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RESEARCH ARTICLE

Effects of organic chromium supplementation to finishing lambs diet on growth performance, carcass characteristics and meat quality

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Abstract
The objective of this study was to evaluate supplemental organic chromium (Cr) to finishing lambs on growth performance, carcass characteristics, and meat quality. Eighteen Suffolk lambs (age (4.5±0.2) mon; (25.8±3.6) kg body weight (BW)) were randomly assigned to three levels of supplemental organic Cr (0.0, 0.2 and 0.4 mg kg^{-1} dry matter (DM)) in a complete random design. Growth performance was evaluated for 70 d, and then lambs were slaughtered to study carcass characteristics and chemical composition of meat. Orthogonal contrasts were performed (contrast one-average level 0.2 ppm Cr *vs*. average level 0.4 ppm Cr; contrast two-level 0 *vs*. average levels (0.2+0.4) ppm Cr). Orthogonal polynomials were used to estimate the linear and quadratic effects of Cr concentrations. Growth and carcass performance were not affected by supplemental organic Cr. Muscle conformation and leg perimeter linearly increased ($P<0.05$) as organic Cr level increased in the diet. Kidney fat decreased linearly ($P<0.05$) as supplemental Cr increased. In *Longissimus dorsi* (LD), the ash content decreased linearly, and shear force (kg cm^{-2}) increased ($P<0.05$) as organic Cr level increased in the diet. It is concluded that organic Cr did not affect growth performance, but it improved positively the muscle conformation, reduced kidney fat, whereas in LD there was an increment in shear force in finishing carcass lambs.

Keywords: carcass, finishing lambs, *Longissimus dorsi*, organic chromium

1. Introduction

Chromium (Cr) is required as an essential nutrient; however, its daily requirements are not established yet, but it seems that they increase under certain stress conditions like exercise, transport and sickness, when urinary excretion of Cr increases (Anderson 1987; NRC 2007). Functions and effects of Cr involve an increment in cellular sensibility to insulin,

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which influences carbohydrate, lipids and protein metabolism (Mertz 1993). It could be considered as a metabolic modifier with potential to increase growth rate, improve feed efficiency, increase carcass leanness, decrease carcass fatness, and improve efficiency and profitability of livestock production (Dikeman 2007). Chromium is necessary in protein synthesis and corporal growth (Mertz 1993); it also improves productivity due to a better energy metabolism (Jacques and Steward 1999). However, the magnitude of the metabolic response of Cr apparently depends on the chemical form, and organic forms are more effective than inorganic ones (Page *et al.* 1993), since the level of absorption of these is very low from 0.4 to 3.0% (Anderson 1987). Therefore it has been suggested that it required the use of organic sources as an alternative for their increased biological availability to be more soluble in all the digestive tract and reduce the risk of negative interactions with other minerals (Lindemann *et al.* 1995). Several studies in ruminants suggest that supplementation with organic forms of Cr decreases the blood levels of cholesterol and triglycerides (Subiyatno *et al.* 1996; Besong *et al.* 2001; Yan *et al.* 2008; Zhou *et al.* 2013). In addition to improving the weight gain in beef cattle (Barajas and Almeida 1999; Valdés *et al.* 2011) and sheep (Domínguez-Vara *et al.* 2009), it improves the characteristics of the carcass reducing back fat deposit, as well as increasing the muscle percent in sheep (Gardner *et al.* 1998; Pollard *et al.* 1999; Domínguez-Vara *et al.* 2009; Kraidess *et al.* 2009), and the area of the eye of chop (Uyanik 2001; Kraidess *et al.* 2009). Nevertheless, there are still inconsistent results by Cr supplementation, and obviously the optimum level for its use in the production of ruminants is not yet completely determined; Chang and Mowat (1992) included 0.4 ppm of Cr in the form of yeast-Cr and Moonsie-Shager and Mowat (1993) used 0.2 ppm of Cr from yeast-Cr, and Pollard *et al.* (1999) evaluated the same source with 0.2 ppm of Cr reporting all of them improvements in the growth of ruminants; on the other hand, Dominguez *et al.* (1999) reported that including 0.2 ppm of Cr methionine did not improve the growth of sheep, and Kegley *et al.* (2000) when included 0.4 and 0.8 ppm of Cr methionine also indicated that in beef cattle, the weight gain was not modified. Sheep studies have focused on evaluating the effect of Cr in nutrient metabolism (glucose, cholesterol, triglycerides) (da Rocha *et al.* 2013; Zhou *et al.* 2013), immunological status and carcass characteristics (Domínguez-Vara *et al.* 2009; Yan *et al.* 2010), but there is little information of this mineral on meat quality in fattening sheep, since the effect of Cr in meat quality parameters have been evaluated mainly in species-like pigs and poultry, reporting increments in protein retained, higher capacity in water retention, as well as, a reduction in meat fat concentration (Lien *et al.* 1999; Amatya *et al.* 2004; Tolimir *et al.* 2007). Therefore, the objective of this study was to evaluate the effects of different levels of organic Cr supplementation on growth performance, carcass characteristics and meat quality in finishing Suffolk lambs.

2. Results

2.1. Growth performance

The results of the voluntary intake, daily weight gain, final live weight and feed conversion are presented in Table 1. There was no difference in any of these variables by effect of the levels of Cr (*P*>0.5).

2.2. Carcass characteristics

In Table 2 are observed the outcomes associated with the carcass characteristics. There are no differences in hot carcass weight and yield of the carcass by effect of Cr (*P*>0.5); the same measures linear carcass, length of leg, width minor and major chest, as well as the area of the *Longissimus dorsi* (LD) were not affected by the levels of Cr, however muscle conformation and leg perimeter were linearly increased (*P*<0.05) as organic Cr level increased in the diet. Contrarily, kidney fat cover decreased linearly (*P*<0.05) as supplemental Cr increased.

Table 1 Growth performance of finishing lambs fed supplement with organic Cr

Growth performance	Organic Cr (mg kg^{-1} dry matter (DM))			SEM[1)]	Contrast	
	0	0.2	0.4		0.2 *vs*. 0.4 ppm Cr	0 *vs*. (0.2+0.4) ppm Cr
Lambs (n)	6	6	6			
Initial body weight (BW) (kg)	25.3	25.5	26.6	2.31	NS	NS
Final BW (kg)	46.9	46.7	49.2	2.51	NS	NS
Total gain (kg)	21.4	21.2	21.6	1.06	NS	NS
Average daily gain (kg d^{-1})	0.31	0.3	0.31	0.01	NS	NS
Dry matter intake (kg d^{-1})	1.66	1.74	1.71	0.07	NS	NS
Feed conversion ratio (feed/gain)	5.4	5.7	5.5	0.35	NS	NS

[1)] SEM, standard error of mean.
NS, no significant (*P*>0.05).
The same as below.

2.3. Meat quality

The results related to the chemical composition and indicators of the quality of the meat are observed in Table 3. The content of moisture, protein, and fat showed no difference for effects by levels of Cr (P>0.05). Contrarily doses of Cr showed a quadratic effect (P<0.05) up on shear force of meat; on the other hand in LD muscle the ash content decreased linearly (P<0.05).

3. Discussion

3.1. Growth performance

Several authors suggest that chromium supplementation improve the growth performance of lambs, but it could not be confirmed in this study with Suffolk lambs. This is similar to the studies of Olsen *et al.* (1996), Gentry *et al.* (1999), Arvizu *et al.* (2011), and Ziyad (2013) who reported that supplemented sheep with organic Cr did not affect their growth; nevertheless, there are investigations that have demonstrated the Cr effect in growth parameters. Domínguez-Vara *et al.* (2009) used 0.0, 0.25 and 0.35 mg kg^{-1} dry matter (DM) of organic Cr in Rambouillet sheep and found a linear decrease in dry matter intake and feed conversion; but a linear increment in final live weight, total gain weight, and daily gain weight as doses of Cr increased; likewise, Estrada *et al.* (2014) to assess different levels of Cr-enriched yeast (1, 2 or 3 g d^{-1}) reported increases in the growth of hair sheep. There are a series of factors that could have caused these discrepancies when Cr was used in animal diet, such as length of supplementation period, nutrient composition of diet (Gentry *et al.* 1999), as well as the previous nutritional management, the basal level of Cr in animals and their age. The most consistent benefits of Cr in productive animal response have been associated with animals under stress; regarding this point, there is evidence that Cr supplemented in diet of calves under transport stress and vaccines, improved initial gaining weight and immune response (Chang and Mowat 1992; Moonsie-Shageer and Mowat 1993). On the other hand, available information on the effects of Cr levels on nutrient metabolism of livestock species is variable; in addition, the Cr status in animals is not easy to establish, and Cr concentrations in blood have

Table 2 Carcass characteristics in finishing lambs supplemented with organic Cr

Carcass characteristics	Organic Cr (mg kg^{-1} DM)			SEM	Contrast		
	0	0.2	0.4		0.2 *vs.* 0.4 ppm Cr	0 *vs.* (0.2+0.4) ppm Cr	Polynomial
Body weight at slaughter (kg)	41.8	42. 6	43.4	1.65	NS	NS	NS
Hot carcass (kg)	19.7	19.7	21.0	0.93	NS	NS	NS
Chilled carcass (kg)	19.0	19.2	20.2	0.98	NS	NS	NS
Hot carcass dressing (%)	47.1	46.2	48.4	2.41	NS	NS	NS
Chilled carcass dressing (%)	45.4	45.1	46.5	2.12	NS	NS	NS
Muscle conformation[1)]	2.4	2.6	2.8	0.13	NS	NS	L
Fatness degree[2)]	3.4	3.6	3.3	0.31	NS	NS	NS
Perirenal fat[3)]	3.6	2.2	2.0	0.18	NS	*	L
Longissimus dorsi area (cm^2)	12.7	12.2	12.8	0.83	NS	NS	NS
Dorsal fat 12th rib (mm)	3.5	3.6	4	0.51	NS	NS	NS
Carcass length (cm)	69.3	70.2	69.4	2.3	NS	NS	NS
Leg length (cm)	30.0	31.3	30.1	1.91	*	NS	NS
Leg perimeter (cm)	38.8	41.2	42.8	1.13	NS	*	L
Hindquarters width (cm)	19	19.9	19.8	1.36	NS	NS	NS
Major thorax width (cm)	21.6	22.2	22	0.58	NS	NS	NS
Minor thorax width (cm)	17.3	17.7	17.8	0.62	NS	NS	NS

1) 1, poor; 2, normal; 3, good; 4, very good; 5, excellent.
2) 1, very lean; 2, lean; 3, rather fatty; 4, fatty; 5, very fatty.
3) Degree kidney fat covers: 1, uncovered; 2, with a large window; 3, with small window; 4, totally covered.
*, P<0.05; L, linear; Q, quadratic. The same as below.

Table 3 *Longissimus dorsi* characteristics in lambs supplemented with organic Cr

Meat quality	Organic Cr (mg kg^{-1} DM)			SEM	Contrast		
	0	0.2	0.4		0.2 *vs.* 0.4 ppm Cr	0 *vs.* (0.2+0.4) ppm Cr	Polynomial
Moisture (g kg^{-1})	732	734	729	5.3	NS	NS	NS
Crude protein (g kg^{-1})	224	221	223	5.2	NS	NS	NS
Fat (g kg^{-1})	59	63	64	4.5	NS	NS	NS
Ash (g kg^{-1})	19	18	17	0.09	NS	NS	L
Shear force (kg cm^{-2})	3.3	3.4	4.4	0.36	NS	NS	Q

not been evaluated either; the amount of Cr intake with diet, their absorption and metabolism are affected by various factors; therefore, the level of Cr intake and absorbed could not have been to satisfied the level of available Cr to stimulate insulin action (Mowat 1994; Bunting 1999), therefore in future research it is important to determine the level of absorption of Cr in sheep.

3.2. Carcass characteristics

The muscle conformation and leg perimeter were linearly increased ($P<0.05$) as organic Cr level increased in the diet. Contrarily, kidney fat decreased linearly ($P<0.05$) as supplemental Cr increased. These results are similar to previous investigations carried out in ruminants. Pollard *et al.* (1999) showed that 0.4 ppm of Cr yeast in beef cattle increased the area of the chops and reduced back fat; Valdés *et al.* (2011) reported a decrease of fat in cattle using different levels of Cr-enriched yeast; meanwhile, Domínguez-Vara *et al.* (2009) studied 0.25 and 0.35 ppm of Cr yeast in finishing lambs and observed an increase in the area of the chop, and a reduction of back fat. Uyanik (2001), Kraidees *et al.* (2009), and Estrada *et al.* (2014) also reported the back fat reduction and increase of the area of the chops. Several studies have shown that the Cr is essential for lipid metabolism; for example, rats and rabbits fed a diet deficient in Cr showed increase in total cholesterol and concentrations of lipids at the level of the aorta (Abraham *et al.* 1982). McNamara and Valdez (2005) studied the effect of Cr propionate on lipogenesis and lipolysis in adipose tissue of Holstein cows at 21 d pre partum and up to 35 d postpartum; Cr increased the net synthesis of fat in adipose tissue and decreased its net release. This may be due to the action of the Cr in the synthesis of cromodulin, and its effect in the insulin receptors and the increase in the flow of glucose to the interior of the adipocytes. On the other hand, Evans and Bowman (1992) showed an increase in the absorption of amino acids and glucose in skeletal muscle of rats that were fed Cr picolinate. This alteration in the absorption of nutrients was associated with alteration of parameters of insulin which is considered chromium dependent. These observations may explain the effect of glucose tolerance, as well as the increase in the percentage of skeletal muscle reported by some researchers. The potential for improvement of amino acid uptake by muscle cells is beneficial for the total deposits of proteins.

3.3. Meat quality

Humidity, protein and fat contents of meat were similar ($P>0.05$) among treatments; results found in this investigation are characteristics of lamb meat (Lin *et al.* 1998; Rubio *et al.* 2000). These results differ to what was reported by other authors in other species, Toghyani *et al.* (2008) comparing two sources (organic and inorganic) and different levels of Cr (0, 0.05 and 0.15 mg kg^{-1} DM) in poultry did not report effect of this mineral on humidity of meat and neither in intramuscular fat; though, protein content was higher in the supplemented animals. Amatya *et al.* (2004) indicated that supplementing poultry diet with different sources of Cr (potassium chromate, Cr chloride, yeast rich in Cr) at a dose of 0.2 mg Cr kg^{-1} DM, protein concentration in meat was higher and fat decreased in animals supplemented with Cr *vs*. control. Also, Kim *et al.* (1996) and Lien *et al.* (1999) when supplemented poultry with 0.16 and 0.20 to 0.40 mg Cr kg^{-1} DM, pointed out that protein increased and fat reduced in meat. Ziyad (2013) to assess different levels (0.5 and 1 mg) of yeast of Cr in Awassi lambs reported an increase in the content of protein and a decrease in the content of fat in meat; Arvizu *et al.* (2011) evaluated the effect of a proteic and energetic supplement and a source of an organic Cr in two sheep genotype (Suffolk×Dorper and Rambouillet) under grazing, and found that Cr decreased (15.3%) fat in meat; however, it is important to take into account that intramuscular fat allows to distinguish some sensorial characteristics like juiciness, tenderness, flavor and digestibility, which is important because intramuscular fat tissue contributes to a better firmness, tenderness and juiciness of meat (Olleta *et al.* 1992). In LD muscle the ash content decreased linearly ($P<0.05$) (Table 3). It does not give a clear idea about Cr content, because ash determination only provides an estimate of total mineral content. There is little information of Cr supplementation effect on other mineral metabolism, but Ani and Moshtaghie (1992) and Anderson *et al.* (1996) reported a decrease in tissue Fe concentration as a response of Cr supplementation, that is why it is necessary to carry out investigations in sheep that allow to determine the Cr status in animals, vital organs and plasma, as well as, Cr retention and other trace elements (Anderson *et al.* 1996). Doses of Cr showed a quadratic effect ($P<0.05$) in the shear force of meat (Table 3). Arvizu *et al.* (2011) indicated that feeding Cr to Suffolk×Dorper and Rambouillet lambs under grazing, did not modify shear force of meat; in contrast, Ria (2002) found that adding Cr propionate to pigs at different growing phases, shear force of meat decreased; Amatya *et al.* (2004) reported that supplementing poultry diet with different sources of Cr (potassium chromate, Cr chloride, yeast rich in Cr) at a dose of 0.2 mg kg^{-1} DM, found effects of Cr, mainly with yeast rich in Cr, on sensorial attributes of meat; on the other hand, from a practical point of view, it is necessary to carry out a complete evaluation of sensorial attributes of meat in sheep treated with Cr, in order to determine if consumers can distinguish the numeric difference of shear force of meat.

4. Conclusion

It is concluded that organic Cr supplementation did not affect growth performance; however, it affected positively the muscle conformation and reduced kidney fat in finishing carcass lambs; the shear force showed a quadratic effect in the meat of sheep.

5. Materials and methods

This experiment was conducted under the supervision and approval of the Academic Committee of the Faculty of Veterinary Medicine and Animal Science Department, University Autonomous of Mexico State, according to regulations established by the Animal Protection Law, enacted by the Mexico State in México.

5.1. Experimental animals and feeding

Eighteen Suffolk lambs (age (4.5±0.2) mon; (25.8±3.6) kg BW) were housed in individual cages in a naturally ventilated barn. A basal diet (BD) was offered daily at 8:00 and 16:00 h which contained (g kg^{-1} DM): corn stover (150), sorghum grain (570), soybean meal (140), canola meal (50), wheat meddling (50), sodium bicarbonate (15), and mineral and vitamin premix (25) which contained Ca, 4 500 g; Zn, 1.5 g; Cu, 20 g; Fe, 140 g; K, 90 mg; Co, 500 g; Mg, 36 g; I, 500 mg; Se 90 mg; Na, 125 g; V_A 3 000 IU kg^{-1}; V_{D3} 750 IU kg^{-1}; V_E 25 IU kg^{-1}. Treatments consisted of BD plus 0, 0.2 or 0.4 mg Cr kg^{-1} DM from Bio-Chrome (Co-Factor III Cr^{3+}), which is a commercially available form of Cr yeast manufactured by Alltech Inc. (Nicholasville, KY, USA), and contained 1 000 mg Cr kg^{-1} DM. All lambs had free access to feed (ensuring 100 g orts per kg of the amount fed daily) and fresh water. Adaptation period to BD and management lasted 15 d. Amount of feed provided, was recorded at each feeding. Daily diet samples were obtained directly from the feed bunk during the morning feeding. One portion (200 g) of each sample was dried in a convection oven at 90°C for 48 h to determine the DM content, and other portion was retained and stored frozen. Samples were composited during the period of the growth performance trial and submitted for laboratory analysis of DM, crude protein (CP), and ash, according to AOAC (1997). Neutral detergent fiber (NDF) was analyzed without a heat-stable amylase and included residual ash following the methods of Van Soest *et al.* (1991). The content of Cr in the BD was analyzed by flame atomic absorption spectrophotometry Perkin Elmer 3110 (1982). Chemical composition (g kg^{-1} DM) of basal diet was CP 144, NDF 312 and ash 62. The metabolizable energy (ME) calculated was 2.66 Mcal kg^{-1} DM. Cr content of BD was 0.05 mg kg^{-1} DM. The weight of sheep was recorded at the beginning of the experiment and then every 14 d to evaluate the daily weight gain, during 70-d experimental period. Feed conversion was calculated as the ratio of kg daily feed intake divided by kg of daily weight gain.

5.2. Carcass characteristics

At the end of experiment, after a period of fasting for 24 h, final live weight was recorded; the next day, the sheep were transported (2.5 h) to the place of slaughter house, where they remained resting for 12 h with water access only. Before of the slaughter, live weight was again recorded. Hot carcass weight was recorded at slaughter. Chilled carcass weight (4°C) was recorded 24 h after slaughter. Carcass conformation, fatness degree, and kidney fat cover were measured based upon a photographic reference diagram and assessed by means of the Colomer-Rocher (1984). The carcass length, leg length and perimeter, hindquarter width, and the major and minor width of the thorax were measured. Incisions between 12th and 13th ribs were done to measure dorsal fat thickness using a ruler in a perpendicular position with relation to external surface of the carcass at 6 cm from the dorsal apophysis of the vertebra according to Colomer-Rocher (1984). In 13th rib, the LD muscle area was measured using the cross-sectional method described by Rust *et al.* (1970).

5.3. Meat quality

Samples of chop between the 10th and the 13th ribs were taken from both sides of the carcass and LD muscle was obtained. These samples were packed, refrigerated for 2 h at 4°C and frozen at –20°C, until their analysis, one month later. The samples were defrosted and LD muscle sections were used to measure shear force with the Warner-Bratzler shear (SALTE R®, G-R Elec. Mfg. Co. Collins Lane, MA). After the meat was defrosted, it was cooked on an electric grill until it reached 70°C of internal temperature, and let get cold at room temperature; cylinders of 2.5 cm length×1.27 cm periphery were cut with a drill (Truper®). These meat cylinders were cut with the blade of Warner-Bratzler instrument and the shear force data (kg cm^{-2}) was recorded following the method of Beltrán and Roncalés (2000). Samples of LD muscle were used to analyze its chemical composition (humidity, fat, protein and ash) according to AOAC (1997).

5.4. Statistical analysis

A completely randomized design was used. Six lambs per treatment were used to study weight gain, carcass evaluation, and meat quality. Data were analyzed using the proc mixed option of SAS (2002). The model included lamb (random), organic Cr supplementation level as a fixed effect (2 degrees of freedom, df), and residual effect (lamb within treatment). Average daily weight gain, feed intake, and feed conversion were analyzed using the same model except for the time (repeated, 4 df) and interaction time×organic Cr supplementation level (8 df) were included in the model. Levels of Cr supplementation (treatments) were partitioned into orthogonal contrasts for evaluating their effects; contrast one (average level 0.2 ppm Cr *vs*. average level 0.4 ppm Cr), contrast two (level 0 ppm Cr *vs.* average levels (0.2+0.4) ppm Cr). Orthogonal polynomials were used to estimate the linear and quadratic effects of Cr concentrations. The Tukey's test was used in comparing means differences and they were accepted when $P<0.05$ (Steel *et al.* 1997). Statistical model used was $Y_{ij}=\mu+\text{CrTrat}_i+E_{ij}$; where Y_{ij} is response variable, μ is general mean, CrTrat_i is treatment effect, and E_{ij} is experimental error.

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