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A N I N T E R N A T I O N A L J O U R N A L

Effect of Partial and Total Replacement of Inorganic by Organic Microminerals Sources on the Quality of Broiler Carcasses

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ABSTRACT

Among the nutrients involved in the chicken diet, the microminerals deserve attention as they exert essential functions in the organism. These compounds can be provided in inorganic (traditional) and organic (chelate) forms. In organic form, the micromimerals can attend a new concept related to a better bio-availability. In this sense, the objective of this work was to evaluate the effect of the partial and total substitution of inorganic by organic sources of microminerals on the animal diet, assessing its concentration in the blood and liver after 21 and 40 days and also in the bones after 40 days. Moreover, the effect on the physical-chemical and sensory characteristics of the muscle after 15 days of storage at 4°C was also evaluated. The animals were divided into five treatments: 100% inorganic, 70% inorganic and 30% organic, 50% inorganic and 50% organic, 30% inorganic and 70% organic and 100% organic-chelate. It is shown that the use of organic sources of microminerals in the diet of poultry induced to an increase of its concentrations in the blood and liver, with no significant alterations in the compositions of bones, compared to the use of inorganic sources. Feed formulated using 50% of organic minerals and 50% of inorganic minerals led to similar results. The diet with organic minerals or mixture with inorganic sources results in a low lipid oxidation in the drumsticks stored at 4°C for 15 days, in comparison with those using only inorganic minerals. No sensory alterations were observed for all different treatments.

Key words: Bio-availability, Broilers, Microminerals, Nutrition.

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INTRODUCTION

It is well knwon that most of environmental problems in areas of intense poultry production and optimization of poultry performance generally depend on the proper animal nutrition (Ribeiro et al., 2008). Microminerals, especially zinc, manganese and selenium, are considered of great importance in the poultry feeding, once these elements are involved in a series of biochemical mechanisms, of vital relevance to the animal development and growth, mainly osseous formation (Brito et al., 2006; Aksu et al., 2012). Such elements are involved in the immunological system, in the energetic methabolism, among other several phisylogical functions relevant to lide maintainnance and enhancement of animal productivity (Close, 1999).
Over the last years, nutriotinists have used minerals in organic form in an attempt to meet mineral poultry demands, but recentely, a growing interest has been obaserved to organic minerals or chelated sources, frequently described as proteinates. Such latter sources are usually produced after hydrolysis of a proteic source, resulting in the formation of a hydrolyzed matter containing a mixture of aminoacids and peptides of wide size variety (Rutz, 2007).
Several works have discussed the effectiveness of the use of minerals in organic form in replacement of inorganic minerals with different results (Star et al., 2012; Brooks et al., 2013; Liu et al., 2013; Salim et al., 2011; Salim et al., 2012; Wang et al., 2012; Brooks et al., 2012). Consequently, organically complexed minerals will continue to be an important issue for current research focuses on understanding the mechanisms and impacts of organically complexed trace minerals on meat quality (Aksu et al., 2012). The Association of American Feed Control Officials (AAFCO, 2000) determines rules and standards for the food intended to animal production, in which the organic minerals are metallic ions chemically bond to an organic molecule, forming structures with unique characteristics of stability and having high mineral bio-availability.
These metals are commonly found in many forms, from complex organic compounds to salts of varied solubility. In the organic form, minerals are absorbed by intestinal carriers of amino-acids and peptides and not by classical intestinal transporters. This prevents the competition among minerals by the same absorption mechanism. Thus, not only bio-availability becomes superior but also minerals in organic form are readly transported to the tissues, where they are kept stored for a a longer time compared to inorganic minerals. However, chelate minerals are usually more expensive when compared to those coming from inorganic sources and traditionaly, an inclusion increase in these inorganic sources is consired much cheaper.
The substitution of inorganic sources by organic minerals in broiler is generally not associated with the improvement of zoo-technical standards, but instead in the parameters observed in the poultries, for the whole chickens and also with the improvement verified in animal carcasses (Costa et al., 2010). The microminerals, especially selenium, has a significant impact in the animal performance and animal immunity, inducing physiological changes in muscular tissue, which can in turns positively affect cattle and chicken meat quality (Hess et al., 2003). This fact may be explained in terms of the improved bio-availability of organic minerals and the action of selenium as a co-factor of glutathione peroxidase and zinc and manganese as co-factors of dismutase super-oxide enzyme, hence acting as preventive anti-oxidants, comprising an important enzymatic defense system against free-radicals and cellular and intra-cellular membranes attacks (Rover et al., 2001).
In this context, taking into account that nutrition represents 60% of chicken production cost, the main objetive of this work was to investigate the comparative

effect of partial and total substitution of inorganic by organic sources (Zn, Se and Mn) on the animal diet and its concentration in the blood, liver and bones and also its effects on muscle physicochemical characteristics (TBARS, pH, acidity and aw) and sensorial analyses.

MATERIAL AND METHODS

Packaging and Experimental Design

Chickens were grown for 40 days in an experimental unity with 2,520 male Cobb chicken used, housed a one day old, with an average weight of 42g.

Treatment description

Hereafter, T1- means 100% inorganic - control; T2- 70% inorganic and 30% organic; T3- 50% inorganic and 50% organic; T4- 30% inorganic and 70% organic; T5- 100% organic (chelate).

Microminerals determination

Determination of microminerals (Se, Zn and Mn) was carried out through blood and liver collecting from, following the procedure describe in AOAC (1990). Blood collect was performed at 21 and 40 days of life, by means of three (03) chicken sacrifice by each treatment, ramdomly chosen in the boxes. Such matterial was obtained by cardiac puncture in controlled environment temperature. Serum was transferred to specific recipients and then submitted to mineral analysis, with the following procedure: in 0.1 g of sample, 1.5 mL H_2SO_4 was added, conducting to a digester at 150 ºC during 30 min.; then, it was added 2.5 mL of hydrogen peroxide heated for 1 h at 150ºC or up to sample clarifying, it was cold and added 2.0 mL of HNO_3, heating during 1 h at 150ºC. Afterwards, MilliQ water was carefully added through tube walls to promote sample dilution. The lectures were carried out in atomic absorption (Varian – SpectrAA 55).

Determination of microminerals in bones

Samples of bones from tibias were placed in forced air-circulating stove at 65°C for 72 h, afterwards 1 mm sieved-milled and packaged in glass flasks. The content of zinc, copper and manganese was determined by flamme atomic spectrophotometry (Varian SpectrAA-220), as described by Milles et al. (2001).

Physicochemical and sensory analysis of meat

In order to follow the oxidative stability of meat during the storage period, analysis of TBARS, pH and acidity of thighs and drumsticks for 0, 7, 10 and 15 days of storage under refrigeration (4ºC).

Concomitantly, sensory analysis was carried out using drumstick muscle at 0, 5 and 12 days of refrigeration storage.

In both cases, sample from three treatments were analyzed: 100% inorganic; 50% inorganic and 50% organic and 100% organic in and attempt to better express the goal of this work, elucidating possible effect differences between organic and inorganic minerals.

To evaluate the lipid oxidative level of crude samples during storage, the reactive test of 2 tiobarbituric acid (TBA) was employed in accordance with the work of Raharjo et al. (1992). Values of TBARS were determined by triplicate of each sample and results were expressed in mg of malonaldehyde per kg of sample.

For pH determination, it was employed 10 g of samples together with 20 mL of deionized water and homogenized by 1 min; pH values were recorded by a digital potentiometer (Digimed®), previously calibrated at pH 4 and 7 (AOAC, 1990).
For acidity determination, 10 g of sample was diluted in 200 mL of distilled water, triturated during 1 min and transferred to volumetric flask of 250 mL, then filling to 250 mL and filtering the resulting solution. It was then transferred 25 mL of the filtered solution to an Erlenmeyer and added 75 mL of distilled water, together with 3 drops of 1% alcoholic phenolphthalein solution and then titration with NaOH 0.1N (pH=8.2). Total acidity was expressed as grams of oleic acid per 100g of sample.
The water activity (aw) was determined following the procedure of Aqualad CX-2 Water Activity - System, by calibrating the equipment with deionized water and NaCl at 0.819 of aw up to stabilization and finally recording aw/temperature.
Sensory analysis was carried out in laboratory scale, with 10 trained tasters from both sexes, different age groups (20 to 50 years old). Samples (~ 2 cm edges) were distributed in plastic recipients, identified with random numbers of three digits together with the evaluation forms. Sensory experiment was conducted following a balanced incomplete block design of type I with a reference-standard in each block, with 10 tasters in two sensory evaluation sections (*in natura* and roasted samples). Each taster evaluated for each section, three samples and expressed how the reference-standard sample diverged from the treated sample, on mixed scale of 9 points (0- none difference; 2- slightly different; 4- moderately different; 6-much different, 8- extremely different). For *in natura* samples, color and odor were evaluated based on the related attributes while for roasted samples aroma, color, taste, texture were considered. Roasted samples were prepared in conventional electric oven at around 200 ºC during approximately 45 min without the addition of salt or any other spices.

Statistical Analysis

Experimental data were submitted to statistical variance analysis (ANOVA) and also with regard to mean values (Tukey test, 5 %) using the Software Statistica® 7.0 (Statsoft - INC®. USA). The regression analysis and fitting procedure were performed through Microsoft Excel software.

RESULTS

Analysis of microminerals from blood and liver

Results regarding the content of zinc, manganeses and selenium in the liver and blood of chicken submitted to treatment with inorganic and organic minerals are presented in Tables 1, 2 and 3, respectively.
It can be seen from these tables that the content of zinc in chicken blood with 21 days life varied in the range of 41.1 to 82.6 mg/kg. Clearly, treatment 3 (50% inorganic and 50% organic) was significantly superior ($p<0.05$) than other treatments. For 40 days life, the content decreased in all treatments, varying from 27.7 to 31 mg/Kg, with no statiscal differences verified amon them.
In liver samples of 21 days the highest zinc content were obtained with treatments 5 (100% organic) and 4 (30% inorganic and 70% organic), whereas for 40 days, the greastet zinc content was observed in treatment 5.

Table 1. Content of Zn (mg/kg) present in blood and liver of poultry submitted to treatment with organic and inorganic minerals.

Treatment	Zinc content (mg/kg)*			
	Blood		Liver	
	21 days	40 days	21 days	40 days
T1 - 100% inorganic	42.6^{b}±5.9	31.0^{a} ±4.5	46.2^{b}±2.9	49.8^{b}±3.2
T2 - 70% inorganic and 30% organic	50.7^{b}±19.8	30.0^{a}±3.8	42.5^{b}±9.2	41.7^{c}±2.7
T3 - 50% inorganic and 50% organic	82.6^{a}±28.1	27.7^{a} ±4.7	47.7^{b}±6.1	48.8^{b}±3.6
T4 - 30% inorganic and 70% organic	41.1^{b}±23.9	29.2^{a}±5.2	51.1^{ab}±3.7	41.0^{c}±4.6
T5 - 100% organic	38.8^{b}±10.0	29.9^{a}±6.0	65.4^{a}±10.0	56.8^{a}±5.3

*Means (± standard deviation) followed by equal lower case letters on the column do not differ statistically at a confidence level of 95% (Tukey's test).

The content of manganese in blood evaluated at 21 days differed significantly ($p<0.05$) only for treatment 3, 23.5 mg/kg (Table 2). At 40 days it can be noticed na increase trend of manganese content in blood as a consequence of the increase in organic to inorganic minerals ratio, with statistical difference after treatment 3. With regard to liver samples, a significant difference was observed in manganese content only for treatment 5 (100% organic) in relation to other treatments for the samples of 21 days. In the liver at 40 days, no significant differences were noted for the treatment with Mn.

Table 2. Content of Mn (mg/kg) present in blood and liver of poultry submitted to treatment with organic and inorganic minerals.

Treatment	Manganese content (mg/kg)*			
	Blood		Liver	
	21 days	40 days	21 days	40 days
T1 - 100% inorganic	19.1^{b}±8.3	14.5^{b}±2.4	14.2^{b} ±5.0	17.4^{a}±3.2
T2 - 70% inorganic and 30% organic	19.3^{b} ± 9.2	16.3^{b} ±2.4	12.3^{b} ±3.3	13.4^{a}±5.1
T3 - 50% inorganic and 50% organic	23.5^{a} ±5.7	17.0^{ab} ±5.0	11.2^{b} ±3.8	15.6^{a} ±5.8
T4 - 30% inorganic and 70% organic	18.2^{b} ±6.1	17.7^{ab} ±4.3	13.8^{b} ± 5.0	13.4^{a} ±8.0
T5 - 100% organic	19.7^{b} ±6.4	22.1^{a} ±3.9	17.6^{a} ±9.2	17.4^{a} ±3.4

*Means (± standard deviation) followed by equal lower case letters on the column do not differ statistically at a confidence level of 95% (Tukey's test).

Inspection of Table 3 shows that a greater absorption of selenium in blood at 21 days for the higher ratios of organic minerals (treatments 3 to 5), but at 40 days equal mineral mixture (50% inorganic and 50% organic) presented the highest contents. Such result was also observed in the liver analysis at 21 days. At 40 days, all treatments that presented oraganic minerals exhibited selenium contents greater that the treatments with 100% inorganic minerals.

Table 3. Content of Se present in the blood and liver of poultry submitted to the treatment with organic and inorganic minerals.

Treatment	Selenium content (mg/kg)*			
	Blood (μg/L)		Liver (mg/kg)	
	21 days	40 days	21 days	40 days
T1 - 100% inorganic	0.067[b] ±0.006	0.075[b] ±0.006	3.45[b] ±0.28	1.56[b] ±0.24
T2 - 70% inorganic and 30% organic	0.067[b] ±0.007	0.082[b] ±0.004	3.73[b] ±0.44	1.75[ab] ±0.21
T3 - 50% inorganic and 50% organic	0.071[ab] ±0.007	0.087[a] ±0.002	4.23[a] ±0.82	2.35[a] ±0.69
T4 - 30% inorganic and 70% organic	0.073[ab] ±0.008	0.078[b] ±0.003	3.90[b]±0.80	1.70[ab]±0.15
T5 - 100% organic	0.083[a] ±0.009	0.083[b] ±0.002	3.85[b] ±0.45	2.10[ab] ±0.15

*Means (± standard deviation) followed by equal lowercase letters on the column do not differ statistically at a confidence level of 95% (Tukey's test).

Analysis of microminerals from bones

Table 4 shows the results concerning the content of zinc, manganese and copper in ash of chickens submitted to organic and inorganic minerals, where one can see that no statistical differences ($p<0.05$) were verified among treatments tested.

Table 4. Content of Zn, Mn and Cu (mg/kg) present in the ash of poultry bones submitted to the treatment with organic and inorganic minerals.

Treatment	Fat-free ash	Micromineral (mg/kg)*		
	(g/100g)	Mn	Cu	Zn
T1 - 100% inorganic	50.76[a] ±2.23	9.85[a] ±0.57	10.57[a]±0.88	374.32[a] ± 2.29
T2 - 70% inorganic and 30% organic	51.93[a] ±0.60	9.87[a]±0.90	9.82[a]±1.01	388.55[a]±33.11
T3 - 50% inorganic and 50% organic	50.09[a]±0.78	9.35[a]±0.74	10.00[a]±0.36	386.38[a]±27.73
T4 - 30% inorganic and 70% organic	49.63[a]±1.14	9.93[a]±1.39	10.42[a]±0.60	389.88[a]±36.02
T5 - 100% organic	50.58[a]±1.71	9.89[a]±0.55	10.54[a]±0.89	373.74[a]±31.80

*Means (± standard deviation) followed by equal lowercase letters on the column do not differ statistically at a confidence level of 95% (Tukey's test).

Physical-chemical analysis

Table 5 presents the time course of lipid oxidation (TBARS) in samples of raw drumsticks chicken submitted to treatment with organic and inorganic minerals kept under refrigeration at 4 ºC during 15 days, considering three treatments (100% inorganic, 50% organic and 50% inorganic and 100% organic).

Table 5. Lipid oxidation (TBARS) of broiler chicken drumsticks submitted to treatment with organic and inorganic minerals (100% inorganic, 50% inorganic and 50% organic and 100% organic) cooled at 4ºC during 15 days.

Treatment	TBARS (mg of MDA/kg of sample)*			
	0 days	7 days	10 days	15 days
T1 - 100% inorganic	$0.13^{aC} \pm 0.04$	$0.42^{aB} \pm 0.03$	$0.49^{aA} \pm 0.03$	$0.57^{aA} \pm 0.09$
T3 - 50% inorganic and 50% organic	$0.11^{aB} \pm 0.05$	$0.19^{bB} \pm 0.03$	$0.33^{bA} \pm 0.04$	$0.31^{bA} \pm 0.02$
T5 - 100% organic	$0.14^{aB} \pm 0.07$	$0.12^{bB} \pm 0.02$	$0.31^{bA} \pm 0.03$	$0.32^{bA} \pm 0.10$

*Means followed by equal lowercase/uppercase letters on the columns/lines do not differ statistically at a confidence level of 95% (Tukey's test).

It can be noted that the three treatments showed similar behavior at zero day TBARS evaluation, a different situation verified at 7 days, in which treatment 1 (100% inorganic) presented higher TBARS value (0.42 mg of MDA/kg) compared to the other treatments. The same situation occurred at 10 and 15 days of evaluation, as a significant increase ($p<0.05$) was observed in TBARS contents at storage conditions related to samples of treatment 1.

Values regarding pH (6.16 to 6.82) and acidity (0.11 to 0.18) did not present significant differences ($p>0.05$) among treatments in the period 0 to 15 days in which drumsticks were kept under refrigeration at 4ºC.

Sensory analysis

With regard to sensory characteristics it was noted that (sobrecoxas) samples of *in natura* chicken treated with different mineral sources did not present statistical differences ($p>0.05$) in relation to aroma and color among treatments of 100% inorganic; 50% organic and 50% inorganic and 100% organic for 15 days storage under refrigeration, attributing no difference in scale for the aroma attribute and slightly different concerning color. The same behavior was observed for the attributes of aroma, taste, texture and color of roasted drumsticks chicken submitted to treatment with organic and inorganic minerals storage at 4 ºC during 15 days, leading to no difference and slightly different attributes decision.

DISCUSSION

According to Kratzer and Vohra (1996), extra supplementation of minerals aiming at increase the animal's availability may cause deleterious effects like diarrhea and imbalances that might lead to reduction of availability of some other minerals. Besides, inhibition of minerals absorption by other substances and/or nutrients when in inorganic form, such as oxalic and folic acids, tannins, fibers, among others. Nevertheless, chelate minerals present better absorption compared to inorganic ones as, in general, they use the absorption ways of organic molecules in which they are bond hence does not causing interactions restriction with other minerals. The mechanism through which the chelating agent improves minerals use depends on the ligand ability towards minerals scavenging, or on its ability to form other soluble complexes with the minerals.

It was observed a higher zinc concentration in blood at 21 days with a mixture of 50% of organic and inorganic minerals, whereas in the liver, at the same period of treatment, with organic minerals in relation to inorganic ones, this trend was not observed at 40 days.

According to Lowe et al. (1991), the content of zinc in blood serum is commonly used to evaluate the concentration of this mineral in the human organism, but for animals in stress state, zinc reduction in serum may occur, though not associated to the deficiency of zinc and hence this may not be an adequate parameter to assess zinc demands, once it is not only affected by the diet. With regard to organic zinc, Tucker (2008) argues that a better performance of chicken supplemented with such mineral is associated with its greater availability. It is kwon that the absorption place of zinc in animals is the small intestine. The main excretion route is the liver through faeces, with only small amounts delivered through urine. The main storage form of zinc is as metallothionein in the liver and its synthesis is induced by the presence of such element in the liver (McDowell, 1992).

Blood analysis at 40 days and liver at 21 days showed high content values of manganeses in treatment 5 (100% organic), which just corroborates the theory of better bio-availability of organic minerals. Manganeses is an essential mineral to chicken development, especially for bone development. Two diseases are reported to come from the lack of such mineral: perose and bone chondrodystrophies, caused by manganese deficiency (Lyons and Insko, 1937).

One of the specific actions of manganese is the mucopolysaccharides synthesis (present in cartilage) and the dismutase superoxide, which was isolated from chicken liver mitochondria (Leach, 1971). Lack of manganese was associated to depression of immunity and central nervous system (Hurley, 1981). Rossi et al. (2007) in investigating the effect of organic minerals on the performance of reproductive system of heavy matrixes concluded that supplementation of manganese in the form of aminoacid complex diminished the initial mortality of chicks without affecting the carcass characteristics.

The higher concentrations of selenium were observed to occur in the presence of organic minerals thus evidencing the greater bio-availability in such form. These results show that a mixture of organic and inorganic minerals lead to a better use of selenium by chicken from the ccomodation up to the period of 40 days life. Upton (2003) states that the two selenium forms, organic and inorganic, may be used as dietary supplement although they differ considerably about physicochemical properties and also regarding absorption and metabolism. During the absorption, selenomethionine is actively transported through intestinal membranes and is accumulated in the liver and muscles. The inorganic selenium absorbed as mineral is less retained in the tissues, with the major part being excreted.

Yoon et al. (2007) studied the effect of organic and inorganic sources of selenium on the performance of chicken matrixes and concluded that different sources did not affect their performance and development, though older chickens retain a more amount of selenium and its use is more efficient when present in lower concentrations in the diet. The authors also reported that organic selenium form exhibited greater bio-availability than the inorganic form, evidencing its retention and staying in blood.

According to Santos et al. (2005) selenium is essential for correct maintainance of several organic functions, like reproduction, growth, and disease prevention as well as to keep the tissues integrity. The metabolic function of selenium is closely connected to vitamin E, as both act protecting biological membranesagainst degenerative oxidation. In that work, authors investigated the antioxidant factors of organic selenium in the performance of hen and observed that the morphology of the chicken oviduct supplemented with organic selenium presented better preservation of the structures responsible for internal and external quality of eggs, hence leading to a global improvement of chcken organism.

The deposition of minerals in tibia as an answer to diet supplementation is a very used parameter and its sensitivity has demonstrated better results compared to other evaluation accomplished in other organs and tissues like liver, kidneys, pancreas and blood. However, in the present work, no significant differences were observed concerning the amount of minerals (copper, manganese and zinc) in tibias evaluated for 6 the different treatments. These results agree with those found by Brito et al. (2006), in assessing the minerals utilization in organic complex form for chikens within the period of 7 to 12 weeks on the performance and bone charateristic. These authors found no significant differences among treatments in terms of performance and uniformity, while with a redcution in the inclusion levels of organic supplement there was a linear decrease in ash content of chicken tibias, though no difference was found between inorganic (control) and organic sources.
Some works on layers, like that of Boruta et al. (2006), in which the performance of layer chicken fed with organic minerals in different levels, concluded that the bone resistance increased and excretion was reduced in all groups. According to Mariutti and Bragagnolo (2009), chicken meat is highly susceptible to lipid oxidation due to the existent high content of unsaturated fatty acids. The formation of cholesterol oxides and degradation of fatty acids, mainly the poly-unsaturated ones, in addition to the volatile secondary compounds coming from lipid oxidation, may be one of the most important factors responsible for the quality and nutritional losses.
Regarding the lipid oxidation, it was observed a significant increase of TBARS values in treatment 1 (100% inorganic) in comparison with other treatments, though a significant increase was also verified for all treatments from 10 days chicken storage. Such observation may be explained in terms of greater bio-availability of organic minerals together with the selenium action as cofactor of glutathione peroxidase enzyme and zinc and manganese as cofactors of dismutase superoxide enzyme, acting, according to Rover et al. (2001), as preventive anti -oxidants, comprising a relevant enzymatic defense system against the attack of free radicals to cellular and intra-cellular membranes.
Boiago (2013) evaluated the performance, carcass yield and qualitative characteristics of chicken breast meat fed with supplemented diets with different concentrations and sources of selenium and concluded that the organic selenium sources afforded lower meat oxidation at the experimental conditions investigated. The authors also observed that higher supplementation of selenium led to an increase of ash percentage in meat.
Lu et al. (2007), in studying the effect of source and levels of manganese on the quality of drumsticks chicken, abdominal fat and lipid oxidation, observed that organic manganese sources were more efficient in reducing the activity of liprotein enzyme over abdominal fat of chickens, hence diminishing abdominal fat deposition.
The pH measurement may be used as evaluation proof/test of meat conservation step, due to the production of amines and ammonia, since a gradual pH increase takes place after *rigor mortis* setup. The pH interval found in this work did not present significant differences and remained close to those reported in the literature (Santos et al., 2005).

CONCLUSIONS

The use of orgaic sources of microminerals (Zn, Mn and Se) in broilers diet conducted to an increase in their concentrations in blood and liver, but with no alterations in bone composition compared to the diet with inorganic minerals form. Feed formulated with 50% organic and 50% inorganic minerals afforded similar results. The diet with organic minerals or mixtures with inorganic minerals led to lower lipid oxidation of drumsticks stored at 4°C for 15 days compared to the diet with uinorganic minerals. Sensory alterations were not experimentally verified through treatments employed in this work.

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