Processing Procedures and Feeding Systems for Sorghum-based Diets Given to Lactating Sows

I. H. Kim*, J. D. Hancock, J. H. Kim[1], G. A. Kennedy[2], R. H. Hines, K. C. Behnke[3] and D. A. Nichols
Department of Animal Sciences and Industry, Kansas State University, Manhattan, KS 66506-0201, USA

ABSTRACT : One hundred and twenty nine primiparous sows were used to determine the effects of alternative processing procedures and feeding systems on the nutritional value of sorghum grain-based diets for lactating sows. Treatments were a ground sorghum control, steam-flaked sorghum and extruded sorghum fed in meal form and the ground sorghum control given as pellets or gruel (1:1 ratio of water and feed on a volume:volume basis). Average daily feed intake was greater for sows fed pelleted and gruel diet forms than sow fed the diets with steam-flaked and extruded sorghum ($p<0.04$). However, no differences occurred in sow weight or backfat losses among the treatments ($p>0.14$). Number of pigs weaned and livability rates were similar among treatments except that steam-flaked sorghum supported greater litter weight gains than extruded sorghum ($p<0.02$). Apparent digestibilities of DM, N and GE in sows fed steam-flaked and extruded sorghum were greater ($p<0.001$) than in sows fed pelleted or gruel diets. Of the various treatments, sows fed extruded sorghum tended to have the highest digestibilities of DM, N and GE, and lowest excretions of DM and N in the faeces. Severity of ulceration was not significantly affected by treatments ($p>0.35$), but keratinization was greatest for sows fed extruded sorghum ($p<0.01$). In conclusion, the alternative processing methods (steam-flaking and extrusion) and feeding system (pellets and gruel) had little effect on sow and litter performance. However, nutrient digestibilities were improved for all treatments that involved heating (steam flaking, extrusion and pelleting) and, thus, these treatments resulted in less fecal excretion of DM and N. ***(Asian-Aust. J. Anim. Sci. 2002. Vol 15, No. 8 : 1186-1190)***

Key Words : Sow, Sorghum, Processing, Feeding, Ulcers

INTRODUCTION

Maximizing intake of digestible nutrients during lactation is important for good sow and litter performance (Brooks and Cole, 1972; King and Williams, 1984a). Lactating sows fed diets containing high energy and (or) protein concentrations lose less body fat and muscle mass (Brendemuhl et al., 1987), return to oestrus sooner (Reese et al., 1982) and have faster-growing litters (O'Grady et al., 1973; King et al., 1993). As an alternative to adding expensive ingredients, Wondra et al. (1995a,b) suggested that fine grinding of maize in sow diets increased nutrient digestibility (DM and energy), thus increasing the effective nutrient density of the diet. Limited information is available concerning the effects of alternative methods of processing and the resulting feeding value of sorghum in pig diets.

Therefore, an experiment was designed to determine the effects of alternative processing procedures of sorghum grain on sow and litter performance, nutrient intake and excretion, nutrient digestibility, and changes in stomach morphology of primiparous sows.

* Corresponding Author: In-Ho Kim. Department of Animal Science, Dankook University, #29 Anseodong, Cheonan, Choognam, 330-714, Korea. Tel: +82-41-550-3652, Fax: +82-41-553-1618, E-mail:inhokim@anseo.dankook.ac.kr
[1] Agribrands Purina Korea, Inc.
[2] Department of Veterinary Diagnosis.
[3] Department of Grain Science and Industry.
Received December 13, 2001; Accepted March 13, 2002

MATERIALS AND METHODS

Sorghum was ground through a 4.8 mm hammermill screen for the control diet. For steam flaking, a chest, situated directly above the flaking mill, was filled to capacity (454 kg) with sorghum grain. The first sorghum (approximately 23 kg) to pass through the rolls was discarded then enough sorghum was collected for use in the feeding experiment. The sorghum grain was steamed at atmospheric pressure (steam chest set at 105°C) for approximately 30 min. The flaked sorghum (190 g moisture/kg) was allowed to air-dry at 60°C prior to mixing into the diet (final moisture concentration of 100 g/kg). To prepare the extruded sorghum, an Insta-Pro™ dry extruder was used. The sorghum was ground in a hammermill and water was added to bring the sorghum to 180 g moisture/kg before extrusion. The screw assembly consisted of four single-flight screws and seven double-flight screws (screw diameter of 13.3 cm). The extrusion conditions were a throughput of 562 kg/h and an average barrel temperature of 124°C. Pelleting was undertaken in a California Pellet Mill™. The diet was preconditioned to 55°C and pelleted through a 38 mm thick die with 4.8 mm diameter holes. Average production rate was 1,610 kg/h with an average exit temperature of 62°C.

A total of 129 primiparous sows (Yorkshire×Duroc×Hampshire×Chester White) was used in the 21 d lactation experiment. On d 110 of gestation, the sows were moved into the farrowing facility, randomly allotted to treatments, and fed 2.3 kg feed/d to allow for adjustment to the diets before parturition. Treatments were a ground sorghum control, steam-flaked and extruded sorghum fed in meal form and the ground sorghum control given as pellets or gruel (1:1 ratio of water and feed on a volume:volume basis). All diets were formulated to contain 0.85% lysine, 0.9% Ca, 0.8% P and 3,200 kcal ME/kg (table 1) and to meet or exceed the nutrient concentrations recommended by NRC (1998). Chromic oxide (1.0 g/kg) was added to the diets as an indigestible marker.

During winter, a propane room heater was used when the temperature was less than 25.5°C, and during summer, drip cooling was used on the sows when the room temperature was greater than 27°C. Heat lamps were provided for the piglets on one side of the crate and creep feed was not provided. The sows were penned individually in 0.61 m×2.13 m farrowing crates and 0.98 m^2 of creep space was provided on both sides of the crate. All litters were standardized at nine or more piglets within 24 h of parturition. The sows were weighed and scanned ultrasonically (731 A Scanoprobe[TM], Ithaco, Ithaca, NY) for backfat thickness at farrowing and d 21 of lactation to determine weight and backfat loss. Backfat thickness was measured at the first rib, last rib and last lumbar vertebra. Final weight and backfat thickness of sows weaned prior to d 21 were adjusted by multiplying their daily weight and backfat losses by 21. Sows with litters less than 17 d of age at weaning were excluded from the data set to avoid excessive adjustments. Pig weights were recorded at farrowing and weaning. Litter weights (for litters weaned early) were adjusted to d 21 using NSIF (1987) equations. The sows were allowed *ad libitum* access to feed and water and feed intake was recorded weekly so that average daily feed intake(ADFI) could be determined. On d 18, grab samples of feces were collected from each sow, dried and ground. Concentrations of Cr (Williams et al., 1962), DM, N and GE (AOAC, 1990) in the feces and diets were determined to allow calculation of apparent digestibilities of DM, N and GE using the indirect marker ratio method. Intakes of digestible DM, N and GE were calculated by multiplying nutrient intakes by their respective apparent digestibilities. The portion of nutrient intake not digested (i.e., total nutrient intake minus that digested) was reported as fecal excretion.

Table 1. Composition of basal diet (as-fed basis)

Ingredients	%
Sorghum	66.70
Extruded soybeans	28.70
Monocalcium phosphate	2.08
Limestone	1.11
Salt	0.50
Vitamin/trace mineral premix[a]	0.40
Sow add pack[b]	0.25
Lysine-HCl	0.06
Antibiotic[c]	0.10
Chromic oxide[d]	0.10
Calculated chemical composition	
ME, kcal/kg	3,200
Crude protein, %	19.80
Lysine, %	0.85
Calcium, %	0.90
Phosphorus, %	0.80

[a] Provided the following per kilogram of the complete diet: vitamin A, 11,025 IU; vitamin D_3, 1,103 IU; vitamin E, 44 IU; vitamin K (menadione bisulfate complex), 4.4 mg; riboflavin, 8.3 mg; niacin, 50 mg; d-pantothenic acid (as d-calcium pantothenate), 29 mg; choline, 166 mg; vitamin B_{12}, 33 μg; Mn, 12 mg; Fe, 165 mg; Zn, 165 mg; Cu, 16 mg; I, 0.3 mg; Se, 0.3 mg and Co, 1.0 mg.

[b] Provided the following per kilogram of the complete diet: choline, 386 mg; biotin, 0.22 mg and folic acid, 1.65 mg.

[c] Provided 100 mg per kg of chlortetracycline.

[d] Used as an indigestible marker.

After weaning, the sows were moved to the breeding-gestation building and confined to gestation crates measuring 0.53 m×1.78 m. The sows were fed 1.8 kg/d of the lactation diet for 10 d, after which they were slaughtered and stomachs scored for severity of esophagogastric ulcers and keratinization (Muggenburg et al., 1964). The scoring system used for ulcers was 0=normal, 1=erosions, 2=esophagogastric ulcers and 3=severe esophagogastric ulcers. The scoring system used for keratinization was 0=normal, 1=mild keratosis, 2=moderate keratosis and 3=severe keratosis.

Data for sow and litter performance and nutrient utilization were analyzed using the GLM procedures of SAS (1988), with farrowing group (a total of six) and treatment as defined sources of variation. Because the stomach scores were categorical data, they were analyzed using the Cochran-Mantel-Haenszel procedure of SAS (an analysis of variance procedure designed for categorical data) with farrowing group and treatment as defined sources of variation. Contrasts used to separate treatment means were: 1) ground sorghum vs other treatments; 2) mash treatments (steam-flaked and extruded sorghum) vs pelleted and gruel diet forms; 3) steam-flaked vs extruded; and 4) pelleted vs gruel.

RESULTS AND DISCUSSION

Average daily feed intake (table 2) was greater for sows fed the pelleted and gruel diets than for sows fed the mash diets with steam-flaked and extruded sorghum ($p<0.04$). This response was primarily because of the relatively low ADFI for sows fed extruded sorghum, and indeed, sows fed steam-flaked sorghum had greater ADFI ($p<0.09$) than sows fed extruded sorghum. However, there were no differences in weight or backfat loss for sows fed the various treatments ($p>0.14$).

Equalizing litters ensured no differences in number of pigs at initiation of the experiment (with an average of 10.1 live pigs/sow). Survivability and number of pigs weaned were

Table 2. Effects of alternative processing procedures and feeding systems for sorghum on performance of sows[a]

	Ground	Steam-flaked	Extruded	Pelleted	Gruel	SE	Contrasts[b]			
							1	2	3	4
No. of sows	30	22	26	26	25	-	-	-	-	-
Sow wt, kg										
Post-farrowing	170.8	168.9	173.3	171.9	175.5	2.5	NS[c]	NS	NS	NS
d 21 of lactation	163.8	162.3	169.5	168.6	171.3	2.7	NS	NS	0.07	NS
Change	-7.0	-6.7	-3.8	-3.3	-4.2	1.6	NS	NS	NS	NS
Sows backfat thickness, mm										
Farrowing	24.6	23.2	25.0	24.4	24.3	0.9	NS	NS	NS	NS
d 21 of lactation	23.7	22.2	24.7	24.7	23.6	0.9	NS	0.06	NS	NS
Change	-0.9	-1.0	-0.3	0.3	-0.7	0.6	NS	NS	NS	NS
Average daily feed intake, kg	4.48	4.33	4.06	4.32	4.53	0.11	NS	0.04	0.09	NS
No. of pigs/litter										
Initial	10.3	10.0	9.9	10.1	10.3	15.1	NS	NS	NS	NS
Weaned	9.5	9.4	9.3	9.2	9.5	13.9	NS	NS	NS	NS
Survivability, %	93.1	94.8	94.0	91.4	93.0	9.0	NS	NS	NS	NS
Litter wt, kg										
Initial[d]	12.9	12.9	12.9	12.9	12.9	-	-	-	-	-
d 21	48.2	49.9	45.9	46.5	45.7	1.2	NS	NS	0.02	NS
Gain	35.3	37.0	33.0	33.6	32.8	1.2	NS	NS	0.02	NS
Return to estrus[e]	0.700	0.600	0.667	0.653	0.760	0.930	NS	NS	NS	NS
Days to estrus[f]	4.9	4.4	4.8	4.7	5.1	0.2	NS	NS	NS	NS

[a] A total of 129 primiparous sows (22 to 30 sows/treatment).
[b] Probability for contrast: 1) Ground vs other treatments; 2) Steam-flaked and extruded vs pelleted and gruel; 3) Steam-flaked vs extruded; and 4) Pelleted vs gruel.
[c] NS=Not significant (p>0.10).
[d] Inital weight of litter used as a covariate.
[e] Proportion of sows returning to estrus within 30 d of weaning.
[f] For sows returning to estrus within 30 d of weaning.

similar (p>0.13) among treatments, however, steam-flaked sorghum supporting the greatest litter weight gains and extruded sorghum the lowest (p<0.02).

Proportion of sows returning to oestrus (p>0.41) and length of interval from weaning to estrus (p>0.17) were similar for all treatments. Other authors have reported that the interval from weaning to mating of first-litter sows can be reduced with increased feed intake (Brooks and Cole, 1972; King and Williams, 1984b), protein intake (King and Williams, 1984b), and energy intake (Reese et al., 1982; King and Williams, 1984b) during lactation. However, results from the present experiment indicated that the decreased feed intake with alternative processing procedures was not a problem, probably because of increased nutrient digestibilities in the feed that sows did consume.

Apparent digestibilities of DM, N and GE (p<0.001) in sows fed steam-flaked sorghum and extruded sorghum were greater than for sows fed pelleted and gruel diets (table 3). Steam flaked sorghum has been evaluated less frequently in pig diets, with little observed benefit compared to feeding ground grain in diets for weaner pigs (Allee, 1976). Sows fed extruded sorghum tended to have the highest digestibilities of nutrients with 13% greater intake of digestible N than sow fed the ground sorghum control. In the finishing pigs, Hines et al. (1990) and Hancock et al. (1991) found in a series of experiments that extruding sorghum reduced ADFI, but increased gain/feed and DM and N digestibilities. However, Noland et al. (1976) found no benefit to extruding sorghum for the weaner pigs. With increased digestibility of nutrients comes decreased excretion of nutrients. Excretion of DM was 22% less for sows fed the alternatively processed sorghums than the ground sorghum control (p<0.001). Thus, current results indicate that diets properly processed (i.e., steam flaking, extruding and pelleting) make pig enterprises more environmentally friendly by decreasing the amount of nutrients, especially DM, that could become environmental pollutants. However, this improvement in digestibility did not translate into an improvement in litter weaning weight.

The number of stomachs given each score for ulceration and keratinization and a mean score for the treatments is provided in table 4. The mean score is based on a scoring system from 0 (normal) to 3 (severe). There was no effect of treatment on severity of ulceration (row mean scores differ test, p>0.74). However, sows fed extruded sorghum had the greatest stomach keratinization scores (p<0.001). Of the twenty five stomachs collected from sows fed extruded

Table 3. Effects of alternative processing procedures and feeding systems for sorghum on apparent digestibility, intake, and excretion of nutrients[a]

	Ground	Steam-flaked	Extruded	Pelleted	Gruel	SE	Contrasts[b]			
							1	2	3	4
DM intake, g/d	4,008	3,895	3,730	3,842	4,110	140	NS[c]	NS	NS	NS
N intake, g/d	113	105	107	108	113	5	NS	NS	NS	NS
Apparent digestibilities										
DM	0.772	0.818	0.843	0.812	0.791	0.420	0.001	0.001	0.01	0.03
N	0.709	0.777	0.838	0.761	0.733	0.590	0.001	0.001	0.001	0.03
GE	0.756	0.809	0.871	0.818	0.777	0.430	0.001	0.001	0.001	0.001
Intake of digestible nutrients										
DM, g/d	3,073	3,205	3,132	3,112	3,213	13.5	NS	NS	NS	NS
N, g/d	80	83	90	83	83	4.3	NS	NS	NS	NS
Fecal excretion										
DM, g/d	935	688	602	728	897	44.5	0.001	0.001	NS	0.01
N, g/d	33	20	17	27	32	1.8	0.001	0.001	NS	0.06

[a] A total of 129 primiparous sows (22 to 30 sows/treatment).
[b] Probability for contrast: 1) Ground vs other treatments; 2) Steam-flaked and extruded vs pelleted and gruel; 3) Steam-flaked vs extruded; and 4) Pelleted vs gruel.
[c] NS=Not significant (p>0.10).

Table 4. Effects of alternative processing procedures and feeding systems on stomach morphology of sows[a]

	Ground	Steam-flaked	Extruded	Pelleted	Gruel	SE	Contrasts	
							1[b]	2[c]
Stomach keratinization								
Total observations	30	22	25	26	25	-	-	-
Normal	5	6	0	1	3	-	-	-
Mild	8	8	6	10	3	-	-	-
Moderate	14	4	10	12	13	-	-	-
Severe	3	4	9	3	6	-	-	-
Mean score[d]	1.57	1.46	2.24	1.83	1.98	0.17	0.001	0.01
Stomach ulceration								
Total observations	30	22	25	26	25	-	-	-
Normal	15	13	15	10	12	-	-	-
Erosions	8	2	3	3	2	-	-	-
Ulcers	6	6	5	11	9	-	-	-
Severe ulcers	1	1	2	2	2	-	-	-
Mean score[e]	0.85	0.84	0.82	1.33	1.10	0.21	NS	NS

[a] A total of 128 primiparous sows (22 to 30 sows/treatment).
[b] Cochran-Mantel-Haenszel statistic (an analysis of variance procedure designed for categorical data), row mean scores differ test.
[c] Cochran-Mantel-Haenszel statistic (an analysis of variance procedure designed for categorical data), nonzero correlation test.
[d] Scoring system: 0=Normal; 1=Mild; 2=Moderate and 3=Severe.
[e] Scoring system: 0=Normal; 1=Erosion; 2=Ulcer and 3=Severe ulcer.
[f] NS=Not significant (p>0.10).

sorghum, nine had keratinization, whereas only three of the 30 stomachs from sows fed the ground sorghum control had keratinization. A number of dietary factors have been shown to affect the incidence and severity of esophagogastric ulcers in pig. Studies have demonstrated that as particle size of cereal grains is reduced, the incidence of ulcers tends to increase in growing-finishing pigs (Nuwer et al., 1964; Mahan et al., 1966; Wondra et al., 1995a) and lactating sows (Wondra et al., 1995b). Chamnerlain et al. (1967), Pocock et al. (1968) and Wondra et al. (1995a) reported that pelleting of diets increased the incidences of ulcers. The ulcerogenic effect of heat-treated (extruded) maize in growing pigs was reported by Perry et al. (1963), Nuwer et al. (1964), Mahan et al. (1966) and Ricker et al. (1967). In the current experiment, eight stomachs of the 128 stomachs collected from sows fed all treatments had severe ulceration but, no symptoms of reduced animal health were noted.

In lactating sows, it is important to maximize litter-size, to increase sow and litter performance, and to have the sow returned to oestrus rapidly after weaning. To do this effectively, body weight and backfat losses during lactation must be minimized. Alternative processing methods (steam-flaking and extrusion) and feeding systems (pellets and gruel) had little effect on sow and litter performance. However, nutrient digestibilities were improved for all treatments that involved heating (steam flaking, extrusion and pelleting) and, thus, these treatments resulted in less faecal excretion of DM and N.

REFERENCES

Allee, G. L. 1976. Effect of processing methods on nutritional value of milo for weaned pigs. J. Anim. Sci. 43:248(Abstr.).

AOAC. 1990. Official Methods of Analysis (15th Ed.). Association of Official Analytical Chemists, Arlington, VA.

Brendemuhl, J. H., A. J. Lewis and E. R. Peo, Jr. 1987. Effect of protein and energy intake by primiparous sows during lactation on sow and litter performance and sow serum thyroxine and urea concentrations. J. Anim. Sci. 64:1060-1069.

Brooks, P. H. and D. J. A. Cole. 1972. Studies in sow reproduction 1. The effect of nutrition between weaning and remating on the reproductive performance of primiparous sows. Anim. Prod. 15:259-264.

Chamberlain, C. C., G. M. Merriman, E. R. Lidvall and C. T. Gamble. 1967. Effects of feed processing method and diet form on the incidence of esophagogastric ulcers in swine. J. Anim. Sci. 26:72-75.

Hancock, J. D., R. H. Hines and T. L. Gugle. 1991. Extrusion of sorghum, soybean meal, and whole soybeans improves growth performance and nutrient digestibility in finishing pigs. Kansas Agri. Exp. Sta. Rep. Prog. No. 641. p. 92.

Hines, R. H., J. D. Hancock, G. E. Fitzner, T. L. Weeden and T. L. Gugle. 1990. Effect of extrusion on the nutritional value of soybeans and sorghum grain in finishing pigs. Kansas Agri. Exp. Sta. Rep. Prog. No. 610. p. 76.

King, R. H., M. S. Toner, H. Dove, C. S. Atwood and W. G. Brown. 1993. The response of first-litter sows to dietary protein level during lactation. J. Anim. Sci. 71:2457-2463.

King, R. H. and I. H. Williams. 1984a. The effect of nutrition on the reproductive performance of first-litter sows. 1. Feeding level during lactation, and between weaning and mating. Anim. Prod. 38:241-247.

King, R. H. and I. H. Williams. 1984b. The effect of nutrition on the reproductive performance of first-litter sows. 2. Protein and energy intakes during lactation. Anim. Prod. 38:249-256.

Mahan, D. C., R. A. Pickett, T. W. Perry, T. M. Curtin, W. R. Featherson and W. M. Beeson. 1966. Influence of various nutritional factors and physical form of feed on esophagogastric ulcers in swine. J. Anim. Sci. 25:1019-1023.

Muggenburg, B. A., S. H. McNutt and T. Kowalczyk. 1964. Pathology of gastric ulcers in swine. Am. J. Vet. Res. 25:1354-1357.

Noland, P. R., D. R. Campbell, R. K. Cage, Jr., R. N. Sharp and Z. B. Johnson. 1976. Evaluation of processed soybeans and grains in diets for young pigs. J. Anim. Sci. 43:763-769.

NRC. 1998. Nutrient Requirements of Swine (10th Ed.). National Academy Press, Washington, DC.

NSIF. 1987. Guidelines for Uniform Swine Improvement Programs. p 10-2. National Swine Improvement Federation, Des Moines, IA.

Nuwer, A. J., T. W. Perry, R. A. Pickett, W. R. Featherston, T. M. Curtin and W. M. Beeson. 1964. Effect of heat processing of various corn fractions on occurrence of ulcers in swine. J. Anim. Sci. 23:887(Abstr.).

O'Grady, J. F., F. W. H. Elsley, R. M. MacPherson and I. McDonald. 1973. The response of lactating sows and their litters to different dietary energy allowances. 1. Milk yield and composition, reproductive performance of sows and growth rate of litters. Anim. Prod. 17:65-74.

Perry, T. W., A. A. Jimenez, J. E. Shively, T. M. Curtin, R. A. Pickett and W. M. Beeson. 1963. Incidence of gastric ulcers in swine. Science 139:349-350.

Pocock, E. F., H. S. Bayley and C. K. Roe. 1968. Relationship of pelleted, autoclaved and heat-expanded corn or starvation to gastric ulcers in swine. J. Anim. Sci. 27:1296-1301.

Reese, D. E., B. D. Moser, E. R. Peo, Jr., A. J. Lewis, D. R. Zimmerman, J. E. Kinder and W. W. Stroup. 1982. Influence of energy intake during lactation on the interval from weaning to first estrus in sows. J. Anim. Sci. 55:590-598.

Ricker, J. T., III, T. W. Perry, R. A. Pickett and T. M. Curtin. 1967. Influence of various grains on the incidence of esophagogastric ulcers in swine. J. Anim. Sci. 26:731-735.

SAS. 1988. SAS/STAT User's Guide (Release 6.03 Ed.). SAS Inst., Inc., Cary, NC.

Williams, C. H., D. J. David and O. Iismaa. 1962. The determination of chromic oxide in feces samples by atomic absorption spectrophotometry. J. Agric. Sci. 59:381-385.

Wondra, K. J., J. D. Hancock, K. C. Behnke, R. H. Hines and C. R. Stark. 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, K. J., J. D. Hancock, G. A. Kennedy, R. H. Hines and K. C. Behnke. 1995b. Reducing particle size of corn in lactation diets from 1,200 to 400 micrometers improves sow and litter performance. J. Anim. Sci. 73:421-426.