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Effects of dried rice distillers' and grain supplementation on the performance of lactating cows

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Abstract

The aim of this study was to evaluate the nutritive value of dried rice distillers' grain (DRDG) as part of the feed concentrate for lactating cows. Twenty-four lactating Holstein cows that were in early lactation, with an average live-weight of 650 kg and producing 29 kg milk daily, were selected. The cows were then divided into three different groups according to milk yield and number of lactations. The treatment involved various levels of DRDG in the diets. The experimental diets were formulated into three iso-nitrogens and iso-energetic diets that included 0, 10, or 20% DRDG in the diet, respectively. After one week of adaptation, the experimental feeding period began, lasting three weeks. For the purpose of promoting palatability, molasses were added to all diets after the first four weeks of feeding. Three cannulated cows were examined in order to investigate the effects of DRDG supplementation on ruminal fermentation.

The results indicated that milk yield and 4% fat-corrected milk for the control and the 10% DRDG groups were higher than the 20% DRDG group ($p<0.05$). Daily dry matter intake also showed a similar trend ($p<0.05$) except during the first month of feeding, when the daily dry matter intake of the 10% DRDG group was higher than the 20% groups ($p<0.05$) (without the molasses addition). With respect to milk composition (milk fat and nonfat solid), the 20% DRDG group demonstrated with lower milk fat and nonfat solids than the other two groups ($p<0.05$). The 20% DRDG group was lower in milk protein than the 10% DRDG group, but was no different from the control group ($p>0.05$). During the experimental period, body weight change and serum urea-nitrogen concentration were no different among the treatment groups ($p>0.05$). The milk urea nitrogen concentration for the 20% DRDG group was higher than the other two groups ($p<0.05$). Ruminal pH value and concentration of ruminal ammonia nitrogen were not significantly influenced by the inclusion of DRDG. Total volatile fatty acids and the acetic-to-propionic acid

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ratio, however, were significantly lower for the cows treated with 20% DRDG than the other two groups (p<0.05).

Keywords: Dried rice distillers' grain; Feeding value; Dairy cow; Lactating performance; Ruminal fermentation

1. Introduction

Rice distillers' grain is a by-product of the processing of rice wine which is produced from the distillation of fermented brown rice, steam cooked at 131°C and 2.6 kg/m^2 pressure. It is an important by-product of the distillers industries in Asian countries. Annual wet rice distillers stillage production in a single local winery in Taiwan alone exceeds 365 000 tons. This volume of wet stillage will create a serious environmental problem if it is spread onto fields.

Research has shown that distillers' grains are considered good sources of protein for dairy cattle (Warner, 1970). It contains a valuable source of supplemental protein with high rumen undegradability, ca. 47% of crude protein as compared to 35% in soybean meal (National Research Council, 1989; Chiou et al., 1996). It also contains other nutrients recovered from fermented grains. These include low soluble carbohydrates, relatively high fiber, high fat and factor that stimulate cellulose digestion in the rumen (Hatch, 1993). The nutrients in distillers' grains are closely related to the grains from which they are made. Most commercially available distillers' grains are produced predominantly from corn. The nutrient content and feeding value of rice distillers' gain is expected to be different from most commercially available sources since the ingredients for rice wine production include primarily rice grain with only a small amount of corn.

There is little information on the feeding and nutritional value of this important by-product from rice. The aim of this study is, therefore, to evaluate the nutritive value of dried rice distillers' grain as part of the concentrate for lactating cows.

2. Material and methods

2.1. Experimental ration formulation

Three experimental diets were formulated into three total mixed rations. Diet 1 was a control diet without the inclusion of dried rice distillers' grain (DRDG). Diets 2 and 3 included 10 and 20% DRDG, respectively. All experimental diets were formulated iso-nitrogenous and iso-energetic, according to the nutrient requirements of the National Research Council (1989), applying a safety factor of 10% to allow for variable ingredient composition. Experimental cows, averaging 650 kg in body weight, produced, on average, 29 kg of milk daily.

Table 1 presents the diet formulation and nutrient analysis. The experimental diets were fed as total mixed rations (TMR) with concentrate and roughage at a ratio of 45 : 55 (dry matter basis). On dry matter basis, roughage consisted of one part alfalfa pellets, one

Table 1
Diet formulation, g/kg

	Control	10% DRDG	20% DRDG
Ingredients			
Alfalfa	100.0	100.0	100.0
Corn silage	350.0	350.0	350.0
Oat hay	100.0	100.0	100.0
Soybean, full-fat	46.0	44.0	42.0
Soybean meal, 44%	83.0	50.0	17.0
Corn, dent yellow	207.0	114.0	20.0
Corn, flake	—	16.0	35.0
Wheat bran	98.0	110.0	120.0
Rice distiller's grains [a]	—	100.0	200.0
Limestone	10.0	10.0	10.0
Iodine salt	3.0	3.0	3.0
Premix [b]	3.0	3.0	3.0
Total	1000.0	1000.0	1000.0
Calculated nutrient value			
Crude protein	153.0	153.0	153.0
Net energy for lactation, KJ/kg	7.943	7.943	7.943
Undegradable N, %CP	36.4	36.4	36.4
Analyzed nutrient value			
Crude protein	154	157	158
Acid detergent fiber	93	229	296
Neutral detergent fiber	352	394	474
Crude fat	49	93	142

[a] The nutrient analysis value of the rice distilers' grains (%DM): NDF, 53.19; ADF, 42.08; NDFIN, 62.47 (% of CP); ADFIN, 34.90 (% of CP); crude protein, 19.90; crude fat, 31.95; crude fiber, 21.99; ash, 1.56; Ca, 0.15; Na, 0.33; K, 0.24; Mg, 0.17; and P, 0.26.
[b] Premix contains (each kg of premix); Vitamin A, 1 100 000 IU; Vitamin E, 3,520 IU; Vitamin D_3; 110 000 IU; Ca, 162 g; Zn, 6.4 g; Mn, 5.3 g; Co, 0.785 g; Cu, 2.56 g; and Se, 0.053 g.

part oat hay and three-and-a-half parts corn silage. The concentrate was mainly yellow corn (raw and flaked), soybean (meal and full fat), wheat bran and DRDG. The average analysis of DRDG (dry matter basis) taken from the winery was as follows; crude protein 20.90%, NDF 53.19%, ADF 42.08%, NDFIP 62.47% (of CP), ADFIN 34.96% (of CP), crude protein 19.90%, crude fat 31.95%, crude fiber 21.99%, ash 1.56%, calcium 0.15%, phosphorus 0.26%, sodium 0.33%, potassium 0.24% and magnesium 0.17%.

The concentrates were mixed daily with the roughage. The moisture content of the corn silage was measured weekly for adjustment of the as-fed ration composition. Molasses was added to the diets after one month of feeding to promote appetite.

2.2. Animal characteristics and management

Twenty-four cows, producing more than 29 kg of milk daily, were selected and allocated to the three dietary-treatment groups according to milk yield and number of lactations. The cows were confined for individual feeding during eating time, and released for exercise after feeding. The cattle were dewormed twice monthly during the experimental period.

After one week of adaptation, the cows began an eight-week feeding trial. These cows were individually fed ad libitum with 2–3 kg orts at three meals per day (03:00, 09:00 and 18:00 h). Water was provided individually with an automatic bowl type drinker. The cows were milked twice daily at 05:30 and 17:30 h.

During the feeding period, dry matter intake and milk yields were recorded daily. The dry matter intake was calculated from the amount fed subtracted from the dry matter ort. Milk samples were taken once weekly. The live-weight of the cows was measured at the beginning, in the fourth week and at the end of the trial. Feed samples, both fed and orts, were taken weekly and dried at 60°C in a ventilated oven for 48 h. At the beginning, in the middle and at the end of the trial, blood samples were taken 6 h post-prandial.

2.3. Rumen fermentation studies

Three dry cows with rumen fistulas were randomly assigned to the three treatments according to a Latin square design. Each treatment period was 12 days with a seven-day preliminary period. Samples of 200 ml ruminal fluid were taken on the eleventh and twelfth day in the morning before feeding, and 1, 2, 3, 4, 6 and 8 h post-prandial. Ruminal pH was measured immediately after withdrawal. The samples were then filtered through four layers of cheese cotton and diluted with 25% metaphosphoric acid. After mixing, the samples were sealed and preserved at −18°C for later analysis of ammonia nitrogen and volatile fatty acids.

2.4. Chemical analysis

The analysis of feed samples was conducted according to the methods of the AOAC. (1984), neutral detergent fiber (NDF), neutral detergent fiber insoluble protein (NDFIP), acid detergent fiber (ADF) and acid detergent fiber insoluble protein (ADFIP) were analyzed according to the methods of Van Soest et al. (1991), using an automatic fiber analyzer (Fibertec System M, Tecator AB) after the starch was eliminated through heat stable α-amylase (Sigma, No. A3306).

Milk composition, comprising fat, protein and total nonfat solids, was analyzed using a milk scanner (Foss Electric, Milko Scan 255 A/B types) according to the infra-red method of the AOAC. (1984). Analysis of serum nitrogen was performed with an automatic blood chemical analyzer (Hitachi 7050) according to the method of Roseler et al. (1993). The pH value of the rumen fluid was measured using a pH meter (Model 6007, Jenco). The concentration of ruminal ammonia nitrogen was analyzed according to Chaney and Marbach (1962) by spectrophotometer (UV-2000, Hitachi). The ruminal concentration of volatile fatty acids was determined according to Erwin et al. (1961) using gas chromatography (G-3000, Hitachi) with the temperature of the column set at 125°C, injector at 200°C, and detector at 200°C, Using N_2 as a carrier gas at a pressure of 4 kg/cm^2 and flowing speed of 25 ml/min, H_2 pressure at 1.1 kg/cm^2 with a flow speed of 23 ml/min, air pressure of 1.0 kg/cm^2 with the flow speed set at 450 ml/min.

2.5. Statistical analysis

A completely randomized design for the feeding trial and a Latin square design for the ruminal studies was applied to determine the dietary effects. Analysis of the variance was calculated with the general linear model (GLM) procedure of the Statistical Analysis System (1985). Duncan's new multiple range test was used to compare the treatment means according to Steel and Torrie (1960).

3. Results and discussion

Since this feeding trial was conducted from March to May in central Taiwan, the environmental temperature began to rise at the end of first month of this feeding trial. The feed intake and milk production showed a trend toward decline. Molasses was therefore added to increase appetite after the first month of feeding in this trial.

3.1. Dry matter intake

Table 2 presents the effect of DRDG inclusion in this diet on the performance of lactating cows. The inclusion of DRDG significantly depressed dry matter intake ($p<0.05$). The cows ate progressively less as the level of DRDG inclusion increased in the diet during the first month of feeding ($p<0.05$). The decrease in average DM intake was 1.30 kg for the 10% and 3.39 kg for the 20% of DRDG inclusion as compared to the control. DM intake increased in the 20% DRDG group by adding 0.02 kg molasses per kg diet to improve palatability during the second month of feeding. The dry matter intake did not improve in the second month from the molasses inclusion due to the increase in ambient temperature which depressed the feed intake. The DM intake was therefore still significantly less with the DRDG inclusion in the diet ($p<0.05$). Since by-products of the distiller industries generally reflect the grain used in fermentation, rice distillers' grain reflects the content of brown rice that is grains, less hull and starch, and contains 22% crude fiber and 32% crude fat (Table 1). The fatty acid composition of DRDG resembles rice bran which contains highly unsaturated fatty acids. The high crude fiber and high unsaturated fatty acids may have contributed to the lower DM intake. Steel and Moore (1968) suggested that an excess amount of dietary fat may depress feed intake and disturb ruminal fermentation. Pantoja et al. (1994) pointed out that DM intake linearly decreases as dietary unsaturated fat increases. Mertens (1985) suggested that dietary neutral detergent fiber (NDF) negatively correlates to the DM intake. Christensen (1991) also suggested a maximum dietary NDF of 36–38%, therefore NDF in excess of the dietary maximum will depress DM intake. The NDF content in the 10 and 20% DRDG group in this trial was 39.4 and 47.4%, respectively, which exceeded the NDF maximum set by Christensen (1991).

3.2. Milk yield

The level of DRDG inclusion significantly influenced the milk yield of the lactating cows ($p<0.05$). Inclusion of 20% DRDG significantly depressed milk production

Table 2
Effect of inclusion level of dried rice distillers' grains in the diet on the performance of lactating cows

Items	Control	10% DRDG	20%DRDG	SEM
DM intake, kg				
1st month	26.67 [a]	25.37 [b]	23.28 [c]	0.68
2nd month	25.28 [a]	23.67 [b]	23.31 [b]	0.97
whole period	26.12 [a]	24.69 [b]	23.50 [b]	0.85
Milk yield, kg				
1st month	32.05 [a]	30.89 [a]	26.72 [b]	1.23
2nd month	28.47 [a]	29.41 [a]	24.05 [b]	1.26
whole period	30.34 [a]	30.19 [a]	25.53 [b]	1.34
4% fat-corrected milk yield, kg				
1st month	29.56 [a]	29.91 [a]	23.15 [b]	1.33
2nd month	26.73 [a]	27.40 [a]	19.54 [b]	1.26
whole period	28.22 [a]	28.69 [a]	21.50 [b]	1.41
Milk composition, %				
Nonfat solid				
1st month	8.89 [a]	8.97 [a]	8.54 [b]	0.12
2nd month	8.80 [b]	8.83 [a,b]	8.92 [b]	0.07
whole period	8.87 [b]	8.96 [a]	8.63 [b]	0.12
Milk fat				
1st month	3.46 [b]	3.74 [a]	3.15 [c]	0.14
2nd month	3.58 [a]	3.51 [a]	2.80 [b]	0.19
whole period	3.52 [a]	3.63 [a]	2.98 [b]	0.17
Milk protein				
1st month	3.27 [b]	3.38 [a]	3.22 [b]	0.07
2nd month	3.36	3.42	3.41	0.08
whole period	3.31 [b]	3.42 [a]	3.28 [b]	0.08
Live-weight change, %				
1st month	103.5 [a]	101.0 [a,b]	99.2 [b]	1.4
2nd month	101.2	105.1	106.0	1.9
whole period	104.8	106.2	105.1	2.1

[a,b and c] Means within the same row without the same superscripts are significantly different (p<0.05).

(p<0.05), where 10% inclusion did not significantly affect milk production in the 1st and 2nd months of feeding. This decline in milk yield by high DRDG inclusion may be attributed to the low feed intake. Most research agrees that the major factor that depresses milk yield is a decrease in feed intake (Davis and Merilau, 1960; Wayman et al., 1962).

3.3. Milk composition

Effect of the level of inclusion of DRDG in the diet significantly influenced the milk composition which includes the percentage of milk protein, milk fat and nonfat solids (p<0.05). High level of DRDG inclusion significantly depressed milk fat (p<0.05), but a low level of inclusion did not significantly influence the percentage of milk fat. The effect of high DRDG inclusion depressing milk fat may be attributed to the high dietary fat and unsaturated fatty acid content in the DRDG. The 20% DRDG diet contained 14.2% fat which exceeded the dietary fat maximum of 7–8% suggested by Palmquist and Conrad (1978). Pantoja et al. (1994) pointed out that the adverse effect of unsaturated fatty acid will disturb ruminal fermentation and depress fiber digestion. These suggestions may explain the low milk fat from the high DRDG inclusion in our data. High dietary DRDG inclusion significantly depressed not only the nonfat solid percentage but also the milk fat concentration ($p<0.05$).

Low level of DRDG inclusion in the diet significantly increased the milk protein percentage ($p<0.05$), whereas a high level of inclusion did not significantly influence milk protein. Dietary factors including the dietary level of fiber and fat influenced the concentration of milk protein. Spicer et al. (1986) suggested a depression effect for nonstructural carbohydrate on milk protein due to the low availability of carbohydrates as an immediate energy source for microbial protein synthesis and growth in the rumen. Tessman et al. (1991) also demonstrated a decrease in milk protein by decreasing concentrate supplements in the diet. Palmquist and Moser (1981) suggested that fat inclusion in the diet may interfere with the insulin functions that influence amino acid transfer into the mammary gland, hence the decline in milk protein synthesis. They suggested a decrease of 0.03 unit milk protein for each 100 g of dietary fat intake. Cant et al. (1991) also demonstrated a decrease in milk protein by changing the energy utilization in the mammary gland due to the inclusion of dietary fat. They also found that high dietary fat impacted the mammary gland absorption of amino acids by depressing blood flow into the gland by 7%. Inclusion of DRDG which increased the dietary level of fat and decreased nonstructural carbohydrates, would result in a decrease in milk protein. The inclusion of DRDG, however, not only changed the dietary level of fat and nonstructural carbohydrates, but also changed cellulose digestion and ruminal microbial fermentation. This may be attributed to the increase of milk protein in a low DRDG inclusion diet and decrease of milk protein in a high DRDG inclusion diet.

3.4. Urea concentration

Table 3 presents the effect of DRDG inclusion on the urea nitrogen concentration of both, blood and milk. Inclusion of DRDG did not significantly influence the blood serum concentration in the middle and at the end of the feeding trial. This may indicate that the level of ruminal ammonia remained quite constant regardless of the levels of DRDG inclusion in the diet. Although DRDG contains high undegradable protein, this may lead

Table 3
Effect of dried rice distiller's grain inclusion in the diet on urea nitrogen in the serum and milk of lactating cows

Item	Control	10% DRDG	20% DRDG	SEM
Milk urea nitrogen, mg/dl				
at beginning	7.93 [a]	7.83 [a]	8.94 [b]	0.29
at end of 1st month	7.68 [a]	7.30 [a,b]	7.24 [b]	0.25
at end of 2nd month	7.82 [a]	7.60 [a]	8.18 [b]	0.32
Serum urea nitrogen, mg/dl				
at beginning	11.43	12.12	11.65	0.81
at end of 1st month	10.25	9.05	9.51	0.49
at end of 2nd month	10.84	10.58	10.58	0.54

[a and b] Means within the same row without the same superscripts are significantly different ($p<0.05$).

Table 4
Effect of dried rice distillers' grain inclusion in the diet on the ruminal fermentation characteristics of dairy cows

Item	Control	10% DRDG	20% DRDG	SEM
pH value	6.09	6.12	6.14	0.03
Ammonia N, mg/dl	28.83	29.01	27.87	1.24
Total VFA, mM	85.79 [a]	88.16 [a]	78.17 [b]	2.28
Acetate, mol%	62.18 [a]	61.44 [a]	57.31 [b]	0.71
Propionate, mol%	19.30 [b]	19.67 [b]	23.20 [a]	0.89
Acetate/propionate ratio	3.22 [a]	3.12 [a]	2.47 [b]	0.19
Isobutyrate, mol%	1.39	1.32	1.33	0.07
Butyrate, mol%	13.38 [b]	14.21 [a]	14.69 [a]	0.27
Iso-valerate, mol%	2.20 [a]	1.90 [b]	1.99 [b]	0.07
Valerate, mol%	1.56	1.45	1.48	0.07

[a and b] Means within the same row without the same superscripts are significantly different ($p<0.05$).

to a lower ruminal ammonia concentration, hence the low serum urea level in the high DRDG inclusion group. All the experimental diets in this trial, however, were adjusted into iso-nitrogenous and equal ruminal protein undegradability. Our data showed a trend toward lower ruminal ammonia nitrogen in the high DRDG inclusion group (Table 4), serum urea concentration, however, did not reflect the lower ruminal ammonia concentration.

A number of studies indicated that urea concentration in the serum and milk is highly correlated (Oltner, 1985). However, this does not agree with our finding in this study, namely that urea concentration in the milk was significantly influenced by the high inclusion of DRDG ($p<0.05$), whereas the serum urea concentration did not show the same trend.

3.5. Ruminal fermentation characteristics

Table 4 presents the effect of dried rice distiller's grain inclusion in the diet on the ruminal characteristics of dairy cows. Adding different levels of distiller's grain did not significantly influence the ruminal pH value and ammonia nitrogen. The ruminal pH values in these experimental animals were higher than 6.2 before feeding, decreasing to 6.1 after feeding and gradually increasing thereafter (Fig. 1). Ruminal ammonia concentration, on the other hand, increased after feeding, reaching a maximum 3 h after feeding, and gradually declined thereafter (Fig. 2). The ammonia nitrogen level was kept above 21.6 mg/dl, greater than the minimum level of 5 mg/dl required for maximum microbial growth (Satter and Roffler, 1975).

Inclusion of a high level of distillers' grains, however, significantly depressed ruminal total VFA concentration (Table 4) (Fig. 3). This suggested a depressive effect on ruminal fermentation due to the high level of DRDG inclusion. High NDF, ADF with high crude fat in the high DRDG diet, contained equal dietary energy to the other treatment diets (Table 1), but supplied less available ruminal energy for microbial growth. This agreed with what Pantoja et al. (1994) suggested, interference with ruminal fermentation and depression of fiber digestion by unsaturated fat, hence a decrease in VFA production.

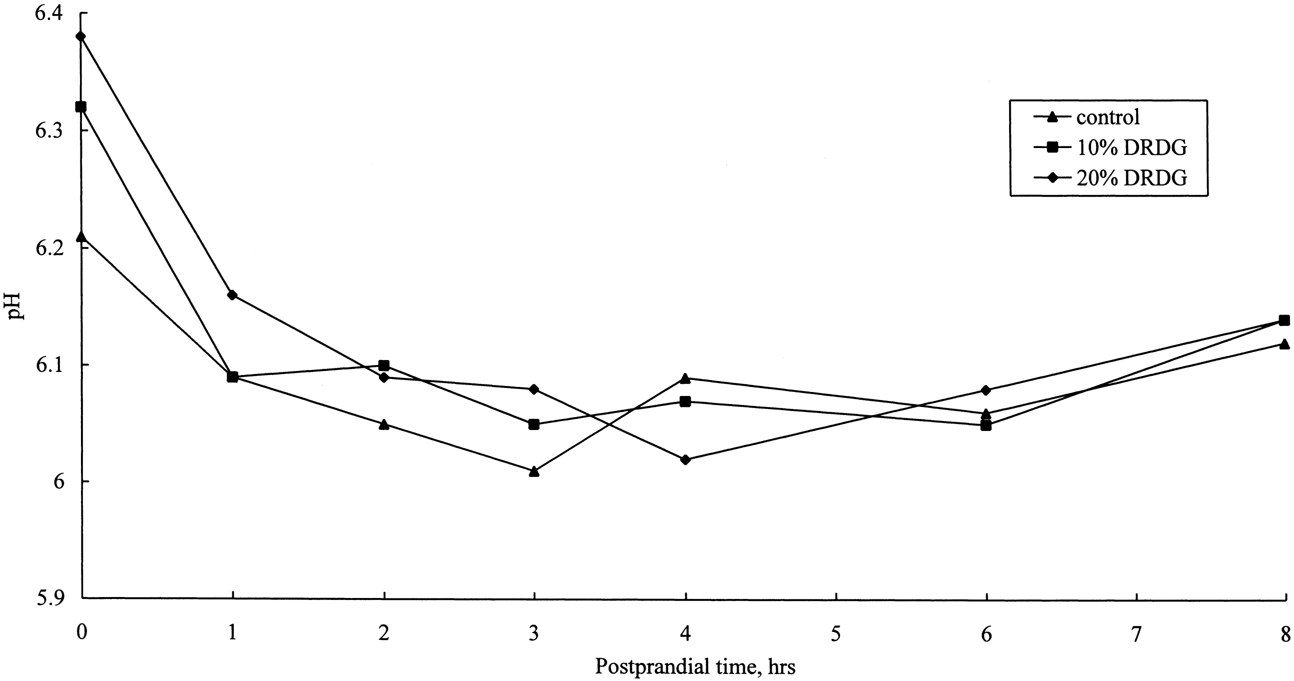

Fig. 1. Effect of dried rice distiller's grain inclusion in the diet on the ruminal pH value.

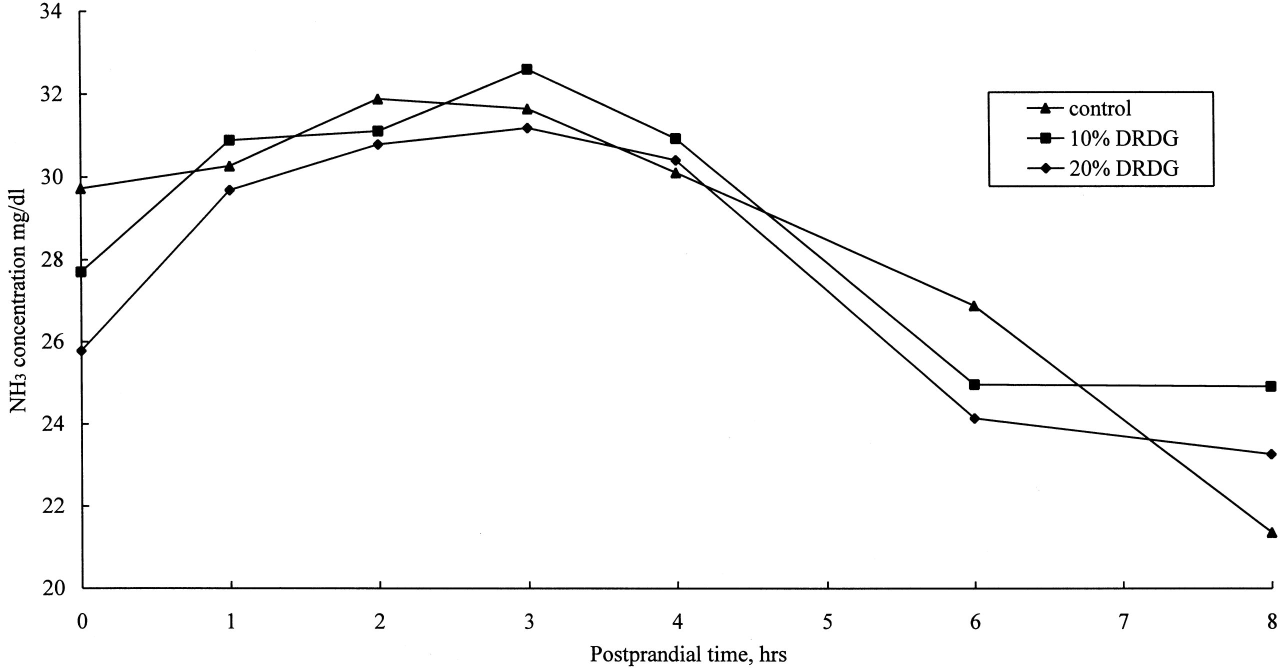

Fig. 2. Effect of dried rice distiller's grain inclusion in the diet on the ruminal ammonia nitrogen concentration.

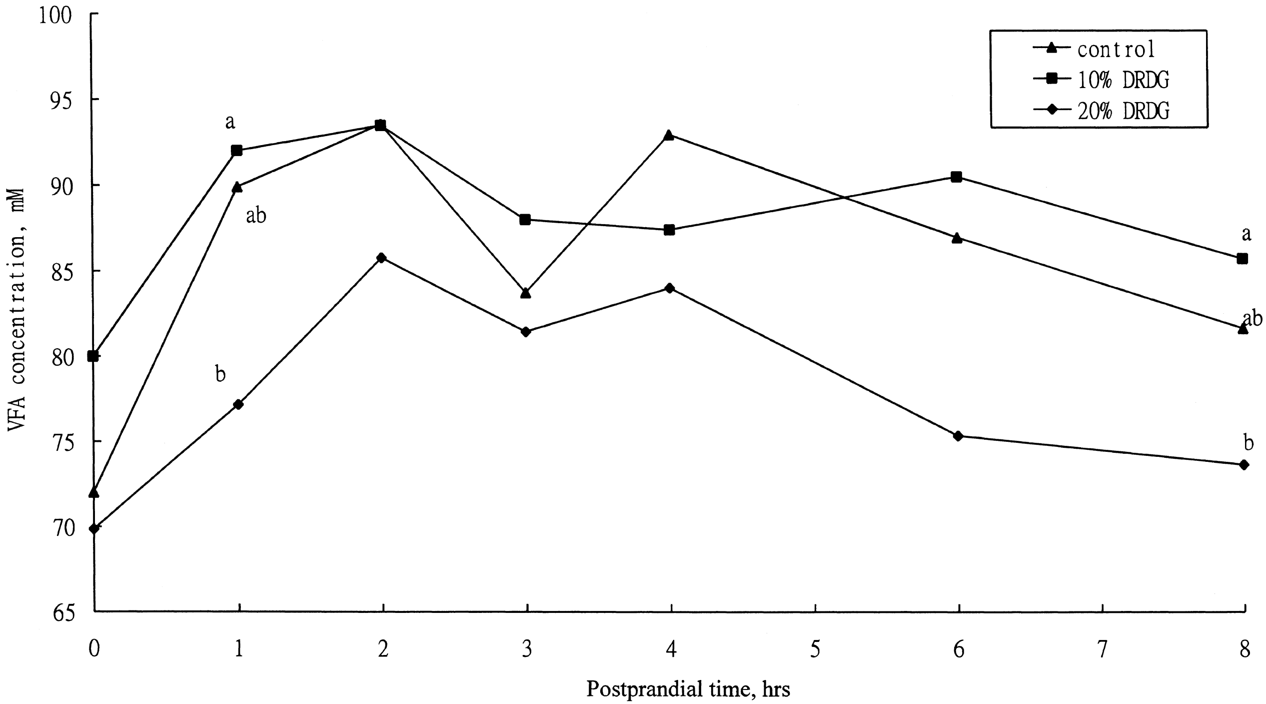

Fig. 3. Effect of dried rice distiller's grain inclusion in the diet on the ruminal total volatile fatty acid concentration. a,b, and c represent means in the same post-prandial hours followed by different letters are significantly different ($p < 0.05$).

Inclusion of DRDG also significantly influenced the molar percentage for various volatile fatty acids except iso-butyrate and valerate ($p<0.05$). High levels of inclusion (20% DRDG) significantly depressed acetate and increased propionate and butyrate resulting in a decreased acetate-to-propionate ratio ($p<0.05$). This lower acetate to propionate ratio was reflected in lower milk fat concentration on account of high inclusion of the distiller's grains (Table 2). However, a low level of DRDG inclusion neither caused a decrease in the acetate-to-propionate ratio nor depressed milk fat (Table 2).

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