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Effects of Monensin and Thiamin and their Combinations on Feedlot Performance, Blood Glucose, BUN Levels and Carcass Characteristics of Mehraban Lambs Fed a High Concentrate Diet

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Abstract: Seventy Mehraban male lambs (initial live weight 43.9±4.3 kg) were used in a 70-day feeding experiment. Lambs were fed with 12 diets in a completely randomized design arranged in a 3×4 factorial trial with three levels of thiamin (0, 4 and 6 mg kg^{-1} DM) and 4 levels of monensin (0, 5, 11 and 22 mg kg^{-1} DM). A 21-day period was included for adaptation to the diets. Basal diet (dry matter basis) consisted of 7.5% corn silage, 8% alfalfa hay, 70% barley grain, 10% wheat bran, 3% cottonseed meal, 1.1% limestone and 0.4% vitamin and mineral supplement. Carcass characteristics, average daily gain and Feed Conversion Ratio (FCR) were not significantly ($p>0.05$) different between diets containing monensin and thiamin or their combinations with control. Daily dry matter intake was lowest ($p<0.05$) for diets 8 (11 mg monensin and 4 mg thiamin per kg DM) and 12 (22 mg monensin and 6 mg thiamin per kg DM) compared with diet 3 (6 mg thiamin per kg DM). BUN level and ruminal fluid pH were not significantly ($p>0.05$) different between diets. Blood glucose of lambs fed with 11 mg monensin/kg DM (50.6 mg dL^{-1}) was higher ($p<0.05$) than control group (45.8 mg dL^{-1}). Monensin tended to improve FCR. Monensin reduced DMI ($p<0.05$) and decreased feed consumption by 9.13-9.75% compared with the control diet. The effect of monensin on blood glucose concentration was significant ($p<0.05$) which was higher for two levels of monensin (11 and 22 mg kg^{-1} DM), compared with the control diet. Ruminal fluid pH was significantly ($p<0.05$) higher with all levels of monensin and at 22 mg kg^{-1} monensin, ruminal ammonia concentration was lowest ($p<0.05$). The overall effect of thiamin was a decrease ($p<0.05$) in BUN concentration.

Key words: Monensin, thiamin, feedlot performance, high concentrate and Mehraban lambs

INTRODUCTION

Shortage of feed is the main constraint in livestock industry in Iran. High feed cost encourages the farmers to look for cheaper feeds or somehow reduce the feed conversion ratio. One method which may increase the feed efficiency is the addition of ionophores to the feed. Ionophores have been defined as substances capable of binding numerous mono-and divalent cations primarily in dimeric complexes that facilitate the passage of metal ions through hydrophobic lipid membrane (Ovehinnikov, 1979). Inophores vary in their affinity for metal ions.

Antibiotic ionophores such as monensin have been widely used to improve feed efficiency of cattle under both feedlot and grazing conditions (Oliver, 1975; Potter *et al*., 1976; Raun *et al*., 1976; Boling *et al*., 1977; Bergen and Bates, 1984) and in lambs (Glenn *et al*., 1977; Joyner *et al*., 1979) and in some cases, increased the daily gain (Calhoun *et al*., 1979). Monensin is a polyether ionophore produced by a strain of *Streptomyces cinnamonensis* that improves energetic efficiency of ruminal fermentation (Hyaney and Hoehn, 1967). Monensin is usually described as an antiporter that facilitates a one-for-one exchange of H^+ and Na^+ across cell membranes; however it can also mediate a K^+ and H^+ exchange (Pressman and Fahim, 1982). Bergen and Bates (1984) implied that monensin would lead to a depletion of interacellular Na^+ rather than an increase, which in turn stimulates the ruminal environment.

Monensin alters ruminal fermentation in animals fed on starch-rich diets. Monensin acts on energy and nitrogen metabolism by decreasing molar proportion of acetic acid and increasing propionic acid (Richardson *et al*., 1976; Wedegaertner and Johnson, 1983; Jalc and Certik, 2005; Shinzato *et al*., 2006) and decreasing methane production (Fuller and Johnson, 1981; Guan *et al*., 2006) and also by increasing non-ammonia nitrogen flow in the duodenum (Russell and Strobel, 1988). It has been suggested that increased production of propionic acid would be energectically more efficient for the ruminant animal (Raun *et al*., 1976;

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Richardson *et al*., 1976), which is supported by the observed decrease in feed requirements for live weight gain that accompany the addition of monensin to feedlot diets (Raun *et al*., 1976; Boling *et al*., 1977). Jalc and Certik (2005) reported that the fermentation efficiency (E) and recovery of H_2 were increased significantly by supplementing diet with monensin in artificial rumen. Also, monensin has inhibitory activity to gram-positive anaerobic bacteria like *Streptococcus bovis* (Muir and Barreto, 1979) that proliferates in the rumen when large amounts of grains are fed. Lactic acid production by *S. bovis* is responsible for the initiation of ruminal acidosis (Slyter, 1976). Acute deficiencies of thimain have been found in ruminants (Loew, 1975) and there are indications that subclinical deficiencies may occur (Brent, 1976). Brent (1976) stated that the development of lactic acidosis due to the feeding of rapidly fermentable materials is conductive to the initiation of polioencephalomalacia. Edwin *et al*. (1968) proposed that polioencephalomalacia was caused by a thiaminase enzyme. Davies *et al*. (1965) found the disease to be responsive to thiamin administration. Brethour (1972) found average daily gain of steers increased from 1.14 to 1.26 kg day^{-1} ($p<0.05$) due to the addition of 1 g thiamin and 100 g sodium bicarbonate to a wheat-based ration. Thiamin supplementation of an all-concentrate diet for feedlot steers resulted in higher feed intake and daily weight gain (Grigat and Mathison, 1982). The objectives of this study was to provide additional information on the possible benefit of the addition of monensin and thiamin to Mehraban male lambs (Iranian fat-tailed sheep) fed with a high concentrate diet.

MATERIALS AND METHODS

This experiment was carried out at the Animal Research Station, College of Agriculture, Shiraz University Iran. The experiment started on 25 July, 2005. Seventy Mehraban male lambs weighing 43.90±4.3 kg were randomly assigned to twelve groups of five and six lambs for two and ten diets respectively, in a 70 day feedlot experiment. Thiamin was fed at 0, 4 and 6 mg kg^{-1} of diet DM and monensin at 0, 5, 11 and 22 mg kg^{-1} of diet DM. A 21 day and 7 day adaption periods were included for the diets containing monensin and diets with no monensin, respectively. Lambs were fed twice daily and each diet was offered as a Total Mixed Ration (TMR). Water and a salt lick were available *ad libitum*. The animals were individually housed indoors in 1×1.5 m pens under normal lighting and their health was monitored continuously. Discarded feed was weighed and sampled for DM and subtracted from DM offered to calculate DMI. Ingredient and nutrient composition of the basal diet is presented in Table 1.

Table 1: Dietary ingredients and nutrient composition of the basal diet for lambs

Ingredients	Percent (DM basis)
Corn silage	7.50
Alfalfa hay	8.00
Barley grain	70.00
Wheat bran	10.00
Cotton seed meal	3.00
Limestone	1.10
Mineral and vitamin mixture*	0.40
Concentrate: roughage ratio	83:17
Nutrient composition (%)	
Crude protein	12.50
NDF	25.46
ADF	11.55
Metabolisable energy (Mcal/kg)	2.75

* Each kg contained: 500000 IU vitamin A, 100000 IU vitamin D_3, 100 mg vitamin E, 190 g Ca, 90 g P, 19 g Mg, 50 g Na, 2 g Mn, 3 g Fe, 0.3 g Cu, 3 g Zn, 0.1 g Co and 1 mg Se

Lambs were weighed every three weeks after withdrawing food and water for 18 h and blood was collected from the jugular vein. The serum was separated after centrifugation at 5000 g for 15 min and stored at-20°C until analysed for blood glucose (using a commercial kit) and urea nitrogen (BUN) (Thomas, 1998). At the end of the experiment, lambs were slaughtered after withdrawing food and water for 15 h. Hot and cold (after 24 h) carcass weights were recorded. Subcutaneous fat depth was measured with a caliper at four points between the 12th and 13th ribs.

Rumen samples were collected using three 2-year old Mehraban rams fitted with ruminal fistula before feeding and again 0.5, 2 and 4 h after feeding. Feeding procedures and diets for fistulated rams were similar to those in the feedlot trial. Rumen fluid pH was measured directly in the whole rumen sample with a pH meter (Metrohem, Swiss). Rumen liquor samples were prepared by straining of the rumen sample through two layers of cheesecloth. The filtrate was treated with 5 mL of 0.2 mol L^{-1} HCl per 5 mL of filtrate and frozen at -20°C until measurement of NH_3-N concentration (Kjeltec Auto Analyser 10304 Hogans, Tecator AB, Sweden).

Food and orts were analysed for DM and total nitrogen (N ×6.25) according to the AOAC (1990) and Acid Detergent Fiber (ADF) and Neutral Detergent Fiber (NDF) were determined by procedures of Van Soest (1963) and Van Soest and Wine (1976), respectively.

Feedlot and carcass characteristics were analysed as a completely randomized design according to GLM procedures of SAS (1997) and serum glucose and urea nitrogen concentrations and ruminal pH and ammonia nitrogen were analysed according to Proc Mixed as Repeated Measures. Differences between the treatment means were tested using Tukey's test.

RESULTS AND DISCUSSION

No death or digestive problems recorded. The effects of monensin and thiamin levels on the observed feedlot performance, blood parameters and ruminal fluid pH and ammonia concentration are presented in Table 2. Only daily Dry Matter Intake (DMI) was affected by treatments ($p<0.05$) among feedlot characteristics. Diets 8 (11 mg kg^{-1} monensin and 4 mg kg^{-1} thiamin) and 12 (22 mg kg^{-1} monesin and 6 mg kg^{-1} thiamin) were consumed significantly less than diet 3 (6 mg kg^{-1} thiamin), with no differences between other diets compared with diet 1. Lower DMI with feeding monensin was in agreement with other reports (Joyner *et al*., 1979). Lower DMI, at least in part, could be due to highter ruminal and blood propionic acid (Baile and Mayer, 1970), higher diet metabolizable energy due to lower loss of energy as methane (Wedegaertner and Johnson, 1983) and a longer retention time (decreased rumen turnover rate) of food in the rumen (Lemenager *et al*., 1978). Monensin did not show a dose related effect on feed intake, which is in agreement with the results of Stock *et al*. (1995) but not with the findings of Burrin *et al*. (1988), who reported decreases in feed intake as the monensin level increased.

Thiamin had no significant ($p>0.05$) effect on feed intake, in agreement with the findings of Grigat and Mathison (1982) who fed an all-concentrate diets supplemented with thiamin to feedlot steers. It seems that the higher ADF content of the diets (Mertens, 1997) and longer adaptation period (NRC, 2001), maintained higher ruminal pH and inhibited the activity of thiaminase producing bacteria (Brent, 1976). Average daily gain ranged 148-196 g, diet 1 had the lowest and diet 3 had the highest numerical values. Small differences in DMI and efficiency were observed between lambs fed 0, 5, 11 and 22 mg kg^{-1} monensin (Data not shown), which agrees with the all-concentrate, dry-rolled corn data of Stock *et al*. (1990). Although not significant, the highest and the lowest feed efficiencies were noted for diet 1 (11.40) and diet 8 (7.70), respectively. This was expected due to noticeable weight gain and less DMI with diet 8 (Table 2).

Improvement in feed efficiency has been reported by Grigat and Mathison (1982) with feedlot steers diet supplemented with 1.9 mg kg^{-1} thiamin which could be attributed to higher microbial protein synthesis (Hoeller *et al*., 1977). Feed efficiency values in the present study were higher than values reported by Joyner *et al*. (1979) with lambs fed with a 50% concentrate diet. The difference between the results might be due to stress during blood sampling, food withdrawing for 18h before periodical weighing and higher initial weight of lambs.

Blood glucose concentration was affected by treatments ($p<0.05$) and was higher for lambs diets supplemented with 11 and 22 mg kg^{-1} monensin compared with diet 1. BUN and ruminal fluid pH were not different among diets ($p>0.05$). Overall, thiamin significantly ($p<0.05$) decrease BUN levels as compared with the control diet (Data not shown). Improvement in ruminal fluid pH with feeding monensin (Table 3) could be a result of lower ruminal lactate production depressed growth of *S. bovis* (Dennis *et al*., 1981).

Monensin, irrespective of the thiamin levels resulted in a decrease in ruminal ammonia concentration (Table 2), which could be a result of inhibition of gram-positive bacteria by monensin and controlling the growth of ureolytic and proteolytic bacteria (Han *et al*., 2002).

Final weight was not different among treatments ($p>0.05$) in agreement with previous reports (Joyner *et al*., 1979; Stock *et al*., 1990). Although monensin can increase the net energy of the diet through increasing molar proportion of propionic acid (Sauer *et al*., 1989) and by reducing methane formation in the rumen (Okelly and Spiers, 1992), it also decreases feed intake which will not affect the final weight (Joyner *et al*., 1979; Stock *et al*., 1995). Joyner *et al*. (1979) fed lambs with diets containing 0, 10, 20 and 30 mg kg^{-1} monensin and reported 2-18% and 7-11% improvements in feed intake and feed efficiency, respectively, which might be due to higher molar proportion of propionic acid (Mass *et al*., 2001), lower methane production (Okelly and Spiers, 1992) and inhibition of protein degradation in the rumen (Poos *et al*., 1979).

Monensin did not significantly affect ($p>0.05$) the back fat thickness; however Fontenot and Huchette (1993) reported increased backfat thickness in cattle with monensin supplementation. This was not unexpected because higher fat production with feeding monensin could be related to the higher blood glucose and insulin concentration (Potter *et al*., 1976). The proportion of concentrate in this experiment was higher than that of Fontenot and Huchette (1993) trial and blood glucose was not increased dramatically with feeding monensin in present study. Blood glucose was significantly ($p<0.05$) higher with lambs fed monensin at 11 and 22 mg kg^{-1} compared with control diet. Blood gluocse ranged between 46.8-49 mg dL^{-1}. The higher blood glucose with feeding monensin can be attributed to the higher molar percentage of propionic acid in the rumen (Benz *et al*., 1989). Non-dramatic changes in blood glucose could be due to the higher concentrate percentage in present study. In addition, the response to monensin supplementation of high concentrate diets is less than diets of high roughage in case of changes in molar proportion of propionic acid (Morris *et al*., 1990).

Table 2: Feedlot performance, blood glucose and urea nitrogen (BUN) concentrations (mg dL^{-1}) and ruminal fluid pH and ammonia concentration (mg dL^{-1}) of Mehraban lambs as influenced by the dietary levels of monensin and thiamin (mean±SE)

Diets	1	2	3	4	5	6
Monensin level*	0	0	0	5	5	5
Thiamin level*	0	4	6	0	4	6
Initial weight (kg)	45.4±3.1^{a}	45.3±3.1^{a}	44.1±3.5^{a}	43.6±3.1^{a}	43.8±3.8^{a}	42.6±6.8^{a}
Final weight (kg)	55.8±5.0^{a}	58.0±3.9^{a}	57.8±5.9^{a}	55.5±3.2^{a}	55.2±5.5^{a}	55.3±5.3^{a}
ADG**	148.6±31.7^{a}	180.0±37.7^{a}	196.4±45.8^{a}	170.6±33.4^{a}	162.9±35.1^{a}	181.0±26.2^{a}
DMI***	1.6±0.1^{ab}	1.6±0.1^{ab}	1.7±0.1^{a}	1.5±0.1^{ab}	1.5±0.1^{ab}	1.5±0.1^{ab}
Feed: gain ratio	11.4±2.0^{a}	9.3±1.5^{a}	8.9±1.6^{a}	9.1±1.7^{a}	9.6±1.7^{a}	8.4±1.6^{a}
Blood glucose	45.8±3.3^{c}	48.4±3.6^{abc}	46.4±3.1^{c}	48.0±4.7^{bc}	47.8±4.9^{bc}	49.8±2.8^{abc}
BUN****	15.8±1.4^{a}	15.4±1.6^{a}	15.0±2.4^{a}	15.4±1.5^{a}	14.7±1.3^{a}	15.0±1.56^{a}
Ruminal pH	5.78±0.18^{a}	5.58±0.25^{a}	5.86±0.17^{a}	5.95±0.18^{a}	5.95±0.12^{a}	5.91±0.14^{a}
Ruminal ammonia	42.9±5.2^{a}	30.85±1.9^{a}	34.1±5.9^{a}	41.2±6.8^{a}	36.5±1.8^{a}	44.5±0.17^{a}
Diets	7	8	9	10	11	12
Monensin level*	11	11	11	22	22	22
Thiamin level*	0	4	6	0	4	6
Initial weight (kg)	45.6±5.0^{a}	41.8±5.9^{a}	42.2±5.3^{a}	45.5±3.9^{a}	42.9±3.4^{a}	45.2±2.2^{a}
Final weight (kg)	56.3±5.9^{a}	54.2±5.9^{a}	54.5±8.6^{a}	57.7±3.7^{a}	54.4±4.1^{a}	56.5±2.8^{a}
ADG**	151.2±41.3^{a}	191.7±35.1^{a}	176.2±58.0^{a}	172.8±28.0^{a}	164.4±44.4^{a}	161.4±24.5^{a}
DMI***	1.5±0.1^{ab}	1.4±0.1^{b}	1.5±0.2^{ab}	1.5±0.1^{ab}	1.5±0.1^{ab}	1.5±0.1^{b}
Feed: gain ratio	10.6±2.5^{a}	7.7±1.0^{a}	8.9±1.8^{a}	8.8±1.3^{a}	9.9±2.6^{a}	9.3±1.7^{a}
Blood glucose	50.6±4.3^{a}	48.9±5.1^{abc}	47.4±7.7^{c}	48.2±4.3^{bc}	49.9±4.6^{ab}	49.0±4.2^{abc}
BUN****	16.0±1.6^{a}	14.6±1.2^{a}	14.5±1.6^{a}	14.9±1.6^{a}	14.8±1.7^{a}	14.6±1.6^{a}
Ruminal pH	5.92±0.14^{a}	5.90±0.21^{a}	5.91±0.23^{a}	5.84±0.21^{a}	5.95±0.22^{a}	5.91±0.18^{a}
Ruminal ammonia	37.7±2.8^{a}	36.1±1.8^{a}	25.4±2.9^{b}	22.5±0.21^{b}	32.7±4.0^{a}	26.0±0.7^{ab}

a, b, c: Means in the same row with different superscript(s) are significantly different ($p<0.05$). * mg kg^{-1} diet DM. ** Average daily gain (g) *** Daily dry matter intake (kg/day) **** Blood urea nitrogen (mg dL^{-1})

Table 3: Blood glucose concentration (mg dL^{-1}) and ruminal fluid pH and ammonia concentration (mg dL^{-1}) of Mehraban lambs as influenced by the dietary levels of monensin (Mean±SE)

	Monensin level (mg kg^{-1} DM)			
Parameters	0	5	11	22
Blood glucose	46.80±3.46^{b}	48.60±4.23^{ab}	48.97±5.99^{a}	48.97±4.36^{a}
Ruminal pH	5.83±0.20^{b}	5.94±0.15^{a}	5.91±0.2^{a}	5.90±0.20^{a}
Ruminal ammonia	35.9±6.8^{a}	40.7±4.9^{a}	33.1±6.2^{ab}	27.1±4.9^{b}

$^{a, b}$ Means in the same row with different superscript(s) are significantly different ($p<0.05$)

There was no significant effect of monensin on BUN concentration. Stephenson *et al.* (1997) reported that feeding monensin before calving had no any effect on BUN concentration but Poos *et al.* (1979) reported a decreasing ruminal ammonia and an increase with BUN in lambs fed monensin. Monensin at all levels (5, 11 and 22 mg kg^{-1}) improved rumen pH ($p<0.05$) which could be due to the lowering lactate producing bacteria (Nagaraja *et al.*, 1982). Ruminal fluid ammonia was lowest ($p<0.05$) with feeding 22 mg kg^{-1} monensin which could be a result of lowering the population of protozoa (Poos *et al.*, 1979) and proteolytic bacteria (Russell and Strobel, 1988) in the rumen at this level.

Thiamin supplementation at all levels did not show any significant ($p>0.05$) effect on feedlot and carcass characteristics, which was not in agreement with findings of Brethour (1972) and Grigat and Mathison (1982). This difference might due to the higher ADF content of the diet (Mertens, 1997) and longer adaptation period (NRC, 2001) of this study. Also Lee *et al.* (1985) reported that rate and efficiency of gain by stressed beef calves were improved over a 28 day period by addition of a combination of vitamin E and a mixture of B-vitamins to a feedlot diet.

Thiamin had no effects ($p>0.05$) on blood glucose and ruminal pH. This was expected since different levels of thiamin had no effect on feed intake. Thiamin supplementation at both levels decreased ($p<0.05$) BUN concentration.

Based on the result and the cost of each kg live weight gain, according to local prices, supplementation of the diet 10-11 months old Mehraban male lambs with 11 mg monensin and 4 mg thiamin kg diet DM is more economical.

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