Asian-Aust. J. Anim. Sci.
Vol. 21, No. 4 : 547 - 554
April 2008

www.ajas.info

Effect of Monensin and Live Yeast Supplementation on Growth Performance, Nutrient Digestibility, Carcass Characteristics and Ruminal Fermentation Parameters in Lambs Fed Steam-flaked Corn-based Diets*

J. Ding, Z. M. Zhou, L. P. Ren and Q. X. Meng**
State Key Laboratory of Animal Nutrition, College of Animal Science and Technology
China Agricultural University, Beijing 100094, China

ABSTRACT : In performance, digestibility and slaughter trials, a total of forty five male weaned lambs were used to examine the effects of monensin and live yeast supplementations on growth performance, nutrient digestibility, carcass characteristics and ruminal fermentation parameters when the lambs were fed steam-flaked corn-based diets. Animals were allotted to one of three treatment diets in a completely randomized design. The three treatment diets were: (1) basal diet (CON) with steam-flaked corn as a sole grain source, (2) basal diet supplemented with monensin (MO), and (3) basal diet supplemented with live yeast (LY). Total average daily intake (ADI) was unaffected by MO and LY supplementations. LY supplementation increased ($p<0.05$) average daily gain (ADG) by 13.1% compared with the CON diet. Both MO and LY supplementations resulted in a significant improvement ($p<0.05$) of feed efficiency over the CON diet (4.47, 4.68 vs. 5.05). Hemicellulose digestibility was higher ($p<0.05$) for lambs in the LY supplementation group (62.4%) as compared with the CON group (55.7%), but no differences were observed in digestibilities of dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF). All carcass traits were not influenced by dietary supplementations. Ruminal pH in lambs fed the LY supplemental diet was more stable than that with the CON diet (6.57 vs. 6.17). Neither MO nor LY supplementation influenced the concentration of ruminal ammonia-N and total volatile fatty acid (VFA), and molar percentages of individual VFA. Plasma urea-N concentration was decreased ($p<0.05$) by MO and LY supplementations, while plasma β-hydroxybutyrate (BHBA), glucose and other blood parameters were unaffected. In conclusion, while both MO and LY supplementations had a positive impact on feed efficiency and LY supplementation stabilized ruminal pH and improved fiber utilization, none of the supplements had the capacity to significantly enhance the carcass characteristics. (**Key Words :** Weaned Lambs, Monensin, Live Yeast, Growth, Digestibility, Carcass Characteristics)

INTRODUCTION

Steam-flaked corn is a widely used grain for ruminants in many countries, because steam flaking is known to effectively improve the feeding value of grains, principally through increasing the rate and extent of grain starch digestion in the rumen and the intestines by increasing the degree of starch gelatinization (Zinn et al., 1995). However, the rapid ruminal fermentation rate of grain starch may yield a potential risk to rumen microbial ecosystem due to the accumulation of organic acids within the rumen (Reinhardt et al., 1997). The rapid rate of pH decline would disrupt normal rumen function, e.g. depressed microbial activity and therefore lower nutrient digestibility, especially for fiber digestion (Grant and Mertens, 1992).

The use of ionophore monensin, a polyether antibiotic, is one of the most common methods for modulating ruminal fermentation. The modes of action of monensin rely on selective growth inhibition of gram-positive organisms (Van Nevel and Demeyer, 1988), reducing lactic acid production (Dennis et al., 1981) and methanogenesis in the rumen (Goodrich et al., 1984) and increasing molar proportion of propionate (Goodrich et al., 1984) and N retention (Adams et al., 1981). The positive production responses of livestock to dietary monensin supplementation have been well-documented, e.g. improvement of feed conversion, particularly in high-grain diets (Boucqué et al., 1982). However, Kohler et al. (2000) reported that certain

* The work was financially supported by the National Natural Scientific Foundation of China (Project No. 30270944 and No. 30125033).
** Corresponding Author: Q. X. Meng. Tel: +86-10-6273-3799, Fax: +86-10-6273-3799, E-mail: qxmeng@cau.edu.cn
Received June 22, 2007; Accepted September 7, 2007

Table 1. Ingredients, calculated analysis and chemical composition of the mixed concentrate diet (g/100 g DM)

Ingredient	
Steam flaked corn grain	64.5
Wheat bran	7.3
Soybean meal	11.0
Cottonseed meal	14.5
Calcium carbonate	0.9
Calcium hydrogen phosphate	0.9
Trace mineral-vitamins premix[1]	0.9
Calculated content[2]	
ME[2] (MJ/kg)	12.4
Analysed content[3]	
Protein (%)	19.3
Starch (%)	44.3
NDF (%)	15.3
ADF (%)	7.3
Ca (%)	0.67
P (%)	0.70

[1] Trace mineral-vitamin premix contained (per kg) 2,100 mg Cu; 1,800 mg Zn; 2,700 mg I; 30 mg Co; 60 mg Se; 1,200,000 IU vitamin A; 330,000 IU vitamin D; 8,700 IU vitamin E.

[2] ME: metabolizable energy, calculated from the tabular value (NRC, 1985).

[3] Values determined in the laboratory.

antibacterials used as growth promoters in animal feeding might increase the horizontal transfer of virulence genes between bacteria, though the effect was not observed from monensin *in vitro*. The use of in-feed antibiotics is subject to critique and raises concerns due to its potential involvement in the antibiotic residue in animal products and development of antibiotic-resistant pathogenic microbes (Mathew, 1998). Therefore, it is necessary to replace antimicrobial feed additives by specific feed additives (Martin et al., 1999).

The use of yeast products is considered as a safe and an attractive alternative approach. Previous reports showed that *Saccharomyces cerevisiae* live cells had an ability to remove oxygen from the rumen environment (Wallace, 1994) and release essential enzymes, vitamins and other nutrients or growth factors, which could facilitate bacteria to have a high viability and activity in the rumen (Wiedmeier et al., 1987). Supplementation of yeast products have been established to stabilize intraruminal milieu and fermentation in ruminants fed high-concentrate diets (Williams et al., 1991), increase nutrient digestibility and animal performance, e.g. feed intake, weight gain and milk yield etc. (Wiedimeier et al., 1987; Haddad and Goussous, 2005; Stella et al., 2007). However, the efficacy of yeast products on manipulation of rumen fermentation and animal performance varies with different diet, especially with different level of concentrate in the diet (Chademana and Offer, 1990; Kawas et al., 2007; Stella et al., 2007). Yeast additives seems to be more effective when they are included in the diet containing high levels of readily fermentable carbohydrates by efficaciously stabilizing ruminal pH (Chaucheyras-Durand and Fonty, 2002; Stella et al., 2007). However, there is little literature regarding supplement of live yeast products to the steam-flaked grain-based diet fed to lambs on their rumen environment and production performance. So, the objective of the present study was to compare the effects of monensin and live yeast supplementations to the steam-flaked corn-based diets fed to the weaned lambs on their growth performance, nutrient digestibility, carcass characteristics and ruminal fermentation parameters to provide some evidence in support that active yeast have the potential to replace in-fed antibiotics.

MATERIALS AND METHODS

Experimental diets and animals

Animals received an experimental basal diet with the following treatments: (1) no additives (CON); (2) monensin (MO) supplementation (Zhejiang Haizheng Veterinary Drug Co., China, 20% commercial premix); (3) live yeast (LY) supplementation (Lallemand Animal Nutrition S. A. France, 20×10^9 cfu/g). The basal diet consisted of the mixed concentrate and roughage. The ingredient and nutrient composition of the mixed concentrate is presented in Table 1. Steam-flaked corn (average bulk density, 390 g/L) was used as a sole grain source. The roughage sources were alfalfa hay containing 15.7% CP, 48.2% NDF, 36.0% ADF, 1.32% Ca, and 0.30% P, and cottonseed hulls containing 5.8% CP, 83.2% NDF, 59.9% ADF, 0.20% Ca, and 0.11% P, respectively. Monensin was added to the concentrate diet with the final concentration of 38 mg/kg DM. Live yeast was provided once a day in the form of capsule at evening feeding time (5 pm) at 0.5 g per animal.

Forty-five weaned male castrated lambs (1/2 Dubo, 1/2 Native Xiaowei Hanyang Sheep), about 3 mo old and weighing 20.5±2.0 kg were assigned to three dietary treatments in a completely randomized design (3 lambs per pen, 5 pens per treatment). The lambs were dewormed with Ivermectin at the recommended dose before the trial started. Animal care and use of all animals in this study were conducted under the approval of the China Agricultural University Animal Science and Technology College Animal Care and Use Committee.

Growth performance trial

The growth performance trial lasted for 49 days, including a 7-day adaptation period and 42-day growth data collection period. Over the duration of this trial, the mixed concentrate and alfalfa hay were fed based on 2.4% and 0.6% body weigh (DM basis) respectively, and lambs were weighed every 2 weeks to adjust the given amount.

Cottonseed hulls and water were always freely accessible to animals. The mixed concentrate and roughages were weighed once daily and hand-fed quarterly daily (6 am, 9 am, 5 pm and 9 pm). Every day the orts were carefully collected by hand and weighed. Lambs were weighed before morning feeding on two consecutive days both at initiation and the end of the trial to determine body weight (BW) gain. The average daily gain (ADG) and average daily intake (ADI) were determined and feed efficiency was calculated.

Digestibility experiment

At the end of the performance trial, the lambs randomly selected from each treatment (2 lambs per pen, 5 pens per treatment) were penned to determine the digestibilities of DM, OM, starch, protein, NDF, ADF and hemicellulose. The experimental period consisted of a 5 days preliminary period and another 5 days for quantitative collections of feces. All lambs were fed with the basal mixed concentrate and alfalfa hay based on 2.4% and 0.6% (on DM basis) of BW as before, and cottonseed hulls were restrictedly fed at 90% of the *ad libitum* intake during the growth performance phase. Other management regime of lambs in this digestibility experiment was the same as the performance trial described previously.

Feces were collected in polyethylene bags attached to the rear of the animal, emptied twice daily, weighed and stored at -20°C for further analysis. At the end of the 5-day collection, individual pen feces samples were thawed, pooled for each pen animals and completely homogenized by hand for 5 min. Defrosted and pooled samples were dried in an air-forced oven at 55°C for 96 h and ground through a 1-mm screen.

Slaughter trial and rumen fluid samples

At the end of the performance trial, a subset of fifteen lambs (one per pen and five per treatment) randomly chosen from each treatment were slaughtered before morning feeding according to the standard procedures of the general technical conditions for animal slaughtering (GB/T 17237-1998, China). Lambs had access to feed and water, until they were slaughtered. Carcass traits, including hot carcass weight, hot dressing percentage (hot carcass weight as a percent of live weight), grade rule (GR) value (Kirton, 1989) and ribeye area were measured. Rumen contents were collected after opening of the rumen. The pH of the rumen contents was measured immediately with pH meter equipped with a glass probe (PHS-3C, Shanghai Leici Instrument Co., China). Rumen contents were strained through four layers of gauze, centrifuged at 10,000×g for 15 min, and stored at -20°C for ammonia nitrogen (NH_3-N) and volatile fatty acid (VFA) analyses.

Blood sampling and biochemical analyses

Jugular blood samples were obtained before the morning feeding at the end of performance trial. A 5-ml blood sample was collected in sealed vacutainers containing heparin via jugular venipuncture, then immediately put on ice. Plasma was obtained from blood after centrifuged at 2,500×g at 4°C for 10 min, then stored at -20°C until analyzed for plasma total protein (PTP) (McBeath et al., 1971), urea-N (Marsh et al., 1965), glucose (Rosevar et al., 1969), β-hydroxybutyrate (BHBA) (Williamson and Mellandby, 1974) triglycerides and cholesterol (commercially available test kits, # 339 and # 352 respectively, Sigma Diagnostics, Sigma-Aldrich Chemical Co., St. Louis, MO).

Chemical analyses

Samples of feeds, orts and feces were analyzed for DM, OM, CP, starch, NDF, ADF and hemicellulose. The DM and OM content of the samples was determined based on AOAC (1997). Total N was determined using a Nitrogen Analyzer (Model Rapid N III, Elementar, Germany) based on the Dumas combustion method (AOAC, 1997). Starch content was measured by the method of enzymatic glucose release according to Xiong et al. (1990). The NDF and ADF contents were determined using methods of Van Soest et al. (1991). Hemicellulose was calculated as difference between NDF and ADF fractions. Ammonia-N concentration of rumen contents was measured by the method of Broderick and Kang (1980) using a spectrophotometer (UV-VIS 8500, Shanghai Tianmei Scientific Instrument Co., China). Ruminal VFA concentration was analyzed by gas chromatography (6890 N, Agilent Technology) with a 30-m HP-INNOWax 19091N-213 (Agilent) capillary column (0.32 mm i.d. and 0.50 m film thickness) according to Li and Meng (2006).

Statistical analysis

Data were statistically analyzed as a completely randomized design by the general linear model procedure (SAS, 1999) with pens as the experimental units. Differences among treatment means were analyzed using the least significant means (SAS, 1999). Initial BW was used as a covariant in the analysis. Treatment effects were considered statistically significant at $p<0.05$.

RESULTS AND DISCUSSION

Growth performance

Effects of monensin and live yeast supplementations on ADI, ADG, feed efficiency are presented in Table 2. ADI and ADG was unaffected by MO supplementation. However, feed efficiency was 11.5% higher ($p<0.05$) than that of the CON diet. It had been documented that monensin

Table 2. Growth performance in weaned lambs fed the steam-flaked corn-based diet supplemented with no addition (CON), monensin (MO) or live yeast (LY)[1]

Item	Treatment			SEM	Significance
	CON	MO	LY		
ADI (g)					
Mixed concentrate	604	595	619	16	NS
Roughage [2]	713	639	760	32	NS
Total	1,318	1,234	1,380	44	NS
ADG (g)	261.1[b]	275.7[ab]	295.3[a]	9.0	*
FE (ADI/ADG)	5.05[a]	4.47[b]	4.68[b]	0.11	*
LBW (live body weight, final) (kg)	31.8	31.7	33.0	1.2	NS

[1] n = 5, Values represent least squares means of 5 pens with three lambs each.
[2] Average daily roughage intake contained the total daily intake of alfalfa and cottonseed hulls, and the average daily intake of alfalfa were 165, 169, 162 g/d in CON, LY, MO group respectively; daily intake of cottonseed hulls were 549, 592, 477 g/d in CON, LY, MO group respectively.
NS: non-significant, and * $p<0.05$.
[a, b] Means within the same row denoted by different letters differ each other ($p<0.05$).

Table 3. Nutrient digestibilities in weaned lambs fed the steam-flaked corn-based diet supplemented with no addition (CON), monensin (MO) or live yeast (LY)[1]

Digestibility (%)	Treatment			SEM	Significance
	CON	MO	LY		
DM	61.5	61.9	64.3	1.2	NS
OM	63.8	63.9	66.4	1.1	NS
CP	57.3	58.0	59.2	1.1	NS
Starch	95.6	96.0	96.2	0.3	NS
NDF	42.7	43.4	47.7	2.1	NS
ADF	35.2	35.9	39.2	2.5	NS
Hemicellulose	55.7[b]	57.1[b]	62.4[a]	1.7	*

[1] n = 5, Values represent least squares means of 5 pens with two lambs in each pen. NS: non-significant, and * $p<0.05$.
[a, b] Means within the same row denoted by different letters differ each other ($p<0.05$).

administration suppressed ADI, but had a slight effect on live weight gain, which consequently increased feed energy efficiency (Boucqué et al., 1982).

No difference was observed in ADI of mixed concentrate and roughage between LY and CON treatments. The ADG of lambs fed the LY diet was 13.1% higher ($p<0.05$) than the lamb fed the CON diet (295.3 vs. 261.1 g/d), and the feed efficiency of lambs fed the LY diet was 7.3% higher ($p<0.05$) than that of the animals fed the CON diet. Haddad and Goussous (2005) indicated that feeding yeast culture increased the digestibilities of DM, OM, CP, NDF and ADF, which resulted in higher ADG and better feed efficiency in fatting lambs fed an 80% concentrate diet, even though DM intake was less affected by yeast supplementation. Stella et al. (2007) found that live yeast addition resulted in an improvement of ADI, which positively affected milk production of dairy goats fed a 47% concentrate diet. However, when lambs were fed 100% concentrate diets, yeast supplementation had less efficacious effect on growth performance and feed efficiency (Kawas et al., 2007).

Nutrient digestibility

Apparent digestibilities of three treatment diets are presented in Table 3. All total tract nutrient digestibilities did not differ between MO supplementation and CON treatments. It was reported that monensin addition did not significantly affect total tract digestions of DM, OM, starch or N of the corn or barley based high-concentrate diets (Surber et al., 1998), and the nutrient digestibility of a 50% concentrate diet (Garcia et al., 2000).

The diet supplemented with LY significantly ($p<0.05$) improved the digestibility of hemicellulose from 55.7% to 62.4% compared with the CON diet. This was consistent with yeast supplementation in the diet of dairy cows that had significantly increased hemicellulose digestibility in a 50% concentrate basal diet (Wiedmeier et al., 1987). Zeleňák et al. (1994) reported that the addition of a live yeast product Yea-Sacc to the diet increased ruminal hemicellulose digestibility when the substrates consisted of 20% or 50% barley *in vitro*. Williams (1989) demonstrated that the number of rumen cellulolytic bacteria was increased by yeast supplementation, especially in high concentrate diets. In the current study, though high level of gelatinized starch in steam-flaked corn used as a sole grain source in the diet fed to lambs would be rapidly fermented in the rumen, the cellulolytic activity of rumen bacteria would not be depressed because rumen pH values were maintained stable by supplementation of live yeasts (Table 5). This explanation was also supported by the results of Chaucheyras-Durand and Fonty (2002) and Stella et al. (2007), in which the live yeast maintained a stabilized

Table 4. Carcass characteristics of weaned lambs fed the steam-flaked corn-based diet supplemented with no addition (CON), monensin (MO) or live yeast (LY)[1]

Carcass characteristic	Treatment			SEM	Significance
	CON	MO	LY		
Live weight (kg)	31.5	31.0	33.6	1.7	NS
Hot carcass weight (kg)	15.0	14.8	16.4	1.1	NS
Grade rule (GR) value[2] (mm)	14.4	12.8	14.0	1.2	NS
Hot dressing percentage (%)	47.5	47.7	48.9	1.7	NS
Ribeye area[3] (cm^2)	19.55	20.23	19.01	1.32	NS

[1] Values represent least squares means of 5 lambs of 5 individual pens.
[2] GR value was measures as the soft tissue depth 110 mm off the midline in the region between the 12 th and 13 th ribs.
[3] Ribeye area was measured by grid reading of the longissimus muscle taken between 12 th and 13 th ribs. NS: non-significant.

Table 5. Rumen pH, ammonia and volatile fatty acid (VFA) concentration and molar ratios of weaned lambs fed the steam-flaked corn-based diet supplemented with no addition (CON), monensin (MO) supplement or live yeast (LY) supplement[1]

Item	Treatment			SEM	Significance
	CON	MO	LY		
Ruminal pH	6.17[b]	6.26[ab]	6.57[a]	0.10	*
Ammonia-N (mg/100 ml)	8.34	7.28	7.22	0.71	NS
Total VFA (mM)	73.85	68.80	66.00	2.75	NS
Individual VFA (molar proportion, %)					
Acetic acid	70.82	70.16	72.96	0.92	NS
Propionic acid	15.10	17.22	15.46	0.62	NS
Butyric acid	10.37	8.48	8.25	0.63	NS
Isobutyric acid	0.94	0.98	0.78	0.06	NS
Valeric acid	1.08	1.06	0.97	0.12	NS
Isovaleric acid	1.69	1.97	1.58	0.14	NS
Acetic:propionic acid ratio	4.69	4.12	4.78	0.26	NS

[1] Values represent least squares means of 5 lambs of 5 individual pens. NS: non-significant, and * $p<0.05$.
[a,b] Means within the same row denoted by different letters differ each other ($p<0.05$).

ruminal pH and consequently a higher cellulolytic activity in the rumen. The increased number of rumen cellulolytic bacteria by yeast supplementation would then contribute to an increased ruminal fiber digestibility, and finally be responsible for the increased ADI (Wohlt et al., 1991). The diet supplemented with LY had no effect on digestibilities of DM, OM, CP, starch, NDF and ADF compared with the CON and MO diets. Previous studies showed that the addition of yeast products tended to increase numbers of total ruminal bacteria (Newbold et al., 1995), resulting in more efficient rumen fermentation and nutrient digestibilities (Chaucheyras-Durand and Fonty, 2002). However, the total tract nutrient digestibilities were not always significantly improved when yeast culture was fed (Andrighetto et al., 1993; Garcia et al., 2000), possibly because hindgut fermentation impaired positive effect in the rumen (Williams, 1989).

Carcass characteristics

The effects of monensin and live yeast supplementation on carcass characteristics of weaned lambs fed the steam-flaked corn-based diets are presented in Table 4. Neither MO nor LY supplementation improved carcass characteristics compared with the CON diet. These results were in good agreement with the previous findings in lambs and cattle species. Gilka et al. (1989) and Owaimer et al. (2003) reported monensin supplementation did not affect the carcass traits of lambs. Similarly, Kawas et al. (2007) failed to find any positive effect of yeast supplementation on carcass characteristics of lambs fed finishing diets. Supplementation of monensin or live yeast in the diets of bulls or steers also did not significantly alter the carcass characteristics or compositions (Boucqué et al., 1982; Mir and Mir, 1994).

Rumen fermentation parameters

Table 5 shows the effects of monensin and live yeast supplementations on ruminal pH, ammonia concentration and volatile fatty acid patterns of weaned lambs fed the steam-flaked corn-based diets. No effect was observed in ruminal pH by MO supplementation, while ruminal pH in LY diet was significantly higher ($p<0.05$) than that in CON diet (6.17 vs. 6.57). Recently, Bach et al. (2006) reported that live yeast (*S. cerevisiae* CNCM I-1077), the same yeast species used as in the present study, efficaciously stabilized ruminal pH values in lactating cows suffered from subclinical acidosis compared with CON (6.05 and 5.49, respectively). Live yeast or yeast culture addition could stabilize ruminal pH primarily by promoting the growth of lactate-utilizing bacteria, which were responsible for

Table 6. Plasma concentrations of metabolic parameter of lambs fed without (CON) or with monensin (MO) and live yeast (LY) supplemented to steam-flaked corn-based diet[1]

Item	Treatment			SEM	Significance
	CON	MO	LY		
Plasma total protein (g/100 ml)	6.43	6.23	6.21	0.09	NS
Plasma urea-N (mg/L)	226.69[a]	189.59[b]	180.81[b]	10.68	*
Glucose (mM)	4.42	4.72	4.60	0.33	NS
BHBA (mM)	0.32	0.28	0.29	0.02	NS
Triglycerides (mM)	0.29	0.30	0.25	0.02	NS
Cholesterol (mM)	1.70	1.87	1.60	0.10	NS

[1] Values represent least squares means of 5 pens with three lambs each. NS: non-significant, and * $p<0.05$.
[a,b] Means within the same row denoted by different letters differ each other ($p<0.05$).

reducing ruminal lactate concentration (Williams et al., 1991). Conversely, monensin enabled ruminal pH to be stabilized mainly by inhibiting lactate-producing bacteria (Dennis et al., 1981). However, this mechanism might play a minor role in regulation of ruminal pH when animals were not involved in acidosis. In the present study, the higher ruminal pH by LY supplementation in steam-flaked corn-based diet would be beneficial for making the ruminal environment more favorable for the activity of cellulolytic bacteria (Stewart, 1977), which could in turn promote the digestion of fiber. This observation was in agreement with the results obtained in the former digestion experiment (Table 3).

The decrease of NH_3-N concentration was not significant in MO group in present study. Yang and Russell (1993) reported that monensin might depress ruminal proteolytic activity, which resulted in a lower ruminal NH_3-N concentration. The effects of monensin on VFA proportions were well confirmed by the previous *in vitro* and *in vivo* studies in sheep (Mbanzamihigo et al., 1996; García et al., 2000; Singh and De, 2005), which had higher propionic acid proportion and lower butyric acid percentage and acetic: propionic acid ratio when fed with grain-based. However, in present study, all effects of monensin on ruminal VFA proportion did not approach to the significant levels.

LY treatment did not affect ruminal NH_3-N concentration. However, it was reported that lower ammonia concentration was observed when yeast culture was supplemented to the high concentrate diet (Alshaikh et al., 2002), which was explained by more ammonia-N incorporated into ruminal microbial proteins (Carro et al., 1992). No differences were detected in the total VFA concentration and molar proportions among the diets. Previous reports showed that the effects of yeast supplementation on rumen fermentation were quite variable. Andrighetto et al. (1993) reported that yeast culture significantly increased total ruminal VFA concentration, but unaffected the molar proportions of individual VFAs and acetate to propionate ratio when sheep were fed a high concentrate diet. *In vitro* study showed that the responses of ruminal VFA production and molar proportions to live yeast supplementation varied with different levels of dietary concentrate and hay substrates (Zeleňák et al., 1994). It seems that the effects of yeast supplementation on rumen fermentation parameters are hardly predictable. The inconsistent results appear to be related to differences in chemical compositions and intake levels of the diets.

Blood parameters

Table 6 shows the results of blood parameters of lambs fed on the steam-flaked corn-based diet supplemented with monensin and live yeast. MO and LY supplementations significantly decreased ($p<0.05$) the plasma urea-N concentration (189.59, 180.81 and 226.69 mg/L for MO, LY and CON diet, respectively). Blood metabolite urea is an indicator of the protein status of ruminants (Sykes, 1978), and the plasma urea-N concentration is related to the level of ammonia absorption from the rumen and/or the deamination of amino acids not deposited in the tissue (Deaville and Galbraith, 1992). Another possibility for the lower plasma urea-N concentration is that additives promote the utilization and deposition of nitrogen in tissues. It had been suggested previously that lambs fed monensin and yeast culture had higher N digestibility and N retention (Adams et al., 1981; Cole et al., 1992). However the current study did not provide direct evidence to support the deduction of either lower absorption level of ruminal ammonia or good N balance in lambs fed with MO and LY supplemented diets in present experimental design.

No differences were detected in plasma glucose, BHBA, PTP, triglycerides and cholesterol concentrations among the three dietary treatments. Additives, such as monensin or live yeast, were reported to influence blood constituents through remodel of ruminal microbial populations, which was reflected by changes in fermentation end products (Juchen et al., 2004), i.e. the increase of propionic acid was associated with increased plasma glucose concentration, and increased ruminal molar proportion of butyrate was associated with raised plasma BHBA concentration. In the current study, all differences of ruminal parameters affected by either MO or LY supplementations did not approach to the significant levels. This might partially explain why most

blood parameters were not changed by MO and LY supplementations.

CONCLUSIONS

Supplementation with LY improved feed efficiency of weaned lambs compared to the control and similar to MO. In addition, LY supplementation stabilized ruminal pH and increased hemicellulose digestibility in lambs receiving steam-flaked corn-based diet compared with the control diet. Present findings indicate that compared with monensin, live yeast supplementation is more effective to stabilize intraruminal milieu, and therefore increases ruminal fibre utilization when lambs are fed rapidly fermentable carbohydrate grain-based diets.

REFERENCES

Adams, D. C., M. L. Galyean, H. E. Kiesling, Joe D. Wallace and M. D. Finkner. 1981. Influence of viable yeast culture, sodium bicarbonate and monensin on liquid dilution rate, rumen fermentation and feedlot performance of growing steers and digestibility in lambs. J. Anim. Sci. 53:780-789.

Alshaikh, M. A., M. Y. Alsiadi, S. M. Zahran, H. H. Mogawer and T. A. Aalshowime. 2002. Effect of feeding yeast culture from ifferent Sources on the Performance of Lactating Holstein Cows in Saudi Arabia. Asian-Aust. J. Anim. Sci. 15:352-356.

Andrighetto, I., L. Bailoni, G. Cozzi and P. Berzaghi. 1993. Effects of yeast culture addition on digestion in sheep fed a high concentrate diet. Small Rumin. Res. 12:27-34.

AOAC. 1997. Official Methods of Analysis. 16th ed., 3rd rev. Association of Official Analytical Chemists International, Gaithersburg, MD.

Bach, A., C. Iglesias and M. Devant. 2006. Daily rumen pH pattern of loose-housed dairy cattle as affected by feeding pattern and live yeast supplementation. Anim. Feed Sci. Technol. Available online at http://www.sciencedirected.com. Accessed Octo. 11, 2006.

Boucqué, Ch. V., L. O. Fiems, B. G. Cottyn, M. Casteels and F. X. Buysse. 1982. Monensin-sodium as a performance-promoting additive for fattening bulls and its impact on carcass and meat quality characteristics. Anim. Feed Sci. Technol. 7:401-410.

Broderick, G. A. and J. H. Kang. 1980. Automated simultaneous determination of ammonia and amino acids in ruminal fluids and *in vitro* media. J. Dairy Sci. 63:64-75.

Carro, M. D., P. Lebzien and K. Rohr. 1992. Influence of yeast culture on the *in vitro* fermentation (Rusitec) of diets containing variable portions of concentrates. Anim. Feed Sci. Technol. 37:209-220.

Chademana, I. and N. W. Offer. 1990. The effect of dietary inclusion of yeast culture on digestion in the sheep. Anim. Prod. 50:483-489.

Chaucheyras-Durand, F. and G. Fonty. 2002. Influence of a probiotic yeast (*Saccharomyces cerevisiae* CNCM I-1077) on microbial colonization and fermentations in the rumen of newborn lambs. Microb. Ecol. Health Dis. 14:30-36.

Cole, N. A., C. W. Purdy and D. P. Hutcheson. 1992. Influence of yeast culture on feeder calves and lambs. J. Anim. Sci. 70:1682-1690.

Deaville, E. R. and H. Galbraith. 1992. Effect of dietary protein level and yeast culture on growth, blood prolactin and mohair fibre characteristics of British Angora goats. Anim. Feed Sci. Technol. 38:123-133.

Dennis, S. M., T. G. Nagaraja and E. E. Bartley. 1981. Effects of lasalocid or monensin on lactate producing or using rumen bacteria. J. Anim. Sci. 52:418-426.

García, C. C. G., M. G. D. Mendoza, M. S. González, P. M. Cobos, C. M. E. Ortega and L. R. Ramírez. 2000. Effect of a yeast culture (*Saccharomyces cerevisiae*) and monensin on ruminal fermentation and digestion in sheep. Anim. Feed Sci. Technol. 83:165-170.

Gilka, J., P. Jelínek, B. Janková, P. Krejčí and J. Habrda. 1989. Carcass traits and meat quality of male lambs fed monensin or lasalocid. Meat Sci. 25:265-272.

Goodrich, R. D., J. E. Garrett, D. R. Gast, M. A. Kirick, D. A. Larson and J. C. Meiske. 1984. Influence of monensin on the performance of cattle. J. Anim. Sci. 58:1484-1498.

Grant, R. J. and D. R. Mertens. 1992. Influence of buffer pH and raw corn starch addition on *in vitro* fiber digestion kinetics. J. Dairy Sci. 75:2762-2768.

Haddad, S. G. and S. N. Goussous. 2005. Effect of yeast culture supplementation on nutrient intake, digestibility and growth performance of Awassi lambs. Anim. Feed Sci. Technol. 118:343-348.

Juchem, S. O., F. A. P. Santos, H. Imaizumi, A. V. Pires and E. C. arnabé. 2004. Production and blood parameters of holstein cows treated prepartum with sodium monensin or propylene glycol. J. Dairy Sci. 87:680-689.

Kawas, J. R., R. García-Castillo, F. Garza-Cazares, H. Fimbres-Durazo, E. Olivares-Sáenz, G. Hernández-Vidal and C. D. Lu. 2007. Effects of sodium bicarbonate and yeast on productive performance and carcass characteristics of light-weight lambs fed finishing diets. Small Rumin. Res. 67:157-163.

Kirton, A. H. 1989. Principles of classification and grading. In: (Ed. R. W. Purchas, B. W. Butler-Hogg and A. S. Davies), Meat Production and Processing. Occasional Publication, No. 11. New Zealand Society of Animal Production, Inc., Hamilton, New Zealand, pp. 143-157.

Köhler, B., H. Karch and K. Schmidt. 2000. Antibacterials that are used as growth promoters in animal husbandry can affect the release of Shiga-toxin-2-converting bacteriophages and Shiga toxin 2 from *Escherichia coli* strains. Microbiol. 146:1085-1090.

Li, Y. L. and Q. X. Meng. 2006. Effect of different types of fibre supplemented with sunflower oil on ruminal fermentation and production of conjugated linoleic acids *in vitro*. Arch. Anim. Nutr. 60:402-411.

Marsh, W. H., B. Fingerhut and H. Muller. 1965. Automated and manual direct methods for the determination of blood urea. Clin. Chem. 11:624-627.

Martin, S. A., S. F. Al-Khaldi, J. D. Evans and H. M. Sullivan. 1999. Potential for manipulating gastrointestinal microflora: Alternatives to antibiotics and ionophores? Recent Res. Dev. Microbiol. 3:441-454.

Mathew, A. G., W. G. Upchurch and S. E. Chattin. 1998. Incidence of antibiotic resistance in fecal *Escherichia coli* isolated from commercial swine farms. J. Anim. Sci. 76:429-434.

Mbanzamihigo, L., C. J. van Nevel and D. I. Demeyer. 1996. Lasting effects of monensin on rumen and caecal fermentation in sheep fed a high grain diet. Anim. Feed Sci. Technol. 62:215-228.

McBeath, D. G., W. J. Penhale and E. F. Logan. 1971. An examination of the influence of husbandry on the plasma immunoglobulin level of the newborn calf, using a rapid refractometer test for assessing immunoglobulin content. Vet. Rec. 88:266-270.

Mir, Z. and P. S. Mir. 1994. Effect of the addition of live yeast (*Saccharomyces cerevisiae*) on growth and carcass quality of steers fed high-forage or high-grain diets and on feed digestibility and *in situ* degradability. J. Anim. Sci. 72:537-545.

Newbold, C. J., R. J. Wallace, X. B. Chen and F. M. McIntosh. 1995. Different strains of Saccharomyces cerevisiae differ in their effects on ruminal bacterial numbers *in vitro* and in sheep. J. Ainm. Sci. 73:1811-1818.

NRC. 1985. Nutrient Requirements of Sheep, 6th ed. National Academy Press, Washington, DC.

Owaimer, A. N., M. S. Kraidees, M. Al-Saiady, S. Zahran and M. A. Abouheif. 2003. Effects of Feeding Monensin in Combination with Zeranol Implants on Performance, Carcass Traits and Nutrient Digestibility of Growing Lambs. Asian-Aust. J. Anim. Sci. 16:1274-1279.

Reinhardt, C. D., R. T. Brandt, K. C. Jr. Behnke, A. S. Freeman and T. P. Eck. 1997. Effect of steam-flaked sorghum grain density on performance, mill production rate, and subacute acidosis in feedlot steers. J. Anim. Sci. 75:2852-2857.

Rosevar, J. W., K. J. Pfaff, F. J. Service, G. D. Molnar and E. Ackerman. 1969. Glucose oxidase method of continuous automated blood glucose determination. Clin. Chem. 15:690-698.

SAS User's Guide: Statistics, Version 8 Edition. 1999. SAS Inst., Inc., Cary, NC.

Singh, G. P. and De Debasis. 2005. Effect of eifferent level of monensin supplemented with cold process urea molasses mineral block on *In vitro* rumen fermentation at different days of Adaptation with Monensin, Asian-Aust. J. Anim. Sci. 18:320-325.

Stella, A. V., R. Paratte, L. Valnegri, G. Cigalino, G. Soncini, E. Chevaux, V. Dell'Orto and G. Savoini. 2007. Effect of administration of live *Saccharomyces cerevisiae* on milk production, milk composition, blood metabolites, and faecal flora in early lactating dairy goats. Small Rumin. Res. 67:7-13.

Stewart, C. S. 1977. Factors affecting the cellulolytic activity of rumen contents. Appl. Environ. Microbiol. 33:497-502.

Stock, R. A., M. H. Sindt, J. C. Parrott and F. K. Goedeken. 1990. Effects of grain type, roughage level and monensin level on finishing cattle performance. J. Anim. Sci. 68:3441-3455.

Surber, L. M. M. and J. G. P. Bowman. 1998. Monensin effects on digestion of corn or barley high-concentrate diets. J. Anim. Sci. 76:1945-1954.

Sykes, A. R. 1978. An assessment of the value of plasma urea nitrogen and albumin concentrations as monitors of the protein status of sheep. In: The Use of Blood Metabolites in Animal Production. Occ. Publ. Br. Soc. Anim. Prod., no. 1, pp. 143-154.

Van Nevel, C. J. and D. I. Demeyer. 1988. Manipulation of rumen fermentation. In: The rumen microbial ecosystem (Ed. P. N. Hobson). Elsevier Applied Science, London, pp. 387-444.

Van Soest, P. J., J. B. Robertson and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-3597.

Wallace, R. J. 1994. Ruminal microbiology, biotechnology and ruminant nutrition: Progress and Problems. J. Anim. Sci. 72:2992-3003.

Wiedmeier, R. D., M. J. Arambel and J. L. Walters. 1987. Effect of yeast culture and *Aspergillus oryzae* fermentation extract on ruminal characteristics and nutrient digestibility. J. Dairy Sci. 70:2063-2068.

Williams, P. E. V. 1989. The mode of action of yeast culture in ruminal diets. A review of the effect on rumen fermentation patterns. Biotechnology in the feed industry. Alltech Tech. Publishers. Nicholasville, Kentuky, USA, p. 65.

Williams, P. E. V., C. A. G. Tait, G. M. Innes and C. J. Newbold. 1991. Effects of the inclusion of yeast culture (*Saccharomyces cerevisiae* plus growth medium) in the diet of dairy cows on milk yield and forage degradation and fermentation patterns in the rumen of steers. J. Anim. Sci. 69:3016-3026.

Williamson, D. N. and J. Mellandby. 1974. D-(-)-3-hydroxybutyrate. In: Methods of enzymatic analysis (Ed. H. E. Berhmeyer). Verlag Chemie, Wenheim, pp. 1836-1839.

Wohlt, J. E., A. D. Finkelstein and C. H. Chung. 1991. Yeast culture to improve intake, nutrient digestibility, and performance by dairy cattle during early lactation. J. Dairy Sci. 74:1395-1400.

Xiong, Y., S. J. Bartle and R. L. Preston. 1990. Improved enzymatic method to measure processing effects and starch availability in sorghum grain. J. Anim. Sci. 68:3861-3870.

Yang, C-M. J. and J. B. Russell. 1993. The effect of monensin supplementation on ruminal ammonia accumulation *in vivo* and the numbers of amino acid-fermenting bacteria. J. Anim. Sci. 71:3470-3476.

Zeleňák, I., D. Jalč, V. Kmet and P. Siroka. 1994. Influence of diet and yeast supplement on *in vitro* ruminal characteristics. Anim. Feed Sci. Technol. 49:211-221.

Zinn, R. A., C. F. Adam and M. S. Tamayo. 1995. Interaction of feed intake level on comparative ruminal and total tract digestion of dry-rolled and steam-flaked corn. J. Anim. Sci. 73:1239-1245.