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RESEARCH ARTICLE

EFFECT OF DIETS SUPPLEMENTED WITH CHELATED OLIGO- ELEMENTS (MANGANESE, ZINC AND IRON) ON GROWTH PERFORMANCE, CARCASS TRAITS, AND MEAT COMPOSITION IN JAPANESE QUAILS (*COTURNIX JAPONICA*)

***Ali OLLIEK and Georges ABI RIZK**

Lebanese University, Faculty of Agronomy, Animal Production Department, Beirut-Lebanon

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Corresponding author:
Ali OLLIEK

ABSTRACT

The current research was conducted to study the effect of diets supplemented with chelated oligo-elements (Manganese (Mn), Zinc (Zn), and Fe (Iron)) on growth performance, carcass traits and meat quality in Japanese quails *(Coturnix japonica)*. A total of 160 Japanese quails were randomly segregated into 4 equal groups: Manganese group "Mn" (Commercial feed + 0.4 g/kg Mn Availa®), Zinc group "Zn" (Commercial feed + 0.3 g/kg Zn Availa®), Iron group "Fe" (Commercial feed + 0.3 g/kg Fe Availa®) and Control group "Control" (Commercial feed only). Birds were raised in collective cages for 52 days of age, where they have been supplemented with ad libitum feed and water. In order to assess the live performance and meat quality, the following traits were measured: Live body weight (LBW), feed conversion ratio (FCR), carcass weight and drip loss (%), carcass yield (%), breast and thigh's weight and yield (%), pH, meat color (L* a* b*), water holding capacity, thawing and cooking losses, and tenderness. Our results had shown that despite the live body weight of any of the groups not being significantly affected (P>0.05) by the diets, but at the 35th day and afterwards, the Fe group showed the highest live body weight among the groups. In addition, the feed conversion ratio at 29 days showed that group Fe had a significant difference with respect to the control group (3.1±0.06 in comparison with 0.35±0.05: P<0.05). The carcass weight of the Fe group (109.9±16.78g) had shown highly significant difference with all of the other groups (90.68±21.59g, 83.33±18.95g, and 90.58±24.92g for Mn, Zn, and control group respectively; P<0.05). The breast weight of the Fe group (27.3±7g) had also shown highly significant difference with respect to the other groups (20.3±5.48g, 18.6±4.67g, and 21.9±4.62g, for Mn, Zn, and control respectively; P<0.05) whereas for the thigh weight, the Fe group (26.7±4.15g) presented a significant difference only with groups Mn and Zn (22.1±5.16g, and 19.2±4.15g for Mn and Zn respectively; P<0.05). As for the meat color, the Lightness (L*) was not affected by the diets (P>0.05), whereas for the redness (a* value), the Mn group had shown a higher (P<0.05) value than all the other groups at both 24 and 48 hours *post mortem*. As for the yellowness (b*-value), Mn group had a significantly (P<0.05) higher b* value than Fe at 48 hours *p.m.* only, with no regards to the control or the Zn groups. Regarding the data presented, the Fe group had shown superiority over the majority of factors; including growth performance and carcass traits.

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INTRODUCTION

The Japanese quail *(Coturnix japonica)* is the smallest avian species farmed for egg and meat production, and it has also assumed worldwide importance as a laboratory bird model for research. This bird is used among others for genetic, physiological, biomedical, behavioral, and embryological studies (Huss *et al.,* 2008). In the poultry world quail meat production is negligible when compared with that of broiler chickens but nevertheless quail is a good source of meat and occupies a relevant place in poultry breeding and contributes to the global poultry industry (Maiorano *et al.* 2011). Therefore, quail meat could be an interesting niche of bussiness.

There are two forms of minerals used in poultry production, one is an inorganic, the other being organic, while the latter being shifted-to by the majority of countries due to its enhanced production values in comparison with its counterpart. For example, Zhao *et al.* (2010) states that chelated oligo-elements are more available for absorption, because of reduced antagonistic reactions with other dietary constituents in the gastrointestinal tract, along with witnessing improvements in tissue development and integrity, and an enhanced immune function which led to an enhanced growth performance. (Zhao *et al*., 2010) also stated that the usage of inorganic minerals led an excreta containing 660% Zn, 560 % Cu in comparison to the organic form, that would contaminate water sources, and reduce crop yields when excreta of that source is being used as crop fertilizer. In Lebanon, recent years has shown an increase in interest in quail farming, despite the sector being primitive to old techniques of rearing with no specialized handling of the quail farms, leaving numerous farms and their respective owners with little to no profit due to the in-efficiency of rearing, especially when it comes to feed rationing, where the majority of farms use turkey or broiler specified feeds, and even if there is a quail-specific diet, most of the time it is insufficient to the quails' requirements. Thus, the use of organic chelated oligo-elements was viable as the usage of small amount of these minerals would theoretically yield a feasible outcome with respect to both carcass and meat's quality and yield. This study was then initiated in order to tackle the deficiency found in the commercial quail feed by the addition of organic chelated oligo-elements Zn and Fe (Availa®) at 0.3 g/kg and Mn (Availa®) at 0.4 g/kg in the basic commercial quail feed ration. That are afterwards being subjected to experimental measures, in order to test the live performance, carcass and meat's both quality and yield, theorizing that these supplements will show improvements in these three categories.

MATERIALS AND METHODS

Experimental Population: On the 7th of May 2018, the experiment was performed with 160 baby Japanese quail (*Coturnix japonica*) (average weight 5±1 g)at the brooder situated in Yohmor Al-Shakif in South Lebanon.

Within the first couple of minutes, the chicks were segregated randomly into 4 equal groups:

- Control group "Control" (n=40; average weight of 5 grams) fed commercial quail feedstuff without any additives.
- Manganese group "Mn" (n=40; average weight of 4 grams) fed commercial quail feedstuff with 0.4 g/kg of Mn 80 Availa® Manganese Amino Acid Complex.
- Zinc group "Zn" (n=40; average weight of 5.8 grams) fed commercial quail feedstuff with 0.3g/kg of Zn Availa®.
- Iron group "Fe" (n=40; average weight of 5.8 grams) fed commercial quail feedstuff with 0.3 g/kg of Fe Availa®.

The birds were raised for 52 days of age in collective cages under continuous lighting (natural and artificial). The rearing temperature was gradually decreased, 38 to 34°C in the first week, 33 to 28°C in the second week, and 27 to 22°C in the third week. Afterwards, it was maintained between 18 and 20°C. Along the experiment, the quails were supplemented with ad libitum feed and water. The commercial diet containing 27% CP, and 2800 Kcal of ME/kg was used for the first 28 days; while the finisher ration had 24% CP and 2900 Kcal of ME/kg. No vaccines were used, but rather a wide spectrum antibiotic Alfaceryl mix was given to prevent infections from gram positive and gram negative bacteria as well as for gastro-intestinal infections. Along their first week of rearing, Alfaceryl was added at a rate of 1 gram per liter.

In vivo performance

Live body weight (LBW)

The recordings of live body weight was taken weekly using a digital balance (±0.01g), with an exception of the day 52 where 10 days separate the recording of live body weight.

Feed Intake (FI): The recording of feed intake was taken weekly by measuring the feed put in the trays and subtracting it from the feed left in the trays.

Feed Conversion Ratio (FCR): As a definition, feed conversion ratio is the measure of the amount of feed required (in Kilograms) to produce 1 kilogram of meat in a given animal. Hence, FCR was calculated using the formula:

FCR= FI/ LBW

Slaughter Survey

Carcass Characteristics: On the 26th of June, exactly 52 days of rearing the chicks, 74 full grown quails have been taken for slaughter to the laboratory in the Lebanese University Faculty of Agronomy and Veterinary Sciences stated in Dekwaneh-Beirut. At slaughter, all birds were individually weighed (after a fasting period of 12 hours), stunned and decapitated. Stunning was performed by a percussive blow to the back part of the head (occiput), and decapitation was performed via a scissors between the cervical vertebrae and the base of the skull according to the EU regulations on the protection of animals at the time of killing (European Communities, 2009). After plucking and evisceration, carcasses were weighted using a digital balance (±0.01g). Each carcass was identified by a rubber ribbon and numbered and kept in the refrigerator at 4°C. 24 hours post mortem, carcasses were dried with filter paper, and reweighed; breast and thigh muscles were removed from the carcasses and weighed individually. Left pectoral muscle was removed and tested at 24 and 48 hours, while the right pectoral muscle was stored frozen in vacuum packages at -20°C for further analysis for thawing and cooking loss, and tenderness.

Carcass and muscle's yield from the quails was calculated respectively

•Carcass yield (%) = (Carcass weight/live body weight)*100
•Muscle yield (%) = (Muscle weight/carcass weight)*100

Meat Quality Measurements: Post mortem muscle pH, color and drip loss (%) were performed on the left breast.

Post mortem breast muscle pH: On 24 hours, and 48 hours *post-mortem,* pH was measured using a portable pH meter equipped with a piercing glass probe. Calibration was done at pH 4.0 and 7.0 prior to use. The probe was inserted deep into the meat (around 0.5 inches), given the pH meter a minute to finalize the reading, and then rinse the probe with distilled water in preparation for the next sample.

Meat Color: A whole piece of breast meat was evaluated for color in 3 replicates at 24 and 48 hours *p.m* using a Colori-Meter. The color of the breast meat was evaluated using the CIE color system, including L* (lightness), a* (greenness and redness), and b* (blueness and yellowness). All measurements were carried out on the surface of the scallop, in an area free of color defects (bruises, blood spots, and hemorrhages).

Water Holding Capacity (WHC)

Drip Loss (%): The left breast muscle was individually weighed at 24 hours *post mortem,* and then it was reweighed after drying it out using a paper towel. At 48 hours, the breast muscle wrapped in polyethylene plastic bags were once again dried out using a paper towel and reweighed. This process enabled the calculation of the drip loss percentage of the breast muscle from its initial weight.

Drip loss (%) = [(Weight before treatment - weight after treatment)/ weight before treatment]*100

Thawing and cooking loss (%): In order to determine thawing loss, the right scallops was packed in polyethylene bags and put in a refrigerator at +4°C for 10 days, afterwards, the samples were dried out and reweighed to calculate the loss percentage due to thawing based on the following formula: Thawing loss (%) = [(weight before freezing – weight after thawing)/ weight before freezing] *100.

On the same day, cooking loss was also estimated by the process of cooking the samples in a water bath for 15 minutes at 80°C, where afterwards they were dried out using a paper towel, and been reweighed.

Meat Tenderness: Meat tenderness was estimated using a penetrometer with a needle of 2.5 g based on a weight of 47.5 g, thus attaining a total weight of 50 g. Cooked samples were cooled to room temperature. The penetrometer needle depth (PND; in mm) was recorded and an average of 3 replications by sample was calculated.

Statistical Analysis: One-way ANOVA (analysis of variance) was used to determine the significance of results of live performance, carcass traits, and meat composition with probability of 95 % (P<0.05) (SPSS 16.0, 2009).All the data was presented as averages ± standard deviation.

RESULTS

Health and Mortality: The mortality rate upon the first 48 hours was at 20%, distributed along the groups, this was due to the initial low weight they had, along with a very cold weather, which neglected the heat from the lamps. Afterwards, mortality stayed at a rate of 4-6 chicks each week, with no significance to the group, to reach an overall mortality rate of 54%.

Live Body Weight (LBW) and feed conversion ratio (FCR): The variation of live body weight (LBW) and feed conversion ratio (FCR) with respect to the different diets supplemented along the experimental period are shown in figure 1. Along the experiment, none of the groups expressed superiority in live body weight (P>0.05) with the control group throughout the 52 days of rearing. Worth to mention however, that the Fe group had shown an advantage over the other groups, despite it being not significant, in live body weight from day 35 (Fe group; 59.1±18.9 g in comparison to its closest contender the Mn group; 54.9±15.01 g), then on day 42 (Fe group; 87.9±28.8 g in comparison to its closest contender being the Zn group 81.9±26.3 g) and at the end of the experiment, on day 52 (Fe group; 162.1± 28.3 g in comparison to its closest contender the control group at 143.8± 13.2 g). As for the feed conversion ratio (FCR), a singular significance was derived from the results, where on the 29th day, the FCR of Fe group showed significant difference in comparison to the control group (3.1±0.06 in comparison with 0.35±0.05: P<0.05).

Carcass weight and Drip loss (%): The results of carcass weight and drip loss (%) among the tested groups are represented in figure 2. The carcass weight of group Fe (109.78±16.87 g) had shown significant difference in comparison to groups Mn (90.68±21.59 g) and Zn (83±18.95 g) (P<0.05), while it showed a relatively significant difference with the Control group (90.58±24.92 g) at (P=0.054). As for Drip loss (%) concerns, there was no significant difference (P>0.05) shown by any group over the other.

Carcass Yield (%): The differences in carcass Yield (%) among the different groups is represented in figure 3. Although there happened to be significant differences in carcass weight among the groups, but as for carcass yield (%), there happens to be no difference to be stated (P>0.05).

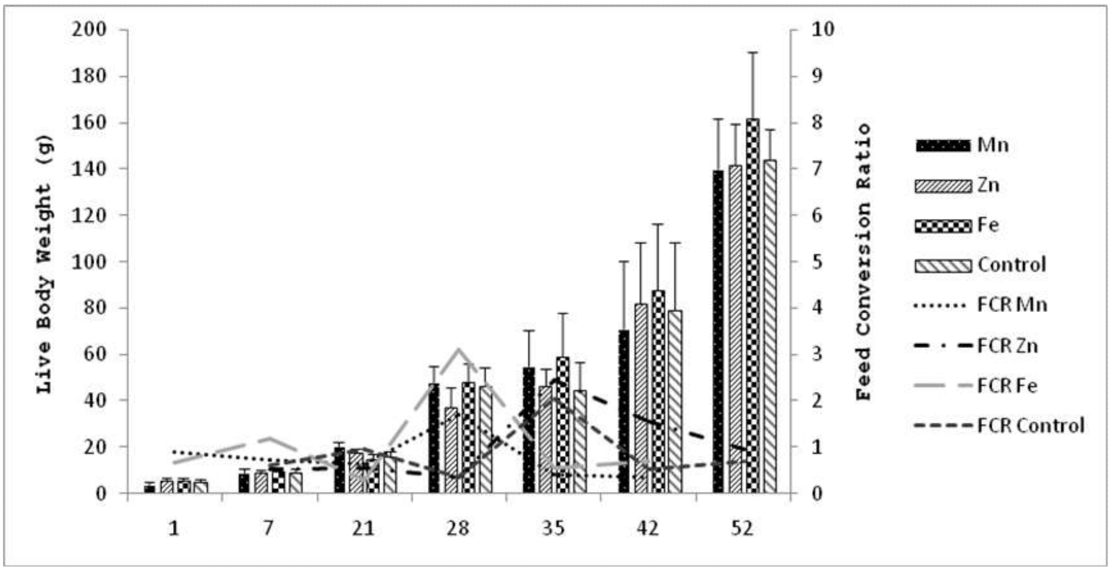
Breast and Thigh's weight and yield (%): The average variation of breast and thigh weight and the breast and thigh's yield (%) among the different diet groups are represented in figure 4 and figure 5 respectively. The results obtained in this study had shown an interlaced difference between the breast and thigh weight among the groups, where Fe (27.3±7g) had shown significant superiority to all other groups (20.3±5.48g, 18.6±4.67g, and 21.9±4.62g, for Mn, Zn, and control respectively; P<0.05). As for thigh's weight, Fe group (26.7±4.15g) had shown significant difference with both Zn and Mn (22.1±5.16g, and 19.2±4.15g for Mn and Zn respectively; P<0.05), but not with the control group however.
As for breast and thighs' percentage yields, there happens to be no significant difference among the groups.

pH Level: The average variation in pH among the groups on 24 and 48 hours *post mortem* is represented in figure 6. The current study didn't show any significant differences in pH levels among the groups, ranging from 5.46 to 5.70 and 5.64 to 5.71 at 24 and 48 hours post mortem respectively. However, note that the Zn group had the highest pH (5.70) level upon 24 hours p.m., only to be contested at 48 hours p.m. by the control group (5.71).

Meat Color: The average readings of the color-meter (L* a* b*) of the breast on 24 and 48 hours are represented in figure 7. The data presented in figure 7 shows that there is no significant difference in Lightness (L* value) among the groups on the two periods. Whereas, the redness (a* value) was higher in Mn (14.79±2.39, 15.3±3.48 at 24 and 48 hours respectively) among all the groups, upon both 24 (12.12±2.92, 12.85±1.86, 12.47±2.45 for Zn, Fe, and control respectively) and 48 hours (13.83±2.06, 13.39±2.86, and 12.53±2.16 for Zn, Fe, and control groups respectively). Finally, the yellowness (b* value) had shown no significant difference between the groups at 24 hours, whereas upon 48 hours, Fe (9.49±2.73) was different (P<0.05) from Mn group (12.16±2.47).

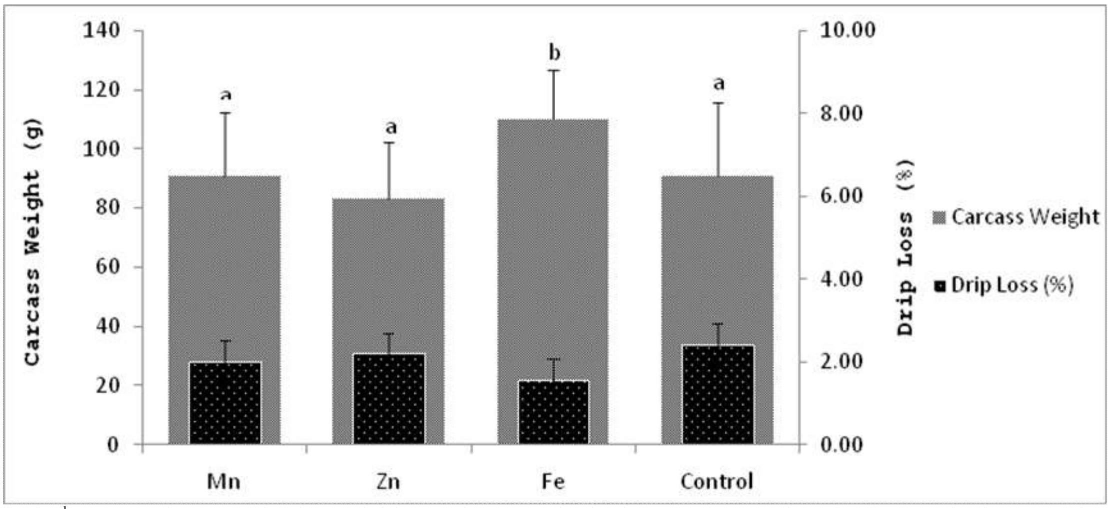
Water Holding Capacity (%): The average variation of drip loss (%) at 24 and 48 hours are represented in figure 8. In this study, Fe's drip loss at 24 hours (1.46±0.8) was different (P<0.05) than both Mn (2.15±0.4) and Zn (2.32±0.4) groups, but not different from control group. However, at 48 hours, there was no significant difference in drip loss (%) among the groups.

Thawing and Cooking Loss (%): The average variation in thawing and cooking loss (%) among groups is represented in Figure 9.



* indicates a significant difference in feed conversion ratio at 29 days of rearingat *(P<0.05)*

Figure 1. Effects of diets supplemented with chelated Manganese (Mn), Iron (Fe), and Zinc (Zn) on the live body weight (in grams), and the feed conversion ratio of Japanese quails.



[a,b]Different letters mean significant difference at *(P<0.05)*

Figure 2. Effect of diets supplemented with chelated Manganese (Mn), Iron (Fe), and Zinc (Zn) on the carcass weight and drip loss percentage in Japanese quails

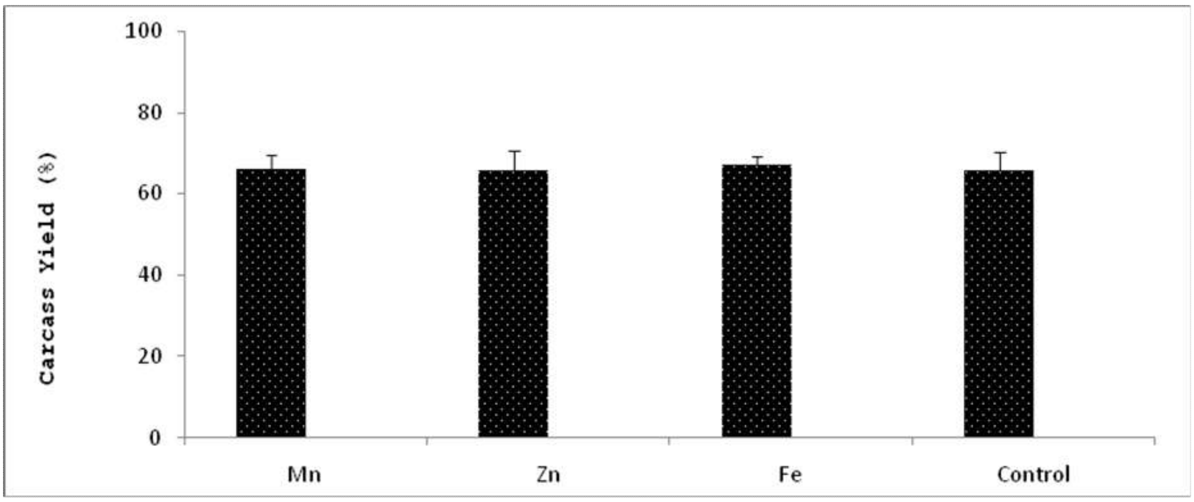
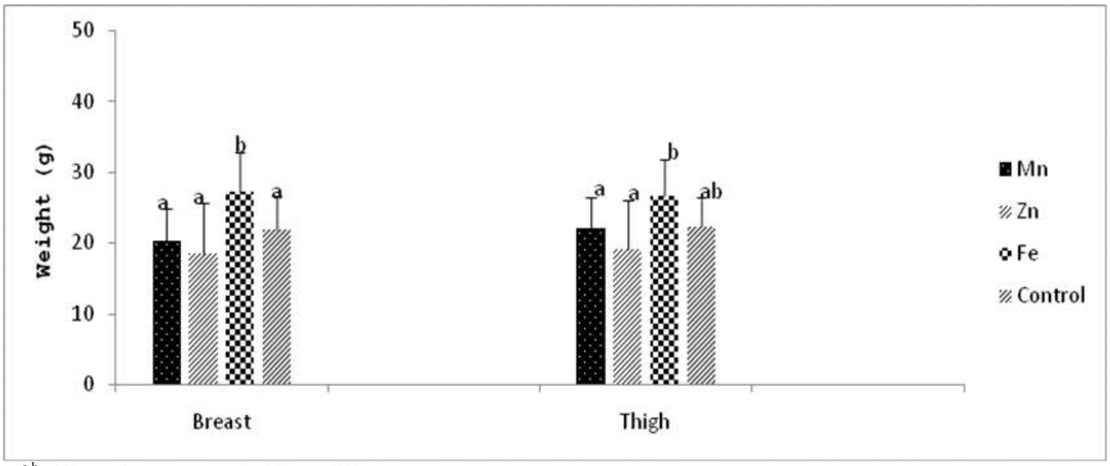


Figure 3. Effect of diets supplemented with chelated Manganese (Mn), Zinc (Zn), Iron (Fe) on the carcass yield percentagein Japanese quails



a,bDifferent letters mean significant difference at *(P<0.05)*

Figure 4. Effect of diets supplemented with chelated Manganese (Mn), Iron (Fe), and Zinc (Zn) on the breast, and thighs' weight (in grams) in Japanese quails

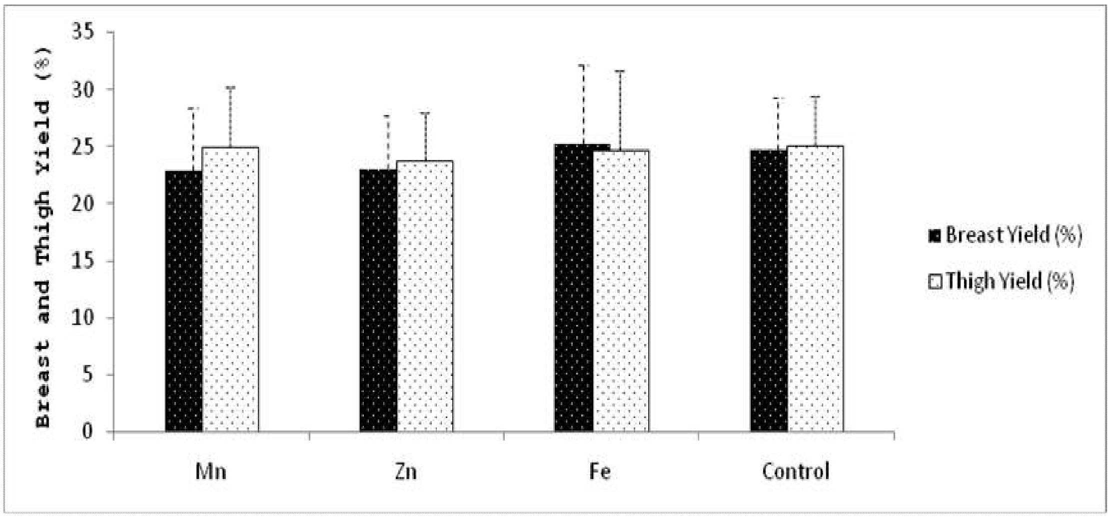
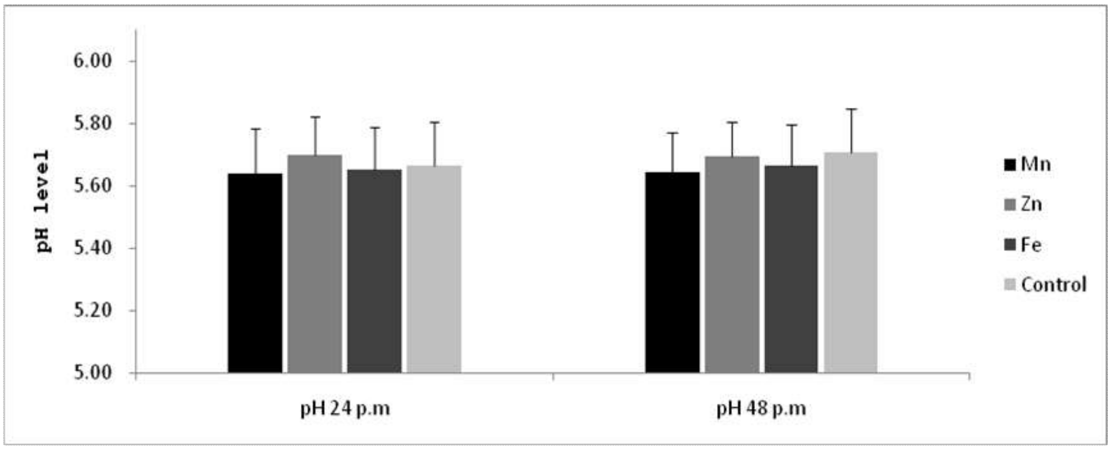


Figure 5. Effect of diets supplemented with Manganese (Mn), Iron (Fe), and Zinc (Zn) on the breast and thigh yield percentage in Japanese quails

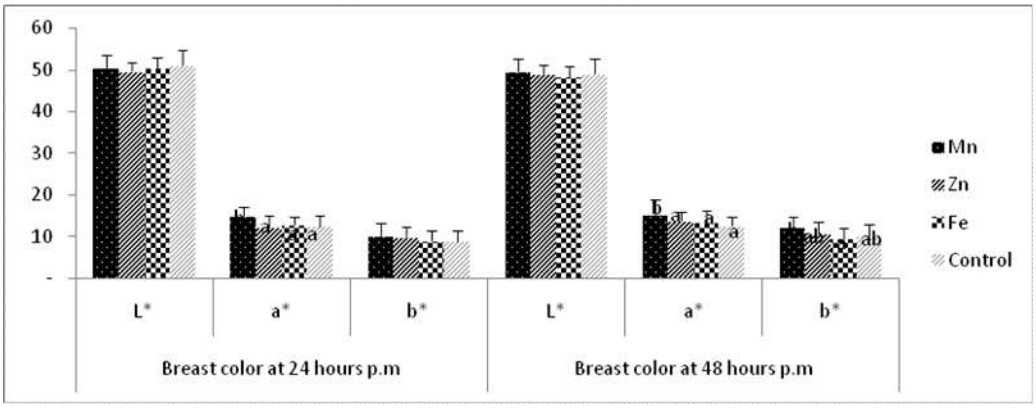


pH 24: pH at 24 hours *post mortem.*
pH 48: pH at 48 hours *post mortem*

Figure 6: Effect of diets supplemented with chelated Manganese (Mn), Iron (Fe), and Zinc (Zn) on the pH level of the meat in Japanese quails

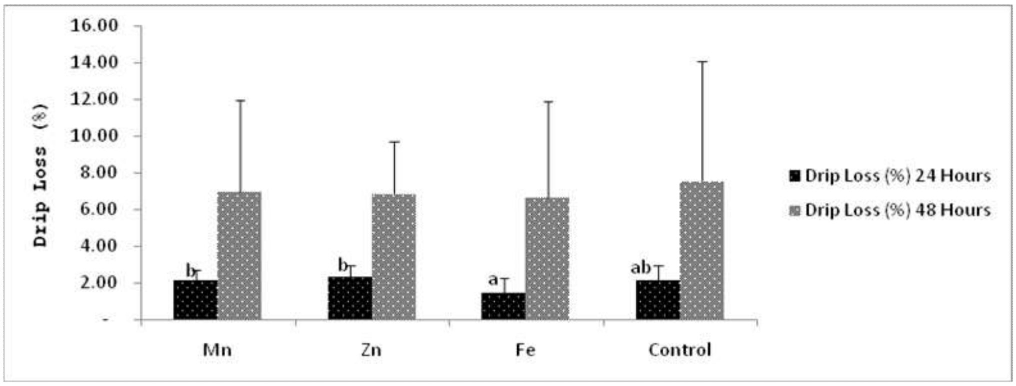
The results in this experiment had shown that cooking loss (%) was not affected by the supplementation of the diets. On the contrary however, thawing loss (%) appeared to have an interlinked significant difference, where the Zn group (4.74±1.26) had shown a significantly higher (P<0.05) thawing loss (%) in comparison with the Fe group (3.04±1.73), while not being different than that of the control or Mn group.

Tenderness: The average variation in Tenderness between the groups is represented in Figure 10.



a,b Different letters indicate significant difference at *(P<0.05)*
L*: Lightness value
a*: redness value
b*: yellowness value

Figure 7. Effect of diets supplemented with chelated minerals; Manganese (Mn), Iron (Fe), and Zinc (Zn) on the L*, a*, and b* on breast meat color values



a,b Different letters indicate significant difference between groups at *(P<0.05)*

Figure 8. Effect of diets supplemented with chelated Manganese (Mn), Iron (Fe), and Zinc (Zn) on the drip loss (%) upon two different times (24 hours, and 48 hours *post mortem*

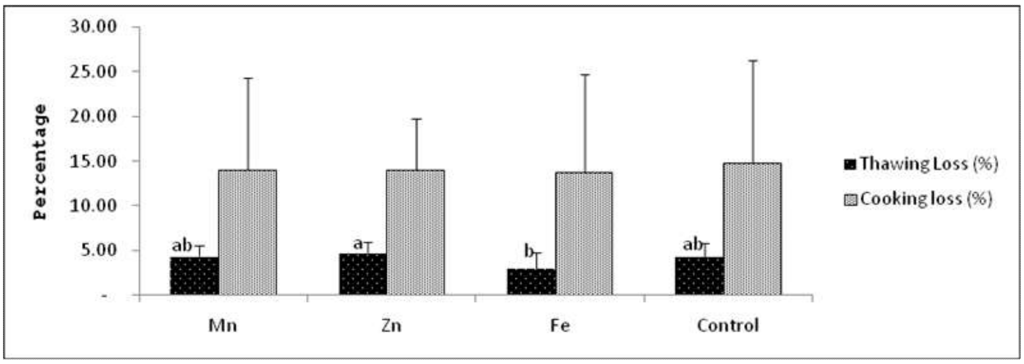


Figure 9. Effect of diets supplemented with Manganese (Mn), Iron (Fe), and Zinc (Zn) on the thawing, and cooking loss percentage. a,b Different letters indicate significant difference between groups at (P<0.05)

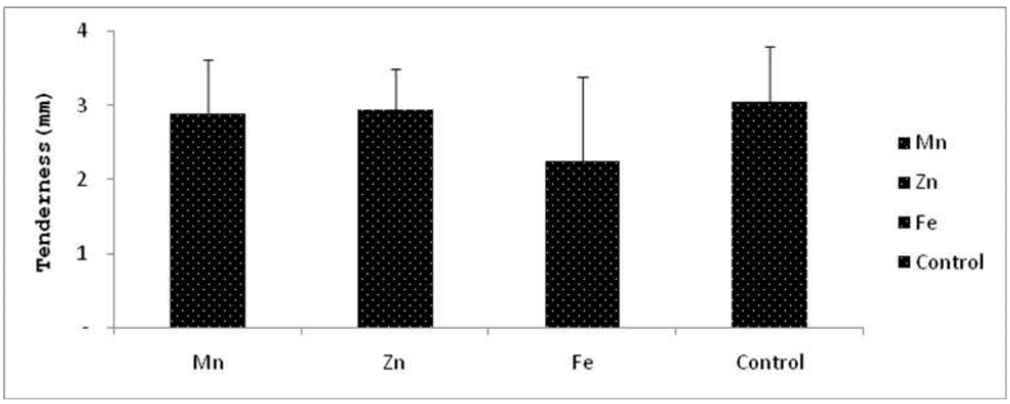


Figure 10. The average value ± standard deviation tenderness values between the different groups (Mn, Zn, Fe, and Control)

The tenderness didn't show any effect imposed by the diets supplemented with the organic chelated oligo-elements. However, note that the control group (3.05±1.31 mm) had the highest value of all the other groups (2.88±0.73, 2.95±0.55, 2.25±1.13 for Mn, Zn, and Fe groups respectively).

DISCUSSION

Live Body Weight (LBW) and feed conversion ratio (FCR): The results in this study were in compliance with the study of Ray *et al.* (2013) where the body of weight of experimental quail did not differ significantly during the first 21st days of the experiment. The results recorded of the Mn group are supported by Henry *et al.* (1989) where it was shown in his works that the earlier workers did not report any significant effect of Mn source on weight gain. Similarly, Namra *et al* (2008) observed that body weight was not affected by the feeding of Zinc, which supports our result. Validating our results even more is that Mishra *et al.* (2013) stated that the body weights of broiler till third weeks of age of all treated groups didn't differ significantly (P>0.05).In contrast however, the findings of Abdallah *et al*. (2009), Sahin (2005), Lalliankimi (2017), Zhao (2010) had shown an increase in body weight upon a certain period of time when using one of the discussed chelated minerals. As for the Feed conversion ratio (FCR), the results were backed-up by the study of Aghaei *et al.* (2017), where they found out that quails supplemented with 80, 120, and 160 mg/kg of Fe showed significant improvements in FCR. This study's results was contradictory to the findings of Zhao (2010), Mishra *et al.* (2013), Rossi *et al.* (2007) who all reported not having any significant difference among their experimental groups with respect to feed conversion ratio.

Carcass weight and Drip loss (%): For the carcass weight, the results comes in contrast with, Rossi *et al.* (2007), and Ray *et al* (2014) where their studies didn't find an effect imposed by chelated-oligo elements on carcass weight in broiler chickens. Despite the contradiction, Liu *et al.* (2011) observed that birds supplemented with 60, 120, and 180 mg/kg of zinc had higher percentage of eviscerated yield in broilers (P<0.05) As for drip loss (%) concerns, the results came in compliance with the study of Saenmahayak *et al.* (2010) that reported that drip loss wasn't affected by organic chelated Zn implementations at 49 days of age. Similarly, Tavares (2014) reported similar results upon inorganic (ITM) and organic (OTM) trace mineral treatments.

Carcass Yield (%): The results indicated in this study are backed-up by several studies such as Mishra *et al.* (2013) study that reported no significant difference in the live weight, dressed weight, eviscerated weight, drum stick yield, thigh yield, back yield, neck yield, breast yield and wing yield of all the treatments of the experimental broilers, correspondingly to Osman and Mona's (2007) study that stated that feeding of organic chelated Zinc had no effect on carcass traits whatsoever. Despite the study's data, some studies had observed different percentage of eviscerated yield in broilers such as Liu *et al.* (2011), in addition to the findings of Britanico *et al.* (2012) that reported a higher dressing percentage in groups supplemented with amino acid chelates of Cu (2.5 g/ton), Zn (11.25 g/ton), Mn (15.0 g/ton) and Fe (18.75 g/ton) respectively, in broilers.

Breast and Thigh's weight and yield (%): Breast-weight values come in accordance to the findings of Zhao *et al.* (2010) where the supplementation of chelated minerals had shown improvement in breast weight. In contrast, Mishra *et al.* (2013) had found that there is no difference in breast and thigh weight among treated groups. As for breast, and thighs' percentage yields, there happens to be no significant difference (P>0.05) among the groups, which is similar to what Ray *et al.* (2014) reported in his study, where the supplementation of organic minerals (Zn, Cu, and Mn) had no effect on thigh and breast yield in Japanese quails.Disagreeing with the afore-discussed studies, Saenmahayak *et al.* (2010) had observed that the breast and thigh's muscle yield (%) was significantly higher (P<0.05) in broilers fed chelated complex Zn. In addition to Zhao's *et al* (2010) verdict of having an improved breast yield in male birds due to the implementation of oligo-elements (Zn, Mn, and Cu) in the diets.

pH Level: Contradictory data regarding pH exist, Narinc *et al.* (2013) reported higher pH (6.17) at 24 hours *p.m*. Genchev *et al.* (2008) suggest that the main reason behind the high pH values found in quail breast muscle were due to the morphology of muscle, which mostly composed by aerobic muscles fiber. Differences in pH could be due to the variation in muscle glycogen content (Berri, *et al.,* 2005). It is well known that the ultimate pH of the muscle is an important contributing factor to meat quality expressed as tenderness, color, and storage live (Van Laack *et al.,* 2000)

Meat Color: The current study's results came in contrast to Aksu *et al.* (2011), whose study showed that the L* value wasn't affected by any of the organic minerals, also, he reported that the redness (a* value) was significantly lower in broilers fed with inorganic minerals in comparison to the ones fed organic minerals.

Water Holding Capacity (%): On average, the drip loss (%) in our experimented groups had shown a higher value in comparison to the findings of Genchev *et al.* (2010), who reported a drip loss (%) range of 1.07 to 0.6%.This can be due to the heat the samples were subjected to prior to freezing.

Thawing and Cooking Loss (%): In comparison to the studies of Narinc *et al.* (2013), Karakaya *et al.* (2005), and Genchev *et al.* (2010), the cooking and thawing loss (%) was, on average, 2 times higher than that of this study. This can be due to the heat the samples were subjected to prior to freezing.

Tenderness: The results of this study corroborate with the findings of Liu *et al*. (2011), who claimed that organic Zn supplementation (Zn- Methionine) does not affect the tenderness of breast meat but it decreases the shear- force of broilers thigh muscles. As well as to agree with the findings of Liu *et al*. (2006) who reported that Mn sources did not affect the shear- force of *Pectoralis* muscle in broilers. Likewise, Salim et al. (2012) published that Zn supplementation did not affect the sensory quality of broilers breast meat.

Conclusion

Chelated minerals offer a high nutritional intake in small dosages of use, due to their high absorption rates and necessity for vital biological processes. This study was conducted to observe the effect of addition of chelated minerals (Zn, Mn, and Fe) in quail's diet, on the mentioned species' growth performance and meat quality. The live body weight, carcass yield (%), pH, breast and thigh's yield, cooking loss, drip loss (%) at 48 hours *post mortem*, and tenderness were not influenced (P>0.05) by the diets supplemented with the oligo-elements. The feed conversion ratio showed a significant difference at 29 days between the Fe group and the control group (P<0.05) affected by the diets supplemented along the experiment. Subsequently, the Fe group showed a significantly higher (P<0.05) carcass weight as opposed to the other groups. Nonetheless, breast and thigh weights has shown a significant difference, where the Fe group has shown higher breast weight (P<0.05) in comparison to other groups, and in thigh's weight, Fe group expressed a higher thigh weight (P<0.05) in regards to all the groups except the control group. Furthermore, the color of the meat has been different between the groups, where group Mn showed a significantly higher redness (a*-value) (P<0.05) than the other groups on both 24 and 48 hours *post mortem.* And despite not being significantly different on 24 hours *post mortem*, but at 48 hours *post mortem* the yellowness (b*-value) of the group Fe was higher than that of the Mn group with no difference (P>0.05) to the other groups whatsoever. As for drip loss at 24 hours *post mortem,* the group Fe has shown a significantly (P<0.05) lower drip loss (%) as opposed to groups Mn and Zn, while not having any difference with the control group. As for the cooking and thawing losses, thawing loss exhibited a significant difference (P<0.05) between group Zn and group Fe, with no regards to the control and Mn group.Our study showed that the usage of Fe had been the most beneficial in terms of *in vivo* performance, carcass traits, and meat quality.

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Conflicts of Interest: The authors declare that there have been no conflicts of interest.

List of Abbreviations

Mn: Manganese
Zn: Zinc
Fe: Iron
LBW: Live body weight
FCR: Feed conversion ratio
WHC: water holding capacity
L*: Lightness value
b*: Yellowness value
a*: Redness value

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