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Short communication

Effect of enriched-chromium yeast on growth performance, carcass characteristics and fatty acid profile in finishing Rambouillet lambs

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ABSTRACT

The objective of the present study was to evaluate the effect of enriched-chromium yeast (YCr) on growth performance, carcass characteristics and *Longissimus dorsi* muscle (LM) composition of finishing lambs. Fourteen Rambouillet lambs (23.3 ± 2.9 kg BW) were assigned to two treatments in a completely randomized design with 7 lambs per treatment: (i) Basal diet (control), (ii) YCr (Basal diet + 0.3 mg of Cr/kg DM). The Cr was supplied as enriched-Cr yeast during the 74 days of the feeding period. The basal diet (13.9 % CP and 7.83 MJ NEm/kg DM) contained 85 % concentrate (ground corn, canola meal, soybean meal, wheat bran, mineral and vitamin premix and sodium bicarbonate) and 15 % ground corn stover. Lambs were weighed on day 1, 42 and 74 of the feedlot experiment. Enriched YCr supplementation had no effect ($P > 0.05$) on animal performance and carcass characteristics of lambs. YCr tended to increase 12th rib back fat thickness ($P < 0.10$), increased ($P < 0.05$) LM pH 45 min postmortem and tended to increase LM pH 24 h postmortem ($P < 0.10$). Meat chemical composition and shear force was not affected ($P > 0.05$) but meat intramuscular fat tended to decrease ($P < 0.10$) in response to YCr supplementation. For meat fatty acids profile, no effect was noted with YCr supplementation.

1. Introduction

Increasing global livestock productivity driven by burgeoning demand for meat necessitates the use of performance enhancing feed additives in ruminant nutrition. In this context, chromium (Cr) has been one of the additives that has been identified as an essential micro mineral (National Research Council. NRC, 2007), metabolic modifier (Domínguez-Vara et al., 2009), influencing insulin activity and modifying carbohydrate, lipid and protein metabolism (Mertz, 1993), increase the performance of cattle, buffaloes (Kumar et al., 2013) and lambs (Domínguez-Vara et al., 2009). Information is available on both organic Cr like Cr propionate (Kapoor et al., 2016) as well as trivalent inorganic Cr like chromium chloride $CrCl_3.6H_2O$ (Kumar et al., 2013), both exhibiting positive influence on ruminant performance. Kitchalong et al. (1995) evaluated the response of growing lambs to supplementation of 0.25 mg/kg Cr from chromium picolinate (CrPic). These authors observed that plasma insulin was elevated ($P < 0.05$) and plasma glucose tended to be reduced ($P < 0.07$) at week two of supplementation; and over the course of the 11-week period of feeding, NEFA level was consistently lower in Cr-fed lambs. However, there was no effect on growth rate but there was a slight reduction in carcass fat content (Kitchalong et al., 1995).

Therefore, our hypothesis was that supplementing enriched-chromium yeast (YCr) will enhance feedlot performance and carcass characteristics of Rambouillet lambs. The objective was to evaluate the effect of YCr supplementation on feedlot performance, carcass characteristics, as well as fatty acid composition of *Longissimus dorsi* muscle (LM) in finishing lambs.

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Table 1
Basal diet composition and chemical analysis.

Ingredient	g/kg DM
Corn stover	150.0
Ground corn	570.0
Soybean meal	140.0
Canola meal	50.0
Wheat bran	50.0
[1]Mineral and vitamin premix	25.0
Sodium bicarbonate	15.0
Chemical analysis	
[2]Dry matter	889.1
[2]Neutral detergent fiber	321.0
[2]Calcium	5.5
[2]Phosphorus	2.6
[2]Crude protein	139.0
[3]Metabolizable energy, MJ/kg DM	11.715
[3]Net energy for maintenance, MJ/kg DM	7.832
[3]Net energy for gain, MJ/kg DM	5.205

[1] Ca, 4500 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; Vit. A, 3000 IU kg^{-1}; Vit. D_3, 750 IU kg^{-1}; Vit. E, 25 IU kg^{-1}.
[2] Determined in the laboratory.
[3] Calculated from diet ingredient composition (NRC, 2007).

2. Materials and methods

2.1. Experimental animals and feedlot management

This study was approved by the Bioethics and Animal Welfare Committee of the Faculty of Veterinary Medicine and Animal Science of the Autonomous University of the State of Mexico and carried out in the Experimental Unit for Animal Production from the same institution. The handling procedures were according the official guidelines for animal care in Mexico (NOM-051-ZOO-1995).

Fourteen non-castrated male Rambouillet cross lambs (23.3 ± 2.9 kg BW) were used in a 74-d feedlot experiment. Seven days before commencing the experiment, lambs were individually weighed, treated against ecto- (Ivermectin; Sanger, 1 mL/50 kg BW) and endo-parasites (Closantel; Fasciontels, 10 mg/kg BW) and vaccinated against *Pasteurella multocida, Mannhemia haemolytica* and *Clostridium* (Multibacterin-7; MSD Animal Health). Lambs were placed in individual pens (1.2 m × 2.5 m) equipped with automatic drinker and feeder. All the animals were fed *ad libitum* with the basal diet (control, Table 1) offered twice a day (0800 and 1600 h). At the beginning of the experiment, lambs were individually weighed and randomly assigned to one of two treatments, as follows: (i) basal diet (control) and (ii) YCr (control + 0.3 mg Cr/kg DM from Bio-Chrome (Co-Factor III Cr^{3+}), available form of Cr yeast manufactured by Alltech Inc. (Nicholasville, KY, USA), and contained 1000 mg Cr/kg DM.

The enriched YCr was top-dressed per lamb immediately after the morning feed delivery. Feed offered and orts were recorded daily; 10 % of feed and orts samples were taken weekly, dried at 55 °C for 48 h to determine their chemical composition. Dry matter, crude protein (Kjeldahl method, N × 6.25), ether extract and ash were determined by official methods (AOAC, 2007). Neutral detergent fiber (NDF) was analyzed according to Van Soest et al. (1991) with a modified ANKOM 200 fiber analyzer with a heat-stable amylase and expressed inclusive of residual ash (ANKOM Tech. Corp, Fairport, NY, USA).

2.2. Carcass characteristics

Once the feedlot period was completed (74 d), lambs were fasted for 12 h before they were transported (2 h) to the municipal slaughterhouse in Capulhuac, Mexico, where they were weighed and slaughtered, according to the slaughterhouse regulations. Hot carcass weight (HCW) was recorded and hot carcass dressing calculated. After 24 h of chilling period at 4 °C, carcass weight was taken and chilled carcass dressing (% of final weight) and carcass shrinkage (% of HCW) were calculated.

A crosscut was performed on the left LM between the 12th and 13th ribs and LM area was measured according to Rust et al. (1970). Back fat thickness (mm) was measured with a digital vernier (Absolute Digimatic 500, Mitutoyo Corporation, Japan) and pH was measured using a potentiometer fitted with a penetration electrode (HANNA model HI 99,163). Kidney-pelvic fat, carcass fatness, and carcass muscle conformation measures were performed in agreement with procedures described by Colomer-Rocher et al. (1988); the perirenal fat code was: 1 (uncovered), 2 (with a large window), 3 (with small window) and 4 (totally covered). Carcass fatness scale was: 1 (very lean), 2 (lean), 3 (rather fatty), 4 (fatty) and 5 (very fatty). The carcass muscle conformation code was as follows: 1 (poor), 2 (normal), 3 (good), 4 (very good) and 5 (excellent), adapted from Colomer-Rocher et al. (1988). Zoometric carcass measures (length, leg length, leg perimeter, hindquarters width and hindquarters perimeter) were measured using hard and flexible graduated rulers (Ruiz de Huidobro et al., 2005).

2.3. Meat quality

Four steak samples from the 10th to 13th ribs were taken from the left side of carcass, vacuum packaged and frozen at −20 °C until laboratory analyses. Dry matter, ash, crude protein and fat were determined according to standard methods of AOAC (2007). LM samples were thawed for 24 h at 4 °C in a cooler protected from drafts, with 90 % relative humidity and cooked on an electric grill until it attained 70 °C of internal temperature and was let to cool at room temperature and then cylinders of 2.5 cm length × 1.27 cm width were cut with a stainless steel blade (Truper® CUT-7X, Co. Mexico) to measure shear force with the help of Warner-Bratzler shear (SALTER®, G–R Elec. Mfg. Co. Collins Lane, MA). Meat cylinders were used to measure toughness and the shear force data (kg/cm^2) was recorded following the method of Beltrán and Roncalés (2000).

2.4. Fatty acids profile

Fat extraction was performed according to the method proposed by Bligh and Dyer (1959), using a 2:1 chloroform-methanol solution, 10 g of ground meat was suspended using a 10:1 solvent:meat ratio. The suspension was exposed to ultrasonic-irradiation for 60 min by using a high efficiency ultrasonic processor (UP200S, Hielscher Ultrasonics) with 200 W of output power and 24 kHz of frequency. The acoustic potency was transmitted using a sonotrode (S14, Hielscher Ultrasonics). After the solution was adjusted to a 2:1:0.8 chloroform:methanol:water proportion, it was mixed and vacuum filtered. The liquid phase was readjusted to a 2:2:1.8 chloroform:methanol:water proportion, transferred to a separation funnel and after sitting for 24 h, the non-aqueous phase was recovered. The fat-chloroform phase was recovered and chloroform was removed using a vacuum rotator evaporator machine (RE300, Yamato) at 45 °C. Thereafter, 300 µl of KOH and 10 mL of methanol were added and ultrasonic irradiation was applied for 60 s. Methanol was evaporated at 50 °C, and 10 mL of hexane was added and filtered with Whatman paper with a pore size of 0.22 µm and stored in chromatographic vials. Fatty acids were determined by gas chromatography, using an Agilent 6890 N chromatograph fitted with a mass spectrophotometer detector (Agilent 5973) in which Helium was used as the carrier gas in an Omega Wax 250 column; a volume of 1 µl was injected, with a flux of 1 mL/min; column temperature ranged from 50 to 270 °C (10 min), with a heating rate of 5 °C/min and a 37-component standard (SUPELCO, TM-2560) was used as a reference.

The results of the fatty acid concentration (FA) are expressed in g/100 g of FA, which correspond to the area under the curve of the detected fatty acid peaks.

2.5. Statistical analysis

The experimental design was a completely randomized design with two treatments and seven lamb per treatment. Each lamb was considered an experimental unit. Data generated were subjected to ANOVA using the PROC MIXED procedure of SAS (SAS Inst. Inc. Cary, NC). Means were compared by applying the probability of difference (PDIFF) option of the least squares means statement. Differences among means with ($P < 0.05$) were accepted as representing statistically significant differences. Tendency was declared at ($P > 0.05$) but (< 0.10).

3. Results and discussion

3.1. Growth performance and carcass characteristics

During the feedlot period, live weight of lambs, daily weight gain, DMI and DMI:gain ratio were not affected ($P > 0.05$). There was a significant effect ($P < 0.05$) on initial (45 min postmortem) meat pH with higher pH noted for YCr treated sheep. There was a tendency ($P < 0.10$) for final pH value (24 h) to be higher in LM of sheep supplemented with Cr. High pH values at 24 h postmortem predispose to dark cuts or DFD (dark, firm, dry) meat that consumers perceive as not being fresh or old meat.

One plausible hypothesis for this higher pH values 24 h postmortem is that YCr supplemented ewes could have had lower glycogen reserves in muscle, thus lowering potential lactic acid production; the lower the lactic acid produced, the higher the 24 h pH (Tarrant, 1988). In the present study, sheep were fasted for 12 h before a 2 -h trip to the municipal slaughterhouse. Additionally, they were held for about 2.5 h before they were slaughtered and that could have influenced the 24 h postmortem pH of the LM.

The YCr tended to increase ($P < 0.10$) the 12th rib back fat thickness (Table 2). Higher content of back fat deposited in the carcass could be associated with the effect of Cr, which increases cellular sensibility to insulin through the action of chromodulin (a low molecular weight Cr binding protein) which is linked to the action of insulin receptors (Mertz, 1993; Vincent, 2004). Insulin has a strong anabolic effect, as it plays a major role in glucose uptake in muscle, adipose tissue and liver (Mertz, 1993; Kumar et al., 2013), and fat synthesis (McNamara and Valdez, 2005). Therefore, when animals consume diets low in fat but high in starch, excess carbohydrates are used to synthesize fatty acids and triglycerides in specific tissues (Wu, 2018). There was no effect ($P > 0.05$) of YCr treatment on kidney-pelvic fat.

Table 2
Effect of enriched-Cr yeast supplementation on feedlot growth performance and carcass characteristics of finishing lambs ($n = 14$).

Item	Cr mg/kg DM			
	0.0	0.30	SEM[1]	*P*-value
Lambs performance				
Initial live weight, kg	23.26	23.31	3.31	0.97
Final live weight, kg	44.84	44.68	0.58	0.85
[2]Daily weight gain, kg/d	0.290	0.300	0.02	0.91
[2]Dry matter intake, kg/d	1.36	1.37	0.07	0.88
[2]Feed conversion, DMI:DWG ratio	4.68	4.56	0.38	0.17
Carcass characteristics				
Hot carcass wt., kg	20.35	20.13		0.76
Chilled carcass wt., kg	19.47	19.40		0.93
Hot carcass dressing, %	46.20	45.85		0.62
Chilled dressing, %	44.19	44.20		0.98
Shrinkage, %	4.35	3.61		0.11
LM area, cm^2	24.43	24.86		0.76
Back fat thickness, mm	1.67	2.26		0.10
Kidney-pelvic fat, %	3.28	3.16		0.64
Fatness degree	3.00	3.16		0.29
Muscle conformation	2.31	2.24		0.81
Carcass length, cm	64.29	63.14		0.58
Leg length, cm	36.14	36.57		0.73
Leg perimeter, cm	37.86	37.64		0.92
Hindquarters width, cm	19.26	19.71		0.41
Hindquarters perimeter, cm	59.57	59.71		0.87
Longissimus thoracis muscle pH				
45 min	6.36	6.57		0.02
24 h	5.98	6.18		0.06

[1] Standard error of the mean.

Table 3
Effect of enriched-Cr yeast (YCr) supplementation on *longissimus thoracis* muscle chemical composition and muscle fatty acid profile of finishing lambs ($n = 14$).

Item	Cr mg/kg DM			
	0.0	0.3	SEM[1]	*P*-value
Muscle chemical composition				
Dry matter, g/kg	259.88	257.10	11.13	0.65
Ash, g/kg	12.57	11.00	2.39	0.24
Protein, g/kg	183.78	179.60	13.34	0.57
Fat, g/kg	35.70	30.90	14.62	0.07
Cooking losses, %	24.30	31.70	8.94	0.14
Shear force, kg/cm^2	2.62	3.90	0.52	0.27
Fatty acid profile of meat intramuscular fat (g/100 g detected FA)				
Myristic C 14:0	1.20	1.19	0.21	0.90
Pentadecanoic C 15:0	0.13	0.11	0.05	0.43
Palmitic C 16:0	22.40	22.80	1.74	0.05
Palmitoleic C 16:1	1.80	1.68	0.36	0.59
Margaric C 17:0	0.68	0.63	0.13	0.51
Cyclopropane fatty acids (CPFA)	0.73	0.53	0.21	0.07
Stearic C 18:0	12.81	13.60	1.66	0.41
Oleic C 18:1 *cis*-9	52.47	52.01	2.90	0.78
C 18:1 trans-11	1.61	1.28	0.30	0.08
Linoleic C 18:2	4.17	3.95	0.78	0.63
Arachidic 20:1 (n-9)	2.01	2.32	0.67	0.43
Saturated fatty acids	41.57	42.35	4.43	0.57
Unsaturated fatty acids	58.43	57.64	2.42	0.57
Unsaturated/saturated ratio	1.41	1.37	0.14	0.58

[1] Standard error of the mean.

3.2. Meat quality traits and fatty acids profile

The DM, ash, and protein of meat were not affected ($P > 0.05$) by YCr supplementation; however, YCr tended to decrease the proportion of meat intramuscular fat by 15.5 %. In addition, YCr had no effect ($P > 0.05$) on the total content of saturated, unsaturated and unsaturated/saturated fatty acid ratio (Table 3); however, higher proportion of unsaturated/saturated fatty acid ratio was observed in both dietary treatments. Lipid composition of ruminant meat tends to have greater amount of saturated fatty acids (specifically C18:0) than unsaturated fatty acids (Wu, 2018) due to biohydrogenation in the rumen. But contrary to this, the present results had more unsaturated fatty acids which could be as a result of the dietary ingredients (corn, soybean meal and canola meal) which provided high amounts of C 18:1, C 18:2, C18:3 to the lambs. Interestingly, in animals, the fatty acid composition of chylomicrons is very similar to the dietary lipids they consume (Wu, 2018), which was reflected in the higher content of unsaturated fatty acids in the present study.

The observed tendency to increase back fat thickness and to reduce intramuscular fat could be due to increased fat accretion rate with YCr supplementation compared with the control.

Supplementation with YCr tended to increase ($P < 0.10$) palmitic acid and decrease ($P < 0.10$) vaccenic acid which could be due to the high energy content of the diet (Song et al., 2018). Compared with our results, Rodriguez-Maya et al. (2019) reported similar range of values for palmitic acid (25.01–26.69 g/100 g) and palmitoleic acid (0.77–1.73 g/100 g) in growing lambs fed similar diets but supplemented with Zn methionine and zinc oxide.

A decrease in vaccenic acid could be as a result of reduced biohydrogenation of unsaturated C18 fatty acids. Vaccenic acid is the main isomer of C18 trans fatty acids (Wolff, 1995) resulting from biohydrogenation of unsaturated fatty acids (Jenkins, 1993).

Cyclopropane fatty acids (CPFA) in LM fat tended to decrease ($P < 0.07$) with the inclusion of YCr. Cyclopropane fatty acids are derived from unsaturated fatty acids and studies have shown that unsaturated fatty acids are affected by higher level of Cr (Rocchetta et al., 2006). Reduction of both unsaturated fatty acids and CPFA in the current study is consistent with this report. There is evidence that CPFA amplify the ability of beneficial bacteria to overcome several stressors which is very important in lactating animals (Mika et al., 2016).

4. Conclusions

Enriched chromium yeast supplementation for finishing lambs did not affect performance and carcass characteristics but tended to increase back fat thickness and reduce intramuscular fat. The effect of chromium yeast supplementation on meat fatty acid profile was only marginal and has no biological significance.

Declaration of Competing Interest

I would like to inform you that we haven't any conflict of interest with any professor.

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