

Effects of Unprocessed or Steam-flaked Corn Based Diets with or without Enzyme Additive on *In Vivo* Nutrient Digestibility and Distribution of Corn Particles in the Feces of Holstein Steers**

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ABSTRACT : Effects of unprocessed (whole) or steam-flaked corn with or without enzyme additives on *in vivo* nutrient digestibilities and distribution of corn particles in the feces of Holstein steers were determined in a 4×4 Latin square experiment using four Holstein steers fed the diets containing 1) whole corn without enzyme additive, 2) whole corn with enzyme additive, 3) flaked corn without enzyme additive, or 4) flaked corn with enzyme additive. With regard to nutrient digestibilities such as DM, CP, CF, NFE, NDF, and ADF, no significant differences were detected among treatments, and also the nutrient digestibilities were not affected by the addition of enzyme additive. When distribution of corn particles in the feces was examined, there were no significant differences in the amount of 2, 8 mm and total corn particles. However, feeding flaked corn resulted in less corn particles (4 mm) in the feces than feeding whole corn ($p < 0.05$). There were no significant differences in amounts of corn particles in the feces due to the addition of enzyme additive. (*Asian-Aust. J. Anim. Sci.* 2002. Vol 15, No. 5 : 708-712)

Key Words : Whole and Steam-Flaked Corn, Nutrient Digestibility, Corn Particle, Feces

INTRODUCTION

Grain sources and processing have been discussed for many years. Cereal grains can constitute 70 to 90% of the diet of finishing beef cattle, and the proportion of cereal starch digested in the rumen is high, ranging from 50 to 94% (Huntington, 1997). Most feed companies in Korea select their grain source based on cost of the grain plus its processing. A variety of processing methods have been devised, which vary in cost and effectiveness. The primary goal of processing is to increase energy (starch) availability and to improve mixing characteristics, bunk management, thereby enhancing animal performance.

Physical processing (e.g. grinding, rolling) reduces the size of feed particles and increase the surface area available for microbial attachment and enzymatic attack (Bowman and Firkins, 1993), thus increasing the rate and extent of ruminal digestion of starch (Walker et al., 1973; Kim et al., 1996). These increased digestibilities are caused by disruption of the protein matrix surrounding the starch granules in the grain endosperm and disorganization of the starch granules (Rooney and Pflugfelder, 1986).

Steam-flaking increases starch digestibility in the rumen and the total starch digested by cattle (Huntington, 1997;

Theurer, 1986). It has been suggested that much of the increase in ruminal starch digestibility by steam-flaking is owing to changes in granular structure of starch, which causes additive effects beyond those of decreasing particle size (Theurer, 1986).

Contrary to the facts mentioned above, it has been demonstrated that whole (unprocessed) corn produces better performance over ground, cracked, or even steam-flaked corn (Vance et al., 1972; Loerch, 1992), when all-concentrate diets are fed *ad libitum* to finishing beef cattle. Vance et al. (1972) originally suggests that whole corn may serve as "roughage factor" when whole corns are incorporated in all-concentrate feed. Therefore, feeding whole corn to beef cattle may ameliorates metabolic disorders, such as blot, acidosis, ruminitis, parakeratosis, liver abscesses and founder, which resulting from the excessively rapid fermentation to organic acids mainly due to prolonged periods of feeding all-concentrate containing processed corns (Huntington, 1997). Thus, using whole corn in feeding all-concentrate for the finishing phase of cattle is economically better choice than using processed ones. Much interest has developed recently in feeding all-concentrate diets containing whole corn to finishing cattle, especially Holstein steers in Korea.

However, researches on whole and processed corns are still controversial since some researchers reported the positive results for incorporating whole corns in diets, others found considerable amounts of undigested corns in feces when whole corns were fed. In addition, enzyme additives for enhancing nutrient digestibility have becoming considerably introduced to the cattle industry in these days (Wenk, 2000). Therefore, the objective of this study was to

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determine effects of whole or steam-flaked corn based diets with or without enzyme additive on *in vivo* nutrient digestibility and distribution of corn particles in the feces of Holstein steers.

MATERIALS AND METHODS

Animal and grain sample preparation

Four Holstein steers with average body weight of 327 kg were used to determine effects of corn processing and addition of enzyme additives on *in vivo* nutrient digestibility and the amount and distribution of corn particles excreted in feces. Grain samples were prepared as followings. Whole corn was used as an unprocessed form. Steam-flaked corn was prepared by steaming (100 ~ 103°C, 40 min.) and then rolling to provide flakes with a density of approximately 377 g/liter.

Experimental design

The experimental design was a 4×4 Latin square with a 2×2 factorial arrangement of treatments. Treatments were: 1) whole corn without enzyme additive; 2) whole corn with enzyme additive; 3) flaked corn without enzyme additive; 4) flaked corn with enzyme additive.

Experimental diet

Ingredients and chemical composition of the experimental diets are shown in table 1. A commercial concentrate for fattening cattle was used as concentrate and the Tall fescue was used as a roughage. Concentrate and Tall fescue in the ratio of 90 to 10 were fed at 1.5% of body weight twice daily (08:00 and 18:00 h). Enzyme additive (EM-TEC[®]) was mainly composed of enzymes produced

from culture of lactic acid bacteria, yeast and bacillus. It had enzyme activity of amylase (7.41 IU/g), protease (25.29 IU/g) and cellulase (1.34 IU/g). Enzyme additive was added in the level of 0.6% in total diet.

Experimental periods

Experimental periods were 13 d. The first 10 d of each period were for adjustment to the new diet and the last 3 d was for sample collection.

Experimental procedure

Fecal samples were obtained at 08:00 h during the last 3 d of each period, were composited on an equal wet weight basis, dried in a forced-air oven at 60°C for 72 h and ground in a Wiley mill (1 mm screen). During the last 3 d of each period fecal samples were composited on an equal wet weight basis to investigate the distribution of corn particles in the feces.

Analytical method

Apparent total tract digestibilities of DM, CP, EE, CF, ash, NDF and ADF were determined using collected fecal samples. Fecal samples were analyzed for proximate principles (Association of Official Analytical Chemists, 1984). NDF, ADF were estimated by Goering and Van Soest (1970) method. The distribution of corn particles in the feces was measured by wet sieving. Fecal samples were dispersed in tap water before sieving, poured into three sieves (sieve apertures of 8, 4 and 2 mm), and then sprayed with water. Corn particles left at each sieve were dried at 60°C air-forced oven for 48 h and weighed. The particle size distribution was expressed as DM cumulative percentage of particles collected on the different screens.

Statistical analysis

Data were analyzed using the general linear model (GLM) procedure of the Statistical Analysis System Institute, Inc. (SAS) (1985). Differences among means were tested for significance using the least significant difference (LSD) procedure of SAS (1985).

RESULTS AND DISCUSSION

In terms of nutrient digestibilities such as, DM, CP, CF, NFE, NDF, and ADF, no significant differences were detected among treatments, and also the nutrient digestibilities were not affected by the addition of enzyme additive (table 2). It has been well known that steam-flaking causes starch gelatinization (intermolecular disruption of H bonds) and increases surface of the corn kernel which is available for microbial attack, resulting in greater ruminal digestion of starch (Nocek and Tamminga, 1991). As reported in a review (Theurer, 1986), the steam-flaked corns

Table 1. Ingredients and chemical compositions of experiment diets

Items	Whole corn	Flake corn
	% as-fed basis	
Ingredients		
Whole corn-based diet	90	–
Flake corn-based diet	–	90
Tall fescue	10	10
	% DM basis	
Composition		
DM	87.20	87.20
CP	13.96	13.54
EE	2.93	3.51
CF	9.13	10.82
Ash	6.65	5.73
NFE	67.33	66.40
NDF	48.39	49.48
ADF	13.93	16.74

Table 2. Effects of corn processing and addition of enzyme additive on nutrient digestibilities

Item	Diet ¹				SEM	Significance ²		
	FC	FC+A	WC	WC+A		P	A	P×A
DMI (kg/day)	4.35	4.31	4.36	4.35	0.01	ns	ns	ns
Digestibility, %								
DM	75.57	75.45	76.70	76.26	0.56	ns	ns	ns
CP	70.07	72.92	71.20	71.26	0.86	ns	ns	ns
CF	55.59	53.53	58.81	55.42	1.65	ns	ns	ns
NFE	82.42	81.82	82.88	80.81	1.28	ns	ns	ns
NDF	66.27	67.48	70.99	66.79	1.84	ns	ns	ns
ADF	48.42	51.55	41.66	28.29	4.22	ns	ns	ns

¹ Dietary treatments: FC, flake corn-based diet without enzyme additive; FC+A, flake corn-based diet with enzyme additive; WC, whole corn-based diet without enzyme additive; WC+A, whole corn-based diet with enzyme additive.

² P, processing effect; A, enzyme additive effect; P×A, interaction of processing and enzyme additive; ns, not significant.

caused a significant increase in ruminal, intestinal, and total digestibilities of starch. Furthermore, *in vitro* (Frederick et al., 1973) and *in situ* (Galyean et al., 1981) studies showed that steam-flaked corn produced greater starch degradation than whole corn. These are contrary to results of the present study, showing that nutrient digestibilities of both the whole and flaked corns were similar between the treatments.

The result of present study is contrary to the result of Murphy et al. (1994), observing that when intake was low, grain processing resulted in remarkable improvements in digestibility of DM, OM, N and starch. However, The present study substantiates the previous researches, showing that at high intakes, corn processing had little effect on nutrient digestibilities (Galyean et al., 1979; Turgeon et al., 1983). Galyean et al. (1979) reported that when 72% corn diets were fed at a rate of 1.25 times maintenance, no differences in total tract digestibility of DM, OM, CP, or starch were detected regardless of whether corn was in whole or ground form. This may be the result of increased numbers of corn kernels present in the rumen leading to increased physical action of the corn kernels on one another, increased eating and rumination time, and increased particle size reduction of the corn kernel. Meanwhile, Ørskov et al. (1974) showed that owing to less surface area being exposed, whole grain might be fermented more slowly than processed grain. The animals spent more time eating and ruminating and ruminal pH was increased substantially.

Due to structure of whole grain, there was greater saliva production and consequently higher pH, ruminitis was completely eliminated (Ørskov, 1973).

When distribution of corn particles in the feces were examined, there were no significant differences in the amount of 2, 8 mm and total corn particles in the feces by processing method (table 3). However, feeding flaked corn resulted in less corn particles than feeding whole corn ($p < 0.05$). There were no significant differences in the distribution of corn particles owing to the addition of enzyme additive. The amount of 4 mm corn particles in the feces were influenced by processing method by showing that excreted corn particles for flaked corn were lower than those for whole corn. Figure shows weight (figure 1-1), proportion (figure 1-2) of particles retained and comparison of treatment at each particle size (figure 1-3). The proportion retained in 2, 4, and 8 mm sieve in the case of flaked corn was 41.87, 25.82 and 32.31%, respectively. Enzyme additive increased the proportion retained in 2 and 4 mm sieve, but decreased that of 8 mm sieve. However, in case of whole corn, proportion of 4 mm particles was the highest. Enzyme additive rather decreased the proportion of 4 mm particles, and increased that of 2 and 8 mm particles. While some whole grain appears in the feces of sheep given whole grain diets, the fiber of the digested grain is generally digested more completely so that the net effect is often an increase rather than a decrease in digestibility (Galyean et

Table 3. Distribution of corn particles (g/DM 100 g feces) excreted into feces

Corn particles size	Diet ¹				SEM	Significance ²		
	FC	FC+A	WC	WC+A		P	A	P×A
2 mm	3.68	3.26	4.27	5.04	0.41	ns	ns	ns
4 mm	2.27 ^a	2.15 ^a	4.48 ^b	4.27 ^b	0.62	*	ns	ns
8 mm	2.84	1.94	3.39	5.42	0.79	ns	ns	ns
Total	8.79	7.35	12.14	14.73	1.73	ns	ns	ns

¹ Dietary treatments: FC, flake corn-based diet without enzyme additive; FC+A, flake corn-based diet with enzyme additive; WC, whole corn-based diet without enzyme additive; WC+A, whole corn-based diet with enzyme additive.

² P=Processing effect, A=enzyme additive, and P×A=interaction of processing and enzyme additive; ns, not significant; * $p < 0.05$.

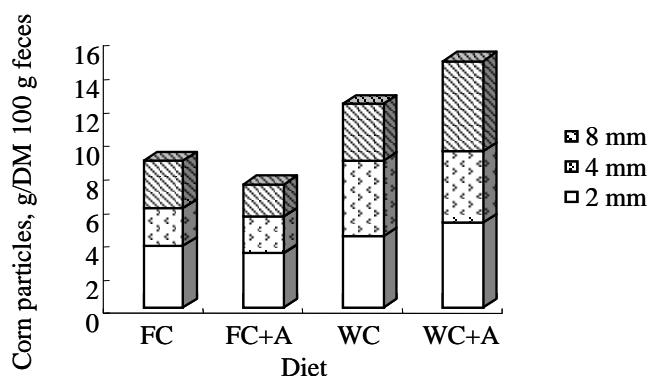


Figure 1-1. Distribution of corn particles in the feces (weight of each particles).

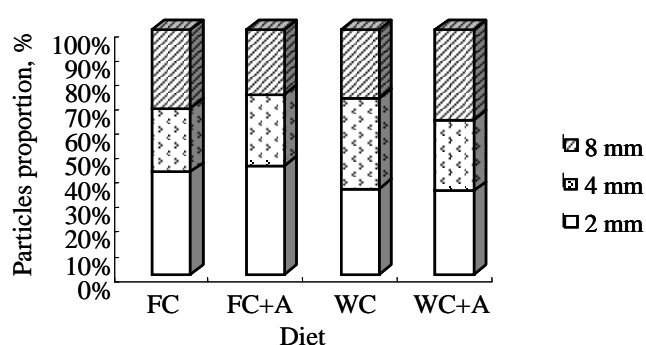


Figure 1-2. Distribution of corn particles in the feces (the proportion of each particles).

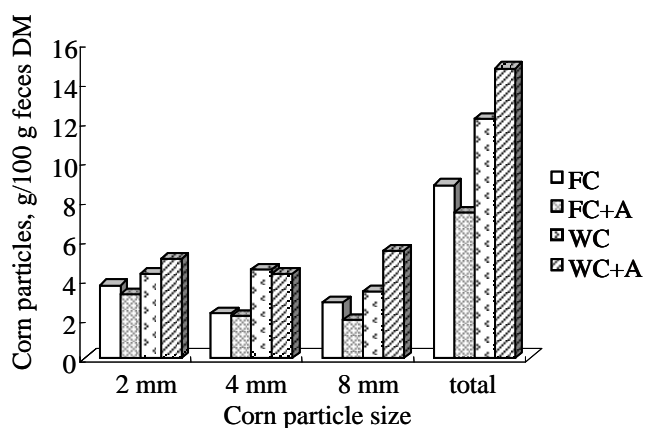


Figure 1-3. Distribution of corn particles affected by processing methods (comparison of treatment at each particle size).

al., 1979). With sheep, therefore, the feeding of grain diets is relatively simple in so far that no processing is required and processing has often a negative effect on health and feed utilization. However, in cattle, considerable quantities of intact kernels were observed in the feces when whole corn was fed, implying that intestinal enzymatic attack on kernels escaping ruminal digestion may be limited. This

result is supported by the finding that up to 30% of the whole grain from cattle given whole grain diets was appeared in the feces, thus an external processing is required (Ørskov, 1986). These previous results are contrary to those of the present study. However, our results support the results of Beauchemin et al. (1994), unlike barely and wheat, corn kernels are extensively damaged during mastication, which may make physical processing unnecessary, resulting in a substantial decrease in feed costs.

Several studies using feed additives as enzyme sources in ruminant diets that contained mainly forage have reported improvements in digestibility (Beauchemin et al., 1995; Feng et al., 1996). Enzyme mixtures may also be beneficial in high-concentrate diets (Beauchemin et al., 1997). Exogenous fibrolytic enzymes may help overcome the depression in fiber digestion that occurs with high-concentrate diets. However, considerable numbers of researchers could not find positive effects of enzyme additives in ruminant performances. Enzyme additives may provide a useful means of improving ruminal digestion of high-concentrate diets, but the most efficacious conditions for their application and the mode of action have yet to be defined. Additional work is necessary to determine the mode of action so that enzyme mixtures can be formulated and used consistently in feedlot diets. No effects of enzyme additives in the present study are clear. However, this may be the results of less amylase activity of the product used in this study, compared with cellulase activity. One can not rule out the possibility that supplementing level was too small to be effective.

Meanwhile, it was reported that whole corn over the processed one was greater in the performance of beef cattle in the finishing period (Vance et al., 1972). Owens et al. (1997) summarized that more extensive processing decreased dry matter intake, resulting in the reduction of average daily gain. In addition, extensively processed grain causes excessive rates of acid production in the rumen and acidosis (Fulton et al., 1979a,b). Owens et al. (1997) also suggested that energetic efficiency evaluated as metabolic energy was higher for whole-shelled corn than dry-rolled corn. Therefore, one can assume that the better performance for whole-shelled corn might be resulted from extensive chewing and/or rumination of the whole corn, which resulting in reducing the incidence of acidosis. Moreover, Stock et al. (1987) observed that feeding whole corn to feedlot cattle decreased the extent of ruminal starch digestion and the incidence of acidosis compared with cattle fed finely ground corn as the source of cereal grain.

It has been also suggested that unprocessed corn can be efficiently fed to beef cattle since the pericarp of the kernel is almost entirely cracked by chewing both during eating and during rumination (McAllister and Cheng, 1996). Since minimizing the surface area available to microbial attack

decreases the rate of starch digestion, thereby maintaining ruminal pH at an optimal level (Galyean et al., 1979), minimal processing of corn grain by slightly cracking the pericarp may slow the rate of starch digestion. Even though results in the present study did not show the superior nutrient digestibility of whole corn against those of flaked corn, we showed similar digestibilities with similar amounts of corn particles in the feces between the two treatments. Therefore, our results suggest that unprocessed corns may be more effectively utilized for the beef cattle, if one considers the cost in processing corn.

REFERENCES

- Association of Official Analytical Chemists. 1984. Official Methods of Analysis. 14th edn. Association of Official Analytical Chemists. Washington, DC.
- Bowman, J. G. P. and J. L. Firkins. 1993. Effects of forage species and particle size on bacterial cellulolytic activity and colonization *in situ*. *J. Anim. Sci.* 71:1623-1633.
- Beauchemin, K. A., T. A. McAllister, Y. Dong, B. I. Farr and K. J. Cheng. 1994. Effects of mastication on digestion of whole cereal grains by cattle. *J. Anim. Sci.* 72:236-246.
- Beauchemin, K. A., L. M. Rode and V. J. H. Sewalt. 1995. Fibrolytic enzymes increase fiber digestibility and growth rate of steers fed dry forages. *Can. J. Anim. Sci.* 75:641-644.
- Beauchemin, K. A., S. D. M. Jones, L. M. Rode and V. J. H. Sewalt. 1997. Effects of fibrolytic enzymes in corn or barley diets on performance and carcass characteristics of feedlot cattle. *Can. J. Anim. Sci.* 77:645-653.
- Feng, P., C. W. Hunt, G. T. Pritchard and W. E. Julien. 1996. Effect of enzyme preparations on *in situ* and *in vitro* degradation and *in vivo* digestive characteristics of mature cool-season grass forage in beef steers. *J. Anim. Sci.* 74:1349-1357.
- Frederick, H. M., B. Theuer and W. H. Hale. 1973. Effect of moisture, pressure, and temperature on enzymatic starch degradation of barley and sorghum grain. *J. Dairy Sci.* 56:596-601.
- Fulton, W. R., T. J. Klopfenstein and R. A. Britton. 1979a. Adaptation to high concentrate diets by beef cattle. I. Adaptation to corn and wheat diets. *J. Anim. Sci.* 49:775-784.
- Fulton, W. R., T. J. Klopfenstein and R. A. Britton. 1979b. Adaptation to high concentrate diets by beef cattle. II. Effect of ruminal pH alteration on rumen fermentation and voluntary intake of wheat diets. *J. Anim. Sci.* 49:785-789.
- Galyean, M. L., D. G. Wagner and F. N. Owens. 1979. Corn particle size and extent of digestion by steers. *J. Anim. Sci.* 49:204-210.
- Galyean, M. L., D. G. Wagner and F. N. Owens. 1981. Dry matter and starch disappearance of corn and sorghum as influenced by particle size and processing. *J. Dairy Sci.* 64:1804-1812.
- Goering, H. K. and P. J. Van Soest. 1970. Forage fibre analysis (apparatus, reagents, procedure and some applications). Agric. Handbook 379, ARS, USDA, Washington, DC.
- Huntington, G. B. 1997. Starch utilization by ruminants: from basics to the bunk. *J. Anim. Sci.* 75:852-867.
- Kim, N. S., J. K. Ha, Y. G. Ko, H. D. Kim, W. Y. Kim and B. O. Kwak. 1996. Effects of corn processing methods on the nutrient utilization II. Effects of processed corn on ruminal degradability of starch and lower gut disappearance rates of dry matter and crude protein in Holstein dairy cows. *Kor. J. Anim. Nutr. Feed.* 20(4):360-370.
- Loerch, S. C. 1992. Maximizing the use of corn grain in growing cattle diets. Ohio Beef Cattle Research and Industry Rep., Anim. Sci. Dept. Ser. 92-1:45-52.
- McAllister, T. A. and K. J. Cheng. 1996. Microbial strategies in the ruminal digestion of cereal grains. *Anim. Feed Sci. Technol.* 62:29-36.
- Murphy, T. A., F. L. Fluharty and S. C. Loerch. 1994. The influence of intake level and corn processing on digestibility and ruminal metabolism in steers fed all-concentrate diets. *J. Anim. Sci.* 72:1608-1615.
- Nocek, J. E. and S. Tamminga. 1991. Site and digestion of starch in the gastrointestinal tract of dairy cows and its effect on milk yield and composition. *J. Dairy Sci.* 74:3598-3629.
- Ørskov, E. R. 1973. The effect of non processing barley on rumenitis in sheep. *Res. Vet. Sci.* 14:110-112.
- Ørskov, E. R., C. Fraser and J. G. Gordon. 1974. Effect of processing of cereals on rumen fermentation, digestibility, rumination time and firmness of subcutaneous fat. *Br. J. Nutr.* 32:59-69.
- Ørskov, E. R. 1986. Starch digestion and utilization in ruminants. *J. Anim. Sci.* 63:1624-1633.
- Owens, F. N., D. S. Secrist, W. J. Hill and D. R. Gill. 1997. The effect of grain source and grain processing on performance of feedlot cattle: A review. *J. Anim. Sci.* 75:868-879.
- Rooney, L. W. and R. L. Pflugfelder. 1986. Factors affecting starch digestibility with special emphasis on sorghum and corn. *J. Anim. Sci.* 63:1607-1623.
- Statistical Analysis System Institute, Inc. 1985. SAS user's guide: Statistics. Version 5 Edition. SAS Institute, Inc., Cary, N.C.
- Stock, R. A., D. R. Brink, R. A. Britton, F. K. Goedeken, M. H. Sindt, K. K. Kreikemeier, M. L. Bauer and K. K. Smith. 1987. Feeding combinations of high moisture corn and dry-rolled sorghum to finishing steers. *J. Anim. Sci.* 65:290-302.
- Theurer, C. B. 1986. Grain processing effects on starch utilization by ruminants. *J. Anim. Sci.* 63:1649-1662.
- Turgeon, O. A., Jr., D. R. Brink and R. A. Britton. 1983. Corn particle size mixtures, roughage level and starch utilization in finishing steer diets. *J. Anim. Sci.* 57:739-749.
- Vance, R. D., R. L. Preston, E. W. Klosterman and V. R. Cahil. 1972. Utilization of whole shelled and crimped corn grain with varying proportions of corn silage by growing-finishing steers. *J. Anim. Sci.* 35:598-605.
- Walker, R. D., G. T. Lane, J. K. Riggs, L. W. Rooney and R. E. Lichtenwalner. 1973. Particle size and digestion of sorghum grain. *J. Anim. Sci.* 44:131.
- Wenk, C. 2000. Recent advances in animal feed additives such as metabolic modifiers, antimicrobial agents, probiotics, enzymes and highly available minerals - review -. *Asian-Aus. J. Anim. Sci.* 13:86-95.