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Effects of Niacin on Milk Production and Blood Parameters in Early Lactation of Dairy Cows

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Abstract: To investigate the effects of niacin supplementation in the diet of high producing cows at early lactation, 21 holstein dairy cows were used in this experiment. Animal were assigned in to three groups based on their milk yield and calving date soon after parturition. They were received a basal diet and 0 (group 1), 6 (group 2), 12 (group 3) g of supplementation niacin per day over a 10 weeks experimental period. Milk volume was recorded and milk samples were collected for each cow at two weeks interval for analysis of fat, protein, lactose and SNF (Solid-None Fat). Blood samples were also taken for the measurement of glucose, triglyceride, Beta-hydroxy butyrate and total protein at two weeks intervals. No significant difference were observed between milk yield, milk fat , protein, lactose and SNF content in cows received niacin compared to the control group ($p>0.05$). Plasma glucose in groups 2 and 3 compared to the control were higher and this difference were statistically significant ($p<0.05$). Blood triglycerides were not significantly affected by niacin supplementation. BHBA were lower in cows received niacin and this difference were significant ($p<0.05$). The trend of changes in the amount of blood total protein were identical in all three groups whole the level of this factor was always higher in control group compared to the others groups. Niacin has showed an increase in the level of plasma glucose and a notable decrease in the amount of blood triglyceride, β-hydroxy butyrate and total protein, which may be due to the effect of this vitamin on the energy metabolism in cows.

Key words: Niacin, ketosis, dairy cow, milk production

INTRODUCTION

Because early lactation is a critical time to establish high milk production and good reproductive performance, the avoidance of metabolic anomalies is important. Fatty Liver and ketosis are two common metabolic disorders during early lactation (Grummer, 1993). Triglyceride (TG) accumulates in the liver when TG synthesis exceeds disappearance via hydrolysis and lipoprotein export. Fat infiltrates the liver prior to or at parturition (Vazquez-Anon *et al*., 1994) and may precede ketosis (Veenhuizen *et al*., 1991). Niacin supplementation may increase milk protein percentage and production (Minor *at al*., 1998). Supplementation of dairy rations with niacin had beneficial effects on milk production and persistency (Madison-Anderson *et al*., 1997). Oral administration of niacin decreased blood ketones and nonesterified fatty acids while increasing blood glucose concentration and milk production of ketotic cows (Fronk *et al*., 1980). Because niacin is involved intimately in energy metabolism, it is possible that supplemental niacin may increase milk production by moderating effects of ketosis on energy stressed, high-producing dairy cows. Niacin is the most comprehensively researched B vitamin in dairy cows. Pires and Grummer (2007) showed that niacin supplementation decreased plasma concentrations of non-esterified fatty acids (NEFA) and ketone bodies in Feed-Restricted Holstein Cows. These results show that niacin reduced adipose tissue mobilization, thereby reducing hepatic uptake of fatty acids and the incidence of fatty liver. Indeed, niacin has been shown to be antilipolytic (DiPalma and Thayer, 1991), binding to inhibitory G protein-coupled receptors and thereby reducing adipocyte cyclic-AMP concentrations and inhibiting lipolysis. Schwab *et al*. (2005) performed a meta-analysis of published data to examine the response of lactating dairy cows to supplemental dietary nicotinic acid (NA). The data set was developed from 27 studies published between 1980 and 1998 where lactation performance responses to targeted supplementation of 6 and 12 g day^{-1} NA were reported. Response variables evaluated were DMI, milk yield and composition, feed efficiency and plasma BHBA, NEFA and glucose concentrations. No efficacy of 6 g day^{-1} dietary supplemental NA was found. Likewise dietary supplementation with 12 g day^{-1} NA did not affect DMI,

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milk fat or protein percentages, or measured plasma metabolites. Drackley (1992) summarized 24 reports with responses from 40 treatment comparisons; on average, 51% of the comparisons showed positive numerical responses to supplemental niacin; milk production was increased in 65% of the studies. Averaged responses to niacin were all positive when only early lactation (less than 15 weeks postpartum) studies were considered. Average DMI and milk production increased by 0.04 and 0.57 kg day^{-1}, respectively; milk components were increased slightly.

The objective of this research was to evaluate the lactation response and blood parameters of high producing cows to supplemental niacin. Particular attention was placed on the milk yield and blood β-hydroxybutrate levels.

MATERIALS AND METHODS

This experiment was conducted at the Animal husbandry of Zanjan (Khorramdarreh) during the summer and fall of 2007. Twenty one multiparous Holstein cows were assigned to three groups for milk production (based on the previous lactation). Cows were housed in free-stall barns and salt and water were available at all times. Control cows received no niacin, but second and third groups received 6 and 12 g niacin per cow per day respectively. All cows were fed alfalfa hay (3 kg), concentrate (14 kg), corn silage (20 kg), beat pulp (2 kg) and molasses (1 kg) per day, post calving. Diets were fed three times a day as TMR; amounts of feed offered and orts were measured daily. Niacin was fed orally, as a solute in water. After calving, cows were weighed every two weeks prior to the morning feeding. Cows were milked three times daily and milk production was recorded at each milking. Blood samples were obtained by jugular puncture 4 h after morning feeding every two weeks to 10 weeks after it. Feed samples were dried at 60°C to determine DM weekly. Dried samples were analyzed for CP, NDF, fat and organic matter (AOAC, 1990). Blood samples were collected into evacuated test tubes containing sodium heparin (Vacutainerâ; Becton Dickson Vacutainer Systems USA, Rutherford, NJ) and immediately transferred to tubes containing dried NaF (0.12 mg of NaF/mL of blood). Plasma was obtained from the blood by centrifugation, stored at -20°C and later analyzed for glucose (kit No. 510; Sigma Chemical Co., St. Louis, MO). Plasma samples were also analyzed for triglyceride using an enzymatic and colorimetric procedure (Kit 10-525, Ziestchem Diagnostic kit, Tehran, Iran). For beta-hydroxybutrate (BHB) analyses 3 mL of ice-cold blood was deproteinized with 3 mL of cold 30% perchloric acid, centrifuged and the supernatant was used for enzymatic determination of BHB (Williamson *et al*., 1962). Milk samples were taken from three consecutive milking once per two weeks and analyzed for milk fat, protein, SNF and lactose concentration by an infrared milk analyzer [Foss Electric (UK) Ltd].

Data were analyzed as repeated measures in time using the MIXED procedure of SAS Institute (1999-2000) and tuckey test was used to separating the means. The analysis of variance model used for each variable was:

$$Y_{ijkl} = \mu + n_i + p_j + (np)_{ij} + e_{ijkl}$$

Where:

Y_{ijkl} = Average value for cow L in treatments
μ = Overall mean
n_i = Effect of niacin treatment
p_j = Effect of different period of sampling
$(np)_{ij}$ = Effect of interaction between niacin treatment and period of sampling
e_{ijkl} = Residual error

RESULTS

Dry matter intake and apparent digestibility: The DMI was similar for each treatment and there were no significant difference between groups. Similarly there were no differences among treatments for OM, NDF and ADF digestibility (Table 1).

Blood metabolites: Cows received supplemental niacin had consistently higher glucose concentrations in blood plasma than cows in control groups (Table 2). Plasma glucose in each group tended to decrease after calving until 4th week post calving. In the niacin-supplemented cows, glucose was higher than control cows ($p<0.05$) from 6-10th weeks after calving. In control group plasma glucose concentration, only increased in 4-6th weeks and then it had been constant. Maximum plasma glucose was observed in third group (12 g niacin) in the 10th week (Table 4). Also, from 4-10th weeks, plasma glucose was higher in cows received niacin, but this increase was only statistically significant in 10th week post calving (Table 4). Concentrations of BHB were consistently lower in niacin supplemented cows after calving than in controls (Table 2). Differences were significant ($p<0.05$) at week 6 and 10 for BHB. After calving, plasma BHB tended to increase, until 6th week, but in cows was received niacin post calving, this increase was slighter. After 6th week, in cows were supplemented with niacin, BHB tended to decrease but this trend were observed after 8th week in control cows (Table 4). The total plasma

Table 1: Dry matter intake and nutrient digestibility of cows receiving no niacin (control) or supplementary niacin

	Treatments[1]				
Items	1	2	3	SE	Niacin effects
[2]DMI (kg day^{-1})	21.3	21.8	21.6	1.04	NS
Apparent digestibility (%)					
DM	67.8	69.1	68.5	0.61	NS
OM	71.6	70.5	71.2	0.63	NS
NDF	55.4	53.7	55.2	0.91	NS
ADF	50.6	51.9	53.1	1.27	NS

[1](1) control group, (2) 6 g niacin per day (3) 12 g niacin per day, [2]Means within rows followed by different letter(s) are significantly different ($p<0.05$), NS: Non-Significant

Table 2: Effects of niacin treatment on blood parameters of dairy cows

	Treatments				
Items	1	2	3	SE	Niacin effect
Blood parameters					
Glucose (mg dL^{-1})	37.10b	44.08a	45.44a	4.71	p = 0.022
Triglyceride (mg dL^{-1})	48.09a	38.76b	41.43b	3.20	p = 0.016
BHB (mg dL^{-1})	12.56a	11.33b	10.48b	0.27	p = 0.021
Total protein (g dL^{-1})	8.10a	7.50b	7.50b	0.27	p = 0.039

[1](1) control group, (2) 6 g niacin per day (3) 12 g niacin per day, [2]Means within rows followed by different letter(s) are significantly different ($p<0.05$)

Table 3: Milk production and it's components in treated cows with niacin

	Treatment				
Items	1	2	3	SE	Niacin effect
Milk production					
Milk yield (kg day^{-1})	39.50	38.30	38.00	2.98	NS
FCM (kg day^{-1})	37.20	35.50	37.20	3.62	NS
Fat (%)	3.60	3.60	3.90	0.40	NS
Protein (%)	3.00	3.10	3.10	0.05	NS
Lactose (%)	4.77	4.79	4.81	0.05	NS
SNF (%)	8.92	8.92	8.94	0.03	NS

[1](1) control group, (2) 6 g niacin per day (3) 12 g niacin per day, [2]Means within rows followed by different letter(s) are significantly different ($p<0.05$), NS: Non-Significant

Table 4: Effects of period of sampling on blood parameters and milk components and yield of treated cows

	Period (1)				Period (2)				Period (3)			
Items	[1]1	2	3	SE	1	2	3	SE	1	2	3	SE
Milk production[2]												
Yield (kg day^{-1})	35.10	32.60	35.00	2.57	43.10	39.10	40.20	2.44	42.30	40.40	40.70	2.30
4%FCM (kg day^{-1})	37.50	36.00	39.20	3.00	44.70	40.10	44.40	3.32	39.10	38.00	40.90	3.28
Fat (%)	4.40	4.80	4.80	0.29	4.20	4.20	4.70	0.30	3.50	3.60	4.00	0.34
Protein (%)	3.10	3.30	3.30	0.07	3.10	3.20	3.20	0.03	2.90	3.10	3.00	0.09
Lactose (%)	4.92	4.87	4.94	0.05	4.89	4.85	4.86	0.06	4.89	4.84	4.82	0.05
SNF (%)	9.11	9.08	8.97	0.09	8.92	8.95	8.89	0.05	8.81	8.82	8.84	0.04
Blood parameters												
Glucose (mg dL^{-1})	38.24	38.67	36.86	2.82	28.71	24.33	29.00	3.91	41.91	47.05	50.00	5.14
Triglyceride (mg dL^{-1})	43.94	44.37	43.33	4.47	43.98	38.72	43.71	3.50	46.33a	36.11b	38.88	2.30
BHB (mg dL^{-1})	11.53	11.42	11.39	0.11	12.38	12.06	12.01	0.16	12.90a	11.51b	11.47b	0.14
Total protein, (g dL^{-1})	8.54	7.58	7.73	0.62	8.95	8.25	8.22	0.34	7.63	7.52	7.37	0.26

	Period (4)				Period (5)			
Items	1	2	3	SE	1	2	3	SE
Milk production[2]								
Yield (kg day^{-1})	38.90	39.70	38.50	2.19	38.20	39.50	35.60	2.40
4%FCM (kg day^{-1})	35.20	34.00	34.40	2.80	29.20	29.50	27.00	2.44
Fat (%)	3.40	3.00	3.30	0.38	2.50	2.30	2.40	0.28
Protein (%)	2.90	2.80	2.90	0.08	2.90	3.00	3.00	0.06
Lactose (%)	4.69	4.71	4.74	0.09	4.55	4.59	4.55	0.07
SNF (%)	8.82	8.79	8.78	0.05	8.78	8.77	8.75	0.07
Blood parameters								
Glucose (mg dL^{-1})	41.68	55.20	55.14	4.84	38.03b	55.16a	56.21a	4.64
Triglyceride (mg dL^{-1})	53.10a	37.95b	41.79b	2.61	53.12a	36.64b	39.47b	2.61
BHB (mg dL^{-1})	11.66	11.36	11.28	0.09	11.23a	10.38b	10.23b	0.07
Total protein (g dL^{-1})	7.58	7.89	7.14	0.20	7.80a	7.21b	7.02b	0.19

[1](1) control group, (2) 6 g niacin per day (3) 12 g niacin per day, [2]Means within rows followed by different letter(s) are significantly different ($p<0.05$)

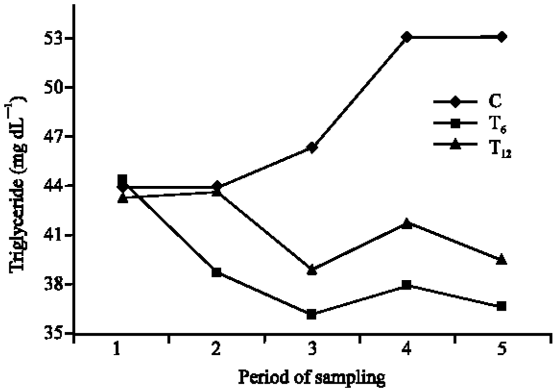

Fig. 1: Effect of niacin on blood triglyceride level in different period of sampling

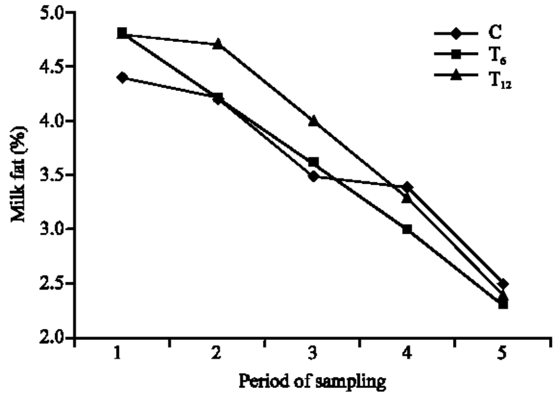

Fig. 2: Effect of niacin on milk fat content in different period of sampling

protein concentrations in each group of cows increased during the first 4 week postpartum and then tended to decrease until 8th week postpartum. This factor in groups 1 and 2 had an increasing trend from 8th week to the end of experiment, but this trend was reduction in the third group. Maximum and minimum plasma protein was observed in control groups on 4th week postpartum and in group 3 at 10th week, respectively (Table 4). The trend of triglyceride level in groups received niacin was descending and in control group it was ascending (Fig. 1). Maximum and minimum concentration of plasma triglyceride was observed in control group at the 10th week and in group that received 6 g niacin at the 6th week post calving, respectively (Table 4). There was a significant difference in general mean of control group with other groups ($p<0.05$).

Milk and its components: Based on current results no significant difference for milk yield and milk components were found among control and niacin treated groups (Table 3). Milk production in each group increased until third sampling period (6th week) and then decreased until the end of experimental periods (10th week). Maximum milk yield were observed in control group at second period of sampling and minimum milk yield were observed in 6 g niacin treated groups at first period of sampling (Table 4). Milk fat content was maximizing after calving and it tended to decrease afterwards (Fig. 2). FCM yield in each three groups showed an increasing trend until second sampling period (4 weeks after calving) and descended after fifth sampling period. Milk protein content tended to decrease after calving to fourth period of sampling and after that. It tended to increase slightly. Maximum and minimum milk protein content were observed in groups 2 and 3 in first period of sampling and in group 2 at fourth period of sampling (Table 4). There were not observed significant difference between groups. Lactose and SNF in milk were not affected by treating with niacin. In each groups lactose and SNF were maximum after calving and then tended to decrease until 8th week after calving (Table 4).

DISCUSSION

Many high-producing cows in early lactation exhibit borderline ketosis (Emery *et al*., 1964). High production imposes a severe metabolic drain that creates a negative energy balance resulting in excessive adipose lipolysis, which often leads to increased hepatic ketogenesis (Fronk *et al*., 1980). The ketosis syndrome is manifested by blood changes that show lowered glucose, elevated NEFA from adipose lipolysis and elevated ketones (Bergman, 1971). Niacin, used in therapeutic doses to treat bovine ketosis, has reduced blood ketone and NEFA concentrations and increased blood glucose (Nurmio *et al*., 1974; Waterman and Scultz, 1972a). In current study, we observed that blood glucose was elevated by using niacin (both doses) and consequently blood ketones (BHBA) were decreased.

Fronk and Schultz (1979) gave daily doses of 12 g nicotinic acid to cows exhibiting sub clinical or clinical ketosis. Before receiving the nicotinic acid treatment, the cows had low blood glucose concentration and elevated blood concentrations of BHBA and NEFA. The results of current experiment showed that adding 6 g niacin perform equal to 12 g dose of this supplement. The greatest response to niacin supplementation occurred between wk 6 and 8 after calving.

Drackley (1992) summarized 24 reports with responses from 40 treatment comparisons. Across all studies and relative to controls, niacin supplementation had minimal effects on DMI (-0.12 kg day^{-1}), milk production (+0.36 kg day^{-1}), or milk component percentages and production. On average, 51% of the comparisons showed positive numerical responses to supplemental niacin and milk production was increased in 65% of the studies. Averaged responses to niacin were all positive when only early lactation (less than 15 weeks postpartum) studies were considered. It is possible that the greater response in early lactation is due to effect of niacin on ketosis.

Fronk and Schultz (1979) showed that milk production increased significantly when ketotic cows were treated with 12 g niacin daily. However, in a later study by Fronk *et al.* (1980) when 12 g niacin was given to over conditioned fresh cows, no difference was observed for milk production or blood metabolites between niacin-supplemented and control cows. However, in their study niacin supplementation was not started until the 8th day postpartum.

Several of the reports summarized by Drackley (1992) included supplementation of dietary fat to the rations. In this situation niacin responses were largely negative and relative to controls, DMI, milk production and 4% fat-corrected milk production were reduced by 0.04 and 0.42 and 0.84 kg day^{-1}, respectively. Milk protein content was increased 0.09% units by niacin supplementation. Kronfeld and Raggi (1964) observed that concentrations of all forms of the nicotinamide adenine nucleotides are lower in mammary tissue during ketosis than when cows are normal. Their results were interpreted to mean that shortage of all forms of these coenzymes, rather than failure to convert oxidized into reduced forms or vice versa, is a metabolic deficiency in ketosis. Therefore, they conjectured that failures in the reductive synthesis of milk fat from acetate and in the oxidation of glucose could be associated with a shortage of the nicotinamide coenzymes. Drackley (1992) also summarized results of niacin supplementation on blood NEFA, β-hydroxybutyrate (BHBA) and glucose concentrations. When cows were fed niacin at 3 to 12 g day^{-1} in early lactation, niacin had no consistent effects on blood NEFA concentrations but BHBA concentrations were decreased by varying degrees in 11 of 14 (79%) comparisons. Niacin increased blood glucose concentrations relative to controls in 10 of 16 comparisons and in present study it is observed in both niacin treatments, plasma glucose were higher than control treated cows. Increased milk production in early lactation could be due to the increased absorption of niacin and subsequent prevention of decreased pyridine nucleotides with niacin supplementation (Riddell *et al.*, 1981). But a lack of response in this experiment can be caused by enough available tryptophan as a precursor of niacin synthesis. The National Research Council (2001) reported that the response of dairy cow in milk production and components to niacin supplementation was varied. Significant improvements in milk production or in blood parameters occur infrequently and stage of lactation and changes in feeding practices rarely increase the likelihood of observing a benefit from niacin supplementation. Few studies included in the aforementioned reviews supplemented more than 12 g day^{-1} niacin or adequately investigated effects in transition cows. Given the benefits observed by French (2004), the molecular action of niacin on adipose tissue and challenges with transition cows in regards to adipose tissue mobilization and concomitant hepatic lipidosis, high-dose niacin supplementation may be beneficial for transition cows.

Presently however, there seems to be little value in supplementing niacin to lactating dairy cattle, especially when response variability and economic returns are considered. Due to the almost complete ruminal destruction of niacin (Zinn *et al.*, 1987; Santschi *et al.*, 2005), use of rumen-protected niacin supplements may be useful in future experiments.

CONCLUSIONS

In the early lactation supplementing niacin, has significant effect on blood metabolites and increase blood glucose levels and decrease blood Ketone bodies. Moreover, adding niacin to diet of dairy cows may improve milk production but in this trial we didn't see this effect. Niacin did not have significant effect on DMI or digestibility. How ever, we offer that, it's better begging to use niacin before calving and continue to use it for 2 mounts after calving.

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