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Effect of Supplemental Chromium Levels on Performance, Digestibility and Carcass Characteristics of Transport-stressed Lambs

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ABSTRACT: A trial was conducted to study the effect of supplemental chromium (Cr) levels from a Cr-yeast source on performance, digestibility and carcass characteristics of transport-stressed lambs. Forty-eight *Naemi* lambs (avg. BW 31.7 kg) were transported by truck for a distance of 1,450 km. On arrival day, the lambs were randomly allocated to four groups receiving diets supplemented with 0.0, 0.3, 0.6 or 0.9 ppm Cr. Each group consisted of four separately housed replicates of three lambs each. The lambs were fed their respective diets *ad libitum* for 84 d (21 d stress period, followed by 63 d growing period). Road transit of lambs resulted in a decreased ($p<0.001$) live body weight of 8.5%. Supplementation of Cr-yeast did not alter the performance of lambs during the stress period. Linear and quadratic increases ($p<0.05$) were observed in DMI and ADG, respectively, with increasing supplemental Cr levels in the diets during the growing period. Values were greater ($p<0.05$) by 14.7% and 20.8%, respectively, for lambs fed 0.3 ppm Cr compared to control, while those fed on the other two levels were intermediate. Over the 84-d feeding period, a trend was noted towards a slight increase in loin eye area and a decrease in body wall fat thickness for lambs fed Cr supplementation compared to the control group. This study suggests that the supplementation of Cr-yeast, especially at 0.3 ppm level, is beneficial for improving the performance of growing lambs whether the animals are stressed or not. (**Key Words :** Chromium Yeast, Performance, Digestibility, Carcass, Lambs)

INTRODUCTION

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).

Recently, a number of studies suggested that supplemental organic Cr may be important in ruminant nutrition, especially in the presence of stressors, such as transit stress or stress during early lactation. Studies with newly-arrived stressed calves have shown a beneficial effect of supplemental Cr from a Cr-yeast source (Chang and Mowat, 1992; Moonsie-Shageer and Mowat, 1993; Mowat et al., 1993) and from an amino acid-chelated Cr source (Mowat et al., 1993; Wright et al., 1994). Supplemental chelated Cr was also shown to improve the immune response of early-lactation dairy cows (Burton et al., 1993; Pechova et al., 2002b; Terramoccia, et al., 2005). Others studies have also indicated that supplemental organic Cr improved performance of lambs (Sano et al., 1997; Gentry et al., 1999), calves (Mowat et al., 1993; Kegley et al., 1997; Pechova et al., 2002a), and pigs (Page et al., 1993; Mooney and Cromwell, 1995; Khajaren et al., 2006, Wang et al., 2008), and reduced morbidity and enhanced immune function (Chang and Mowat, 1992; Burton et al., 1993; Moonsie-Shageer and Mowat, 1993; Mowat et al., 1993; Chang et al., 1994; Kegley et al., 1997; Lien et al., 2005; Mufarrej et al., 2008). Furthermore, supplemental Cr was shown to improve carcass characteristics by decreasing fat deposition and increasing muscle content in lambs (Kitchalong et al., 1995), steers (Pollard et al., 2002), pigs (Page et al., 1993; Lindemann et al., 1995; Mooney and Cromwell, 1995; Kornegay et al., 1997), and chickens (Ward et al., 1993). Similarly,

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Table 1. Basal diet (Control, 0 ppm Cr supplementation) composition and analysis

Ingredients	Content (% as DM)
Alfalfa hay	27.0
Yellow corn	37.3
Barley	23.5
Soybean meal	9.2
Sodium bicarbonate	1.0
Ground limestone	0.9
Dicalcium phosphate	0.5
Salt	0.4
Mineral and vitamin premix[1]	0.2
Cr premix[2]	variable[3]
Chemical analysis[4]	
DM %	89.0
OM %	92.9
CP %	14.71
GE (Mcal/kg)	4.41
ME (Mcal/kg, tabulated)	2.74
DE (Mcal/kg)	3.20
CF %	8.48
NDF %	50.8
ADF %	16.3
Ca %	1.00
P %	0.41
Concentrate:roughage ratio	73:27

[1] Mineral and vitamin premix, contain per kilogram: CO, 300 mg; Cu, 20,000 mg; I, 700 mg; Fe, 10,000 mg; Mg, 150,000 mg; Mn, 40,000 mg; Se, 150 mg; Zn, 50,000 mg; and vit. A, 5,000,000 IU; vit. D, 500,000 IU; vit. E, 10,000 IU.

[2] Cr -yeast (1,000 mg of Cr/kg of Cr -yeast; Alltech, Lexington, KY).

[3] Supplemental Cr diets (0.3, 0.6 and 0.9 ppm Cr) were obtained by replacing the exact amounts of Cr premix with a similar amount of corn in the basal (control) diet.

[4] Laboratory analysis as DM basis.

consumption of Cr picolinate supplement by humans was shown to decrease body fat and increase muscle mass (Kaats et al., 1991).

The present study was conducted to determine the effect of adding different levels of supplemental organic Cr from a Cr-yeast source on performance, nutrient digestibility, nitrogen (N) utilization and carcass characteristics of transport-stressed growing lambs.

MATERIALS AND METHODS

Animal, diets, design and performances measures

Forty-eight 4-6 mo old Naemi lambs were transported by truck for a distance of 1,450 km (approximately 30 h drive), from Al-Watania farm, in Al-Jouf province to the animal production farm at King Saud University in Riyadh, Saudi Arabia. The lambs were weighed (avg. BW 31.7 kg) shortly before transportation, following 16 h of feed and water deprivation. Upon arrival, the lambs were re-weighed (avg. BW 29.0 kg), ear tagged, and treated with injectable ivermectin for internal and external parasites. They were penned in groups of three lambs per pen and randomly assigned to four pens per treatment. Treatment levels were: 0.0, 0.3, 0.6 and 0.9 ppm of supplemental Cr, incorporated into a growing diet (NRC, 1985; Table 1) consisting of 73% concentrate and 27% roughage on a DM basis. Chromium was supplied from a Cr-yeast source (1,000 mg Cr/kg, Alltech Biotechnology Centre, Nicholasville KY). During the entire trial period, the lambs were housed in 2×3.4 m pens in an open barn with concrete floor. They were freely fed alfalfa hay for the first 6 d after arrival while the experimental diets were gradually introduced from day 3. Because of expected high stress and low initial DM intakes, the lambs receiving 0.3, 0.6 and 0.9 ppm of Cr supplements were given extra Cr supplementation (2.4, 4.8 and 7.2 mg per day per lamb, respectively) for the first 2 d (Chang and Mowat, 1992; Moonsie-Shageer and Mowat, 1993; Mowat et al., 1993). To ensure that each lamb consumed Cr, the Cr premix was mixed with 60 g ground corn, and scattered onto a small amount of hay before offering the diet. On days 3 and 4 the quantity of Cr was reduced to half, followed by further reductions on days 5 and 6. On day 7, experimental diets were wholly started and the lambs were allowed to consume their respective diets *ad libitum*. The experimental period lasted 84 d (21 d stress period followed by 63 d growing period). Orts were weighed on days 2, 4 and 7 and then weekly afterwards for DM intake determination. During the first 4 d, water consumption was recorded. The lambs were weighed at 3-wk intervals throughout the trial period. Each time the animals were denied feed and water for 16 h prior to weighing. The lambs were visually monitored for morbidity and their rectal temperatures were recorded periodically. Feed ingredients and samples of experimental diets were taken, ground and stored pending chemical analysis.

Digestibility trial

Four lambs from each treatment were randomly selected and housed in individual shaded metabolic crates to conduct the digestibility trial. The amount of diet offered to each lamb was the average of daily intake during the last 7 d of the growing period. The diet was weighed daily and then offered to each animal in 2 equal meals for a 4 d adaptation period in the crate followed by a 7 d collection period. Samples of feed offered and refused were kept daily pending chemical analysis. Daily fecal and urine outputs of each lamb were collected and weighed; composite and representative samples (20% and 10% aliquots for feces and urine, respectively) were taken. Fecal samples were dried at 55°C for 48 h and stored for chemical analysis. Urine was collected in a plastic bucket containing 100 ml 4 N HCl solution to prevent ammonia nitrogen loss. Urine samples were mixed in a jar for N estimation. Composite samples of

Table 2. DMI and water consumption of transport-stressed lambs during the first week of arrival[z]

Item	Levels of supplemental Cr (ppm)				SEM[x]
	0.0	0.3	0.6	0.9[y]	
DM intake (kg/d)					
0-2 d	0.68[ab]	0.73[a]	0.65[b]	0.71[ab]	0.011
2-4 d	1.03	1.11	1.05	1.06	0.017
0-4 d	0.86	0.92	0.85	0.88	0.011
Week- 1	0.96[ab]	1.03[a]	0.95[b]	0.95[b]	0.015
Water intake (L/d)					
0-4 d	3.10	2.88	2.89	2.69	0.085

[a, b] Means within rows not sharing the same letter (s) differ ($p<0.05$).

[x] Pooled standard error of mean.

[y] 0.0 = control (0.0 ppm Cr), 0.3 = control+0.3 ppm supplemental Cr, 0.6 = control+0.6 ppm supplemental Cr, 0.9 = control+0.9 ppm supplemental Cr; as Cr-yeast.

[z] Values represent least squares means, data are means of 4 pens, 3 lambs each per treatment.

feeds and feces were ground through a 1 mm screen then analyzed for DM at 105°C overnight and ashed at 550°C for OM determination. The CF and CP were determined according to AOAC (1990) methods. The methods of Goering and Van Soest (1970) were used for NDF and ADF determinations. Gross energy (GE) was determined by a parradiabitic bomb calorimeter.

Carcass evaluation

At the end of the trial, 6 lambs per treatment were randomly selected on a basis of average weight of each treatment group and, after fasting for 18 h, were slaughtered at the abattoir for carcass evaluation. The heart, liver, kidneys and pelvic fat were removed and their weights recorded. Hot carcass weight was recorded, and the carcass split down the center of the backbone into two sides. The right side was chilled at 2°C for 24 h for the determination of loin eye area and body wall fat thickness. The exposed surface of the 12-13th rib cross section was traced onto acetate paper and the *longissimus dorsi* muscle area was determined using a planimeter. The body wall fat thickness (11 cm lateral to the midline between the 12-13th rib) was also measured. The 9-11th rib sections were obtained by ribbing between the 8-9th and 11-12th rib, and physically dissected into two components: soft (lean and fat) tissue and bone. The soft tissues were ground, blended and homogenized, then sub-samples were taken, kept in plastic bags and stored frozen at -20°C for later analysis of CP, EE, water and ash (AOAC, 1990).

Statistics

Data were subjected to analysis of variance using the General Linear Model (GLM) procedure of the Statistical Analysis System Institute, Inc. (SAS, 1998) according to the following model:

$$Y_{ij} = \mu + C_i + e_{ij}$$

Where Y_{ij} = Measurements of the variables,

μ = Common mean,

C_i = Effect of the i^{th} treatments (Cr levels; 0.0, 0.3, 0.6 and 0.9 ppm), and

e_{ij} = Residual error.

Linear and quadratic polynomial contrasts were used to evaluate the difference between treatment effects and orthogonal contrast. Control vs. Cr supplementation was also tested. Individual animals were used as the experimental unit for all data, except that of DM intake and feed efficiency where pen was used as the experimental unit. Least squares means of each treatment were compared for polynomial contrasts, and significance was determined at $p<0.05$, $p<0.01$ and a tendency at $0.05<p<0.10$; the values are presented in the tables and figure with pooled standard error of the mean.

RESULTS AND DISCUSSION

Transportation

Animals transported from one place to another are exposed to stressful conditions both due to long distances transportation and deprivation of feed and water during transit. Those stressors cause, at least, losses of appetite and body weight. Transportation of the lambs (n = 48) for about 1,450 km (~30 h) resulted in a significant ($p<0.001$) decrease in their average body weight from 31.7 to 29.0 kg (i.e., 8.5%). A marked decrease of 8.1-8.4% in body weight of calves was also reported following transportation for a period of 2 d (Hutcheson et al., 1984). Likewise, Kent and Ewback (1986) noted a 4.5% loss in calf body weight after 6 h of transportation, and the loss increased to 6.1% after 18 h of transportation. Similar results were also reported by others investigators (Galyean et al., 1981; Cole et al., 1982; Phillips et al., 1985). In the present study, dry matter intake during the first week of arrival was low (Table 2), particularly during the first 2 d (2.3% of body weight, 53% of NRC, 1985 recommended level). This result is comparable to that reported by Wright et al. (1994) in calves during the first 3 d after arrival (50% of NRC, 1984). This low feed intake might have been due, in part, to fasting causing movement of the stomach, reduced microbial fermentation, and consequent shrinkage in body weight. Cole and Hutcheson (1981) and Cole et al. (1988) noted that rumen fermentation capacity was reduced by as much as 75% after 48 h feed and water deprivation and this reduction remained for more than 4 d post re-feeding. Two days later, DMI increased to 3.6% of body weight and by the end of the first week, it had returned to the normal level recommended by NRC (1985). Del Barrio et al. (1993)

Table 3. Performance of transport-stressed lambs fed different levels of supplemental Cr as Cr-yeast[zy]

Item	Levels of supplemental Cr (ppm)				SEM[w]	PC[v]
	0	0.3	0.6	0.9[x]		
No. of lambs	12	12	12	12		
Live wt (kg)						
Initial	29.0	28.9	29.0	29.0	0.109	
Final	46.1[b]	49.1[a]	47.8[ab]	47.5[ab]	0.493	Cr*, Q[+]
Gain	17.2[b]	20.3[a]	18.9[ab]	18.7[ab]	0.459	Cr*, Q[+]
DM intake (kg/d)						
0-21 d	1.07	1.13	1.04	1.10	0.018	
21-84 d	1.36[b]	1.56[a]	1.46[ab]	1.54[a]	0.029	Cr**, L*
0-84 d	1.29[b]	1.45[a]	1.35[ab]	1.44[a]	0.024	Cr**, L*
Daily gain (kg/d)						
0-21 d	0.218	0.233	0.193	0.213	0.009	
21-84 d	0.202[b]	0.244[a]	0.235[ab]	0.224[ab]	0.007	Cr*, Q*
0-84 d	0.205[b]	0.241[a]	0.225[ab]	0.222[ab]	0.005	Cr*, Q[+]
Gain:DM intake ratio						
0-21 d	0.203	0.205	0.186	0.192	0.006	
21-84 d	0.159	0.157	0.158	0.149	0.003	
0-84 d	0.168	0.166	0.165	0.158	0.003	

[a,b] Means within rows not sharing the same letter (s) differ ($p<0.05$).

[v] Polynomial contrasts, Cr = 0.0 vs. Cr, L = linear, Q = quadratic. [+] $p<0.10$, * $p<0.05$, ** $p<0.01$.

[w] Pooled standard error of mean.

[x] 0.0 = control (0.0 ppm Cr), 0.3 = control+0.3 ppm supplemental Cr , 0.6 = control+0.6 ppm supplemental Cr, 0.9 = control+0.9 ppm supplemental Cr; as Cr-yeast.

[y] Gain data are means of 12 lambs per treatment, while for other parameters data are means of 4 pens, 3 lambs each per treatment.

[z] Values represent least squares means. Feeding period lasted 84 day.

reported that transport-stressed animals need 6-9 days post-arrival to return to their pre-transportation DMI. The reduced DMI during the first week of arrival was reported in calves by other investigators (Hutcheson et al., 1984; Chang and Mowat, 1992; Moonsie-Shageer and Mowat, 1993; Wright et al., 1994; Chang et al., 1995).

Performance

Dry matter intake during the first week of arrival was not affected ($p>0.05$) by supplemental Cr as Cr-yeast compared to the control (Table 2). However, lambs fed 0.3 ppm Cr consumed higher DMI than lambs fed the other two levels of Cr supplementation ($p<0.05$) or the control ($p>0.05$). This finding is consistent with previous trials with either organic (Cr-yeast or chelated-Cr) or inorganic ($CrCl_3$) sources of Cr supplementation in stressed calves (Chang and Mowat, 1992; Mowat et al., 1993; Wright et al., 1994; Chang et al., 1995). In the present study, supplemental Cr had no significant ($p>0.05$) effect on water consumption of the lambs during the first 4 d after arrival (Table 2). A similar result was previously reported by Wright et al. (1994) in stressed calves during the first 3 d post arrival.

The trend of performance expressed as DMI, ADG and feed efficiency was similar in all lambs during the first 21 d after arrival (stress period), indicating that Cr supplementation had no significant effect during that period as compared to the control (Table 3). A possible explanation could be that pooled Cr in the body of these lambs was not depleted as a result of transportation and feed deprivation to the extent that the lambs would respond positively to the additional dietary Cr. Another possible explanation is the good conditioning of lambs prior to transport which allowed them to better tolerate the stressors of transport and handling. Furthermore, Awassi (Naemi) lambs are known for their adaptation to harsh, semi-arid and arid environments, as well as their resistance to diseases, and ability to move over long distances under nomadic conditions (Al- jassim et al., 1999). No information is available in the literature on the effect of supplemental Cr on the performance of transport-stressed lambs; however, Chang et al. (1995) have found no beneficial effect on performance of calves when given 0.75 ppm inorganic Cr from $CrCl_3$ during the first 28 d after transportation. On the other hand, several researchers have reported a beneficial effect on performance of calves with supplemental trivalent chromium as Cr-yeast, chelated-Cr or CrNic during the stress period i.e., within 21-30 d post arrival (Chang and Mowat, 1992; Moonsie-Shageer and Mowat, 1993; Mowat et al., 1993; Wright et al., 1994; Chang et al., 1995; Kegley et al., 1997). Based on this observation, we speculate that lambs may have greater resistance to transportation stressors than calves. However, in the present study, Cr supplementation significantly ($p<0.01$) increased DMI of lambs throughout the growing period (21-84 d) compared to

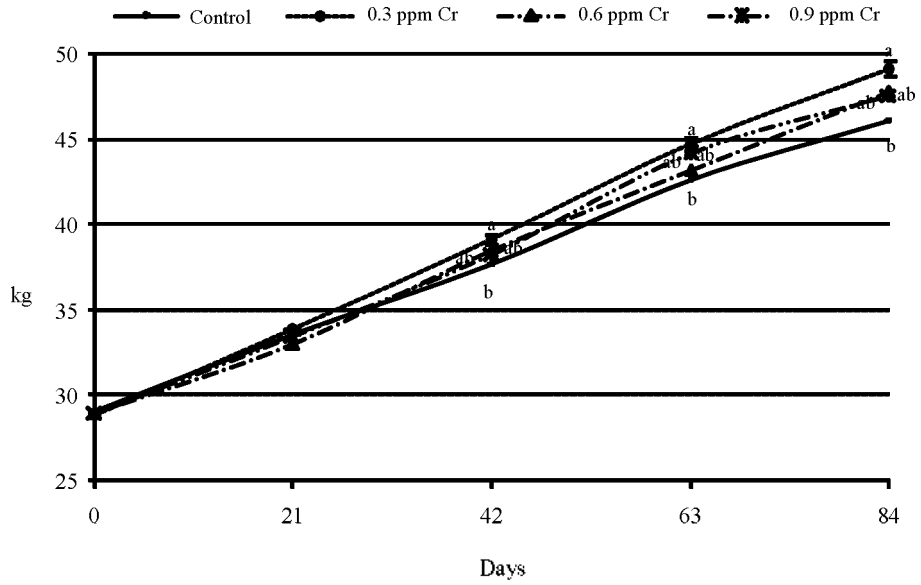

Figure 1. Effect of supplemental levels of chromium as Cr-yeast on live body weight of lambs. Values are least squares means (n = 12 lambs/treatment). Control = (0.0 Cr), 0.3 = control+0.3 ppm supplemental Cr, 0.6 = control+0.6 ppm suppl. Cr, 0.9 = control+0.9 ppm suppl. Cr, as Cr-yeast. Pooled standard error of means at d 0, 21, 42, 63 and 84 were 0.109, 0.209, 0.296, 0.378, and 0.493, respectively. [a, b] Means within treatment in every day not sharing the same letter (s) differ ($p<0.05$).

controls, and the effect was linear ($p<0.05$). This effect was also noted over the 84 d feeding period, with the highest value (12.4% increase; $p<0.05$) in lambs fed either 0.3 or 0.9 ppm and an intermediate value (4.6% increase; $p>0.05$) in those fed 0.6 ppm Cr compared to the control. Also, supplemental Cr increased ($p<0.05$) ADG for all lambs during the growing period, which exhibited a quadratic ($p<0.05$) response. The effect of various supplementary levels of Cr-yeast on live body weight of lambs throughout the experiment is illustrated in Figure 1. When the ADG was computed over the entire 84 d feeding trial, lambs fed diets containing 0.3 ppm Cr gained faster by 17.6% (0.241 kg; $p<0.05$) than those fed diets containing no Cr supplementation (0.205 kg), while the other two treatments were intermediate. The increase of ADG in these lambs could be attributed to the increase in DMI. Thus, Cr supplementation might improve the performance of growing lambs, by improving insulin function. On the other hand, feed efficiency was not significantly affected by Cr supplementation either during the stress or the growing periods, indicating that Cr supplementation merely accelerates the growth rate of lambs which reduces the time needed to reach a target weight. Our findings were consistent with those of other studies on non-stressed growing lambs (Sano et al., 1997; Gentry et al., 1999) and calves (Mowat et al., 1993; Kegley et al., 1997; Pechova et al., 2002a). An increase in growth rate and breast size was also observed in turkeys receiving supplemental Cr as $CrCl_3$ (Steele and Rosebrough, 1979, 1981; Anderson et al., 1990). Likewise, Suksombat and Kanchanatawee (2005) reported that supplementation of 0.2 ppm of organic Cr as Cr-yeast or CrPic tended to improve growth performance and carcass characteristics of broilers. Similarly, studies on pigs during the growing and fattening periods indicated that Cr supplementation in the form of CrPic has a beneficial effect on performance (Page et al., 1993; Mooney and Cromwell, 1995, Wang et al., 2008). The present results, however, disagree with those reported by some workers in lambs (Kitchalong et al., 1995; DePew et al., 1996; Forbes et al., 1998) and calves (Chang and Mowat, 1992; Chang et al., 1992, 1995; Bunting et al., 1994; Wright et al., 1994; Kegley and Spears, 1995; Mathison and Engstrom, 1995; Kegley et al., 1997, 2000; Swanson et al., 2000) and with pigs (Evock-Clover et al., 1993; Amoikon et al., 1995; Wenk, 1995; Min et al., 1997; Pollard and Richardson, 1999; Lee et al., 2000; Gang et al., 2001; Lien et al., 2005). These authors reported that Cr supplementation did not alter the growth performance.

Digestibility and nitrogen utilization

The digestibility coefficients of all nutrients in the experimental diets and the nutritive value expressed as digestible CP and DE were not affected ($p>0.05$) by Cr supplementation (Table 4). Results of N balance, however, indicated that N intake in lambs fed 0.3 or 0.9 ppm Cr were higher ($p<0.05$) than in those fed the other two levels due to increased DMI ($p<0.05$). When compared to the control, N balance was not significantly affected by Cr supplementation, but numerically improved by an average of 12% in all lambs fed Cr and by 29% in lambs fed the 0.3

Table 4. Effect of supplemental levels of Cr from Cr-yeast on digestion coefficients, nutritive values and nitrogen utilization of the diets by lambs[z]

Item	Levels of supplemental Cr (ppm)				SEM[x]	PC[w]
	0.0	0.3	0.6	0.9[y]		
DM intake kg^{-d}	1.25[b]	1.48[a]	1.18[b]	1.53[a]	0.058	
Digestibility coefficients (%)						
DM	72.5	73.0	72.3	71.2	0.428	
OM	74.7	75.1	74.5	73.5	0.379	
CP	64.2	64.5	63.7	61.4	0.663	
GE	72.7	73.1	73.1	71.6	0.410	
NDF	68.1	70.0	69.5	68.8	0.613	
ADF	41.6	43.0	42.8	40.4	1.04	
Nutritive values (%)						
DCP[1]	9.45	9.44	9.40	9.02	0.097	
DE[2]	3.20	3.21	3.22	3.16	0.017	
Nitrogen balance						
N intake g^{-d}	29.30[b]	34.75[a]	27.79[b]	36.00[a]	1.36	
N excretion						
Fecal g^{-d}	10.46[b]	12.34[ab]	10.13[b]	13.90[a]	0.559	L^{+}
Urinary g^{-d}	8.39	8.89	7.10	10.97	0.971	
N retention:						
g^{-d}	10.45	13.51	10.56	11.13	1.16	
% (of absorbed N)	34.56	38.26	38.71	30.94	3.32	
% (of N intake)	53.78	59.62	60.31	50.45	5.12	

[a,b] Means within rows not sharing the same letter (s) differ ($p<0.05$).

[w] Polynomial contrasts, L = linear; [+] $p<0.10$. [x] Pooled standard error of mean.

[y] 0.0 = control (0.0 ppm Cr), 0.3 = control+0.3 ppm supplemental Cr, 0.6 = control+0.6 ppm supplemental Cr, 0.9 = control+0.9 ppm supplemental Cr; from Cr- yeast.

[z] Values represent least squares means, data are means of 4 lambs per treatment.

[1] Digestible crude protein. [2] Digestible energy.

ppm level. This result is consistent with the findings of Bunting et al. (1994) and Kitchalong et al. (1995) who reported that supplemental Cr as CrPic did not significantly influence any measure of N balance criteria. However, our results contrast with those of Britton et al. (1968) who stated that 37 μg Cr as $CrCl_3$ significantly increased ($p<0.05$) N retention in lambs. This apparent discrepancy might be attributed to the chemical form of the Cr used (i.e., organic CrPic or Cr-yeast vs. inorganic $CrCl_3$), or differences in the Cr status of the studied lambs.

Carcass evaluation

Supplemental Cr increased ($p<0.05$) kidney weight and tended to increase ($p<0.10$) slaughter weight compared to controls (Table 5). Lambs fed 0.3 ppm Cr had ($p<0.05$) higher slaughter, carcass and kidney weights than those fed diets containing no Cr, and numerically higher than those fed other Cr levels. Dietary treatments had no significant effect on other carcass traits. Over the 84-d feeding period, an inclination towards a linear numerical increase ($p = 0.26$) in loin eye area and decrease ($p = 0.22$) in body wall fat thickness, by averages of 8.7% and 9%, respectively, were observed across all lambs fed Cr compared to control. These results generally agree with those reported by other investigators in non-stressed lambs (Gentry et al., 1999; Pollard and Richardson, 1999; Pollard et al., 2002). Recently, Xiaogang Yan et al. (2008) reported that supplementation of 0.4 ppm Cr-yeast decreased ($p<0.05$) the rate of deposition of intramuscular fat compared to the 0.8 ppm level or control. Also, Wang et al. (2008) reported that supplementation of 0.2 ppm CrPic increased ($p<0.05$) longissimus muscle area by 17.29% compared to control. Feeding Cr did not alter moisture, CP, EE and ash contents of the separated soft tissue. Body composition could be altered by a proportional increase in net protein synthesis and/or by a reduction in lipogenesis (Bunting et al., 1994). In our study, N utilization was not significantly affected by Cr supplementation, but numerically improved compared to the control (Table 4), suggesting that Cr-yeast had little influence on the efficiency of protein deposition.

CONCLUSIONS

Supplementation of Cr-yeast to transport-stressed lambs does not alter their performance up to 21 d post arrival. This contrasts with calves, in which Cr supplementation following transportation enhances performance of the stressed animals. On the other hand, Cr supplementation is beneficial in improving production characteristics of lambs during the entire growth period up to 84 d, whether the

Table 5. Effect of supplemental levels of Cr-yeast on carcass characteristics of lambs[zy]

Item	Levels of supplemental Cr (ppm)				SEM[w]	PC[v]
	0.0	0.3	0.6	0.9[x]		
Slaughter wt. (kg, SW)	46.3[b]	48.9[a]	47.3[ab]	47.8[ab]	0.408	Cr[+]
Carcass wt. (kg, CW)	23.5[b]	24.9[a]	23.6[ab]	23.8[ab]	0.241	
Dressing percentage	50.8	50.9	50.0	49.9	0.377	
Organ wt. (% of SW)						
Liver	1.44	1.48	1.55	1.44	0.036	
Heart	0.32	0.34	0.32	0.34	0.005	
Kidneys	0.24[b]	0.29[a]	0.27[ab]	0.25[ab]	0.007	Cr* Q*
Pelvic and kidneys fat	1.09	0.92	1.14	1.00	0.062	
Carcass traits						
Body wall fat (cm)	1.99	1.78	1.83	1.82	0.059	
Loin eye area (cm^2)	15.2	15.9	16.7	16.9	0.627	
The 9-11[th] rib-sections wt. (g)	624	591	578	559	17.6	
Soft tissue: Bone[1]	4.96[b]	4.93[b]	6.07[a]	4.69[b]	0.196	Q[+]
Soft tissue wt. (% of rib-sections)	83.1[b]	83.0[b]	85.7[a]	82.3[b]	0.461	
Chemical composition (%)[2]						
Moisture	47.40	48.22	47.60	48.70	0.807	
Crude protein	12.34	12.74	12.68	13.39	0.274	
Ether extract	39.64	38.44	39.04	37.25	1.06	
Ash	0.62	0.60	0.69	0.66	0.015	

[a,b] Means within rows not sharing the same letter (s) differ ($p<0.05$).

[v] Polynomial contrasts, Cr = 0.0 vs. Cr, Q = quadratic, [+] $p<0.10$, * $p<0.05$. [w] Pooled standard error of mean.

[x] 0.0 = control (0.0 ppm Cr), 0.3 = control+0.3 ppm supplemental Cr, 0.6 = control+0.6 ppm supplemental Cr, 0.9 = control+0.9 ppm supplemental Cr; as Cr-yeast.

[y] Data are means of 6 lambs per treatment, feeding period lasted 84 days.

[z] Values represent least squares means. Carcass weight values are used as a covariate for carcass traits.

[1] Determined by the physically dissected the 9-11[th] rib sections into two components: soft tissue (lean and fat tissues) and bone.

[2] Chemical analysis of the separated soft tissue of the 9-11[th] ribs sections.

animals were stressed or not.

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