

Effect of dietary NDF levels on nutrient digestion in hindgut of sheep*

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ABSTRACT

Four 4-month-old wethers fitted with ileal canulas were fed iso-caloric and iso-nitrogenous diets containing different NDF levels (30.0 to 45.0%) in a 4 × 4 Latin square design to evaluate the effects of dietary NDF levels on nutrient digestion in hindgut of sheep. The percent of hindgut digestion of DM, OM, CP, NDF, ADF, hemicellulose and cellulose in total tract digestion was 28.0 to 31.8%, 19.3 to 21.9%, 14.1 to 16.2%, 22.3 to 25.1%, 22.0 to 25.2%, 22.7 to 25.1% and 18.1 to 21.5%, respectively. Lower (30%) or higher (45%) NDF content in diet of sheep depressed fibrous fraction digestion anterior to hindgut, and hindgut complementally increased digestion of fibrous fractions.

KEY WORDS: NDF, nutrient, hindgut, digestion, sheep

INTRODUCTION

The hindgut of ruminant includes caecum, colon and rectum. The caecum and first region of the proximal colon act as a single compartment, which is the main site of fermentative digestion in hindgut. It was indicated that the hindgut made a significant contribution to fermentative digestion in ruminants, particularly when they were fed diets of low nutritive value. Forage to concentrate ratio is one of the main factors on nutrient digestion in ruminants, however, limited studies determined its effect on nutrient digestion in hindgut (Lewis et al., 1985; Siciliano-Jones et

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al., 1989), and the results were variable. In these trials, the animals were fed *ad libitum*, thus, had different feed intake, and feed intake could affect digestibility of dietary nutrients. Neutral detergent fibre (NDF) is a main index to reflect forage to concentrate ratio of diet. This study was conducted to determine the effects of NDF levels of diets with iso-caloric and iso-nitrogen on nutrient digestion in hindgut of sheep with same feed intake.

MATERIAL AND METHODS

Animals and diets

Four 4-mo-old cross-bred (Small-Tailed Han sheep×Poll Dorset) wether lambs (BW 23.5±0.6 kg) were used in a 4×4 Latin square design. Each was fitted with an ileal cannula of 5 mm internal diameter. The ileal cannula was placed approximately 15 cm cranial to the ileo-caecal junction. The surgery was completed 3 weeks before the experiment. Animals were housed individually in pens. To ensure full consumption, diets were fed restrictedly and 900 g (DM basis) feed were fed at 06.00 and 18.00 in two equal allotments. Water was freely available at all times. The ingredients and chemical composition of experimental diets were presented in Table 1. Diets were formulated to be 30, 35, 40 and 45% NDF, respectively, be iso-caloric and iso-nitrogenous and meet the CP requirements for 50 g of gain/d (NRC, 1985).

Experimental procedure

Each experimental period lasted 15 days, with the first 11 days for dietary adaptation and 4 days for sample collection. On days 12-13, faecal samples were collected. Ileal samples were collected on days 14-15. From 06.00 on d 14 to 04.00 on d 15, ileal digesta samples were taken at 2 h intervals. From 07.00 on d 15 to 05.00 on d 16, ileal digesta samples were taken at 2 h intervals. Twenty-four ileal samples from each lamb were composited for each period by the mixing of equal portions of each. Feed, faecal and ileal samples were dried at 50°C in an air-forced oven.

Chemical analyses

All samples were analysed for DM, organic matter (OM) and CP content according to AOAC (1990), for NDF, acid detergent fibre (ADF), hemicellulose (HC) and cellulose (CEL) content according to Van Soest et al. (1991) and Yang (1993). Feed, faecal and ileal samples were analysed for 4M-HCl-insoluble ash (AIA) (Van Keulen and Young, 1977).

Table 1. Ingredients and chemical composition of experimental diets

Items	NDF30	NDF35	NDF40	NDF45
<i>Ingredients, %</i>				
Chinese wild rye-grass hay ¹	0.0	30.0	50.0	59.0
maize stover ¹	37.5	16.5	0.0	0.0
cracked maize	46.7	39.7	27.9	11.2
wheat bran	0.0	0.0	12.0	14.7
soyabean meal	14.7	12.7	7.0	5.0
cotton meal	0.0	0.0	2.0	5.5
soyabean oil	0.0	0.0	0.0	3.5
ground limestone	0.2	0.2	0.2	0.2
NaCl	0.6	0.6	0.6	0.6
trace mineral premix ²	0.3	0.3	0.3	0.3
<i>Chemical composition, % DM</i>				
dry matter	89.9	89.9	90.4	90.2
organic matter	94.4	93.5	92.0	91.3
crude protein	14.0	14.0	14.0	14.3
Ca	0.3	0.3	0.3	0.4
total P	0.3	0.3	0.3	0.4
neutral detergent fibre	30.0	35.0	40.0	45.0
acid detergent fibre	16.7	21.2	23.8	27.7
hemicellulose	14.2	14.9	16.0	17.3
cellulose	10.9	14.5	16.8	19.6
Metabolizable energy ³ , MJ/kg	9.1	9.1	8.9	9.0

¹ Chinese wild rye-grass hay and mize stover were coarsely chopped (2 cm length)

² containing, mg/kg: Zn 8400, Mn 6000, Fe 4000, Cu 3000, I 260, Co 50, Se 20

³ values based on NRC (1985)

Calculations and statistical analyses

AIA was used as an endogenous marker for calculating the apparent digestibilities of major nutrients. According to the percentage values of AIA and nutrients in feed, faecal, and ileal samples, total tract and ileal apparent digestibilities were calculated. Hindgut apparent digestibility was obtained by subtracting ileal apparent digestibility from total tract apparent digestibility.

Data were analysed using ANOVA procedures of SAS (1999), and the means were compared by Duncan-test.

RESULTS AND DISCUSSION

The dietary NDF levels effected ($P < 0.01$) the ileal DM digestibility of sheep, with lowest value for sheep fed the diet containing 45% NDF, and had not effect ($P > 0.05$)

on the hindgut digestibility of DM or OM and its percent in total tract digestion, but, with highest value for sheep fed the diet containing 45% NDF (Table 2).

Dietary NDF levels had not effect ($P>0.05$) on CP digestibility in ileum and hindgut. But, the CP ileum digestibility of sheep fed the diet containing 45% NDF was lower than others, and its percent of hindgut digestion in total tract digestion was higher. Lewis et al. (1985) found that the percentage of CP caecum digestion of sheep fed diets of, %: 60 maize: 40 hay and 80 maize: 20 hay were 21.6 and 22.0, which accounted for 37.96 and 34.10% of total tract digestion of CP, respectively. In present experiment, the percent of CP digestion in hindgut accounted for 14.1 to 16.2% of the total digestible CP. However, Siciliano-Jones et al. (1989) indicated that CP digested in the large intestine of cow fed diets containing, %: 20 hay: 80 grain and 80 hay: 20 grain only accounted for 3.2 and 0.3% of total tract digestion of CP, respectively, which

Table 2. Effect of dietary NDF levels on DM, OM and CP digestion in sheep

Items	Diet				SEM ¹
	NDF30	NDF35	NDF40	NDF45	
<i>Digestion of dry matter</i>					
total tract, % intake	72.1 ^a	71.9 ^a	71.2 ^a	69.9 ^b	0.4
ileum, % intake	51.9 ^{aA}	51.6 ^{aA}	50.2 ^{aAB}	47.7 ^{bB}	0.5
hindgut, % intake	20.2	20.3	21.0	22.2	0.7
hindgut digestion, % in total tract	28.0	28.3	29.5	31.8	0.8
<i>Digestion of organic matter</i>					
total tract, % intake	73.7	73.6	72.8	72.0	0.4
ileum, % intake	59.4 ^{aA}	59.2 ^{aA}	57.6 ^{bB}	56.2 ^{bB}	0.3
hindgut, % intake	14.2	14.4	15.2	15.7	0.5
hindgut digestion, % in total tract	19.3	19.6	20.9	21.9	0.6
<i>Digestion of crude protein</i>					
total tract, % intake	72.7	72.8	73.1	72.5	1.0
ileum, % intake	62.5	62.4	62.0	60.7	0.6
hindgut, % intake	10.2	10.4	11.0	11.7	0.6
hindgut digestion, % in total tract	14.1	14.3	15.1	16.2	0.7

¹ standard error of the mean; ^{a,b,c} means within a row lacking a common superscript letter indicates significant difference at $P<0.05$ and ^{A,B} at $P<0.01$

may be resulted from incomplete recovery of the indicator (chromic oxide). Hoover (1978) mentioned that ammonia absorption from the hindgut contributed 39% of the total nonprotein nitrogen absorbed into body fluids, and was probably a major source of nitrogen recycled to the rumen. The ileal NDF and HC digestibility of sheep fed four diets were similar, but the ileal ADF and CEL digestibility of sheep fed 30 and 45% NDF diets were lower than those of sheep fed 35 and 40% NDF

diets (Table 3). The result indicated that lower (30%) or higher (45%) NDF in diet decreased fibrous fractions digestion anterior to hindgut. Dietary NDF level did not affect the hindgut NDF, ADF, HC and CEL digestibility of and the percent of hindgut digestion of fibrous fractions in total tract digestion of sheep, but common trend was that corresponding values of 30 and 45% NDF diets were higher than those of 35 and 40% NDF diets, and it indicated that digestion of fibrous fractions escaped rumen fermentation then reaching hindgut complementally increased.

Table 3. Effect of dietary NDF levels on fibrous fraction digestion in sheep

Items	Diet				SEM*
	NDF30	NDF35	NDF40	NDF45	
<i>Digestion of neutral detergent fibre</i>					
total tract, % intake	51.9	52.5	52.1	51.6	0.3
ileum, % intake	38.8	40.7	40.2	38.7	0.7
hindgut, % intake	13.1	11.8	11.9	12.9	0.5
hindgut digestion, % in total tract	25.1	22.3	22.9	25.1	1.1
<i>Digestion of acid detergent fibre</i>					
total tract, % intake	50.7	51.4	50.8	49.9	0.5
ileum, % intake	37.9 ^{bc}	40.1 ^a	39.4 ^{ab}	37.4 ^c	0.5
hindgut, % intake	12.8	11.3	11.4	12.5	0.5
hindgut digestion, % in total tract	25.2	22.0	22.5	25.1	1.0
<i>Digestion of hemicellulose</i>					
total tract, % intake	53.2	54.0	54.0	54.2	0.6
ileum, % intake	39.9	41.7	41.3	40.7	1.5
hindgut, % intake	13.3	12.3	12.7	13.5	1.3
hindgut digestion, % in total tract	25.0	22.7	23.6	25.1	2.4
<i>Digestion of cellulose</i>					
total tract, % intake	50.9	52.8	54.6	52.7	0.9
ileum, % intake	39.9 ^D	43.3 ^B	44.2 ^A	41.6 ^C	0.6
hindgut, % intake	11.0	9.5	10.4	11.1	0.5
hindgut digestion, % in total tract	21.5	18.1	19.1	21.1	0.8

* standard error of the mean; ^{a, b, c} means within a row lacking a common superscript letter indicates significant difference at $P < 0.05$ and ^{A, B, C, D} at $P < 0.01$

Lewis et al. (1985) reported that hindgut digestion of NDF, ADF and CEL of sheep fed diets with, %: 60 maize: 40 hay and 40 maize: 60 hay accounted for 15.9 and 12.9%, 29.7 and 33.6%, and 23.4 and 36.8% of the total digestible NDF, ADF and CEL, respectively. In present experiment, the percent of hindgut digestion of NDF and ADF in total tract digestion was 22.3 to 25.1% and 22.0 to 25.2%, respectively. Callison et al. (2001) mentioned that large intestinal NDF digestion of dairy cow accounted for 9.5 to 18.9% of the total digestible NDF. Siciliano-Jones et al. (1989)

reported that large intestinal NDF and ADF digestion of sheep accounted for 4.9 to 15.5% and 5.0 to 14.9% of the total digestible NDF and ADF, respectively. Possible reasons causing the difference of fibrous fractions digestion in hindgut may include feed sources, forage maturity, concentrate to forage ratio, feed intake, and so on.

Hoover (1978) reviewed that, in ruminants, the hindgut digestion of HC accounted for 30 to 40% of the total HC digested per day, and the hindgut digestion of CEL accounted for 18 to 27% of the total CEL digested. In present experiment, the percent of hindgut digestion of HC and CEL in total tract digestion of sheep was 22.7 to 25.1% and 18.1 to 21.5%, respectively.

CONCLUSIONS

It is concluded that increasing dietary NDF levels from 30 to 45% a little increased the percent of hindgut digestion of DM, OM and CP in total tract digestion of sheep, and dietary NDF level had not significant effect on the percent of hindgut digestion of NDF, ADF, HC and CEL in total tract digestion, but corresponding values fed 30 and 45% NDF diets were higher than those of 35 and 40% NDF diets. Hindgut digestion has a compensating or equalizing effect on total tract digestibility.

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