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Rumen Fermentation and Nutrient Digestibility in Goats Fed a Tallow-Rich Ration Fortified with Yeast

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Abstract: The hypothesis tested was that supplementation of the ration with yeast would negate the inhibitory effect of high-fat intake on rumen fermentation in goats. In a 3×3 Latin square-design, three rumen-fistulated goats were given free access to grass silage and either a low-tallow concentrate or a high-tallow concentrate without or with added yeast. Feed intake, apparent fiber digestibility, rumen pH and volatile fatty acids were measured. When the goats were fed the high-fat diet without yeast, dry matter intake with silage was significantly higher than when either the low-fat diet or the high-fat diet with yeast was supplied. The apparent digestibilities of macronutrients were not significantly affected by the dietary treatments. Group-mean digestibility of neutral detergent fiber was lowered by 0.4% units after feeding the high-fat diet without yeast and by 1.3% units when the high-fat diet with yeast was supplied. The ruminal pH and concentrations of volatile fatty acids were not influenced by dietary treatment. It is concluded that the addition of yeast to a high-tallow ration did not improve feed intake and rumen function in goats.

Key words: Goats, tallow, yeast, rumen fermentation, nutrient digestibility, Thailand

INTRODUCTION

One approach to increase energy intake by ruminants is the feeding of fat-rich concentrates (Coppock and Wilks, 1991). It would be expected that supplemental fat improves growth performance of meat goats but Marinova *et al.* (2001) reported that addition of sunflower oil to the concentrate did not influence average daily gain of young goats. It is well-known that high dietary levels of fats inhibit ruminal fermentation and thus diminish the utilization of dietary fiber (Coppock and Wilks, 1991; Vafa *et al.*, 2009; Polviset *et al.*, 2010). Possibly, in the goats fed supplemental sunflower oil (Marinova *et al.*, 2001), there was inhibition of fiber utilization that counteracted the growth-enhancing effect of the intake of extra energy in the form of fat.

The inhibitory effect of high-fat intake on fiber digestibility is explained by disturbance of ruminal fermentation through depression of the cellulolytic bacteria (Coppock and Wilks, 1991). In contrast, the addition of yeast to the ration of ruminants has been shown to stimulate cellulolytic bacteria (Newbold *et al.*, 1996; Chaucheyras and Fonty, 2001; Monsoni *et al.*, 2007). It may be hypothesized that yeast supplementation can overcome the inhibitory effect of high-fat intake on rumen fermentation. In this study with rumen-fistulated goats, the hypothesis was tested. The goats were fed high-tallow concentrates without or with added yeast and feed intake, apparent fiber digestibility, rumen pH and volatile fatty acids were measured. In sheep, yeast supplementation did not affect the number of protozoa in the rumen (Galp, 2006; Tripathi *et al.*, 2008) but the feeding of a ration rich in sunflower seed oil lowered the number of protozoa (Ivan *et al.*, 2001). Thus, it was considered of interest to look at the combined effect of fat and yeast on ruminal protozoa in this study with goats.

MATERIALS AND METHODS

Three rumen-fistulated, male goats were used in a 3×3 Latin-square design. The animals were housed individually. The dietary treatments consisted of

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concentrates containing either 3 or 6% tallow without or with yeast supplementation. The yeast preparation used was Yea-Sacc (Alltech) which is a live yeast culture based on a *Saccharomyces cerevisiae* strain.

The yeast was supplied at a daily dose of 10 g per goat; it was mixed with a small amount of concentrate that was fed manually to ensure ingestion. Table 1 shows the ingredient composition of the concentrates. As source of roughage, the goats received grass silage. The analysed composition of the grass silage and the concentrates is shown in Table 2. Each feeding period lasted 28 days. During the first 21 days, feed intake was measured. Then, the goats were kept in metabolism crates for 7 days. Feces were collected quantitatively during the last 5 days of each feeding period. The goats had free access to the grass silage and concentrates. Any feed left-overs were measured daily.

Feed samples were collected weekly and pooled for analysis. Feed and feces samples were dried at 60°C for 72 h, ground and analyzed for dry matter, crude protein, ash, Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) as described earlier (Jansen *et al*., 2000). Macronutrient digestibility was expressed as percentage of intake and calculated as (nutrient intake nutrient in feces) x nutrient intake^{-1} x 100.

At the end of each feces collection period, rumen samples were collected through the fistula at 0, 2 and 4 h post feeding. The pH of rumen samples was measured immediately. Rumen fluid samples of 20 mL were acidified with 2 mL of 6 N HCl to inhibit microbial activity and frozen at -20°C until the analysis of volatile fatty acids analysis using HPLC as described (Samuel *et al*., 1997).

Table 1: Ingredient composition of the experimental concentrates

	Diet code	
Parameters	Low fat	High fat
Ingredient (g/100 g)		
Cassava chips	59	56
Tallow	3	6
Constant components[1]	38	38
Total	100	100

[1]The constant components consisted of (g): rice bran, 10; soybean meal, 8; dried tomato pomace, 8; whole cotton seed, 3; molasses, 5; urea, 2; salt, 1; ground oyster shell, 0.3; dicalcium phosphate, 0.4; sulfur, 0.2; trace element mixture, 0.1

Table 2: Analysed composition of the grass silage and the concentrates

Ingredients	Grass silage	Low fat	High fat
Macronutrient (g/100 g)			
Dry matter	93.6	86.6	86.9
Ash	10.1	6.2	7.8
Organic matter	89.2	93.8	92.2
Crude protein	5.4	15.0	15.4
Crude fat	1.3	4.2	8.8
NDF	74.7	24.7	24.6
ADF	47.9	17.8	18.1

The numbers of the protozoa, Entodinium and Isotricha were determined according to Purser and Moir (1966). The data are shown as treatment means and SEM for three goats. Statistically significant differences between treatment means were identified with the use of Duncan's multiple range test. The level of statistical significance was pre-set at $p<0.05$.

RESULTS AND DISCUSSION

When the goats were fed the high-fat diet without yeast, absolute dry matter intake with silage was significantly higher than when either the low-fat diet or the high-fat diet with yeast was supplied (Table 3). When silage intake was expressed as percent of body weight or per unit of metabolic weight, the increase as induced by the high-fat diet without yeast was still higher but statistical significance was not reached anymore. The intakes of concentrate and total feed were not significantly influenced by the composition of the ration. The apparent digestibility of macronutrients was not significantly affected by the dietary treatments (Table 4). However, the high-fat rations systematically increased group-mean fat digestibility by on average 3.1% units. Group mean digestibility of NDF was lowered by 0.4%

Table 3: Feed intake by the goats when fed the experimental diets

	Diet code			
Feed composition	Low fat	High fat	High fat +yeast	SEM
Intake (g dry matter/day)				
Silage	283[a]	408[b]	309[a]	1.60
Concentrate	444	462	442	2.90
Total	727	870	750	2.90
Intake (body weight%)				
Silage	0.97	1.20	0.97	0.12
Concentrate	1.50	1.38	1.34	0.12
Total	2.46	2.58	2.31	0.11
Intake (g kg^{-1} metabolic body weight)				
Silage	22.5	28.9	22.9	0.52
Concentrate	21.7	17.1	20.1	0.56
Total	44.1	46.0	43.0	0.36

Means within the same row not sharing the same superscript letter are significantly different

Table 4: Apparent digestibility of macronutrients in the goats when fed the experimental diets

	Diet code			
Ingredients	Low fat	High fat	High fat +yeast	SEM
Digestibility (intake%)				
Dry matter	88.5	87.5	87.4	0.61
Organic matter	90.2	88.7	90.2	0.57
Crude protein	88.8	86.5	87.5	0.61
Crude fat	91.2	94.1	94.5	0.34
NDF	86.1	85.7	84.8	0.64
ADF	81.9	83.0	83.6	0.62

units after feeding the high-fat diet without yeast and by 1.3% units when the high-fat diet with yeast was supplied. In contrast, group-mean digestibility of ADF was increased by the high-fat rations. When the goats were fed the low-fat ration, post-feeding group mean pH values for the ruminal fluid were higher than when they were consuming the high-fat diets (Table 5). The concentration in the ruminal fluid of total volatile fatty acids and the percentages of acetate, propionate and butyrate were not significantly influenced by the dietary treatments.

The high-fat diets did not affect the pre-feeding number of entodinium in ruminal contents but post feeding, there was a significant increase (Table 6). At 2 h post feeding, the increase was higher for the high-fat diet without yeast than for the diet with added yeast. The high-fat diet without yeast significantly raised the pre-feeding number of Isotricha in the rumen. At 2 h post feeding the number was lowest when the high-fat diet with yeast was fed. The diet effects had disappeared by 4 h after feeding. This study with rumen-fistulated goats confirms the well-known effects of supplemental fat feeding on the apparent digestibility of NDF and crude fat. The high-fat diets versus the low-fat diet lowered group mean digestibility of NDF and raised that of crude fat.

Table 5: Volatile fatty acids and pH in ruminal fluid of the goats when fed the experimental diets

	Diet code			
Experimental diets	Low fat	High fat	High fat + yeast	SEM
TVFA (mmol L^{-1})				
Pre feeding	98.30	71.70	99.30	1.90
2 h post feeding	107.10	101.70	103.00	0.62
4 h post feeding	103.30	95.50	100.00	0.77
Acetate (TVFA%)				
Pre feeding	63.40	63.00	61.90	0.62
2 h post feeding	58.80	59.60	63.00	0.68
4 h post feeding	59.40	59.30	55.50	0.87
Propionate (TVFA%)				
Pre feeding	26.60	27.80	25.50	0.40
2 h post feeding	24.60	27.70	27.00	0.86
4 h post feeding	26.10	32.30	28.80	0.75
Butyrate (TVFA%)				
Pre feeding	10.10	9.20	12.60	0.57
2 h post feeding	16.50	12.70	13.30	0.50
4 h post feeding	14.50	12.20	11.90	0.43
pH				
Pre feeding	6.82	6.81	6.65	0.11
2 h post feeding	6.50	6.22	6.17	0.11
4 h post feeding	6.27	6.01	6.01	0.33

TVFA = Total Volatile Fatty Acids

Table 6: Numbers of protozoa in ruminal fluid of the goats when fed the experimental diets

	Diet code			
Experimental diets	Low fat	High fat	High fat + yeast	SEM
Entodinium (number x 103 mL^{-1})				
Pre feeding	33	33	33	10.0
2 h post feeding	33^{c}	100^{a}	67^{b}	9.0
4 h post feeding	33^{c}	67^{a}	67^{a}	7.4
Isotricha (number x 103 mL^{-1})				
Pre feeding	38^{b}	53^{a}	42^{b}	1.7
2 h post feeding	45^{a}	45^{a}	32^{b}	1.1
4 h post feeding	25	25	25	1.1

Means within the same row not sharing the same superscript letter are significantly different

Earlier studies (Hristov *et al*., 2009; Vafa *et al*., 2009; Polviset *et al*., 2010) have also shown that high-fat intakes depress the digestibility of fiber in ruminants. In rumen-fistulated beef steers we have found that fat feeding raised the apparent, total gastrointestinal tract digestibility of crude fat (Polviset *et al*., 2010). This effect can be explained by an increase in the absolute amount of undigested crude fat in feces and subsequent lowering of the fraction of endogenous fat.

The present effects of high tallow intake on NDF and crude fat digestibility did not reach statistical significance but this relates to the relatively low statistical power of this study due to fact that only three rumen-fistulated goats were used. The main hypothesis tested in this study was that the feeding of live yeast would negate the inhibitory effect of high-tallow intake on rumen fermentation. More specifically, it was hypothesized that a fat-induced depression of the cellulolytic bacteria would be counteracted by a yeast-induced stimulation of cellulolytic bacteria.

For the testing of the hypothesis, it is a prerequisite that high versus low intake of tallow would have caused less fiber fermentation, less acetate production and higher ruminal pH. The group-mean apparent digestibility of NDF was indeed slightly decreased after the inclusion of extra tallow in the concentrate but the high-tallow ration lowered post-feeding, group-mean ruminal pH and did not influence the ruminal concentration of acetate. These data indicate that the high-tallow intake did not have the anticipated effects on rumen function so that testing the hypothesis was not feasible. On the other hand, this study should allow to disclose an effect of yeast if any as the only dietary variable on feed intake and rumen function.

An interesting finding was that the high-tallow ration without yeast significantly raised the voluntary intake of grass silage. This effect might be specific for tallow. Bernard *et al*. (2005) found that sunflower oil at a level of 3.5% of the dry matter intake did not affect feed intake in goats.

The high-fat ration with yeast did not increase the intake of dry matter with grass silage. This is a surprising observation when compared with literature data. Belewu *et al*. (2004) reported that yeast supplementation improved feed intake in goats. Supplemental yeast has

also been shown to raise feed intake in dairy cows (Erasmus *et al*., 1992). In goats and sheep (Ahmed and Ibrahim, 2007), the ingestion of a yeast culture stimulated rumen fermentation (El-Ghani, 2004). The lack of effect of yeast supplementation on feed intake in this study agrees with the other observations.

The addition of yeast to the high-tallow ration did not stimulate apparent digestibility of NDF did not lower ruminal pH and did not raise ruminal acetate concentrations. Thus, the feeding of yeast did not stimulate rumen fermentation so that the passage of ingested feed through the rumen was not increased. As a consequence, yeast supplementation did not raise voluntary feed intake.

On the basis of a study by Ivan *et al*. (2001), it was anticipated that the high-fat ration would lower the number of ruminal protozoa. However, there was an increase in the post-feeding number of entodinium and an increase in the pre-feeding number of Isotricha. The addition of yeast to the high-tallow ration had lowered ruminal Entodinium and Isotricha at 2 h post feeding. Earlier research on sheep showed that yeast supplementation did not affect the number of protozoa in the rumen (Galp, 2006; Tripathi *et al*., 2008). Thus, there is no clear picture as to the effect of yeast feeding on ruminal protozoa in small ruminants.

This may be caused by differences in experimental set ups of the various studies and the species of protozoa that were assessed.

CONCLUSION

It is said from the study that the addition of yeast to a high-tallow ration did not improve feed intake and rumen function in goats. It must be emphasized that the high-tallow intake did not have the anticipated effects on rumen function which may have interfered with the testing of the yeast effects in this study.

It cannot be excluded that higher fat intake or the use of an oil rich in polyunsaturated fatty acids instead of tallow would have elicited beneficial effects of yeast. The toxic effect of fatty acids on ruminal bacteria depends on the amount and type of fat. Especially, oils with a high degree of unsaturation disturb ruminal fermentation (Coppock and Wilks, 1991).

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