fasted states (Steiner et al., 1968; McManus and Isselbacher, 1970), illustrating the importance of nutrient intake in maintaining mucosal integrity.

Some researchers (Robertson et al., 1985; Bark et al., 1986) have shown that after weaning there is a period of temporary starvation during which piglets fail to consume sufficient feed to cover their maintenance energy requirement. McCracken (1984) and McCracken and Kelly (1984) suggested that villus atrophy and reductions in digestive enzyme activity after weaning may be related more to the lack of a continuous supply of substrate than to any antigenicity of the diet or inherently low levels of disaccharidase activity. In the present study, significant differences between a mash diet and a processed diet (pellet or expanded crumble) were not found, but the villus height of pigs fed pellet diets was 6% higher compared with pigs fed mash diets.

Effects of feeding and processing methods of diets on the length and weight in gastrointestinal organs of weaned pigs are presented in table 4. The length and weight of gastrointestinal tract were not significantly different among treatments, but the weights of liver and pancreas were increased by 5-15% through expanding process regardless of feeding methods. Kelly et al. (1991) demonstrated that these marked differences in live weight contributed to the difference in the weight of the digestive tract of pigs weaned at 14 d age during the 5 d post-weaning. However, in the present study, the difference in live weight did not affect the weight of gastrointestinal organs.

Based on the parameters mentioned above, the present study indicates that wet feeding of processed diets may not affect the weight and length of the small intestine, but that wet feeding of a pelleted diet can be helpful for weaned

Table 4. Effects of feeding and processing methods of diets on the length and weight of the gastrointestinal tract of weaned pigs

Treatments	Dry			Wet			SE[1]
	Mash	Pelleted	Expanded crumble	Mash	Pelleted	Expanded crumble	
Body weight (kg)	12.19	12.59	12.54	12.99	13.20	12.23	0.32
Small intestine[2] length (mm)	102.4	101.6	97.5	102.8	95.9	94.8	2.29
Organ weight[3]							
Small intestine (g)	61.8	61.9	53.1	71.3	63.6	53.7	3.24
Stomach (g)	7.9	6.4	7.6	8.1	7.4	8.2	0.31
Liver (g)	31.2	31.9	33.5	29.2	31.8	33.2	0.11
Pancreas (g)	2.4	2.3	2.5	1.9	2.1	2.6	0.85
Total (g)	103.4	102.5	96.6	110.5	104.8	96.6	3.81

	Feeding methods	Processing methods	Interaction (P value)
Bodyweight	0.6191	0.8447	0.8260
Small intestine length	0.6454	0.6489	0.9088
Organ weight			
Small intestine	0.5910	0.3294	0.8567
Stomach	0.3811	0.3245	0.8978
Liver	0.2410	0.2151	0.4179
Pancreas	0.6486	0.4081	0.8853
Total	0.5276	0.9228	0.7816

[1] Pooled standard error, [2] Small intestine length (mm)/kg body weight, [3] Gastrointestine weight (g)/kg body weight.

pigs to maintain the villus height which corresponds to the improved performance.

Nutrient digestibility

Table 5 shows the results of the metabolic trial measuring nutrient digestibility of weaned pigs. The metabolic trial was conducted at 3 weeks after weaning. In this trial, wet feeding of processed diets did not produce beneficial effect ($p>0.05$), but pigs fed a pelleted diet tended have higher nutrient digestibility than those fed a mash diet or an expanded crumble diet. Particularly, pigs fed a WP diet showed 5.3% improvement in phosphorus digestibility compared with those fed a DM diet. This result is in agreement with several studies reported previously (Jongbloed, 1987; Ohh et al., 1996). Jongbloed (1987) observed that the absorption of phosphorus was improved as an effect of crushed cells when steam pelleting the diets. The effect of the pelleting temperature on phytase activity was reported in a later investigation (Jongbloed and Kemme, 1990). When the temperature reached ≥80°C, phosphorus digestibility was dramatically decreased, presumably due to a reduction in phytase activity in the diets. Skoglund et al. (1997) reported a 7% reduction in phytase content, when the diet was pelleted at 81°C. In the present trial, pigs fed an expanded crumble diet showed the lowest phosphorous digestibility, which might result from reduced phytase activity in the diets. Digestibilities of dry matter, crude protein and energy were similar among processing methods. Herkelman et al. (1990) reported that extrusion of corn did not affect N or lysine digestibility but that extruded corn had a greater energy value than ground corn for nursery pigs. Bolduan et al. (1993) demonstrated that the expansion process did not improve GE and N, but significantly increased crude fiber digestibility by 40%.

Pigs fed a WP diet showed 1-5% higher digestibility than those fed a DM or DEC diet, but there was no significant difference. Similar to this result, Chae et al. (1997) reported that wet feeding had a tendency to improve nutrient digestibility, but there was no significant differences between wet feeding and dry feeding.

The present study suggests that the use of pellet diet, not an expanded diet, may be helpful to improve nutrient digestibility of piglet diets. However the expanded crumble diet decreased digestibility of some nutrients, which might be related to adverse effects caused by high temperature processing.

Feed cost

Effects of feeding and processing methods of diets on feed cost in weaned pigs is presented in table 6. Total feed cost per pig (TFC) for the overall period was higher ($p<0.05$) in the mash diet group than in the processed diet groups. However, total weight gain (TWG) was 8.4% lower in pigs fed a mash diet. This result seems to be related with FCR. Feed cost per kg weight gain (FCG) was the lowest in the expanded crumble groups regardless of feeding methods.

Compared with the mash diet, the expanded crumble

Table 5. Effects of feeding and processing methods of diets on nutrient digestibility of weaned pigs[1]

Treatments	Dry			Wet			SE[2]
	Mash	Pelleted	Expanded crumble	Mash	Pelleted	Expanded crumble	
Dry matter (%)	91.9	92.4	92.3	92.2	93.1	92.3	0.20
Crude protein (%)	92.6	92.2	92.7	92.8	93.4	92.0	0.19
Crude fat (%)	93.5	93.7	93.8	93.7	94.7	93.6	0.25
Calcium (%)	87.9	86.7	86.2	88.9	89.0	86.5	0.44
Phosphorus (%)	80.6	82.0	82.3	81.9	84.9	80.7	0.59
Energy (%)	92.4	92.9	92.4	92.6	93.4	92.6	0.19

	Feeding methods	Processing methods	Interaction (P value)
Dry matter	0.3936	0.3712	0.7483
Crude protein	0.4813	0.5836	0.1349
Crude fat	0.5529	0.7181	0.6851
Calcium	0.1503	0.1381	0.6039
Phosphorus	0.4839	0.2730	0.3167
Energy	0.4461	0.2883	0.9332

[1] 12 pigs weighing 9.35 kg body weight were used to measure nutrient digestibility, [2] Pooled standard error.

Table 6. Effects of feeding and processing methods of diets on feed cost of weaned pigs

Treatments	Dry			Wet			SE[1]
	Mash	Pelleted	Expanded crumble	Mash	Pelleted	Expanded crumble	
FC (₩)[2]	646.6	640.5	641.3	646.6	640.5	641.3	-
TWG (kg/pig)	9.23	10.48	10.78	9.95	10.13	10.2	0.20
TFI (kg/pig)	13.92	13.56	13.42	14.66	13.70	13.21	0.26
TFC (₩/pig)	8,990	8,699	8,694	9,479	8,775	8,471	456.30
TCG (₩/pig)	976.6[a]	831.5[b]	808.0[b]	954.9[a]	868.2[b]	832.7[b]	16.06
NP (₩/pig)	2,645[c]	5,445[ab]	6,060[a]	3,584[bc]	4,668[abc]	5,108[ab]	341.04

	Feeding methods	Processing methods	Interaction (P value)
TWG	0.6196	0.2146	0.4043
TFI	0.6974	0.0872	0.8172
TFC	0.6563	0.0649	0.9367
TCG	0.4280	0.0001	0.4413
NP	0.4543	0.0090	0.3722

[1] Pooled standard error. [2] Cost per kg feed: Ingredient cost (mash, ₩ 646.6/kg feed; pellet, ₩ 638.1/kg feed; expanded crumble, ₩ 637.8/kg feed)+Processing cost (pellet ₩ 2.4/kg feed; expanded crumble ₩ 3.5/kg feed).

* Abbreviation: TWG, total weight gain per pig; TFI, total feed intake per pig; TFC, total feed cost per pig; FCG, feed cost/kg body weight gain; NP, net profits per pig (TWG×₩ 2,018/kg -TFC -the rest of production cost (₩ 7,000)).

[a,b,c] Means with different superscript in the same row differ at $p<0.05$.

diet decreased FCG by 15%. The net profit per pig (NP) was higher when piglets were fed processed diets (an expanded crumble diet and a pelleted diet) rather than a mash diet. In this study, wet feeding did not affect FCG and NP. The present study suggests that feed cost in weaned pigs can be reduced by the use of processed diets and that net profits may be 70 to 80% higher.

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