Effects of Varying Levels of Flaked Corn Starch Abomasally Infused on Nitrogen Retention and the Efficiency of Energy Conversion in Fattening Steers[a]

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ABSTRACT : The experiment was carried out to evaluate the effect of varying levels of flaked corn abomasally infused on energy metabolism and nitrogen metabolism in fattening steers. The starch levels of flaked corn of abomasally infused were 0, 300, 600 and 900 g/d. Four mature fattening steers fitted with permanent abomasum cannulas were allocated to a 4 × 4 Latin square design were fed at 1.2 maintenance requirement a basal diet of Chinese wildrye (*Aneurolepidium Chinense*). Compared with 0 g/d (control group), digestible nitrogen, retention nitrogen (RN, g/d) and the efficiency of digestible nitrogen converted into retention nitrogen (RN/DN, %) of 300, 600 and 900 g/d groups were higher ($p<0.05$). The post-ruminal starch digestion of flaked corn were 71.36, 80.27 and 64.71% when the amounts abomasally infused were 300, 600 and 900 g/d, respectively. When the amount of starch abomasally infused was more than 600 g/d, the post-ruminal digestion of starch decreased. 300, 600 and 900 g/d starch infusion groups showed higher metabolizable energy intake (ME) and net energy gains (NEg, MJ/d) than the control group, and the efficiencies of metabolizable energy converted into body weight (Kf, %) of these groups were higher than the control group by 38.31, 73.18 and 67.06% ($p<0.05$). Kf (Y, %) had a positive curved relation to starch of flaked corn abomasally infused (X, g/d), $Y=36.1605X^{0.0760}$ (n=16, r=0.9308). (***Asian-Aus. J. Anim. Sci. 2000. Vol. 13, No. 4 : 470-473***)

Key Words : Starch, Infusion, Cattle, Digestion, Fiber, Nitrogen Retention, Energy Conversion

INTRODUCTION

Starch is the major energy component of grains. Corn contains 72% of dry matter as starch (Huntingon, 1997), and the fermentation of starch in the rumen is accompanied by inevitable losses in heat and methane (Hungate, 1966). This has led to an interest in understanding the extent to which starch is fermented in the rumen rather than digested post- ruminally, and in devising methods for manipulating the site of its digestion. Many research results support the concept that the efficiency of energy conversion of growing ruminants is greater if starch is digested post-ruminally rather than in the rumen (Owens et al., 1986; Roony and Pflugfelder, 1986; Nocek and Tamminga, 1991; Feng and Li, 1995).

The levels of grain starch intake have been reported to affect starch digestion. Huntington (1997) reported the capacity to digest starch in the intestine ranges from 45 to 88% of starch entering the duodenum. The objectives of this experiment were to determine the digestion post-ruminally of starch in flaked corn and the effects of varying levels of flaked corn abomasally infused on the digestion of fiber, nitrogen retention and the efficiency of energy conversion in fattening steers.

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MATERIALS AND METHODS

Animals and diets

Four fattening steers (body weight 400±40 kg) with permanent abomasum cannulas were individually housed in two open-shut respiration chambers in a climatic chamber at 25℃ with free access to drinking water. Four fattening steers fed each of four diets according to a 4×4 Latin square design. The diets were (1) 1.2 maintenance requirement (ARC, 1980) Chinese wildrye hay without concentrates or any supplement (*Aneurolepidium Chinense*) (7 kg/d, as-fed basis) (control group); (2) 1.2 maintenance requirement Chinese wildrye+abomasally infused 429 g/d flaked corn (300 g/d starch), the corn flaked by dry heat for 30 minutes; (3) 1.2 maintenance requirement Chinese wildrye+abomasally infused 857 g/d flaked corn (600 g/d starch); (4) 1.2 maintenance requirement Chinese wildrye+abomasally infused 1186 g/d flaked corn (starch 900 g/d). Characteristics of the diets are shown in table 1.

Experimental procedure

Feed was offered in equal portions at 08:00 and 16:00 daily. The flaked corn diluted with water in a bottle was infused into the abomasum 4 times every

Table 1. Characteristics of flaked corn and Chinese wildrye (fresh matter basis)

	DM (%)	OM (%)	N (%)	NDF (%)	ADF (%)	Starch (%)	GE (MJ/kg)
Chinese wildrye	92.51	88.28	1.01	71.99	30.73	-	17.32
Flaked corn	95.75	94.06	1.19	2.27	0.76	70.02	18.16

Table 2. Effect of varying levels of flaked corn abomasally infused on DM, OM, NDF, ADF and starch digestion in fattening steers

Item		Flaked starch infused (g/d)			
		0	300	600	900
Intake	DMI (kg/d)	5.84±0.32	6.42 (0.41*)±0.34	6.95 (0.82*)±0.45	7.45 (1.13*)±0.52
	OMI (kg/d)	5.58±0.31	6.14 (0.40*)±0.44	6.66 (0.81*)±0.48	7.15 (1.12*)±0.55
	NDFI (kg/d)	4.55±0.34	4.77 (0.01*)±0.40	4.94 (0.02*)±0.36	5.21 (0.03*)±0.45
	ADFI (kg/d)	1.94±0.16	2.04±0.11	2.09 (0.01*)±0.18	2.24 (0.01*)±0.20
Digested	DM (kg/d)	3.37±0.24	4.00±0.28	4.26±0.55	4.28±0.38
	OM (kg/d)	3.19±0.28	3.91±0.26	4.17±0.42	4.25±0.33
	NDF (kg/d)	2.64±0.21	2.84±0.30	2.76±0.22	2.85±0.18
	ADF (kg/d)	1.05±0.10	1.39±0.09	1.34±0.13	1.43±0.11
	Starch (g/d)	-	$214.08^{B}\pm32.13$	$481.62^{A}\pm41.25$	$582.39^{A}\pm60.77$
DM digestion (Total tract)		$7.77^{b}\pm4.28$	$62.36^{a}\pm4.95$	$61.34^{a}\pm4.99$	$57.51^{b}\pm3.94$
OM digestion (Total tract)		$58.26^{b}\pm3.67$	$63.73^{a}\pm5.63$	$62.74^{a}\pm5.76$	$59.46^{b}\pm6.78$
NDF digestion (Total tract)		57.57 ±6.21	59.49±5.66	55.78±4.99	54.78±3.25
ADF digestion (Total tract)		$54.27^{b}\pm4.92$	$67.84^{a}\pm5.93$	$64.35^{a}\pm7.84$	$63.78^{a}\pm5.71$
Starch digestion (Postruminal)		-	$71.36^{b}\pm6.87$	$80.27^{a}\pm9.66$	$64.71^{c}\pm6.66$

[a,b,c,d] Mean significant at 5% level; [A,B,C,D] Mean significant at 1% level.

* Mean DM, OM, NDF, ADF intakes from corn.

day. Experimental periods consisted of a 7-day adjustment period followed by a 3-day collection of faeces and urine, and then by respiration measurements over 3 consecutive days in two large open-shut respiration chambers (Blaxter et al., 1972). Urine and faeces were collected from animals in the respiration chambers. Urine was acidified by adding 20% HCl during collection. Samples of faeces and diets were dried at 60℃ and ground to pass a 1 mm screen.

Chemical analysis and statistics

Feed, faeces and urine samples were analyzed for DM, organic matter (OM), neutral detergent fiber (NDF), acid detergent fiber (ADF) and nitrogen (N) according to the procedures of Yang (1995). The energy content of all materials was determined by adiabatic oxygen bomb calorimetry. Methane (CH_4), CO_2 and O_2 concentrations measured by automatic gas analysers were recorded by the computer that controlled the operation of the respiration chambers, and the computer was programmed to calculate heat production (HP) from those data. The starch contents of feed and faeces were determined with glucoamylse and HCl hydrolysis procedures (Ning, 1992). The net efficiency of use of ME for growth and fattening (Kf) was calculated as $(NE_{high}-NE_{low})/(ME_{high}-ME_{low})$, where the subscript 'high' represents the NE and ME values measured with a flaked corn infusion, and 'low' refers to the control diet. Duncan's multiple range test was employed in the analysis of the results as a 4×4 Latin square design using the Statistical Analysis System (SAS, 1985).

RESULTS

The digestion of DM, OM, NDF, ADF and starch in fattening steers abomasally infused with varying levels of flaked corn are shown in table 2.

Because of variation in the quality of Chinese wildrye, cattle refused some of poor quality and DMI from Chinese wildrye was not the same in all groups. Compared with control, total digestible tract DM and OM digestion for 300 g/d and 600 g/d flaked starch infusion were higher ($p<0.05$), and ADF digestion for 900 g/d flaked starch infusion was higher ($p<0.05$). NDF digestion did not show a significant difference between treatments ($p>0.05$). DM and OM digestion for 300 g/d and 600 g/d flaked starch infusion were higher than those for 900 g/d ($p<0.05$). When the amount of flaked corn increased, DM, OM, NDF and ADF digestion decreased. The post-ruminal digestion of flaked starch for 600 g/d abomasally infused was higher than that for 300 g/d and 900 g/d ($p<0.05$); 300 g/d was also higher than 900 g/d ($p<0.05$).

The N balances with varying levels of flaked corn abomasally infused are shown in table 3.

Table 3. Effects of varying levels flaked corn abomasally infused on N balance experiment in fattening steers

Item	Cooked	Corn	Starch	Infused (g/d)
	0	300	600	900
N intake (g/d)	$56.87^{c} \pm 4.76$	$70.80^{b} \pm 6.88$	$77.57^{a} \pm 6.98$	$82.31^{a} \pm 7.41$
Faeces N (g/d)	$34.47^{b} \pm 2.69$	$35.24^{b} \pm 2.66$	$41.31^{ab} \pm 3.11$	$46.60^{a} \pm 2.88$
Urine N (g/d)	20.62 ± 1.77	23.29 ± 2.31	23.29 ± 1.55	21.34 ± 1.98
Digestible N (g/d)	$22.40^{b} \pm 1.14$	$35.56^{a} \pm 2.68$	$36.56^{a} \pm 2.33$	$35.71^{a} \pm 3.41$
Retention N (g/d)	$1.78^{b} \pm 0.77$	$12.27^{a} \pm 1.01$	$13.27^{a} \pm 1.37$	$14.37^{a} \pm 0.89$
RN/DN (%)	$7.95^{b} \pm 0.06$	$34.51^{a} \pm 2.55$	$36.30^{a} \pm 2.68$	$40.24^{a} \pm 2.97$
RN/N intake (%)	$3.13^{b} \pm 0.22$	$17.33^{a} \pm 0.67$	$17.11^{a} \pm 0.97$	$17.46^{a} \pm 2.66$

^{a,b,c,d} Mean significant at 5% level; N intake contains N of abomasum flaked infusion.

Table 4. Effects of varying levels of flaked corn abomasally infused on energy balance and the efficiency of metabolizable energy converted into body weight gain (Kf) in fattening steers

Item	Cooked corn starch infused(g/d)			
	0	300	600	900
General energy (MJ/d)	$109.41^{A} \pm 8.77$	$120.37^{BC} \pm 9.66$	$133.21^{AB} \pm 10.11$	$139.38^{A} \pm 14.88$
Faeces energy (MJ/d)	$48.11^{B} \pm 3.58$	$46.97^{B} \pm 6.87$	$53.01^{AB} \pm 4.64$	$61.47^{A} \pm 6.88$
Urine energy (MJ/d)	$2.53^{B} \pm 0.14$	$3.23^{AB} \pm 0.22$	$3.21^{AB} \pm 0.12$	$3.52^{A} \pm 0.34$
Methane energy (MJ/d)	5.73 ± 0.33	6.01 ± 0.44	5.09 ± 0.33	6.11 ± 0.57
Heat production (MJ/d)	45.86 ± 3.21	46.71 ± 6.77	44.42 ± 3.25	46.66 ± 5.36
Digestible energy (MJ/d)	$61.30^{b} \pm 3.68$	$73.40^{a} \pm 8.87$	$80.20^{a} \pm 8.40$	$78.37^{a} \pm 6.65$
Metabolizable energy (MJ/d)	$53.04^{c} \pm 3.25$	$64.17^{b} \pm 4.71$	$71.90^{a} \pm 6.98$	$68.74^{ab} \pm 5.36$
HP/ME (%)	$87.30^{A} \pm 5.98$	$87.42^{A} \pm 6.87$	$62.09^{A} \pm 3.89$	$67.97^{B} \pm 7.68$
Net energy (MJ/d)	$7.18^{c} \pm 0.33$	$17.45^{b} \pm 0.98$	$27.48^{a} \pm 1.68$	$22.09^{ab} \pm 3.01$
Kf (%)	$36.13^{b} \pm 2.58$	$49.97^{a} \pm 3.88$	$62.57^{a} \pm 7.61$	$60.36^{a} \pm 5.33$

^{a,b,c,d} Mean significant at 5% level; ^{A,B,C} Mean significant at 1% level.

N intake increased significantly with inceasing flaked corn infusion ($p<0.05$). Digestible N (DN), retention N (RN), RN/DN and RN/N intake of 300 g/d, 600 g/d and 900 g/d groups were higher than those of control group ($p<0.05$), but there were not significant differences among 300 g/d, 600 g/d and 900 g/d groups ($p>0.05$). Urine N had not significant difference in different treatments ($p>0.05$).

Effects of varying starch levels of flaked corn abomasally infused on energy balance and the efficiency of metabolizable energy conversion are shown in table 4.

Methane energy and HP showed no significant differences among treatments ($p>0.05$). Because GE intakes of 300 g/d, 600 g/d and 900 g/d flaked starch infusion groups were higher than those of control group, FE and UN for 300, 600 and 900 g/d were higher than those of the control group. Similarly, DE, ME and NE_g were also higher than those of the control group, and Kf (%) were greater than control by 38.31%, 73.18% and 67.00% respectively ($p<0.05$). Kf (Y) showed a positive curvilinear relationship with starch in the flaked corn abomasally infused (X, g/d); the regression equation was $Y=36.1605X^{0.0760}$ ($n=16$, $r=0.9308$).

DISCUSSION

The capacity for digestion of starch in the small intestine of ruminants is limited by lack of enzymes involved in hydrolysis of carbohydrate and by limited capacity for absorption of glucose. If the amount of starch into the small intestine is large, the digestion of starch in the small intestine of ruminants will decrease. This research showed that the capacity for digestion of starch in flaked corn in the small intestine in fattening steers is limited to 600 g/d. When the amount of starch in flaked corn was more than 600 g/d, the post-ruminal digestion of starch in flaked corn decreased. The digestion of starch in flaked corn of 300 g/d and 600 g/d abomasally infused were 71.36% and 80.27%, but the digestion of 900 g/d abomasally infused decreased to 64.71%. Orskov (1986) reported that the capacity for digestion of raw starch in the small intestine is limited to 100-200 g/d in sheep, gelled starch could be digested in quantities to 200-300 g/d, and the capacity would ultimately be limited by lack of enzymes involved in hydrolysis of short di- and oligosaccharides and also by capacity for absorption of glucose. Huntington (1997) reported the capacity to digest starch in the intestine ranges from 45 to 85% of starch entering the duodenum, with that capacity apparently limited by the poor supply of pancreatic amylase.

When a large amount of flaked corn was infused into abomasum, the amount of digestible starch in the small intestine increased, supplied glucose to the cattle, and produced more nicotinamide adenine dinucleotide phosphate (NADPH). The amount of glucose coming from amino acids consequently decreased, and the efficiency of digestible N converted into N retention and N retention increased. Spicer et al. (1986), Nocek and Tamminga (1991), Cameron et al. (1991) and Zhang (1997) reported the same results as this research.

As N intake increased more than N excretion as corn infusion increased, DN and RN of 300, 600, 900 g/d groups were higher than those of control group. The results of this experiment were obtained with diets that provided different N intakes (table 2). Further work is required to evaluate the effect of flaked corn abomasally infused on N and energy metabolism when N intake and energy intake is the same in fattening steers.

As the amount of flaked corn infusion increased, glucose and NADPH production increased. NADPH is important component in fat synthesis so the efficiency of ME converted into fat (Kf) rose, as well as there being an increased N retention.

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