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EFFECT OF SOURCE AND CONCENTRATION OF ZINC ON GROWTH PERFORMANCE, MEAT QUALITY AND MINERAL RETENTION IN NEW ZEALAND RABBITS

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Abstract: Zinc supplementation in rabbit diet favours deposition of this mineral in meat and, therefore, contributes to satisfying the daily requirements of Zn in humans that consume it. A trial was conducted to study the effect of two sources ($ZnSO_4$ and Zn-methionate) and two concentrations of Zn, along with a control (without Zn supplementation), on weight gain, meat quality and muscle retention in New Zealand White (NZW) rabbits during fattening stage. Treatments were randomly assigned to 100 NZW rabbits 40 days old, in a completely randomised experimental design using a factorial arrangement of treatments (2×2+control). The experimental period was 30 d. In each experimental treatment, weight gain, feed consumption and meat quality were recorded, as well as the retention of Zn in serum, liver, loin and hind leg. Results showed no differences (P>0.05) in weight gain and food consumption, which can be attributed to diet-added Zn sources ($ZnSO_4$ and Zn-methionate). Food conversion was better with the organic source at the highest concentration (P<0.05). Regarding meat quality, no differences were found (P>0.05) in hind legs for source effect and Zn concentration, while in loin, differences (P=0.02) were found in the colour parameter of L* and B* when the organic source of Zn (Zn-methionate) was supplied. Most retention of Zn on the loin occurred when a concentration of 25 mg Zn kg^{-1} of Zn-methionate was added, which could be important to provide larger amounts of Zn for human consumption.

Key Words: growth performance, loin, meat quality, mineral retention, rabbit tissues.

INTRODUCTION

Zinc (Zn) is an essential trace mineral (Kambe *et al.*, 2015), which acts as a cofactor in more than 300 enzymes (El-Hack *et al.*, 2017) and as a basic component of a family of transcription factors (Xu *et al.*, 2017). It is also involved in the normal growth of superior animals (Sloup *et al.*, 2017), in reproduction (Oliveira *et al.*, 2004), DNA synthesis, cell division, gene expression (Cui *et al.*, 2017) and immune protection (Liu *et al.*, 2011; Yan *et al.*, 2017). However, Zn requirements in non-ruminants are affected by the interaction with antinutritional factors such as phytic acid (Bao and Choct, 2009; Saleh *et al.*, 2018), which is present in the plant ingredients of diets, decreasing digestibility and absorption of Zn in the gastrointestinal tract in chickens (Salim *et al.*, 2012; Zakaria *et al.*, 2017), rabbits (Meshreky *et al.*, 2015) and pigs (Xu *et al.*, 2017), and thus becoming a limiting factor in production.

Studies in rabbits supplemented with Zn-oxide showed an improvement in the weight of pregnant females and their litters at birth (Cavalcante and Ferreira, 2000; Alikwe *et al.*, 2011), whereas in males the semen characteristics were improved (Oliveira *et al.*, 2004). Organic Zn is considered an alternative source, due to its better absorption and use (Alimohamady *et al.*, 2019). Supplementation with 80 mg of Zn kg^{-1} in the form of zinc lactate decreased the incidence of diarrhoea in

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fattening rabbits (Yan *et al.*, 2017). The addition of 100 mg Zn kg^{-1} of Zn in the form of Glycinoplex-Zn® or Bioplex-Zn® improved the availability of Na, K, Fe, Mn and Zn, and in the meat it increased cholesterol concentration, water retention capacity and energy value (kJ 100 g^{-1}) of the *Longissimus dorsi* muscle (Chrastinová *et al.*, 2016). Supplementation with 200 mg Zn kg^{-1} in the form of Zn-methionate in growing rabbits increased protein digestibility, weight gain and immune response (Meshreky *et al.*, 2015). However, the studies carried out on meat quality considering different concentrations of Zn in the diet are limited. However, Čobanová *et al.* (2018) observed that growing rabbit diets enriched with Zn increased the deposition of Zn in the liver. So, it was hypothesised that the different concentrations of supplemented Zn do not affect the meat characteristic and there is a greater accumulation in meat. The objective of this study was therefore to evaluate the effect of two sources and two concentrations of Zn on weight gain, meat quality and Zn content in muscle, blood and liver of young New Zealand White (NZW) rabbits.

MATERIALS AND METHODS

Ethical statement

All procedures for handling, sampling and slaughter of animals were carried out in accordance with the rules of the regulations for the use and care of experimental animals, approved by the Institutional Ethics Committee of the "Colegio de Postgraduados" (Postgraduate College) (April/2018).

Animals

A total of 100 NZW rabbits, from both sexes and 40 d of age, weighing 905.1±50.5 g, were randomly assigned to five treatments. Rabbits were housed in individual cages of galvanised material (35×40×50 cm), with an automatic "pacifier type" drinking system and manual feeders, at the facilities of the "Colegio de Postgraduados" experimental rabbit farm. Its geographical coordinates are 19.52° N, 98.88° W, at an altitude of 2250 metres above sea level. Experimental animals were housed under the same environmental, hygienic and managerial conditions. During the

Table 1: Composition of basal diet for fattening rabbits on dry matter basis.

Ingredient	Amount %	Calculated composition of the diet	
Alfalfa meal	48.70	Digestible energy (kcal kg^{-1})	2185
Wheat bran	30.00	Crude protein[3]	15.72
Tejocote meal (*Crataegus mexicana*)	10.00	Crude fibre[3]	15.67
Maize	7.50	Dry matter[3]	89.56
Cane molasses	1.00	Ether extract[3]	3.83
Colza oil	1.00	Ash	9.55
Vitamins Premix [1]	0.10	Acid detergent fibre[4]	22.31
Minerals premix [2]	0.30	Neutral detergent fibre[4]	32.94
Lysine HCL (L-98%)	0.20	Lignin	5.09
Methionine (DL-99%)	0.18	Hemicellulose	10.58
Salt (NaCl)	0.10	Starch	10.74
Threonine (L-98%)	0.10	Lysine	0.79
Tryptophan (L-98%)	0.15	Methionine+Cystein	0.64
Sodium bicarbonate	0.37	Threonine	0.66
Dicalcium phosphate	0.20	Tryptophan	0.34
Coccidiostat	0.10	Zinc (mg kg^{-1})[3]	25.5

[1]Vitamins: A 10000 IU, D_3 1000, E 20.00 mg, K_3 1.00, B_1 1.00, B_2 3.00, B_6 1.00, niacin 28.00, pantothenic acid 10.00, folic acid 0.20, biotin 0.1, choline 250 and vit B_{12} 0.01 mg/kg in diet.
[2]Cu 4, I 0.25, Fe 15, Mn 5, Co 0.10 and Se 0.1 mg kg^{-1} of diet.
[3]Determined using the standard procedures of AOAC (2005).
[4]Determined using the procedures of Van Soest et al. (1991).
The content of digestible energy was calculated by the equation of Wiseman et al. (1992).

study, the environmental temperature was 22±1.5°C and the experimental period consisted of 5 d of diet adaptation followed by 30 d of evaluation.

Experimental diets

The basal diet (BD) (Table 1) was prepared according to the recommended requirements by De Blas and Wiseman (2010), except for Zn. The sources of Zn evaluated were: inorganic as $ZnSO_4$ ($ZnSO_4 \cdot H_2O$ with 36.43% of Zn, Sigma Aldrich®) and organic as Zn-methionate (with 12% of Zn, Zinpro®), using two Zn concentrations on each source. Rabbits were fed the pelletised diets (3.5 mm diameter) and had free access to water.

An array of factorial treatments 2×2+1 (2 sources×2 zinc concentrations+one control group) was used under a completely randomised design, whose treatment combinations were as follows: T_1=BD with no Zn addition, only the input from ingredients, T_2=BD+25 mg Zn kg^{-1} as $ZnSO_4$, T_3=BD+75 mg Zn kg^{-1} as $ZnSO_4$, T_4=BD+25 mg Zn kg^{-1} as Zn-methionate and T_5=BD+75 mg Zn kg^{-1} as Zn-methionate.

Variables and sample collection

Average daily weight gain (DWG) and daily feed intake (DFI) were recorded weekly; feed conversion rate (FCR) was calculated as kg of feed kg^{-1} of weight gain. At the end of the experiment, the animals were slaughtered at 70 d of age at the institutional slaughterhouse facility. Blood samples were collected at slaughter into "vacutainer" probe tubes without anticoagulant to facilitate separation of the serum, keeping the probe tubes in an inclined position for 3 h at room temperature; the blood was then centrifuged at 3000 rpm for 15 min at 4°C to obtain the serum, which was stored at –20°C until its analysis. Live weight was recorded at slaughter and the performance of the carcass was calculated following harmonised criteria proposed by Blasco and Ouhayoun (1996). Colour parameter and pH of meat were measured 10 min after slaughter. Liver, loin and hind leg samples were obtained from each experimental unit and stored in Ziploc® bags at –80°C until the determination of Zn, protein, fat, moisture, collagen and water retention capacity.

Meat quality analysis

The pH values in meat were estimated using a portable direct reading meter (HANNA INS. INC. Mod. HI 99161. Rhode Island, USA) in *Longissimus thoracis* and *Biceps femoris* for loin and hind leg, respectively. The colour parameter was measured in the same tissue used for pH determination using a colorimeter (Minolta CR-400/410, Tokyo, Japan), by making four measurements clockwise. The water holding capacity was determined based on the technique described by Pérez and Ponce (2013). Food Scan™ equipment (FOSS North America, 8091 Wallace Rd, Eden Praire, MN, USA) equipped with an infrared spectrophotometer with artificial neural network calibration and associated database was used to estimate the fat, moisture, protein and collagen in technical products, as described and validated by Anderson (2007).

Zn content in serum, feed, liver and muscle

For determination of Zn in blood serum, the methodology described by López-Alonso *et al.* (2017) was considered, with the following modifications: a pre-digestion with 2 mL of serum and 2.5 mL of nitric acid (69% w/v) was performed for one hour at room temperature; subsequently, 0.5 mL of H_2O_2 (33% w/v) was added and placed into a digester. The temperature was raised to 180°C and the samples were digested for one hour. Once cooled, they were adapted to 10 mL with deionised water and determined by atomic absorption spectrophotometry (AAS) (Varian 220 Fast sequential, Australia). For food, liver, loin and leg samples, 1 g of wet weight tissue or sample was considered, dehydrated at 90°C for 8 h; subsequently, the material was incinerated at 550°C for 12 h in a muffle furnace (Furnace, Scorpion Scientific, A-51130) considering the methodology of Hassan *et al.* (2017), with the following modifications: samples were digested with 10 mL of 3N HCL; they were then placed into a beaker covered with clock glass at 200°C in a digester block, until a light yellow solution was obtained. Once the vapours ceased, the digested solution was filtered with Whatman® paper 42. The extract was adapted to 50 mL using deionised water, from which an aliquot of 3 mL was taken, and 6 mL of deionised water were added, and determinations were made using AAS. As a quality control of the analytical measurements made in Zn in the three tissues analysed, the following actions

were performed: in serum, the recovery of Zn was evaluated by the method of addition; 5 mg Zn L^{-1} (n=3) were added to a sample with 2.46 mg Zn L^{-1}. For the liver, loin and leg the homogeneity was evaluated; for this purpose, a composite sample consisting of four subsamples of the organ was considered. Finally, an analysis of reagent targets was included for each batch of samples analysed.

Statistical analysis

The data for weight gain, feed consumption, carcass weight, mineral deposition and meat quality were analysed using a completely randomised design with a factorial treatment arrangement, which included the sources and concentrations of Zn added to the diet and their interaction. The data were expressed as average±standard error, using the GLM procedure of SAS (SAS Institute Inc., ver 2013, Cary, NC, USA). The means for treatments were compared using the Tukey Test ($P<0.05$).

RESULTS

Weight gain response in rabbits

Results for the addition of Zn to the diet of fattening NZW rabbits are shown in Table 2. The DGW and DFI were no different ($P>0.05$) between the control, source or concentration of Zn treatments analysed. With the exception of the FCR that showed interaction ($P<0.05$), which was lower when the organic source was used with the highest concentration of Zn, on the contrary, when using the $ZnSO_4$ source, the FCR increased (Figure 1).

Meat quality

Meat characteristics: pH, coloration, collagen content, protein, fat, moisture and water retention capacity of *Biceps femoris* muscle from the hind leg showed no differences ($P>0.05$) between the control treatment, source or concentration of Zn. However, in the *Longissimus thoracis* muscle of the loin an effect was found in L* and B* colour parameter ($P<0.05$), when supplemented with the Zn-Met source (Table 3). In addition, the source and concentration interaction was significant for the B* colour in the loin muscle; using the high concentration of the Zn-Met source ($P<0.05$), the response tended to decrease, compared to the $ZnSO_4$ source (Figure 2). The loin muscle had no differences ($P>0.05$) in collagen, protein, fat, and moisture and water retention capacity for source effect and Zn concentration.

Table 2: Average for daily weight gain (DWG; g/d), daily feed intake (DFI; g/d), feed conversion rate (FCR), live body weight (LW; g) and carcass weight (CW; g) according to the source and concentration of Zn added to the diet.

		Zn source			Zn conc			*P*-value		
Items	Control	$ZnSO_4$	ZnMet	SEM	25	75	SEM	Source	Conc	S×C
DWG1	32.8	33.0	35.3	2.63	33.1	35.3	2.57	0.346	0.400	0.091
DWG2	37.4	36.5	37.8	1.73	36.3	38.0	1.76	0.391	0.334	0.110
DWG3	36.1	36.1	37.4	1.81	37.3	36.2	1.75	0.887	0.550	0.711
DWG4	34.2	36.3	33.4	1.67	36.5	33.2	1.73	0.137	0.051	0.649
DFI1	87.5	88.6	89.3	4.94	86.5	91.4	4.80	0.088	0.324	0.768
DFI2	109.9	108.4	115.3	4.22	110.3	105.6	4.19	0.459	0.474	0.556
DFI3	127.7	127.1	131.2	3.95	128.0	130.4	3.81	0.818	0.562	0.909
DFI4	149.1	147.9	154.8	3.96	152.2	150.4	3.87	0.385	0.645	0.397
FCR	3.78	3.72	3.77	0.09	3.71	3.79	0.10	0.602	0.359	0.005
LW	2038	2031	2075	42.37	2035	2071	42.24	0.355	0.445	0.094
CW	1115	1112	1120	25.46	1100	1136	26.39	0.756	0.145	0.255

Zn Conc: Zn Concentration, DWG1: DWG in week 1, DWG2: DWG in week 2, DWG3: DWG in week 3, DWG4: DWG in week 4, DFI1: DFI consumption week 1, DFI2: DFI consumption week 2, DFI3: DFI consumption week 3, DFI4: DFI consumption week 4, FCR: Feed conversion, LW: Live weight, CW: carcass weight, Monohydrated zinc sulphate ($ZnSO_4$ H_2O with 36.43% zinc), Zinc-methionate (Zn-Met 12% zinc). SEM: Standard error of the mean. No statistical differences between treatments ($P<0.05$).

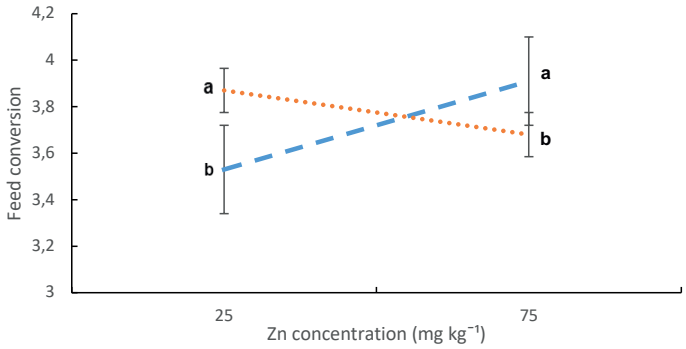

Figure 1: Interaction source × concentration of Zn added to the rabbit diet and its effect on feed conversion rate. – – $ZnSO_4 \cdot H_2O$; ●●● Zn-Met. [ab]Means±standard deviation at a Zn concentration not sharing letters were significantly different at $P<0.05$.

Zinc content in tissue

Zn content in blood serum (Table 4) was higher for the control, for which Zn was not added ($P=0.03$), with only the addition of dietary ingredients (25.5 mg Zn kg^{-1} of diet). Meanwhile, liver was the organ with the highest Zn content, but showed no differences ($P>0.05$) between control, source or concentrations of Zn analysed. The retention of Zn in *Longissimus thoracis* muscle of the loin was higher ($P=0.02$) when using of 25 mg Zn kg^{-1} concentration.

Table 3: Average values of rabbit meat quality indicators by adding two sources of Zn (Zinc sulphate and Zn-Methionate) at two concentrations (25 and 75 mg Zn kg^{-1}) in the diet.

		Zn source			Zn conc			*P*-value		
Items	Control	$ZnSO_4$	ZnMet	SEM	25	75	SEM	Source	Conc	S×C
Hind leg										
pH	5.76	5.69	5.70	0.06	5.72	5.67	0.06	0.831	0.468	0.852
L*	48.75	48.21	46.31	1.16	47.34	47.17	1.20	0.486	0.895	0.692
A*	18.09	17.81	17.51	0.59	17.91	17.37	0.61	0.653	0.410	0.363
B*	5.30	5.26	5.01	0.31	5.26	5.02	0.33	0.841	0.443	0.924
Collagen[1]	1.17	1.22	1.15	0.04	1.19	1.18	0.04	0.121	0.897	0.990
Protein [1]	21.97	22.09	22.29	0.15	22.21	22.17	0.13	0.215	0.786	0.508
Fat[1]	2.76	2.71	2.96	0.16	2.71	2.97	0.16	0.135	0.132	0.738
Moisture[1]	74.58	74.50	74.33	0.17	74.51	74.31	0.15	0.319	0.261	0.946
WHC	26.80	27.05	24.32	1.70	25.80	25.63	1.71	0.551	0.906	0.564
Loin										
pH	5.68	5.72	5.62	0.09	5.72	5.62	0.10	0.281	0.308	0.496
L*	47.67[a]	46.89[a]	43.82[b]	1.00	45.23	45.42	1.06	0.024	0.847	0.448
A*	12.16	11.78	11.76	0.48	11.73	11.80	0.42	0.837	0.895	0.348
B*	4.17[a]	4.18[a]	3.71[b]	0.18	3.88	4.01	0.18	0.019	0.563	0.011
Collagen[1]	1.17	1.21	1.09	0.05	1.15	1.14	0.05	0.321	0.943	0.786
Protein [1]	21.54	21.72	21.78	0.16	21.76	21.73	0.16	0.708	0.847	0.973
Fat[1]	6.09	5.42	6.12	0.39	5.67	5.87	0.36	0.087	0.62	0.875
Moisture[1]	71.55	72.10	71.44	0.32	71.87	71.67	0.26	0.053	0.536	0.963
WHC	24.85	24.07	22.51	1.44	23.92	22.63	1.41	0.412	0.490	0.520

Zn Conc: Zn concentration, L*: Luminosity, A*: Red index, B*: Yellow index, WHC: Water holding capacity.
[1]Expressed in g 100 g^{-1}. Zinc sulphate monohydrate ($ZnSO_4$ H_2O with 36.43% zinc), Zinc-methionate (Zn-Met 12% zinc). SEM: Standard error of the mean. Different letters within rows indicate significant difference ($P<0.05$).

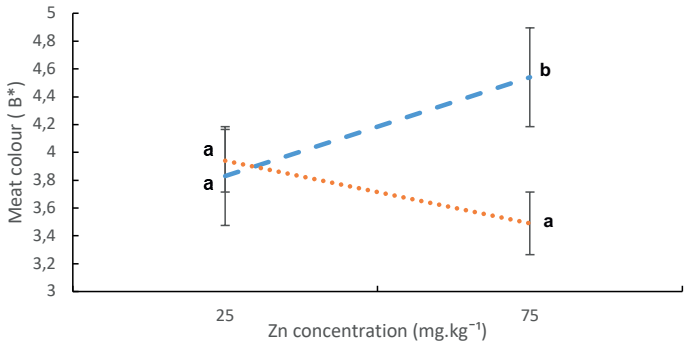

Figure 2: Interaction of the source×concentration of Zn in rabbit diet and its effect on the B* index *Longissimus thoracis* muscle. – – $ZnSO_4 \cdot H_2O$; ••• Zn-Met. [ab]Means±standard deviation at a Zn concentration not sharing letters were significantly different at $P<0.05$.

DISCUSSION

The inclusion of different concentrations of Zn in diet has been widely used, but the results are inconsistent. Previous studies concluded that there were no differences in DWG and DFI (Nessrin *et al.*, 2012; Chrastinová *et al.*, 2015), in agreement with the results of this study using $ZnSO_4$ *vs.* Zn-Met at two concentrations in diet during the fattening stage of rabbits. Therefore, DWG is not influenced by the inclusion of Zn at high concentrations. However, Yan *et al.* (2017) reported a DWG improvement (24.9 g *vs.* 27.7 g) with 80 mg Zn kg^{-1} of diet in the form of $ZnSO_4$ *vs.* Zn-Met, respectively. Meanwhile, in fattening chickens, similar results are reported when the organic sources of Zn were included (Salim *et al.*, 2012; Zakaria *et al.*, 2017). FCR was improved by using the concentration 75 mg Zn kg^{-1} of Zn-Met; the organic sources had better digestibility coefficients (NDF, ADF, Na, K, and Mn) compared to the inorganic source (Meshreky *et al.*, 2015; Chrastinová *et al.*, 2016).

There is little information regarding the inclusion of Zn and its effect on the characteristics of rabbit meat. In our study, the pH was similar between control and treatments in the *Biceps femoris* muscle of the hind leg, coinciding partially with what was reported by Chrastinová *et al.* (2015), showing that pH is not influenced by different concentrations of Zn, but by the ante-mortem management factor (Apata *et al.*, 2012). The coloration and proximal composition (protein, fat, moisture and collagen) in the hind leg muscle was similar in all treatments, showing that the physical and nutritional properties in the hind leg (Dalle Zotte and Szendrő, 2011) are maintained regardless of the inclusion of Zn.

In the case of *Longissimus thoracis* muscle of the loin, the colour parameter values (L* and B*) decreased when using the Zn-Met inclusion. This could be related to three positive effects of organic sources; first, Zn from organic

Table 4: Average Zn retention values (ppm) in rabbit tissues by adding two sources of Zn (zinc sulphate and Zn-methionate) to two concentrations (25 and 75 mg Zn kg^{-1}) on diet.

		Zn source			Zn Conc			*P*-value		
Items	Control	$ZnSO_4$	ZnMet	SEM	25	75	SEM	Source	Conc	S×C
Serum	2.86[a]	2.35[b]	2.41[b]	0.110	2.54[ab]	2.21[b*]	0.136	0.013	0.030	0.660
Liver	38.21	37.08	32.62	1.965	35.95	33.75	2.162	0.097	0.410	0.070
Hind leg	10.79	11.42	11.13	0.791	10.97	11.55	0.996	0.767	0.570	0.070
Loin	9.20[b]	11.94[ab]	10.78[ab]	0.936	12.80[a]	9.92[ab]	1.276	0.345	0.022	0.265

Zn Conc: Zn Concentration, Zinc Sulphate Monohydrate ($ZnSO_4 \cdot H_2O$ with 36.43% zinc), Zinc-Methionate (Zn-Met 12% zinc). SEM: Standard error of the mean. Different letters indicate significant difference ($P \leq 0.05$) (n=10).
*Analyte recovery of 87±4 % (n=3). [ab]Means within a row not sharing superscript were significantly different at $P<0.05$.

source has a higher degree of availability at the level of the small intestine, related to inorganic sources (Chrastinová *et al.*, 2016; Cui *et al.*, 2017); second, the zinc-methionine complex prevents insoluble complexes from forming in the digestive tract (free form of the ion of Zn) and facilitates the transport of Zn through the intestinal mucosa (Meshreky *et al.*, 2015; Zakaria *et al.*, 2017); third, the transfer of Zn from the intestinal mucosa up to the plasma is regulated by metallothioneins that are dependent on Zn, which influences the maintenance of colour (National Research Council, 2005). It should be noted that the A* colour parameter is above the interval indicated by De Blas and Wiseman (2010), which could be related to the inclusion of fruit as hawthorn (*Crateagus* spp.) flour in the diet, an ingredient with pectin and antioxidants such as flavonoids, carotenoids and vitamin C (García-Mateos *et al.*, 2013; Cervantes-Paz *et al.*, 2018). In general, the loin coloration benefited from the use of the organic sources, and colour is one of the main attributes considered by consumers (Apata *et al.*, 2012). In addition, no content modifications of protein, fat, moisture and collagen in the loin provided by the rabbit meat were determined (Dalle Zotte and Szendrő, 2011). Research on broiler chickens reported an increase of collagen in the skin when high concentrations of organic Zn were used. This advantage helps to keep cells firmly attached and gives greater resistance and flexibility to the skin (Rossi *et al.*, 2007).

The amount of Zn in blood serum has a rapid circulation rate and little storage in the body; therefore, Zn has to be present in the diet (Sloup *et al.*, 2017). In this study we found no positive effect between Zn source or concentration and the content of Zn in the blood, which was greater in the control group, in agreement with Nessrin *et al.* (2012), who reported higher retention of Zn in plasma, hair and urine in the rabbit control group (without inclusion of Zn in the diet). Therefore, this could be attributed to reuse of Zn by the intake of soft faeces to cover the minimum requirements of Zn in the body. Soft faeces are composed of protein, amino acids, B-complex vitamins and minerals (De Blas and Wiseman, 2010). However, specifically in microminerals, the proportion that is reused with respect to what is ingested is unknown. In chickens (Ivanišinová *et al.*, 2016; Olukosi *et al.*, 2018), lambs (Alimohamady *et al.*, 2019) and goats (Jia *et al.*, 2009), a positive association of Zn inclusion and blood retention has been reported.

Retention of Zn in the liver was similar between the sources and concentrations studied compared to the control; these findings contradict other studies (Čobanová *et al.*, 2018) that included 200 mg Zn kg^{-1} in organic form, which increased the retention of Zn in the liver, as well as the results of Hassan *et al.* (2017) with 60 mg Zn kg^{-1} of Zn oxide nanoparticles, which increased the amount of Zn in water, although to a lesser extent than in our study. A possible reason for such discrepancies could be the different Zn organic compounds used and their absorption efficiency (Shannon and Hill, 2019), while in laying hens (Abedini *et al.*, 2017), and rats (Nagalakshmi *et al.*, 2016) the ascending concentrations of diet Zn increased its retention in the liver.

In loin, concentration of 25 mg Zn kg^{-1} in diet favoured retention of the element in the muscle. However, the use of the highest concentration of Zn caused a decrease in the concentration of Zn in the muscle, coinciding with what was reported by Cavalcante and Ferreira (2000). This could be related to the status and requirement of Zn in the body, Zn-transporters and proteins associated with the transport to the cells, as a consequence, and although Zn is available it is not required by organism, resulting in a low absorption of the element (Kambe *et al.*, 2015).

Zn is necessary for the structure and function of metallothioneins and superoxide dismutase (Liu *et al.*, 2011), so regular dietary intake is required to meet the physiological needs of the rabbit (Swain *et al.*, 2016). In addition, by promoting a greater deposition of Zn in rabbit meat, it opens the possibility of generating a functional product to meet the nutritional requirements of Zn in humans. For the human diet, meat is the main source of Zn (Salim *et al.*, 2012). Further studies with different levels of Zn are needed to determine the best response in the deposition of the element in the rabbit meat without affecting its quality.

CONCLUSION

Zn supplementation in rabbits during fattening stage affected the feed conversion and meat colour when organic source is used. Supplementation of 25 mg Zn kg^{-1} in diet increased deposition of Zn on the rabbit's loin, which is important to provide larger amounts of Zn for human consumption.

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