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Influence of forage type on feed intake, chewing activity and rumen pH in goats

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ABSTRACT

This study was conducted to investigate the effects of forage type on feed intake, chewing activity and rumen pH in goats. Neutral detergent fibre (NDF) concentration in dry matter (DM) was 44.86, 64.92 and 77.91% for lucerne hay (LH), maize silage (MS), and wheat straw (WS), respectively. In Experiment 1, three fistulated goats were used to measure the degradation kinetics of MS, LH and WS. Effective ruminal degradability of DM, and NDF was higher for LH compared with MS and WS. In Experiment 2, six yearling Saanen × Guanzhong goats (32.3 ± 1.6 kg) fitted with ruminal cannulas were used in a replicated 3×3 Latin square design. MS diet contained 32% NDF from MS. In the other two diets, 60% MS NDF was substituted by NDF from LH and WS, respectively. When expressed as min per day, LH tended to increase time spent in chewing. However, when expressed as min per kg forage NDF intake, WS increased chewing time. Average rumen pH was lower for goats fed LH diet than MS and WS diet. These results suggest that NDF effectiveness to stimulate chewing and maintain rumen pH increases as NDF concentration increases and ruminal degradability decreases in forages.

KEY WORDS: forage, neutral detergent fibre, chewing activity, rumen pH, goat

INTRODUCTION

Forage fibre stimulates chewing and then secretion of salivary buffers which neutralize fermentation acids and maintain rumen pH. Physically effective fibre has been defined as that portion of the diet stimulates chewing activity and salivary buffer production (Mertens, 1997). NRC for dairy cows (2001) recommended minimum concentration of forage NDF (FNDF) to maintain the ruminal and cow health. The recommendation originates from experiments using diets containing high quality

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forages. Low quality forages, such as wheat straw and rice straw, have been widely used to alleviate the shortage of high quality forages in developing countries.

NRC (2001) recommendations do not account for differences in forage quality. There is little information available documenting the relative physical effectiveness among different forages. Therefore, the objectives of present study were: 1. to evaluate physical effectiveness differences between high and low quality forages, and 2. to investigate relationship among physical effectiveness and degradation characteristics of NDF.

MATERIAL AND METHODS

Forage preparation

Lucerne hay (LH), maize silage (MS) and wheat straw (WS) were chopped by the same cutter with the same theoretical length of cut. Samples were sieved and sequentially through screens with the following aperture sizes: 19.00, 8.00, 1.18 mm, and bottom pan.

Experiment 1

Three fistulated into rumen goats were fed the diet containing 60% maize silage and 40% concentrate. Samples of dried forages were ground through a 1 mm screen and material less than 75 μm was removed by hand sieving. Approximately 2.0 g of DM of test forage was weighted into nylon bags (6 cm × 9 cm) with a pore size of 50 μm. The bags were placed into rumen on 09.00 and were removed after intervals of 0, 6, 12, 24, 48, or 72 h and washed in cold running water until the washing ran clear.

Degradability coefficients were calculated according to Bowman and Firkins (1993):

$$P = A, \text{ when } 0 < t < L; \text{ and } P = A + B\,(1 - e^{-C\,(t-L)}), \text{ when } t > L$$

Effective ruminal degradability was calculated using the equation of Wang et al. (2004):

$$D = A + [BC / (C + K)]\, e^{-(C+K)\,L}$$

where: t - incubation time, L - discrete lag time, P - the cumulative amount degraded at time t, A - the readily soluble fraction, B - the fraction potentially degraded in the rumen, C - the constant rate of degradation of B, D - the effective ruminal degradability, K - ruminal outflow rate.

A nonlinear regression method of SAS (1990) was used to estimate degradability coefficients of DM, and NDF of forages.

Experiment 2

Six yearling Saanen × Guanzhong goats (32.3±1.6 kg) fitted with ruminal cannulas were used in a replicated 3×3 Latin square design. The silage diet contained 32% of DM from MS NDF. In the other two diets, 60% MS NDF was substituted by LH NDF and WS NDF, respectively. Goats were fed a TMR three times daily at 08.00, 13.00 and 18.30 h.

Experimental treatment periods were 13 d for dietary adjustment followed by 5 d of data collection. Diets were mixed daily. Dry matter intake was measured from 14 to 17 days of each period. Goats were monitored for chewing activity for a continuous 24-h period on the first day (d 14) at each collection period according to Krause et al. (2002). Rumen samples were taken on d 18 of each period, and were filtered through four layers of cheesecloth. Rumen liquid pH was immediately determined.

Dietary and faecal samples were dried at 55°C for 48 h and ground through a 2 mm screen. Dry matter (DM) and nitrogen content of diets were analysed according to the procedures of the AOAC (1990). Fibre analysis was performed as described by Clark and Armentano (1993).

Data were analysed as a replicated 3×3 Latin square design using the GLM procedures of SAS (1990). The statistical model included period, goat, and dietary treatment. Means were separated by Duncan's multiple range tests.

RESULTS AND DISCUSSION

Concentrations of NDF and ADF were greatest for WS, intermediate for MS, and least for LH ($P<0.05$; Table 1). In contrast, the ratio of ADF to NDF was greatest for LH, intermediate for MS, and least for WS ($P<0.05$). The results were supported by NRC (2001). Previous studies have shown physical effectiveness of forage NDF is highly related to particle length (Krause et al., 2002). In present experiment, the proportion of particles size of three forages did not differ ($P>0.05$) because the samples were sieved through the same screens.

Table 1. Chemical composition of maize silage, lucerne hay and wheat straw

Item	Forage type			SEM[1]	P-value
	maize silage	lucerne hay	wheat straw		
Dry matter , %	22.7	86.7	89.3	---	---
Crude protein, %	6.9	18.3	4.7	---	---
NDF % of dry matter[2]	64.92[b]	44.86[c]	77.91[a]	1.92	<0.001
ADF % of dry matter[3]	39.78[b]	33.18[c]	42.17[a]	1.12	<0.001
% of NDF	61.29[b]	74.03[a]	54.13[c]	2.55	<0.001

[1] SEM - standard error of means; n=12; [2]NDF - neutral detergent fibre

[3] ADF - acid detergent fibre; [a, b, c] row means with common superscripts do not differ ($P>0.05$)

Table 2. Ingredient and nutrient composition of experimental diets

Item	Diet, % of dry matter		
	maize silage	lucerne hay	wheat straw
Ingredient			
maize silage	50.0	20.0	20.0
lucerne hay	0	43.5	0
wheat straw	0	0	24.7
maize grain	33.0	33.0	33.0
wheat bran	5.1	1.7	5.9
soyabean meal	10.0	0	6.4
rapeseed meal	0	0	8.0
dicalcium phosphate	0.50	0.50	0.60
limestone	0.60	0.50	0.60
salt	0.50	0.50	0.50
vitamins and minerals premix[1]	0.30	0.30	0.30
Nutrient composition[2]			
dry matter	36.0	55.4	55.7
crude protein	12.49	12.77	12.58
Neutral detergent fibre from forage			
total	32.46	32.50	32.22
frommaizesilage	32.46	12.98	12.98
fromlucernehay	0	19.52	0
fromwheatstraw	0	0	19.24

[1] contained, %: limestone 90, Zn 0.35, Fe 0.30, Mn 0.20, Cu 0.10, I 0.010, Co 0.010, Se 0.010; IU/g: vit. A 6.000, vit. D 1.500 and vit. E 1.0; [2] values based analysis

Soluble fraction of DM did not differ for MS and LH but was less ($P<0.05$) for WS (Table 3), which is supported by the work of Bourquin and Fabey (1994). Soluble fraction of NDF did not differ ($P>0.05$) among forages, and was close to zero. Effective ruminal degradability of DM and NDF ($P<0.05$) for LH was higher than MS and WS, which is consistent with other study (Bourquin and Fahey, 1994).

Goats fed the WS diet ate less ($P<0.05$) DM compared with those fed MS and LH diet (Table 4). FNDF intake was significantly higher ($P<0.05$) for goats fed LH diet than that of goats fed WS and MS diet. These results agree with previous study (Haddad and Husein, 2001). Chewing activity and rumen pH were measures of the physically effectiveness of NDF. When expressed as min per day, LH tended to increase ($P=0.12$) time spent in chewing. However, when expressed as min per kg FNDF intake, chewing time was greatest for goats fed WS diet, intermediate for MS, and least for LH ($P<0.05$). Average rumen pH was lower ($P<0.05$) for goats fed LH diet than MS and WS diet. This might be partially explained by the lower chewing time per kg FNDF intake. Based on the data on chewing activity and rumen

pH, both fibre of MS and WS were similar physical effectiveness, but LH fibre was less effectiveness. Previous researches have shown that WS is more effectiveness to stimulate chewing and maintain rumen pH than LH in cattle (Shain et al., 1999) and in sheep (Haddad and Husein, 2001). Our results tend to support this conclusion.

Table 3. Degradation kinetics of dry matter and neutral detergent fibre of maize silage, lucerne hay and wheat straw

Item	Forage type			SEM[1]	P-value
	maize silage	lucerne hay	wheat straw		
Drymatter					
lagtime,h	14.9[a]	8.7[b]	13.6[ab]	1.2	0.031
soluble fraction, %	22.8[a]	22.2[a]	14.1[b]	1.4	<0.001
potentially degraded fraction, %	26.2	26.7	30.8	1.6	0.311
degradation rate, %/h	0.020	0.036	0.026	0.004	0.112
indigestible fraction, %[2]	51.0	51.1	55.1	1.6	0.376
ruminal effective degradability, %[3]	29.0[b]	32.6[a]	23.4[c]	1.4	<0.001
Neutral detergent fibre					
lagtime, h	5.9[a]	2.1[b]	5.2[ab]	0.8	0.045
soluble fraction, %	1.7	1.1	2.6	0.4	0.170
potentially degraded fraction, %	30.0[b]	44.5[a]	35.2[ab]	2.6	0.020
degradation rate, %/h	0.026[b]	0.047[a]	0.037[ab]	0.004	0.042
indigestible fraction, %[2]	68.3[a]	54.4[b]	62.2[ab]	2.4	0.014
ruminal effective degradability, %[3]	13.6[c]	28.3[a]	19.4[b]	2.2	<0.001

[1] SEM - standard error of means; n=9; [2] indigestible fraction = 100 - soluble fraction - potentially degraded fraction; [3] effective ruminal degradability was calculated using ruminal outflow rate set arbitrarily at 0.02 %/h; [a,b,c] row means with common superscripts do not differ (P>0.05)

Table 4. Effects of forage type on feed intake, chewing activity and rumen pH in goats

Item	Diet			SEM[1]	P-value
	maize silage	lucerne hay	wheat straw		
Dry matter intake, g/d	685[a]	736[a]	589[b]	48	0.006
FNDF intake, g/d[2]	210.6[b]	241.3[a]	188.4[b]	14.2	0.005
Chewing activity					
eating time, min/d	296	315	280	23	0.504
min/g FNDF intake	1.46	1.45	1.73	0.18	0.366
ruminating time, min/d	427	438	421	17	0.683
min/g FNDF intake	2.15	1.97	2.36	0.15	0.127
total chewing time, min/d	721	754	701	19	0.117
min/g FNDF intake	3.61[ab]	3.42[b]	4.09[a]	0.28	0.046
Average rumen pH	6.25[a]	6.05[b]	6.20[a]	0.05	0.015

[1] SEM - standard error of means; n=18; [2] FNDF - neutral detergent fibre from forage
[a,b] row means with common superscripts do not differ (P>0.05)

In present study, physical effectiveness measured chewing time and rumen pH increases as forage NDF concentration increases and ruminal degradability decreases. These results are consistent to others. Welch and Smith (1970) reported that rumination time increases as forage quality decreases. Mertens (1997) reviewed several studies and concluded that physical effectiveness linearly increases as the NDF concentration in forages increases.

CONCLUSIONS

Based on the data of these two experiments, physical effectiveness increases as forage NDF concentration increases and ruminal degradability decreases. Therefore, in order to maintain rumen health, forage NDF recommendations in dairy ruminant diets containing low quality forages can be properly decreased on the basis of NRC (2001) recommendation.

REFERENCES

AOAC, 1990. Association of Official Analytical Chemists, Official Methods of Analysis. 15th Edition. Arlington, VA

Bourquin L.D., 1994. Ruminal digestion and glycosyl linkage patterns of cell wall components from leaf and stem fractions of alfalfa, orchardgrass, and wheat straw. J Anim. Sci. 72, 1362-1374

Bowman J.G.P., Firkins J.L., 1993. Effects of forage species and particle size on bacterial cellulolytic activity and colonization in situ. J. Anim. Sci. 71, 1623-1633

Clark P.W., Armentano L.E., 1993. Effectiveness of neutral detergent fiber in whole cottonseed and dried distillers grains compared with alfalfa haylage. J. Dairy Sci. 76, 2644-2650

Haddad S.G., Husein M.Q., 2001. Nutritive value of lentil and vetch straws as compared with alfalfa hay and wheat straw for replacement ewe lambs. Small Ruminant Res. 40, 255-260

Krause K.M., Combs D.K., Beauchemin K.A., 2002. Effects of forage particle size and grain fermentability in midlactation cows. II. Ruminal pH and chewing activity. J. Dairy Sci. 85, 1947-1957

Mertens D.R., 1997. Creating a system for meeting the fiber requirements of dairy cattle. J. Dairy Sci. 80, 1463-1482

NRC, 2001. Nutrient Requirements of Dairy Cattle. 7th revised Edition. Nationall Academy of Science. Washington, DC

SAS, 1990. SAS-STAT. User's Guide. Vol. 1 and 2. Version 6. 4th Edition. SAS Institute Inc. Cary, NC

Shain L.D., Stock R.A., Klopfenstein T.J., Herold D.W., 1999. The effect of forage source and particle size on finishing yearling steer performance and ruminal metabolism J. Anim. Sci. 77, 1082-1092

Wang Y., Spratling B.M., ZoBell D.R., Wiedmeier R.D., McAllister T.A., 2004. Effect of alkali pretreatment of wheat straw on the efficacy of exogenous fibrolytic enzymes. J. Anim. Sci. 82, 198-208

Welch J.G., Smith A.M., 1970. Forage quality and rumination time in cattle. J. Dairy Sci. 53, 797-800