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Development of Iron and Zinc Enriched Meat of Japanese Quails as Functional Food

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ABSTRACT

A study was carried out to develop iron and zinc enriched meat as functional food by supplementing organic Fe and Zn to Japanese quails. A total of 600 day old quail chicks were allotted to five treatment groups (T_1 to T_5) of 120 chicks each with four replicates consisting of 30 birds per replicate. Control diet (T_1) was formulated by incorporating inorganic iron (120 mg/kg) and zinc (25 mg/kg) according to NRC (1994) specifications. For each of the treatments (T_2-T_5), inorganic Fe and Zn of control diet were replaced by organic Fe (Fe-methionine) and Zn (Zn-methionine) at recommended level (T_2), two (T_3), three (T_4) and four times (T_5) of NRC (1994) recommendations. The results at the end of 6[th] week showed that carcass characteristics, organ weights and sensory evaluation did not significantly different among dietary treatments. The Fe content was significantly (Pd"0.01) higher in T_3 (240 mg/kg Fe-methionine) for breast, thigh, liver and heart and in T_4 (360 mg/kg Fe) group for gizzard and minced meat when compared to control group having inorganic Fe (120 mg/kg). The Zn content was significantly higher in T_5 for breast and in T4 for thigh, liver and heart. In minced meat the Fe and Zn content was significantly ($P<0.01$) higher in birds fed with diet consisting 240 mg of Fe/kg and 75 mg of Zn/kg (T_4) from Fe-methionine and Zn-methionine in comparison to all other dietary groups. No significant difference was noticed in tibia Fe content. However, Zn concentration in the tibia was highest (Pd"0.01) in T_4 (75 mg/kg Zn) group when compared to all other dietary groups. The study revealed that increasing levels of organic iron and zinc up to 240 and 75 mg/kg, respectively, have beneficial effect on iron and zinc enrichment of meat in Japanese quails without affecting the carcass characteristics and sensory attributes.

Key words: *Quail, organic iron, zinc, carcass characteristics, muscle, heart, liver, gizzard, tibia.*

INTRODUCTION

Micronutrients play an important role in human health and immunity. The intake of several essential trace elements is suboptimal in many countries around the world (Black *et al*., 2008; WHO, 2008) particularly in women and children in resource-poor households, with devastating consequences for public health and social development. Erick *et al*. (2009) reported that as many as 2 billion people are at risk of zinc deficiency and 1.6 billion suffer from iron deficiency. Three quarters of the populations of such nature were reported to live in Asian continent (Vinodini, 2003). Anemia due to iron deficiency was considered to be one of the top ten contributors to the global burden of diseases (WHO, 2006). The deficiency of iron in the soil was found to be largest in many parts of India. In case of Indians, the quantitative intake of iron was much lower than the Recommended Dietary Allowance (RDA) as a result of high phytate content and low bioavailability of iron (2 to 20 per cent) (Singh, 2009).

Zinc is an essential element for physiologic and metabolic functions such as physical growth, immuno-competence, reproductive function and neurobehavioral development (Hotz and Brown, 2004). Zinc deficiency is an important cause of morbidity due to infectious and growth-faltering among young children. Increased demand of zinc

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due to rapid growth and decreased intake of zinc due to inadequate feeding practices predispose preschool children, especially living in communities of low socioeconomic level at an elevated risk of zinc deficiency (Black.2003). In the plant foods, especially cereal grains and legumes the bioavailability of iron and zinc is low due to the presence of phytate. The richest food sources of iron and zinc are animal products as they do not contain phytate, particularly the organs and flesh of beef, pork and shell fish (Brown and Wuehler, 2000; Hotz and Brown, 2004). As a result, they are particularly good sources of absorbable iron and zinc. Therefore, food base approach of Fe and Zn supplementation may the cost effective way of solving the micronutrients deficiency in wide population. Thus enrichment of animal foods with iron can solve the problem of iron deficiency anemia in wide population in an efficient and much easier way. It was a well established fact that white meats, such as breast meat of broilers were low in iron content than red meats, such as beef (Cook and Monsen, 1976).

The trace elements Fe and Zn are essential for livestock nutrition. Higher doses of trace elements for poultry birds are also designed to enrich the product (meat and egg) from the aspect of human nutrition. The excess supplementation of iron over and above the requirement would enable the increase accumulation of iron and thus enrichment of iron in broiler meat (Seo *et al*., 2008). However, scanty information is available on enriching the Japanese quail's meat with organic Fe and Zn supplementation to their diets. Iron and zinc enriched quail meat may meet the demand of customers looking for such functional products. The bioavailability of iron and zinc depends on the forms or sources through which these are supplemented to birds. Organic sources of iron and zinc in the state of chelation with amino acids or peptides are more effectively absorbed and biologically more available to the body (Ashmead and Zunino, 1992) and thus expected to more accumulation in the organs and muscle tissues. Therefore, the present study was planned to examine the effect of supplementing different levels of iron and zinc from organic sources for enriching the quail meat.

MATERIALS AND METHODS

Experimental birds and treatments**:** A biological trial of six weeks (0 to 42 days of age) duration was conducted at the Department of Poultry Science, Veterinary College Bangalore using a total of 600 one-day old Japanese quail chicks in order to develop the iron and zinc enriched meat by supplementing iron and zinc from organic sources. The chicks were randomly distributed into 5 dietary treatments (T_1-T_5), each treatment having 4 replicates of 30 birds each. All the birds were maintained in electrically heated battery brooders throughout the experimental period under standard managemental conditions. The chicks in the control group (T_1) were provided with a corn-soya-based diet (Table 1) formulated by incorporating inorganic iron ($FeSO_4.7H_2O$) and zinc ($ZnSO_4.H_2O$). Inorganic Fe and Zn of the basal diet were replaced by organic Fe (Fe-methionine) and Zn (Zn-methionine) procured from Pristine Organics Private Ltd, Bangalore (9 per cent Fe and 13 per cent Zn) at recommended level (T_2: 120 mg of Fe/kg and 25 mg of Zn/kg diet), twice (T_3: 240 mg of Fe/kg and 50 mg of Zn/kg diet), thrice (T_4: 360 mg of Fe/kg and 75 mg of Zn/kg diet) and four times (T_5: 480 mg of Fe/kg and 100 mg of Zn/kg diet) of NRC (1994) recommendations. All the five experimental diets were formulated to be iso-nitrogenous (24% CP) and iso-caloric (2900 Kcal of ME/kg). All chicks were allowed free access to feed and water throughout the feeding period. All methods regarding bird care in this experiment were approved by the Animal Ethical Committee of the university (KVAFSU, Bidar, Karnataka, India).

***** Each 100g contains, Calcium Carbonate- 33.28g, Magnesium Oxide-1.48g**,** Ferrous Sulphate- 1.40 g, Copper Sulphate- 0.05g, Manganese Sulphate- 0.04 g, Potassium Iodide-0.001g, Zinc Sulphate- 0.21g, Potassium Chloride- 17.09g, and Sodium Selinate -0.001g.

****** Each 100g contains, Vitamin AD3 (Vitamin A- 10,00,000 IU/g, Vitamin D-200000 IU/g)- 0.165g,

Table 1: Composition of the basal diet

Ingredient	Quantity (Kg)
Maize	53.0
Soybean	44.4
Di calcium phosphate	1.0
Salt	0.4
*Mineral Premix	1.0
**Vitamin Premix	0.1
DL-Methionine	0.1
Total	100.0
Nutritive value (Calculated)	
ME (kcal/kg)	2903
Crude Protein (%)	24.30
Calcium (%)	0.81
Phosphorus (%)	0.45
Lysine (%)	1.53
Methionine	0.5

Vitamin D3 (Vitamin D-40 MIU/g)- 0.001g, Vitamin K3-0.103g, Vitamin E -2.4g, Thaimine Mononitrate- 0.206g, Riboflavin- 0.513g, Pyridoxine Hdrochloride- 0.309g, Cayanocoblamine- 0.00031g, Folic Acid -0.103g, Niacin- 4.124g, Ca-D-Pantothenate- 1.031g, Biotin - 1.5g, Maltodextrine- 89.545g.

***Carcass quality*:** Two birds per replicate in each dietary treatment making a total of 40 birds (8 birds per treatment) were selected randomly at the end of 6 week feeding experiment, weighed and starved for 12 hours before the actual slaughter, but the drinking water was provided *ad lib.* The birds were killed by severing the jugular vein and carotid artery on one side of the neck, allowed to bleed for 1 to 2 minutes, scalded at 54°C for 2 minutes in dunking scalder and defeathered mechanically for 30-60 seconds in a rotary drum picker. The carcass traits *viz* blood loss, feather loss, dressing yield, ready to cook yield and giblets (liver, heart and gizzard) were recorded and expressed in terms of percent live weight.

***Organoleptic evaluation*:** Two birds from each treatment were randomly selected and sacrificed as per the conventional standard slaughter technique. The ready-to-cook meat pieces of breast and right thigh region of sacrificed bird under different dietary treatments were cooked simultaneously under pressure (1 kg/cm^2 for 10 min), cooled to ambient temperature prior to subjecting the cooked meat for sensory evaluation. The cooked meat was served for evaluation of its sensory quality by a panel of ten semi-trained judges using an 8 point hedonic scale on the standard proforma for sensory attributes of the meat such as appearance, flavor, texture, tenderness and overall acceptability.

***Analysis of iron and zinc*:** At the end of the experiment (6 wks) eight birds from each treatment were randomly selected and slaughtered, eviscerated and tibia bone, muscles (breast, thigh, over all minced meat) and giblets were collected. The left tibia from each bird sampled were pooled group-wise and pressure cooked for 1 h. Attached muscle and cartilage were removed and washed with distilled water and oven dried. The tibiae were then weighed and ashed in a muffle furnace at 600 ± 5°C for 4 h. and the ash sample from each replicate was solubilized in 15 ml of 1: 2 HCl and the mineral extract was filtered into a volumetric flask. The muscle and giblet samples were oven dried at 60°C for 12 h and finely ground and digested with concentrated HNO_3 and HCl at the ratio of 2: 1 (AOAC, 1990). The extract of bone and muscle samples were then filtered through Whatman paper 42 and diluted using deionized water to the required volume. The Fe and Zn contents were analyzed according to AOAC (1990) by an Atomic Absorption Spectrometer (Perkin-Elmer AAnalyst 300, USA) at wavelength of 248.3 nm and 214.5 nm (Anonymous, 1982) respectively using NIST standards.

Statistical analysis: All the data pertaining to various parameters were analyzed statistically by ANOVA using SPSS.17 statistical software. The significant mean differences between treatments were determined at $P<0.05$ using Duncan's Multiple Range Test (DMRT) as modified by Kramer (1957).

RESULTS AND DISCUSSION

***Carcass characteristics and organoleptic evaluation*:** The effects of supplemental Fe and Zn on the carcass characteristics, organ weights and sensory evaluation of the Japanese quail meat are shown in Table 2. Carcass characteristics, organ weights and sensory evaluation of the meat showed non-significant (P>0.05) difference among dietary groups. However, the birds fed with higher level of organic (Fe-methionine) Fe (240 mg/kg) and organic (Zn-methionine) Zn (50 mg/kg) showed relatively higher percentage of dressing yield, ready to cook yield and liver weight (%) compared to other dietary groups. The birds fed with inorganic (control) iron ($FeSO_4.7H_2O$) and zinc ($ZnSO_4.H_2O$) showed relatively higher weights (%) for heart and gizzard.

During sensory evaluation, meat obtained from the birds fed with T_3 diet consisting higher level of organic Fe (240 mg/kg) and Zn (50 mg/kg) received relatively better score for appearance, flavor and T_4 diet (360 mg of Fe and 75 mg of Zn) for texture, juiciness and overall acceptance compared to meat of birds fed with similar level of inorganic (T_1) and organic (T_2) Fe (120 mg/kg) and Zn (25 mg/kg).

Iron and zinc concentration in meat and bone (tibia): The iron content in muscles and tibia by treatment group are shown in Table 3 and Fig.1. The Fe content in muscles was highest in breast (239 µg/g) followed by thigh (220 µg/g) and minced meat (127.50 µg/g), where as in organs Fe content was highest in liver (493 µg/g) followed by heart (323.33 µg/g) and gizzard (185 µg/g) in control group (inorganic supplementation).

The Fe content in muscles and organs increased significantly as the levels of Fe supplementation

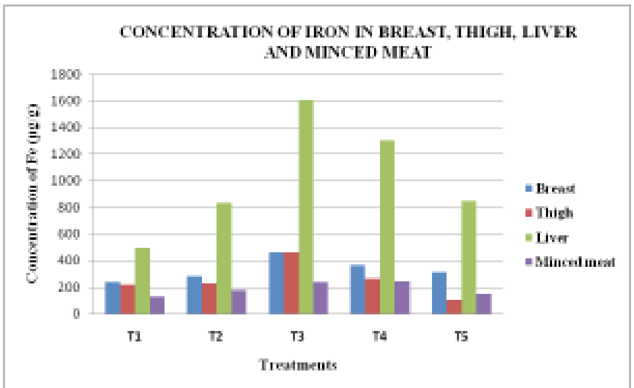

Fig.1: Effect of feeding organic iron and zinc on iron concentration of meat and liver.

increased in the diet and highest Fe content was observed in liver (1600 µg/g) by supplementing 240 mg of Fe (Fe-methionine). When compared with inorganic (FeSO4) source, organic source at same level (120mg/kg) of supplementation (T_1 vs. T_2) showed significantly (Pd"0.05) higher accumulation of Fe in different tissues. However, the level of Fe deposition in tibia (Fig.3) was not affected (P>0.05) by the increased level of Fe supplementation (120 to 480mg/kg diet) from organic (Fe-methionine) source.

The zinc content in muscles and organs by treatment group are shown in Table.4 and Fig.2. The level of Zn accumulation varied significantly (Pd"0.01) among the treatment groups. The Zn content in breast, thigh, liver and gizzard was not affected by the dietary source (inorganic or organic) at the same level of supplementation (25 mg/kg). However heart, tibia and minced meat contained significantly (Pd"0.01) higher Zn in organic group (T_2) than inorganic group (T_1) at the same level of Zn supplementation (25mg/kg diet).

Among different levels of Zn supplementation from Zn methionine, T_4 (75 mg/kg) group showed higher (Pd"0.05) Zn deposition in different tissues. The highest Zn deposition was in tibia (357.50 µg/g) followed by liver (170.75 µg/g), heart (125 µg/g) and minced meat (76.75 µg/g) at 75 mg/kg of Zn supplementation from Zn-methionine. An increasing trend in Zn deposition was observed in various organs and tissues in organic level of Zn supplementation (Zn-methionine) in diets up to 75 mg/kg levels. The Zn content of liver varied significantly (Pd"0.01) by the dietary levels of Zn supplementation. The Zn content in liver ranged from 72.75µg/g (T_1) to 170.75µg/g (T_4). There was no significant difference in Zn deposition in gizzard from Zn-methionine source. However, the Zn deposition in heart and minced meat was significantly (Pd"0.05) higher in T_4 group (75mg/kg from Zn-methionine) when compared to other dietary treatments. The Zn content in tibia (Table.4) ranged from 212 µg/g (T_1) to 357.50 µg/g (T_4) and the Zn deposition was lowest (Pd"0.01) in the tibia of T_1 (25 mg/kg) group supplemented with

Table 2: Effect of feeding organic iron and zinc on carcass characteristics, organ weights and sensory evaluation of Japanese quail meat.

Treatment	Source of Fe and Zn	Level of Inclusion Iron (mg/kg)	Level of Inclusion Zinc (mg/kg)	BloodLoss (%)	Featherloss (%)	Dressedyield (%)	Readyto cookYield (%)	Heart (%)	Liver (%)	Gizzard (%)	Appearance	Flavor	Texture	Juiciness	Over all acceptance
T1	Inorganic	120	25	4.28± 0.47	7.85± 0.48	69.26±1.47	74.19±1.42	0.91± 0.08	2.16± 0.23	1.77± 0.15	5.71± 0.42	5.71± 0.36	6.14± 0.46	5.57± 0.37	5.78± 0.46
T2	Organic	120	25	4.45± 0.46	8.04± 0.42	69.70±1.14	74.29±1.17	0.69± 0.04	1.93± 0.20	1.58± 0.16	5.57± 0.61	5.71± 0.42	6.14± 0.26	5.71± 0.18	5.82± 0.32
T3	Organic	240	50	3.82± 0.33	7.22± 0.29	70.30±1.22	75.51± 1.12	0.78± 0.06	2.25± 0.22	1.49± 0.09	6.00± 0.38	5.86± 0.40	6.57± 0.30	6.00± 0.38	5.75± 0.44
T4	Organic	360	75	4.08± 0.26	7.24± 0.45	69.65±1.93	74.39±1.88	0.81± 0.11	2.03± 0.21	1.71± 0.13	5.71± 0.42	5.57± 0.48	6.57± 0.37	6.28± 0.28	5.86± 0.46
T5	Organic	480	100	4.64± 0.59	6.91± 0.30	69.94±1.48	74.46±1.37	0.81± 0.05	2.18± 0.22	1.56± 0.08	5.43± 0.48	5.28± 0.42	6.14± 0.46	5.57± 0.53	5.61± 0.43
P-Value				0.711	0.250	0.991	0.991	0.375	0.837	0.541	0.934	0.897	0.817	0.590	0.995

Table 3: Effect of feeding organic iron and zinc on iron concentration in the muscle tissues and tibia of Japanese quails.

Treatment	Source of Iron	Level of inclusion (mg/kg)	Fe (µg/g) Breast	Thigh	Liver	Gizzard	Heart	MincedMeat	Tibia
T1	$FeSo_{4.}7H_2O$	120	239.00^{a}±4.17	220.00^{b}±8.86	493.00^{a}±23.25	185.00^{a}±4.22	323.33^{a}±5.56	127.50^{a}±1.83	197.50±15.67
T2	Fe-methionine	120	280.00^{ab}±9.25	230.00^{b}±8.01	830.00^{b}±31.16	220.00^{b}±2.67	387.50^{c}±7.25	178.50^{c}±1.342	57.50±35.09
T3	Fe-methionine	240	463.33^{d}±20.75	465.00^{d}±9.35	1600.00^{d}±70.71	225.00^{bc}±3.27	476.66^{d}±8.16	240.00^{d}±0.87	302.50±73.79
T4	Fe-methionine	360	366.66^{c}±20.75	266.66^{c}±4.08	1300.00^{c}±53.45	300.00^{d}±5.34	355.00^{b}±8.23	245.00^{d}±1.07	245.00±42.13
T5	Fe-methionine	480	310.00^{b}±20.87	105.25^{a}±6.35	850.00^{b}±13.36	232.50^{c}±4.11	326.66^{a}±1.54	153.33^{b}±1.33	250.00±12.82
P -Value			0.00	0.00	0.00	0.00	0.00	0.00	0.54

Means bearing different superscripts in rows differ significantly (Pd"0.01).

Table 4: Effect of feeding organic iron and zinc on zinc concentration in the muscle tissues and tibia of Japanese quails.

Treatment	Source of Zinc	Level of incorporation (mg/kg)	Zn (µg/g) Breast	Thigh	Liver	Gizzard	Heart	MincedMeat	Tibia
T1	$ZnSo_{4.}H_2O$	25	43.50^{a}± 1.21	57.00^{ab}± 1.03	72.75^{a}± 6.77	112.50^{a}± 1.64	99.00^{a}± 0.65	44.75^{a}± 0.18	212.50^{a} ±2.03
T2	Zn-methionine	25	47.00^{ab}± 4.28	55.25^{ab}± 0.94	92.50^{a}± 9.58	122.50^{ab}± 1.64	115.00^{b}± 3.27	61.30^{b}± 0.49	295.00^{b}±2.83
T3	Zn-methionine	50	49.75^{ab}± 1.05	52.25^{a}± 3.49	100.00^{a}± 11.69	132.50^{b}± 1.63	115.00^{b}± 3.27	65.75^{c}± 0.21	290.98^{b}±2.33
T4	Zn-methionine	75	53.00^{ab}± 3.85	64.00^{b}± 4.09	170.75^{b}± 28.61	122.50^{ab}± 3.13	125.00^{c}± 1.89	76.75^{d}± 0.64	357.50^{c}±4.04
T5	Zn-methionine	100	55.75^{b}± 5.49	53.50^{ab}± 5.68	95.25^{a}± 5.61	130.00^{b}± 7.56	117.50^{b}±1.64	66.75^{c}±0.252	95.00^{b} ±2.70
P -Value			0.000	0.000	0.001	0.008	0.000	0.000	0.000

Means bearing different superscripts in rows differ significantly (Pd"0.01).

inorganic Zn ($ZnSO_4$) in comparison to Zn-methionine (T_2 to T_5) fed groups.

Iron and zinc deficiency are the most frequent nutritional disorders and one of the leading factor for increased morbidity, mortality and impaired development of children as well as affecting pregnant women (Bao *et al*., 2009). Food-base approach of Fe and Zn supplementation is the most cost effecting way of mineral supplementation to target group for overall improvement of public health. In the present study an attempt had been made to enrich the meat of Japanese quails with iron and Zn supplementation from organic sources. Currently, supplementation of mineral from organic source has gained popularity because of their higher bioavailability and thus higher deposition in tissues over the inorganic sources of mineral supplementation (Vieira, 2004).

***Carcass characteristics and organoleptic evaluation*:** In the present study no significant differences pertaining to carcass characteristics and sensory evaluation and relatively higher percentage of dressing yield and better score for organoleptic evaluation in birds fed with higher level of organic Fe (240 and 360 mg) and Zn (50 and 75 mg) over inorganic Fe and Zn supplemented groups. These findings are in agreement with Osman and Mona (2007), Namra *et al.* (2008) and Abdallah *et al.* (2009). They did not notice any significant difference in chemical composition of broiler meat and carcass traits when broilers were fed with organic iron and zinc. It indicates that supplementation of diets with higher level organic Fe and Zn at least did not have any adverse effect on carcass characteristics and sensory attributes.

***Iron and zinc concentration in meat and bone (tibia)*:** The Fe and Zn deposition in muscles and organs of Japanese quails was significantly (Pd”0.01) higher from Fe-methionine and Zn-methionine sources, which may be due to higher gut absorption and thus higher accumulation of Fe and Zn from organic sources. Seo *et al.* (2008) reported that the Fe content in the liver is significantly influenced by the supplementation source and level of iron. The Fe content is higher in the Fe-methionine treatment groups than $FeSo_4$ treatment groups and higher level (240 mg/kg) treatment groups showed higher level of deposition than lower level (120 mg/kg) treatment groups of

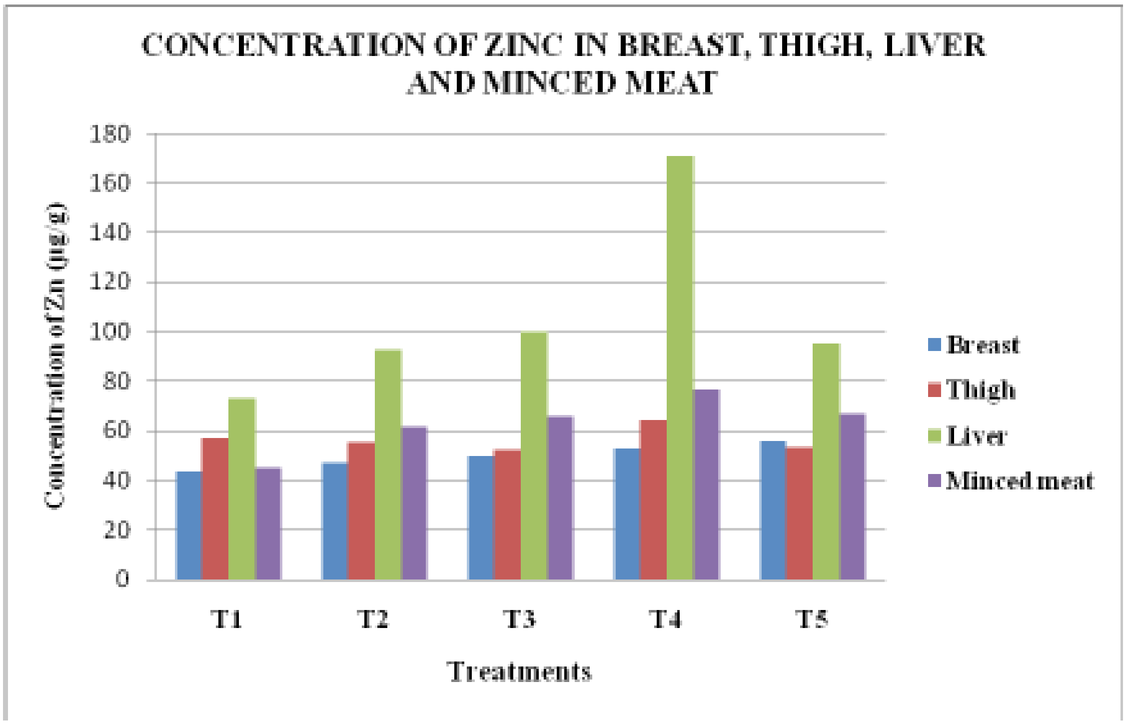

Fig.2: Effect of feeding organic iron and zinc on zinc concentration of meat and liver.

the same supplementary source. Park *et al*. (2004) reported that Fe-methionine chelate is much more effective than $FeSO_4$ in enriching Fe content of eggs. Wei *et al.* (2005) reported that supplementing Fe-methionine at the level of 100 ppm Fe resulted in satisfactory iron enrichment and increasing the supplementation level to 200-300 ppm did not showed any further response in iron enrichment. However, there is no available information on the effect of Fe-methionine chelate on the Fe enrichment in Japanese quails meat.

In the present quail study, supplementation of 240 mg Fe as Fe-methionine resulted in better response than the lower (120 mg Fe) and higher level in iron enrichment of quail meat. Similar to the findings of Seo *et al*. (2008) in broiler, in the present study in Japanese quails, the Fe deposition was significantly (Pd"0.05) increased in breast (239 to 463µg/g) and thigh muscles (220 to 465 µg/g) by supplementing Fe from Fe-methionine. The bone (tibia) Fe content was not affected by dietary source as well as level of Fe supplementation from Fe-methionine. Whereas, accumulation of Fe in liver was significantly (Pd"0.05) and approximately four times increased on Fe supplementation at the level of 240 mg (Fe-methionine) in the quail diets. This might be due to the tendency of Fe to deposit in liver as it is the main storage organ for Fe in the body.

Organic Zn sources such as Zn-methionine or Zn-proteinate have been clearly demonstrated to be significantly more bioavailable than inorganic source in pigs and poultry (Hahn and Baker, 1993; Idowu *et al*., 2011) and consequently, organic forms of the element have been used with increasing frequency by the feed industry (Yildiz *et al*., 2006). The higher bioavailability of chelated minerals may be due to the shielding of the mineral positive charge during chelation. This allows the mineral to withstand the binding activity of the negatively charged mucin layer and results in lower competition between minerals of similar charge in their resorption from the gut and transfer to the enterocyte (Power, 2006).

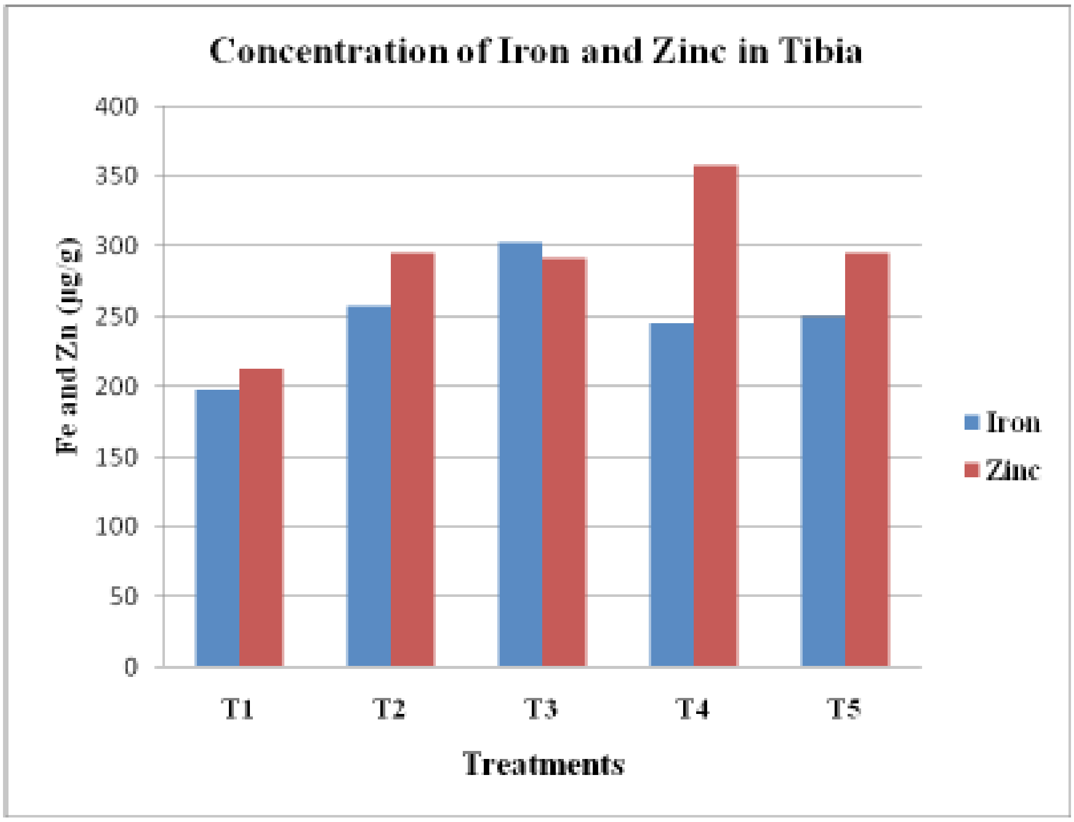

Fig.3: Effect of feeding organic iron and zinc on iron and zinc concentration of tibia.

In the present study, Zn supplementation at different levels (25, 50, 75 and 100 mg/kg diet) had significant effect on meat quality in Japanese quail. The liver Zn content was significantly (Pd"0.01) higher in quails supplemented with Zn-methionine at 75 mg level and Zn deposition was increased by 2.35 times in compared to inorganic Zn supplementation. When compared with different levels of Zn supplementation from Zn-methionine, the increase of Zn deposition in liver was 1.7 times higher at 75 mg Zn supplementation than 25mg Zn supplementation. The Zn content in minced meat increased significantly (Pd"0.01) on Zn-methionine supplementation as well as increased level of Zn supplementation from this source.

In contrary to Fe, the Zn content in bone (tibia) significantly (Pd"0.01) increased on increased level of dietary Zn supplementation. Highest deposition of Zn in tibia was found at 75 mg/kg dietary level of supplementation. The Zn content in the tibia was significantly (Pd"0.01) higher in diets supplemented with organic (Zn-methionine) source than $ZnSO_4$ (inorganic) source at the same level (25 mg/kg diet) of supplementation, which further confirmed that the bioavailability of Zn from Zn-methionine was higher than $ZnSO_4$ in Japanese quails. The findings of present study confirmed the previous reports in pigs (Paik, 2001; Wei *et al*., 2005), broiler (Hudson *et al*., 2004) and layer birds (Lim and Paik, 2003; Idowu *et al*., 2011). Highest (Pd"0.01) level of Zn deposition in tibia of the birds fed with 75 mg of organic Zn per kg diet is in accordance with the findings of Bruerton. (2005) who noticed that chelated Zn increased broiler tibia level by 35% more than inorganic sulfate.

CONCLUSION

The bioavailability and accumulation of iron and zinc could be increased by supplementing these minerals as iron and zinc-methionine in the diet of Japanese quails. The increased level of Fe (240mg/kg diet) and Zn (75 mg/kg diet) would give better response in terms of Fe and Zn enrichment in muscles and organ meats of Japanese quails. This food-base approach of Fe and Zn enrichment in Japanese quail meat could be used for developing cost effective functional foods (Fe and Zn enriched) for improving the human health.

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