Effect of crumbled diet on growth performance, market day age and meat quality of growing-finishing pigs

Dinh Hai Nguyen, Jae Won Park and In Ho Kim

Department of Animal Resource and Science, Dankook University, Cheonan-si, South Korea

ABSTRACT
This study was conducted to determine the effect of crumbled diet on growth performance, market day age, and meat quality of growing-finishing pigs. A total of 120 crossbred pigs ([Landrace × Yorkshire] × Duroc) with an average initial body weight (BW) of 25.89 ± 1.93 kg at 68 days of age were randomly allotted to 2 experimental diets based on initial BW (15 replicate pens per treatment, 4 pigs per pen; 2 barrows and 2 gilts). The trial lasted for 120 days. Dietary treatments included: (1) T1 (mash diet); (2) T2 (crumble diet). During the overall study period pigs fed the T2 (crumble diet) had significantly greater (P < .05) average daily gain (ADG) and gain to feed ratio (G:F). Moreover, the number of pigs reaching market age at day 177 was higher in pigs fed crumble diet than mash diet. No significant differences were observed in back-fat thickness, meat colour, sensory evaluation, cooking loss, drip loss, water holding capacity, and longissimus muscle area (LMA) between T1 and T2 groups. Our results revealed that the growth performance was significantly enhanced in pigs fed with the crumble diet. The crumble diet reduced market day age and meat quality of growing-finishing pigs.

1. Introduction
Feed represents a significant portion of production cost during the finishing phase of growth. Therefore, producers are constantly evaluating ways to improve growth performance while lowering feed cost. Physical forms (mash, pellet, extrusion, and crumble) of feed are crucial factors determining the meat yield of pigs (Kim et al. 2000; Kim et al. 2002a). These feed forms directly influence the cost of mixed feed and the production of pigs. The economic importance of pigs becomes apparent when it is realized that 55–75% of the total production cost of pigs is feed cost. For this reason, efficient use of feed is extremely important for pig production. Pelleted diets have been shown to be an effective feed processing method to improve feed efficiency in nursery and finishing pigs (Stark et al. 1993; Wondra et al. 1995b). An increase of 4–6% in gain to feed ratio (G:F) has been reported when pigs are fed pellet diets vs. meal diets via conventional dry feeders (Wondra et al. 1995b). Besides the advantages of less separation, easier handling, less dust, and better hygienic quality (Flatlandsmo and Slagsvold 1971), pellet feed seems to improve growth and feed efficiency (Braude 1967; Vanschoubroeck et al. 1971; Hanke et al. 1972; Baird 1973; Braude and Rowell 1966). However, pellet feed does have disadvantages. It is a contributor to oesophagogastric changes (oesophagogastric parakerosis, erosions, and ulcers) in the stomach of pigs (Gamble et al. 1967; Flatlandsmo and Slagsvold 1971; Kim et al., 2002b). With the knowledge of this negative influence of whole, Pettersson and Björklund (1976) pellets on the mucous membrane of the stomach and the relatively high production cost, interest in crumble feed has increased. Lower production cost for crumble feed compared to whole pellet feed has been reported because it is not necessary to select crumble feed. According to Yang et al. (2001), feed cost per kg weight gain (FCG) was the lowest in the expanded crumble group regardless of feeding methods. Consequently, crumble diet may reduce feed cost for farmers. Recently this form of feed is becoming popular in broiler production due to its convenience for feeding. Reece et al. (1984) have observed that pigs fed with a crumble form of feed with high energy level and high protein profile have the best feed conversion. Jahan et al. (2006) have reported that the highest body weight gain is in the crumble feed group compared with mash and pellet feed groups. However, data concerning the potential benefits of crumble diets in pigs are rare. Therefore, the objective of this study was to determine the effect of crumbled diet on growth performance, market day age, and meat quality of growing-finishing pigs.

2. Materials and methods
The experimental protocol used in this study was approved by the Animal Care and Use Committee of Dankook University.

2.1. Preparation of mash diet and crumble diet
In the first step, before grinding and mixing feedstuff to become mash form it goes through a scalper. This removes everything such as metal (ferrous and non-ferrous), stones, string, paper, wood, and so on. Then, the pelleting process starts with a bin in which the mixture of mash is stored. From there, the mash will flow by gravity into the pellet mill. The
diet was preconditioned to 55°C and pelleted through a 38 mm thick die with 4.8 mm diameter holes. The hot, extruded mash (pellets with the average exit temperature of 62°C) flows by gravity into a cooler where it is held for three to 6 minutes while being cooled and dried by a flow of air. The air is drawn through the mass of pellets and passed into a dust-collecting device. From the cooler, the product flows through or around a pair of crumble rolls. For producing fine crumble product, the pellets are passed between the crumble rolls to be crushed (cracked) to a smaller size. Crumble form is made by the pellets are passed between the crumble rolls to be crushed (cracked) to a smaller size. Crumble form is made by crushing pellet form to a consistency coarser than mashed.

2.2. Experimental design, animals, housing, and diets

A total of 120 crossbred pigs [(Landrace × Yorkshire) × Duroc] with an average initial BW of 25.89 ± 1.93 kg at 68 days of age were randomly allotted to 2 experimental diets based on initial BW, with 15 replicate pens per treatment and 4 pigs per pen with 2 barrows and 2 gilts. The trial lasted for 120 days. Dietary treatments included: (1) T1 (mash diet); (2) T2 (crumble diet). Diets were formulated to meet or exceed NRC nutrient requirements (Table 1). Pigs were housed in an environmentally controlled slatted plastic floor facility in 24 adjacent pens with identical size (1.8 m × 1.8 m). Room temperature was stably sustained at approximately 24°C. Each pen was equipped with a self-feeder and a nipple drinker to allow ad libitum access to feed and water throughout the experimental period.

Both crumbled and pelted diet were corn-soybean meal-based diet (grower; corn 58.22%, soybean meal 22.91%; finisher, corn 60.42%, Soybean meal 12.87%).

Table 1. Composition of the experimental diets (as-fed basal).

| Item                          | Grower (0–33 d) | Finisher (33–120 d) |
|-------------------------------|----------------|---------------------|
| Ingredients (%)               |                |                     |
| Corn                          | 58.22          | 60.42               |
| Lupin                         | 2.00           | 3.00                |
| Wheat bran                    | 3.00           | 3.00                |
| Rice polishing                | 2.20           | 3.00                |
| Soybean meal (CP 45)          | 22.91          | 12.87               |
| Rappedese meal                | 2.00           | 3.00                |
| DDGS                          | 2.00           | 3.00                |
| Palm kernel meal              | 3.00           | 5.00                |
| Yellow grease                 | 2.20           | 2.52                |
| Molasses (Cane)               | 1.67           | 1.10                |
| Limestone                     | 0.51           | 0.49                |
| Mono- and Dicalcium Phosphate | 0.33           | 0.30                |
| Salt                          | 0.05           | 0.02                |
| DL-Methionine                 | 0.66           | 0.84                |
| L-Lysine HCl (25%)            | 0.04           | 0.02                |
| L-Threonine                   | 1.00           | 1.10                |
| L-Tryptophan (10%)            | 0.02           | 0.02                |
| Min-Vit premix                | 0.35           | 0.35                |
| Phytase (1000FTU)             | 0.05           | 0.05                |
| Calculated composition       |                |                     |
| Crude protein (%)             | 17.80          | 15.30               |
| Calcium (%)                   | 0.73           | 0.69                |
| Phosphorus (Total) (%)        | 0.50           | 0.48                |
| Phosphorus (Dig.) (%)         | 0.27           | 0.26                |
| Net Energy (MJ/kg) (%)        | 9.99           | 9.99                |
| SID, Lysine (%)               | 0.93           | 0.77                |

1Provided per kg diet: 20,000 IU of vitamin A; 4000 IU of vitamin D3; 80 IU of vitamin E; 16 mg of vitamin K3; 4 mg of thiamine; 20 mg of riboflavin; 6 mg of pyridoxine; 0.08 mg of vitamin B12; 120 mg of niacin; 50 mg of Ca-pantothenate; and 2 mg of folic acid and 0.08 mg of biotin.

2.3. Sampling and measurements

2.3.1. Growth performance

Individual pig BW and pen feed consumption were recorded on days 33, 110 and 120 to calculate the average daily gain (ADG), average feed intake (ADFI), and gain to feed ratio (G:F).

2.3.2. Market day age

The number of pigs reaching market day age was calculated by checking marketing body weight (115 kg) on days 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, and 188.

2.3.3. Meat quality

At the end of the experiment, all pigs were transferred to a slaughterhouse and treated with conventional procedures. Back-fat thickness of all pigs was measured at 6 cm off the midline at the 10th rib using a real-time ultrasound instrument (Piglot 105; SFK Technology, Herlev, Denmark). Carcasses were chilled at 2°C for 24 h. A piece of the right loin was taken through a perpendicular cut between the 10th and the 11th rib. Before meat quality evaluation was performed, meat samples were thawed at ambient temperature. Reflectance spectrometry measurements of lightness (L*), redness (a*), and yellowness (b*) values were determined using a Minolta CR410 chroma meter (Konica Minolta Sensing, Inc., Osaka, Japan). Sensory evaluation (colour, marbling, and firmness scores) was evaluated according to National Pork Producers Council standards (NPPC, 1991). At the same time, duplicate pH values of each sample were measured with a pH meter (Fisher Scientific, Pittsburgh, PA, USA). Water-holding capacity (WHC) was measured according to the methods of Kauffman et al. (1986). Briefly, 0.2 g sample was pressed at 3000 psi for 3 min onto 125-mm-diameter filter paper. The areas of the pressed sample and expressed moisture were delineated and determined with a digitizing area-line sensor (MT - 105; M.T. Precision Co. Ltd., Tokyo, Japan). A ratio of water area to meat area was calculated, giving a measure for WHC (smaller ratio indicating higher WHC). Longissimus muscle area (LMA) was measured by tracing the longissimus muscle surface at the 10th rib using the aforementioned digitizing area-line sensor. Drip loss was measured using approximately 2 g of meat sample according to the plastic bag. The drip loss was measured on day 1 then after 3 days, 5 days, and 7 days by weighing the samples using a method described by Honikel (1998). The weight of each sample was taken before and after cooking to determine cooking loss defined as cooked weight divided by uncooked weight multiplied by 100.

2.4. Statistical analysis

Data were analysed by ANOVA using the GLM procedure of SAS (SAS Institute 1996), with the pen being defined as the experimental unit. Differences among all treatments were separated by Duncan’s multiple range tests. Results were expressed as the least-squares means and SE. Probability values less than 0.05 were considered significant.
3. Results

3.1. Growth performance

The effect of crumble diet on growth performance is summarized in Table 2. No substantial difference was observed in average daily gain (ADG), average daily feed intake (ADFI), and gain to feed ratio (G:F) between T1 and T2 in the first period (0–33 days). However, ADG was increased significantly ($P < .05$) during days 33–110, days 110–120, and the overall period (0–120 days) when pigs were fed with crumble diet T2 instead of mash diet T1. In addition, our results revealed that pigs fed with crumble diet T2 had a significantly higher ADFI in the second phase (33–110 days). In addition, pigs fed with crumble diet had significantly higher G:F in the last phase (110–120 days) and the overall phase (0–120 days).

3.2. Market day age

Results of market day age are summarized in Table 3. A total of 42 pigs in the T2 group (crumble diet) reached marketing age on day 177. However, only 37 pigs in the T1 group (mash diet) reached marketing age on day 177. After day 188, the number of pigs that could not reach the marketing age was 3 in the T1 group and 2 in the T2 group.

3.3. Meat quality

The effect of dietary treatments on growth performance is given in Table 4. There was no significant difference in back-fat thickness, meat colour ($L^*, a^*, b^*$), sensory evaluation (including: colour, firmness, marbling), cooking loss, drip loss (day 1, day 3, day 5, and day 7), WHC, or longissimus muscle area (LMA) between the T1 group and the T2 group ($P > .05$).

4. Discussion

Currently, studies on crumble diet for pigs are limited. However, we could speculate the effect of crumble diet based on previous studies. In the present study, ADG, ADFI, and G:F were improved in pigs fed with crumble diet. Previous studies have reported that crumble diet could improve both daily gain and feed efficiency of pigs (Hanke et al. 1972; Baird 1973; Braude and Rowell 1996). Similar results have been reported by Braude (1967) and Vanschoubroek et al. (1971) in different trials. Pettersson and Björklund (1976) have also found that piglets of Spargodt (1972/73) fed with crumble diet have improved BW gain of 20% and feed efficiency of 7%. Armstrong (1994) and Peisker (1994) have demonstrated greater feed intake and faster growth when piglets (4–8 weeks of age) were fed with an expanded crumble diet rather than unprocessed diets. According to Wondra et al. (1995a), reducing particle size improved the growth performance of finishing pigs with maximum nutrient digestibility in pelleted diet that was corn milled to 400 µm compared to 1000, 800, and 600 µm. Jahan et al. (2006) have reported the highest body weight, body weight gain, and feed consumption in the crumble group and concluded that the crumble form of feed is better than mash or pellet form for the production of commercial broiler for 21–56 days. In addition, Auckland and Fulton (1972), Runnels et al. (1976) and Reece et al. (1985) also have reported that crumble feed could increase the body weight of broiler than other forms of feed. Sinha et al. (1994) and Reece et al. (1985) have reported that the mash form has resulted in significantly ($P < .05$) lower body weight gain than the crumble form of feed in broilers. Owsley et al. (1981) have reported that reduction in particle size of sorghum from 1262 µm to 802 µm to 471 µm improved the apparent digestibility of DM, starch, N, and GE measured at the terminal ileum of the total digestive tract of growing pigs; this positive effect might be beneficial for improving growth performance. In addition, Pettersson and Björklund (1976) illustrated the positive effect for increasing daily gain has not yet been clearly elucidated. One reason may be better hygienic quality. The hygienic advantages of crumbs are discussed by Anderson (1973) after practical studies, which might support our results.

In this study, although no significant difference was observed in back-fat thickness, meat colour, and sensory evaluation (including: colour, firmness, and marbling), cooking loss, drip loss, WHC, and LMA between the T1 group and the T2 group, pigs fed with crumble diet had a slight increase in LMA and WHC with a slight decrease in back-fat thickness, cooking loss, and drip loss. These results were in line with those of Pettersson and Björklund (1976) who showed that

---

**Table 2.** Effect of crumble diet on growth performance in growing-finishing pigs.

| Items                  | T1          | T2          | SE2  |
|------------------------|-------------|-------------|------|
| Day 0–33               |             |             |      |
| ADG, g                 | 684         | 698         | 17   |
| ADFI, g                | 1484        | 1489        | 26   |
| G/F                    | 0.462       | 0.469       | 0.01 |
| Day 33–110             |             |             |      |
| ADG, g                 | 858b        | 895a        | 12   |
| ADFI, g                | 2662b       | 2719a       | 18   |
| G/F                    | 0.323       | 0.329       | 0.005|
| Day 110–120            |             |             |      |
| ADG, g                 | 867b        | 926a        | 19   |
| ADFI, g                | 2810        | 2816        | 25   |
| G/F                    | 0.309b      | 0.329a      | 0.007|
| Overall (Day 0–120)    |             |             |      |
| ADG, g                 | 803b        | 839a        | 9    |
| ADFI, g                | 2318        | 2342        | 10   |
| G/F                    | 0.346b      | 0.359a      | 0.004|

1Abbreviation: T1 = mash diet; T2 = crumble diet.
2Standard error.
3Means in the same row with different superscripts differ significantly ($P < .05$).

**Table 3.** Effect of crumble diet on market day age in growing-finishing pigs.

| Items                  | T1          | T2          |     |
|------------------------|-------------|-------------|-----|
| Pig day age, day2      |             |             |     |
| 177                    | 37          | 42          |     |
| 178                    | 1           | 0           |     |
| 179                    | 2           | 1           |     |
| 180                    | 2           | 1           |     |
| 181                    | 3           | 3           |     |
| 182                    | 4           | 1           |     |
| 183                    | 1           | 3           |     |
| 184                    | 3           | 4           |     |
| 185                    | 2           | 1           |     |
| 186                    | 1           | 0           |     |
| 187                    | 1           | 2           |     |
| Over 188               | 3           | 2           |     |

1Abbreviation: T1 = mash diet; T2 = crumble diet.
2Number of pigs that reached market weight (115 kg).
Table 4. Effect of crumble diet on meat quality in growing-finishing pigs.†

| Items                              | T1       | T2       | SE²   |
|------------------------------------|----------|----------|-------|
| pH                                | 5.72     | 5.69     | 0.02  |
| Back-fat thickness, mm             | 20.6     | 19.7     | 0.3   |
| Meat colour                        |          |          |       |
| L*                                 | 57.47    | 58.20    | 0.50  |
| a*                                 | 18.50    | 18.73    | 0.41  |
| b*                                 | 10.00    | 10.47    | 0.33  |
| Sensory evaluation                 |          |          |       |
| Colour                             | 1.64     | 1.69     | 0.05  |
| Firmness                           | 1.64     | 1.63     | 0.07  |
| Marbling                           | 1.56     | 1.56     | 0.03  |
| Cooking loss (%)                   | 29.01    | 28.50    | 0.54  |
| Drip loss (%)                      |          |          |       |
| Day 1                              | 7.14     | 7.14     | 0.97  |
| Day 3                              | 11.98    | 10.97    | 1.69  |
| Day 5                              | 15.23    | 14.09    | 1.57  |
| Day 7                              | 18.09    | 17.02    | 1.36  |
| WHC (%)                            | 62.75    | 63.82    | 1.05  |
| Longissimus muscle area, cm²       | 48.61    | 50.57    | 0.97  |

†Abbreviation: T1 = mash diet; T2 = crumble diet; L*=lightness; a* = redness; b* = yellowness.
²Standard error.
†Means in the same row with different superscripts differ significantly (P < .05).

there was no statistically significant difference in carcass quality between crumble feed and meal. Moreover, according to Hsia and Lu (2004), reducing back-fat thickness of live pigs could decrease fat retention in the body, consequently increasing LMA, which could support our results.

5. Conclusion

In conclusion, this study revealed that the growth performance of pigs fed with a crumble diet was significantly enhanced. In addition, the crumble diet had a good effect on market day age and meat quality, although the effect was not significant. Therefore, future investigations are necessary to shed light on the effect of crumble form feed and mash form feed on growth performance, meat quality, and market day age in growing-finishing pigs.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Anderson L. 1973. Slutredovisinng av erfarenheder ved utfodring med pellerat svinfoder. Srensk Ver. Tidn. 25: 809–812.
Armstrong H. 1994. Nutritional implications of expanded feed. Tecnica Molitoria. 45:385–385.
Auckland JN, Fulton RB. 1972. The effects of dietary nutrient concentration, crumbles versus mash and age of dam on the growth of broiler chicks. Poult Sci. 51:1968–1975.
Baird DM. 1973. Influence of pelleting swine diets on metabolizable energy, growth and carcass characteristics. J Anim Sci. 36:516–521.
Braude R. 1967. The effect of changes in feeding patterns on the performance of pigs. Proc Nutr Soc. 26:163–181.
Braude R, Rowell JG. 1966. Comparison of meal and pellets for growing pigs fed either in troughs or off the floor. J Agric Sci. 67:53–57. Flatlandsmo K, Slagsvold P. 1971. Effect of grain particle size and pellets on development of gastric ulcers in swine. J Anim Sci. 33:1263–1265.
Gamble CT, Chamberlain CC, Merriman GM, Lidvall ER. 1967. Effects of pelleting, pasture and selected diet ingredients on the incidence of esophageal–gastric ulcers in swine. J Anim Sci. 26:1054–1058.
Hanke HE, Rust JW, Meade RJ, Hanson LE. 1972. Influence of source of soybean protein, and of pelleting, on rate of gain and gain/feed of growing swine. J Anim Sci. 35:958–962.
Honikel, KO. 1998. Reference methods for the assessment of physical characteristic of meat. Meat Sci. 49:447–457.
Hsia LC, Lu GH. 2004. The effect of high environmental temperature and nutrient density on pig performance, conformation and carcass characteristics under restricted feeding system. Energy (kcal DE). 23–600.
Jahan MS, Asaduzzaman M, Sarkar AK. 2006. Performance of broiler fed on mash, pellet and crumble. Int J Poult Sci. 5:262–270.
Kauffman, RG, Eikelenboom G, Van Der Wal PG, Merkus GSM, Zaar M. 1986. The use of filter paper to estimate drip loss of porcine musculature. Meat Sci. 18:191–200.
Kim IH, Hancock JD, Hines RH. 2000. Influence of processing method on ileal digestibility of nutrients from soybeans in growing and finishing pigs. Asian Australas J Anim Sci. 13:192–199.
Kim IH, Hancock JD, Hong JW, Cabrera MR, Hines RH, Behnke KC. 2002a. Corn particle size affects nutritional value of simple and complex diets for nursery pigs and broiler chicks. Asian Australas J Anim Sci. 15: 872–877.
Kim IH, Hancock JD, Kennedy GA, Hines RH, Behnke KC, Nichols DA. 2002b. Processing procedures and feeding systems for sorghum-based diets given to lactating sows. Asian Australas J Anim Sci. 15: 1186–1190.
NPPC. 1991. Procedures to evaluate market hogs. Des Moines, IA: Natl. Pork Prod. Council.
NRC. 1998. Nutrient requirement of pigs. 10th rev. ed. Washington, DC: Natl. Acad. Press.
Owsley WF, Knabe DA, Tanksley TD. 1981. Effect of sorghum particle size on digestibility of nutrients at the terminal ileum and over the total digestive tract of growing-finishing pigs. J Anim Sci. 52:557–566.
Peiser M. 1994. Influence of expansion on feed components. Feed Mix. 2:26–31.
Pettersson A, Björklund NE. 1976. Crumbles contra Meal for Bacon Pigs: Effect on Daily Gain, Feed Efficiency, Carcass Quality and on the Oesophageal Part of the Stomach. Acta Agriculturae Scand. 26:130–136.
Reece FN, Lott BD, Deaton JW. 1984. The effects of feed form, protein profile, energy level, and gender on broiler performance in warm (26°C) environments. Poult Sci. 63:1906–1911.
Reece FN, Lott BD, Deaton JW. 1985. The effects of feed form, gridding method, energy level, and gender on broiler performance in a moderate (21 C) environment. Poult Sci. 64:1834–1839.
Rannels TD, Malone GW, Klopp S. 1976. The influence of feed texture on broiler performance. Poult Sci. 55:1958–1961.
Sinha SC, Digyijal S, Pandita NN. 1994. Effect of feeding grower mash ration on the performance of broilers. Poultry Today Tomorrow. 4:26–30.
Stark CR, Hines RH, Behnke KC, Hancock JD. 1993. Pellet quality affects growth performance of nursery and finishing pigs. Kansas State University. Agric. Exp. Station Coop. Extension Serv. 93:71–74.
Vanschoubroek F, Coucke L, Van Spaendonck R. 1971. The quantitative effect of pelleting feed on the performance of piglets and fattening pigs. Nutr. Abstracts and Rev. 41:1–9.
Wondra KJ, Hancock JD, Behnke KC, Hines RH, Stark CR. 1995a. Effects of particle size and pelleting on growth performance, nutrient digestibility, and stomach morphology in finishing pigs. J Anim Sci. 73:757–763.
Wondra KJ, Hancock JD, Behnke KC, Stark CR. 1995b. Effects of mill type and particle size uniformity on growth performance, nutrient digestibility, and stomach morphology in finishing pigs. J Anim Sci. 73:2564–2573.
Yang JS, Lee JH, Ko TG, Kim TB, Chae BJ, Kim YY, Han IK. 2001. Effects of wet feeding of processed diets on performance, morphological changes in the small intestine and nutrient digestibility in weaned pigs. Asian Australas J Anim Sci. 14:1308–1315.