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Effect of Dietary Chromium Supplementation on Growth Performance, Rumen Fermentation Characteristics and Some Blood Serum Units of Fattening Dairy Calves under Heat Stress

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Abstract: Twenty four fattening dairy calves were assigned to investigate the effect of dietary Chromium (Cr) supplementation (0 or 3 mg Cr/head/day from organic preparation) on the growth performance and rumen fermentation characteristics as well as on some blood serum parameters under heat stress (35-40°C). Chromium supplementation significantly ($p \leq 0.05$) increased total feed intake across the whole experimental period by about 10% when compared with the control. Moreover chromium supplementation improve body weight at the end of the experiment, weight gain and feed conversion ratio across the whole experiment by about 7.5%, 13% and 2.7% respectively when compared with the control. Serum insulin concentration increased whereas cortisol concentration decreased, when compared with the control group. Also Cr supplementation showed a trend towards improving rumen fermentation characteristics. It could be concluded that dietary Cr supplementation at level of 6 mg/head/day may offer a potential protective management practice to lessen the effect of heat stress in fattening dairy calves.

Key words: Fattening calves, chromium, growth performance, rumen fermentation

INTRODUCTION

High environmental temperatures and humidity are detrimental to the productivity of commercial farm animals (Morrison, 1983). Farm animals have known Zones of Thermal Comfort (ZTC) that are primarily dependent on the species, the physiological status of the animals, the relative humidity, velocity of ambient air and the degree of solar radiation (NRC, National Research Council, 2001). Economic losses are incurred by the Saudi Arabian livestock industries because farm animals are raised in places and seasons where temperature conditions venture outside the ZTC.

Trivalent Chromium (Cr) is a structural component of a glucose tolerance factor which potentiates the action of insulin; it is also an essential trace element for normal metabolism of carbohydrate, lipids, protein and nucleic acids in humans and laboratory animals (Anderson, 1987; Abraham *et al*., 1991; Mertz, 1993). Moreover, Cr supplementation protects against stress-induced losses of several trace elements (Schrauzer *et al*., 1986). The magnitude of metabolic response to Cr apparently depends on the chemical form of Cr; the organic form seems to be utilized more effectively than the inorganic form (Page *et al*., 1993).

Feedlot cattle may be subjected to a considerable amount of stress and multiple stressors during the marketing process and upon arrival at the feedlot (Loerch and Fluharty, 1999). The stress reduces performance of cattle (Morrison, 1983). Chromium supplementation has shown be effective to diminish adverse effects of stress, reducing cortisol level and improving immunity (Chang and Mowat, 1992; Kegley and Spears, 1995), frequently these facts becomes in enhanced growth performance (Moonsie-Shageer and Mowat, 1993). However, the amount of chromium needed to be supplemented to improve performance remains unclear; Moonsie-Shageer and Mowat (1993), found response with 0.2 and 1.0 ppm of supplementary Cr, but performance was not modifies with 0.6 ppm of chromium. Kegley *et al.* (1997), increased Average Daily Gain (ADG) supplying diets with 0.4 ppm of chromium. Barajas and Almeida (1999), observed increments in ADG supplementing 1.0 ppm of chromium. In other experiment (Barajas *et al*., 1999), found maximal performance with 0.4 ppm of chromium, while 1.0 ppm of Cr has not effect.

This study was conducted with the objective of determine the effect of organic chromium supplementation on growth performance, feed intake, some blood parameters and rumen fermentation characteristics of fattening dairy calves reared under heat stress.

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MATERIALS AND METHODS

This experiment was conducted to investigate the effect of chromium supplementation on dry matter intake, growth performance, some blood parameters and rumen fermentation characteristics of fattening dairy calves reared under heat stress from approximately 12 weeks.

Housing and management: The experiment was started on early June 2007, for 20 weeks and lasted until the end of October in a dairy farm at the eastern area of Saudi Arabia. Twenty four calves were used in this study. The calves were allotted into two equal groups and each group were assigned to two separate pens (12 calves per pen).

Daily maximum and minimum temperature and humidity indices were recorded for the whole experimental period. Temperature Humidity Index (THI) was calculated on monthly basis according to the following equation (Ingraham *et al.*, 1974): THI = T - (0.55 - 0.55RH) x (T - 58); where T is the temperature (°C) and RH is the relative humidity%/100. The environmental temperature averaged (38.9, 40.5, 37.2 and 35°C during June, July, August and September) with high relative humidity (80%, 79%, 88% and 78% for the 4 months respectively) and the recorded THI were 97, 99, 96 and 90.

Feeding and experimental design: The first group (12 calves) was assigned to the control diet and the second group (12 calves) to the chromium supplement treatment. Calves received chromium supplement for successive 12 weeks. Chromium supplementation was from organic trivalent preparation (Dinakrome product produced by Dinatec, Gainesvilles, GA, USA) consisting of 300 ppm of organic Cr, 8% crude protein with a maximum of 12% moisture. The product was offered at a rate of 10 g/calf/day (3 mg of chromium). Chromium supplementations were individually offered top dressed on the diet during morning feeding. Several measures were taken to keep chromium supplementation errors to a minimum. First, calves in the treated group were kept at pen wide enough to hold all of them at the same time while feeding. Second, the supplemented quantity for each calf (10 g of the product) was weighed into small bags and offered individually during morning feeding and observed until completely fed.

Feed intake and body weight: Dry calf starter and B. hay intakes were recorded daily throughout the experimental period and average daily feed was calculated. The diet consisted of berseem hay and concentrate. The concentrate (calf starter) during the first month of the experiment and changed after that to the calf finishing concentrate (Table 1) offered in pellet form. The diet designed to meet or exceed nutrient recommendations of the calves (NRC, 2001). Calves were weighed individually on arrival and then every 4 weeks. Body weight gains calculated as: weight gain = (Final Body weight-Initial body weight). Feed Conversion Ratio (FCR) was calculated by dividing total feed intake and gain for each groups.

Analytical procedure: Collected feed samples were analyzed for Dry Matter (DM), moisture and ash contents according to (AOAC, 1990), crude protein using Kjeldahl method according to Randhir and Pradhan (1981) and ether extract was determined according to Bligh and Dyer (1959) technique as modified by Hanson and Olly (1963). Phosphorus was determined by using spectrophotometer according to (Cockerell and Holliday, 1975) while, calcium was estimated by titration with EDTA according to David (1976).

Blood sampling and analysis: Blood sample were collected by jugular vein puncture and placed in non-additives blood collection tubes to produce serum from a sub-sample of 5 randomly selected calves from each

Table 1: Physical and chemical composition of the used diets

	Concentrates		Chemical analysis			Berseem hay chemical analysis	
Ingredients	Starter	Finisher	Items	Starter	Finisher	Items	%
Yellow corn %	39.00	43.4	Moisture %	21.1	11.6	Moisture %	8.2
Sorghum %	9.50	19.0	Dry matter %	87.9	85.4	Dry matter %	91.8
Barley %	27.35	20.0	Organic M %	83.5	83.0	Organic M %	79.9
Soybean meal %	18.50	13.0	C. protein %	18.2	16.2	C. protein %	24.9
Vegetable oil %	0.50	0.0	Eth. extract %	3.1	2.8	Eth. extract %	3.6
DCP* %	0.25	0.0	Ash %	4.4	5.4	Ash %	11.9
Limestone %	1.40	1.1	Calcium %	0.9	0.5	Calcium %	1.3
Salt %	0.40	0.4	Phosphorus %	0.4	0.3	Phosphorus %	0.3
Premix %	0.10	0.1					
Molasses %	3.00	3.0					

*DCP = Dicalcium phosphate (20% phosphorus and 25% calcium).

**Cattle premix produced by Centraly's Co. (France) contains the following elements per Kg. (10000000 IU vitamin A, 1000000, IU vitamin D_3, 10000 mg vitamin E, 100000 mg magnesium, 50000 mg manganese, 45000 mg zinc, 50000 mg iron, 6000 mg copper, 800 mg iodine, 100 mg selenium treatment groups at the end of the experimental period. Serum was separated by centrifugation at 3000 rpm for 10 min and analyzed for concentration of blood serum glucose, total protein, albumin and globulin according to (Trinder, 1969; Doumas *et al.*, 1981; Reinhold, 1953; Coles, 1974) respectively. Insulin and cortisol were measured by radioimmuno assays (Pharmacia RIA 100; Pharmacia Diagnostics, Uppsala, Sweden) and coat-A-count Kits from Diagnostic Products Corporation [(TKC, DPC), Los Angeles, CA, USA, respectively] according to the manufacturer's instructions.

Ruminal fermentation characteristics: Ruminal fluids were collected at 0, 4 and 8 h after feeding from 3 calves from each group on 28 of each period of the experiment. Ruminal fluids collected through a speculum were inserted into the calf mouth and a lubricated rubber tube was inserted through the speculum into the rumen via the esophagus. Ruminal contents (250 ml) were removed using an electric pump. Samples were monitored visually to ensure they were not contaminated with saliva. The pH was measured immediately using pH meter (Orion research model 201). The whole contents were squeezed through 4 layers of cheesecloth. The samples were acidified to pH 2 with 50% H_2SO_4 and frozen at -20°C for later determination of Volatile Fatty Acids (VFA) and ammonia (NH_3-N) concentrations. Concentrations of ammonia and VFA in ruminal fluids were analyzed by colorimetry (Weatherburn, 1967) and by GLC (varian 3700, varian specialists Ltd, Brockville, Ontario, Canada) respectively.

Statistical analysis: The analysis of variance for the obtained data was performed using Statistical Analysis System (SAS, 1996) to assess significant difference of treatment effects.

RESULTS AND DISCUSSION

Feed intake: Effect of dietary chromium supplementation on feed intake is presented in Table 2. Statistical analysis of the obtained data revealed that chromium supplementation significantly ($p \leq 0.05$) increased concentrate and roughage intake across the whole experimental period by about 9.5% and 13% respectively when compared with the control. Moreover, chromium supplementation significantly ($p \leq 0.05$) increased total feed intake across the whole experimental period by about 10% when compared with the control. Chromium treatment tended to improve feed intake of fattening calves under heat stress and our data are supported by those obtained by Moonsie-Shageer and Mowat (1993), observed 14% of increment on DMI feeding diets supplemented with 0.2 ppm and 1.0 ppm from high-Cr yeast. Barajas *et al.* (2005) indicated that chromium increase dry matter intake (6.297 vs. 6.573 kg day^{-1}). This animal response can be interpret, that as chromium diminished the adverse effects of stress (Almeida and Barajas, 2002), facilitate the adaptation of cattle to feedlot environment and is reflected as an increment in voluntary feed intake. Modification of stress associated behavior may be a mechanism to improve fed intake of newly received calves (Loerch and Fluharty, 1999). Cr tended (p = 0.09) to enhances in 17% feed/gain ratio (5.410 vs. 4.487 kg kg^{-1}). Improvements between 19% and 23% on feed/gain ratio has been reported by others authors (Chang *et al.*, 1995; Barajas *et al.*, 1999). Also, Kraidees *et al.* (2009) Cr supplementation significantly ($p<0.01$) increased DMI of lambs throughout the growing period (21-84 d) compared to controls.

Growth performance: Chromium supplementation non significantly increased (Table 3) body weight of calves at 12th, 16th and 20th weeks of calves age by about 3.1%, 4.8% and 5.2% respectively when compared with the control which fed on the basal diet without chromium supplementation. However, chromium supplementation increased ($p \leq 0.05$) body weight at the end of the experiment by about 7.5% during the stress condition when compared with the control.

Table 2: Effect of dietary chromium supplementation on feed intake (kg/calf/day) during experimental period

	Experimental groups	
Calves (age/week)	Control group	Chromium treated group
No. of observations	12	12
Concentrate intake (kg/calf/day)		
9-12 weeks	2.55±0.02^b	2.79±0.03^a
13-16 weeks	3.95±0.01^b	4.23±0.01^a
17-20 weeks	4.43±0.03^b	4.98±0.03^a
21-24 weeks	5.86±0.02^b	6.45±0.02^a
Average (9-24) weeks	4.20±0.03^b	4.60±0.03^a
Roughage intake (kg/calf/day)		
9-12 weeks	0.56±0.0^b	0.67±0.0^a
13-16 weeks	0.76±0.0^b	0.89±0.0^a
17-20 weeks	0.65±0.0^b	0.75±0.0^a
21-24 weeks	0.77±0.0^b	0.79±0.0^a
Average (9-24) weeks	0.69±0.0^b	0.78±0.0^a
Average total feed intake (kg/calf/day)	4.89±0.0^b	5.38±0.0^a

Values are means±standard error. Mean values with different letters at the same row differ significantly at ($p \leq 0.05$)

Table 3: Effect of dietary chromium supplementation on body weight (kg/calf) development during the experimental period

Calves (age/week)	Experimental groups Control group	Chromium treated group
No. of observations	12	12
W8	95±2.4[a]	94±2.5[a]
W12	128±2.6[a]	132±3.2[a]
W16	168±4.3[a]	176±5.2[a]
W20	210±5.5[a]	221±5.8[a]
W24	241±5.2[b]	259±6.2[a]

Values are means±standard error. Mean values with different letters at the same row differ significantly at ($p \leq 0.05$)

Body weight gain (Table 4) non significantly improved ($p \geq 0.05$) of fattening calves under heat stress by chromium supplementation during first three months of the experiment when compared with the control, while chromium supplementation significantly ($p \geq 0.05$) body gain at the last month of the experiment by about 22.5% and improved ($p \geq 0.05$) total body gain by about 13% when compared with the control.

Moreover, chromium supplementation improved FCR (Table 4) of calves reared under heat stress during 1st, 2nd and 4th month of the experimental period by about 3.8%, 1.2% and 10% respectively, while deteriorate FCR during 3rd month of the experiment by about 5% when compared with the control. However, chromium supplementation improved FCR of fattening calves reared under stress condition across the whole experimental period by about 2.7% when compared with the control.

Body weight gain and FCR improvement are in agreement with those obtained by Barajas *et al.* (2005) noticed that Chromium methionine supplementation tended (p = 0.06) to increase 2.5% ending calves weight (251.38 vs. 257.75 kg), also Barajas *et al.* (2008a), Chromium supplementation increased ($p<0.01$) ending bulls weight (466 vs. 500 kg) and average daily gain (1.28 vs. 1.47 kg/d). The increase of body gain in these calves could be attributed to the increase in Dry Matter Intake (DMI). This expatiation agree with those obtained by Kraidees *et al.* (2009).

However, our data are disagree with those obtained by some workers in lambs (DePew *et al.*, 1996; Forbes *et al.*, 1998) and calves (Kegley *et al.*, 1997; 2000; Swanson *et al.*, 2000). These authors reported that Cr supplementation did not alter the growth performance.

Blood serum units: Effect of dietary chromium supplementation of calves reared under heat stress condition on some blood parameters are presented in Table 5. The obtained data indicated that chromium supplementation non significantly ($p \geq 0.05$) improved blood serum glucose concentration by about 7.6% when compared with the control. Moreover, chromium supplementation non significantly increased blood serum total protein concentration by about 12% and significantly ($p \leq 0.05$) decreased blood serum albumin concentration by about 14.9% when compared with the control, while in contrast with albumin concentration chromium supplementation significantly increased ($p \geq 0.05$) blood serum globulin concentration by about 79% when compared with the control. The obtained data indicated that chromium supplementation improve immune response of fattening calves reared under heat stress condition. Immune response improvement by chromium supplementation observed in stressed animals by Burton *et al.* (1994); Almeida and Barajas (2001; 2002) who noticed that chromium supplementation had improved humoral immunity in newly arrived beef cattle.

Heat stress causes an increase in cortisol production (Louise, 2003) and chromium supplementation helps to alleviate the effect of stress and reduced ($p \geq 0.05$) blood serum cortisol concentration of calves reared under heat stress during our experimental period by about 36%

Table 4: Effect of dietary chromium supplementation on body gain (kg/calf) and Feed Conversion Ratio (FCR) during experimental period

Calves (age/week)	Experimental groups Control group	Chromium treated group
No. of observations	12	12
Body weight gain (kg/calf)		
9-12 weeks	33±0.9[a]	38±1.1[a]
13-16 weeks	40±1.3[a]	44±1.7[a]
17-20 weeks	42±1.8[a]	45±2.1[a]
21- 24 weeks	31±1.9[b]	38±2.2[a]
Total body gain (kg/calf)	146±2.7[b]	165±2.8[a]
Feed Conversion Ratio (FCR)		
9-12 weeks	2.64	2.54
13-16 weeks	3.30	3.26
17-20 weeks	3.39	3.56
21-24 weeks	5.90	5.30
Average FCR	3.75	3.65
FCR improvement relative to control	100.00	-2.70

Values are means±standard error. Mean values with different letters at the same row differ significantly at ($p \leq 0.05$)

Table 5: Effect of dietary chromium supplementation on some blood parameters of calves

	Experimental groups	
Items	CG	CTG
No. of observations	5	5
Glucose (mg/dl)	57.70±2.34[a]	62.10±3.11[a]
Total protein (g/dl)	52.50±3.54[a]	58.90±4.21[a]
Albumin (g/dl)	37.70±1.43[a]	32.10±2.12[b]
Globulin	14.80±0.99[b]	26.80±1.46[a]
Insulin (µU/dl)	9.54±1.45[a]	11.21±1.11[a]
Cortisol (µg/dl)	2.56±0.55[a]	1.63±0.43[a]

Values are means±standard error. Mean values with different letters at the same row differ significantly at ($p \leq 0.05$). CG = Control Group; CTG = Chromium Treated Group

Table 6: Effect of dietary chromium supplementation on rumen fermentation characteristics of fattening calves

	Experimental groups	
Items	CG	CTG
No. of observations	12	12
Rumen pH	6.21±0.22[a]	6.34±0.34[a]
NH_3-N (mg/100 ml)	12.20±0.91[a]	11.21±0.45[a]
Total volatile fatty acids (mM)	86.70±3.83[a]	85.10±3.12[a]
Acetate (A) mol/100 ml	60.56±0.99[a]	61.22±1.46[a]
Propionate (P) mol/100 ml	23.54±0.67[a]	24.50±1.77[a]
Butyrate (mol/100 ml)	15.90±0.55[a]	14.28±0.43[a]
A:P ratio	2.57	2.50

Values are means ± standard error. Mean values with different letters at the same row differ significantly at ($p \leq 0.05$). CG = Control Group; CTG = Chromium Treated Group

when compared with the control. These results were in agreement with those obtained by Chang and Mowat (1992). Chromium supplementation at 200 or 1000 ppb in DM from an organic source to beef cattle reduced serum cortisol levels by 40% and 60% (Almeida and Barajas, 2001). Serum insulin concentration increased ($p \geq 0.05$) by about 17.5% when compared with the control whereas cortisol concentration decreased with dietary chromium supplementation. This is reflecting a typical metabolic relationship between insulin (anabolic) and corticosterone (catabolic) having opposite effects to one another in metabolism. These finding indicates that anabolic insulin activity enhanced by chromium supplementation improves fat synthesis joint with muscle accretion. This explanation supported by those obtained by Barajas *et al.* (2008b) and Kraidees *et al.* (2009).

Rumen fermentation characteristics: It was observed that chromium supplementation increased ($p \geq 0.05$) rumen pH (Table 6) by about 2.1% and reduced ($p \geq 0.05$) rumen liquid ammonia by about 8.1% when compared with the control untreated group. Moreover, chromium supplementation had no significant effect on rumen Volatile Fatty Acids (VFA) production, however, chromium slightly increased ($p \geq 0.05$) propionate by about 4% and reduced ($p \geq 0.05$) butyrate by about 10.2% when compared with the control group.

Conclusion: Dietary chromium supplementation in fattening dairy calves diets appear to be improve body weight development and body gain and consequently slightly improve FCR. On the other hand, supplemental chromium (3 mg/head/day) may offer a potential protective management option to lessen the effects of heat stress on fattening calves through reduction of blood serum cortisol concentration and raising the insulin levels, with subsequent improvement of DMI. Moreover, chromium supplementation seems to slightly improve rumen fermentation through more propionate production and that require further investigation to proof the effect.

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