Indian Journal of Poultry Science (2024) 59(3): 257–264, Research Article
https://doi.org/10.56093/ijps.v59i3.04

Effect of dietary incorporation of various forms of zinc and selenium on the production performance and carcass characteristics of Japanese quails

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(Received on May 24, 2024; accepted for publication on September 03, 2024)

ABSTRACT

Pandian, S.V., Karthikeyan, N., Churchil, R.R. and Ramesh, J. 2024. Effect of dietary incorporation of various forms of zinc and selenium on the production performance and carcass characteristics of Japanese quails. Indian Journal of Poultry Science, 59(3): 257-264

An experiment was conducted to explore the effect of various forms (organic, inorganic and nano) of dietary Zn and Se on production performance and carcass qualities in Japanese quails (n=288). Six diets were formulated (NRC, 1994) with Zn and Se (mg/kg), *viz.*, control (T_1; not supplemented), 25 and 0.2 (T_2; inorganic), 50 and 0.4 (T_3; enhanced inorganic), 25 and 0.2 (T_4; organic), 12.5 and 0.1 (T_5; 50% nano) and 6.25 and 0.05 (T_6; 25% nano). Enhanced inorganic (T_3) group was having significantly ($p \leq 0.05$) lower fifth week body weight and body weight gain when compared to negative (T_1) and positive control (T_2). Significant ($p \leq 0.05$) differences were noticed in four to six-week feed consumption, first two weeks feed conversion ratio (FCR) among the treatments. There was no significant ($p \geq 0.05$) difference in livability, per cent loss of blood and dressing yield. Feeding higher level (2X) of inorganic Zn and Se (T_3) and one fourth of the requirement through nano forms (T_6) reduced the cost of production (COP) by Rs. 11.85and 9.26, respectively, when compared to negative control (T_1). Significantly ($p \leq 0.05$) higher eviscerated yield was noticed in both nano supplemented groups with respect to negative control and organic mineral groups. It can be concluded that dietary supplementation of inorganic Zn and Se at higher level (2X; T_3) or one fourth of the requirement through nano (T_6) sources could be of beneficial for improving the European Economic Factor (EEF) and reducing the cost of production.

Keywords: Zinc, Selenium, Organic, Nano, Japanese quail, Production performance, Carcass characteristic

INTRODUCTION

In the poultry production system, diversified poultry farming is gaining importance to cater the demand of consumers for various type of poultry meat other than chicken. Among the alternative poultry farming system, rearing of Japanese quail for meat and egg production is commonly practiced by the farming community. In the present-day context, new generation Japanese quails demand timely revision of essential nutrients and their sources, therefore knowledge on the nutrient retention and bioavailability of nutrients and wastage prevention is required for the exploitation of their genetic potential. Macro and micro minerals are considered as important nutrients for the livestock and poultry including Japanese quail and involved in various biochemical reactions and physiological functions. In addition to the formation of skeleton, they are also involved in the regulation of body colloidal state, assisting in the regulation of acid-base balance and a cofactor of an enzyme system (McDowell, 2003). Among the various trace minerals, zinc is a very important trace mineral and acts as a co-factor for more metallo-enzymes with a significant role in fat, carbohydrate and protein metabolism. It is required for feathering, body and skeletal growth, skin quality and reproduction. In addition to this, it improves immunity, immune-modulation and disease resistance in chicken. It plays an important role in various bio-chemical metabolism including cell proliferation, gene regulation and acts as an antioxidant against stress (Fraker *et al.*, 2000; Blanchard *et al.*, 2001; Ibs and Rink, 2003; Song *et al.*, 2009).

Selenium (Se) is an integral part of the glutathione peroxidase (GSH-Px) enzyme system and plays a main role in antioxidative functions. As a natural antioxidant, Se is responsible for the maintenance of cell membrane stability. In addition to mineral contents and antioxidant properties of meat as influenced by Se, considerable attention has been given to fatty acid composition, which also determines the nutritional value of meat. Selenium is a trace element, which plays a key role in developmental, reproductive and immune functions of livestock and poultry.

Hence, supplementation of these trace minerals at prescribed level is essential for optimum growth, maintenance of health and reproduction. Moreover, the cost involved in the supplementation of trace mineral mixture in Japanese quail feed largely depends on the level of these trace minerals. Therefore, the present research was carried out to evaluate the response of feeding various forms (inorganic, organic or nano) of Zn and Se in the diet on the production performances and carcass characteristics of Japanese quails.

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MATERIALS AND METHODS

Management of birds and dietary plan

A total of 300 one-day old Japanese quail (straight run) chicks procured from a single hatch from the College of Poultry Production and Management, Hosur were serially wing banded, individually weighed and distributed at random to the six experimental groups with four replicates per treatment and each replicate had twelve chicks. The experimental birds were housed in two-tiered brooder cum grower cages fitted with incandescent bulbs for brooding and adequate care was taken to provide optimum and uniform management to all the treatment groups.

The birds were fed *ad libitum* with respective Japanese quail (JQ) brooder experimental rations in separate feed troughs from 0 to 6 weeks. The experimental diets were prepared in accordance with NRC (1994) guidelines with modifications in the levels of Zn and Se (mg/kg), *viz.*, non-supplemented control (T_1), 25 & 0.2 (T_2; inorganic), 50 & 0.4 (T_3; enhanced inorganic), 25 & 0.2 (T_4; organic), 12.5 & 0.1 (T_5; 50% nano) and 6.25 & 0.05 (T_6; 25% nano). Inorganic sources of Zn and Se, namely zinc oxide (ZnO) and Sodium selenite (Na_2SeO_3.5H2O) were procured from ThermoFisher Scientific, India and Loba chemie Pvt. Ltd., Mumbai, respectively. Organic zinc (Zn proteinate; Availa ZN; Zinpro, USA) and organic selenium (selenium yeast, Sel-Plex®, Alltech, USA) were also procured from the manufacturers/distributors in India. Nanoparticles of Zn and Se were synthesized by utilizing the ZnO and sodium selenite through physical method by ball milling technique.

The ingredient composition and nutritive value of JQ brooder diets is provided in Table 1 and 2, respectively.

Table 1: Ingredient composition (kg/MT) of Japanese quail brooder ration

Ingredients	Brooder
Maize	327.000
Broken Rice	168.000
Soybean de-oiled cake	114.000
De-oiled ground nut cake	320.800
RB Oil	29.000
Calcite	12.400
Di-calcium phosphate	12.000
DL-Methionine	1.700
L-Lysine hydrochloride	4.800
L-Threonine	2.300
Common salt	3.200
Vitamin premix[$]	0.500
Trace mineral mixture[#]	1.000
Choline chloride	1.500
Nagronex – SNB (Prebiotic - MOS)*	0.500
Liver tonic powder (Tefroli)	0.300
Toxin Binder (UTPP Biotech)	1.000
Total	1000.000

[$]Cargill – Provimi vitamin premix, Each kg of vitamin premix contain s Vit. A 30 MIU, D3 8 MIU; E 100 g, menodione sodium bisulphate (Vit K derivative) 6 g, B1 8 g, B2 16 g, B3 (niacin) 100 g, B5 (calcium D pantothenate) 28 g; B6 (pyridoxine) 12 g, B9 (folic acid) 3 g; B12 60 mg, antioxidant and anti-caking agents and carriers Q.S.

[#]Each kg of brooder cum grower trace mineral mixture contains Zn 25 g, Manganese 60 g, Iron 120 g, Iodine 0.3 g, Copper 0.5 g, Selenium 0.2 g; (NRC 1994; X concentration) Zn and Se was eliminated / replaced at varying levels with different sources (inorganic, organic or nano forms) in respective groups; ***Nagronex – SNB is a proprietary fermentation product with *Saccharomyces cerevisiae* cell wall extract, dried *Bacillus subtilis* spores from Provet Pharma Pvt. Ltd, Chennai

Table 2: Nutrient composition (%) of the Japanese quail (JQ) brooder diet fed to the experimental birds

Nutrients	Calculated (Anlaysed)
Crude protein	24.00 (24.46)
Metabolizable energy (Mcal/kg)	2.915
Calorie protein ratio	121
Crude fibre	4.07 (5.30)
Lysine	1.35
Methionine	0.51
Cystine	0.38
Arginine	2.25
Threonine	1.02
Tryptophan	0.24
Calcium	0.85 (1.01)
Total Phosphorus	0.61(0.65)
Available Phosphorus	0.35

Figures in parenthesis indicate analytical value

Performance and dressing parameters

Body weight was recorded at weekly intervals (6 weeks) and body weight gain was calculated. The birds were fed *ad libitum* and the total replicate wise feed consumption was calculated by quantifying the remaining feed. Mortality of birds was recorded during the first six weeks of experimental period and the livability was calculated.

European economic factor (EEF) = [Livability x Average body weight (kg) / Mean age (35 d) × FCR (35 d)] × 100

Cost of Production = Total cost of all inputs / JQ sold; Production cost (per JQ) was calculated from the chick cost (Rs. 7/chick), feed cost, miscellaneous cost (litter material, labour cost, medicine and electricity, etc.; Rs. 3 per JQ purchased)

At 6 weeks of age, two birds from each replicate of the respective group were selected randomly and slaughtered to study the carcass traits. Parameters such as preslaughter live weight (g), blood loss (%), dressed weight (%) and eviscerated yield (%) were recorded at the time of slaughter (sixth week). Proximate principles of breast meat such as, moisture, protein and fat were analyzed by following the standard procedure of AOAC (2012).

Statistical analysis

Various data collected was statistically analysed through "SPSS-16.0" software package as per the standard statistical methods (Snedecor and Cochran, 1997). All the data were subjected to ANOVA and the significant mean differences were tested as per Duncan's multiple range test and significance was declared at $p \leq 0.05$.

RESULTS AND DISCUSSION

Production performance

Mean body weight of various groups of Japanese quails supplemented with different dietary sources of zinc and selenium during first six weeks of age is presented in Table 3. At fifth week, Japanese quails supplemented with inorganic form of Zn and Se (25 and 0.2 ppm; T_2) as per NRC (1994) in the diet had significantly ($p \leq 0.05$) higher mean body weight and gain (cumulative) with respect to enhanced (2X) inorganic Zn and Se fed group. Body weight and gain during the remaining period of study (1-4 and 6th week) showed a non-significant ($p \geq 0.05$) difference among the treatments which are similar with the findings of Gheisari *et al.* (2010) who also studied various organic chelates of trace minerals such as zinc, manganese and copper along with their inorganic sources on the production performance of commercial broiler and reported a non-significant effect on broiler body weight. Selim *et al.* (2015), who investigated the effects of inorganic, organic, and nano Se sources in broiler chickens found that organic Se supplementation at 0.3 ppm increased body weight gain significantly ($p \leq 0.05$). Sizova *et al.* (2021) also reported that nano Zn improved the live weight (4.6%) as compared to birds receiving organic form of Zn.

Cumulative feed consumption and Feed conversion ratio

Cumulative feed consumption (CFC; Table 4) was not affected significantly ($p \geq 0.05$) during the first three weeks of the trial which is in accordance with Zhang *et al.* (2022) who have studied the influence of ZnO nanoparticles and $ZnSO_4$ at various concentrations (40, 80, and 160 mg/kg) on 21-day-old broilers and found no significant ($p \geq 0.05$) influence in average daily gain, body weight or feed conversion ratio. Asheer *et al.* (2018) also reported a numerical difference in CFC and FCR while replacing 25 to 100% of the Zn requirement with nano Zn in a six-week commercial broiler trial. A significant ($p \leq 0.01$) difference was noticed in CFC between two levels of nano minerals (4th and 5th week) and between negative control and inorganic or organic (5th week) minerals supplemented groups. Significantly higher CFC per bird was noticed in the negative control (T_1) and supplementation of nano Zn and Se at 50 per

Table 3: Effect of in feed supplementation of various forms of zinc and selenium on body weight (g) in Japanese quail (Mean ± SE)

Treatment	Age (in weeks)						
	0 Day	1	2	3	4	5	6
T_1-No supplemental Zn & Se (Negative control)	10.18±0.17 (48)	37.60±0.97 (46)	77.7±2.39 (45)	113.98±4.10 (34)	175.98±4.78 (33)	223.46^{a}±5.11 (33)	232.7±6.61 (33)
T_2- Inorganic Zn & Se (Positive control; X)	10.25±0.11 (48)	39.76±1.13 (42)	83.4±2.35 (41)	119.36±3.48 (38)	181.44±4.17 (36)	225.96^{a}±4.31 (36)	240.3±6.26 (35)
T_3- Enhanced inorganic Zn & Se (2X)	10.75±0.14 (48)	38.71±1.03 (46)	76.53±2.80 (45)	110.51±3.65 (44)	164.56±4.75 (43)	208.53^{b}±4.55 (43)	220.17±6.22 (43)
T_4- Organic sources of Zn & Se (X)	10.11±0.12 (48)	35.36±1.12 (46)	76.58±2.31 (41)	111.69±3.17 (35)	168.2±4.55 (35)	213.30^{ab}±4.29 (35)	227.86±4.31 (35)
T_5 - Nano sources of Zn & Se (½ X)	10.43±0.14 (48)	38.39±0.97 (40)	78.18±2.30 (40)	110.05±4.09 (29)	174.13±4.68 (28)	216.87^{ab}±4.90 (28)	229±5.68 (28)
T_6 - Nano sources of Zn & Se (¼ X)	10.08±0.18 (48)	36.57±0.97 (46)	77.49±2.35 (45)	113.44±2.53 (42)	169.96±2.99 (41)	214.23^{ab}±3.41 (41)	230.17±3.63 (41)
F value	2.789*	2.240^{NS}	1.099^{NS}	0.950^{NS}	2.032^{NS}	2.309*	1.496^{NS}

Figures in the parenthesis indicate number of observations

^{NS} Not Significant; *Significant (P < 0.05)

Means in columns not sharing a common superscript differ significantly (p<0.05) cent (T_5). The results of the present work on reduced feed intake noticed while supplementing higher concentration of Zn (T_1, T_2 and T_3) is in accordance with Rouhalamini *et al.* (2014) who have investigated the effect of different levels of Zn (0, 40, 80mg/kg) through zinc sulphate and chromium (0, 500, 1000 mg/ kg; Cr picolinate) on the feed efficiency of Japanese quails and found the higher the supplementation Zn reduced feed intake but had a significant effect on FCR but had no effect on body weight gain.

Feed conversion ratio (Table 5) was also significantly ($p \leq 0.01$) affected only during first two weeks of age. The birds fed with 25 and 0.2 ppm of inorganic Zn and Se (T_2) in the diet had a significantly ($p \leq 0.05$) better FCR than the organic group (T_4). The findings were in agreement with Attia *et al.* (2013) who conducted research in Pekin ducks to evaluate the impact of two different source of Zn and concluded that better FCR was recorded with birds which received inorganic Zn when compared with organic source. Results of the present work are in accordance with prior studies which showed poor feed efficiency in Guangi yellow chickens (Zhou and Wang, 2011), broilers (Cai *et al.*, 2012) and layer chickens (Mohapatra *et al.*, 2014) when no selenium was provided.

The groups supplemented with inorganic Zn and Se (T_2 and T_3) had a significantly ($p \leq 0.05$) better feed efficiency than the negative control (T_1) during second week might be due to the role of selenium as a part of antioxidant enzymes such as thioredoxin reductase and glutathione peroxidase (Mercurio and Combs, 1986) and the secretion of digestive enzymes (Lagana *et al.*, 2007). Supplementation of Zn might have caused expression of metallothionein, trapping free radicals which leads to a better FCR (Sahin *et al.*, 2005).

Livability

A non-significant ($p \geq 0.05$) influence was noticed in livability among the treatment groups. Similar findings were reported on the trials carried out with various amino acid chelates synthesized with Cu, Zn, Mn and Fe (Britanico *et al*., 2012) and with organic Zn, Mn or Cu on Arbor Acres female broiler chicks (El-Husseiny *et al*., 2012).

Cost of production (COP) and European Economic Factor (EEF)

As the Japanese quails are sold in the market on per unit basis with an approximate body weight of 200 g, COP was calculated only up to 35 d. The effect of replacing inorganic Zn and Se with other highly bioavailable forms in the diet resulted in the highest cost of production (Rs. 54.26) in the group supplemented with nano forms of Zn and Se (T_5) due to poor livability (58.33%) noticed. Feeding enhanced (2X) level of inorganic Zn and Se (T_3) and nano forms at 25 per cent (T_6) of NRC (1994) requirement reduced the COP by Rs.11.85 and 9.26, respectively when compared to negative control group (T_1).

Improved European economic factor (EEF) was obtained in enhanced inorganic group (T_3) which is 3.61 points higher than negative control and other groups supplemented with various forms of Zn and Se. The group supplemented at lower doses of nano Zn and Se (T_6) showed an increased EEF (16.17) than their respective higher doses (T_5) supplemented group (10.74). The organic group (T_4) had 1.87 points lower in EEF than their inorganic counterpart (T_2). Improved

Table 4: Effect of in feed supplementation of various forms of zinc and selenium on cumulative feed consumption (g) of Japanese quail (Mean±SE), n=4

Treatment	Age (in weeks)					
	1	2	3	4	5	6
T_1- No supplemental Zn & Se (Negative control)	61.17±0.66	168.29±7.71	281.13±17.64	504.01^{ab}±17.64	765.39^{a}±21.86	1002.87^{a}±27.06
T_2- Inorganic Zn & Se (Positive control; X)	60.60±2.38	155.45±6.97	261.26±5.40	473.84^{bc}±10.97	684.86^{b}±11.29	934.99^{cd}±9.45
T_3- Enhanced inorganic Zn & Se (2X)	60.45±3.60	145.89±12.80	251.22±9.64	432.38^{c}±7.76	637.57^{b}±9.34	857.58^{d}±5.65
T_4 - Organic sources of Zn & Se (X)	58.47±5.75	163.07±9.12	272.65±4.49	471.60^{bc}±18.18	678.37^{b}±19.02	902.48^{cd}±19.96
T_5 - Nano sources of Zn & Se (½ X)	61.74±1.03	156.06±11.52	268.09±8.79	527.05^{a}±15.73	742.26^{a}±14.66	958.71^{ab}±9.06
T_6 - Nano sources of Zn & Se (¼ X)	59.23±2.95	156.06±11.52	266.95±5.99	465.63^{bc}±12.02	679.12^{b}±17.11	915.25^{bc}±19.82
F value	0.144^{NS}	0.612^{NS}	1.839^{NS}	5.303**	8.495**	8.591**

^{NS} Not significant, **Highly Significant ($p \leq 0.01$)

Means in columns not sharing a common superscript differ significantly ($p<0.01$)

Table 5: Effect of in feed supplementation of various forms of zinc and selenium on feed conversion ratio (FCR) of Japanese quail (Mean ± SE), n=4

Treatment	Age (in weeks)					
	1	2	3	4	5	6
T_1-No supplemental Zn & Se (Negative control)	2.210[ab]±0.054	2.474[c]±0.063	2.570±0.037	2.828±0.049	3.308±0.094	4.075±0.278
T_2 - Inorganic Zn & Se (Positive control; X)	2.065[a]±0.068	2.154[a]±0.067	2.372±0.075	2.697±0.069	3.077±0.037	3.919±0.196
T_3 - Enhanced inorganic Zn & Se (2X)	2.172[ab]±0.039	2.250[ab]±0.062	2.493±0.074	2.782±0.065	3.182±0.068	4.018±0.174
T_4 - Organic sources of Zn & Se (X)	2.340[b]±0.064	2.452[bc]±0.087	2.563±0.040	2.843±0.037	3.182±0.031	3.898±0.169
T_5 - Nano sources of Zn & Se (½ X)	2.118[a]±0.034	2.257[ab]±0.040	2.583±0.107	3.032±0.087	3.384±0.104	4.047±0.186
T_6 - Nano sources of Zn & Se (¼ X)	2.191[ab]±0.044	2.321[abc]±0.071	2.566±0.086	2.855±0.080	3.270±0.123	4.043±0.083
F value	3.169*	3.431*	1.198[NS]	2.709[NS]	1.688[NS]	0.150[NS]

Figures in the parenthesis indicate number of observations
*Significant (p≤0.05), [NS] Not significant
Means in columns not sharing a common superscript differ significantly (p≤0.05)

Table 6: Effect of in feed supplementation of various forms of zinc and selenium on cumulative per cent livability of Japanese quail (Mean ± SE)

Treatment	Age (in weeks)					
	1	2	3	4	5	6
T_1-No supplemental Zn & Se (Negative control)	95.83±2.40(46)	93.75±3.98(45)	70.83±11.02(34)	68.75±12.89(33)	68.75±12.89(33)	68.75±12.89(33)
T_2- Inorganic Zn & Se (Positive control; X)	87.50±5.37(42)	85.41±6.25(41)	79.16±8.67(38)	75.00±7.60(36)	75.00±7.60(36)	72.91±6.24(35)
T_3- Enhanced inorganic Zn & Se (2X)	95.83±2.40(46)	93.75±3.98(45)	91.66±4.81(44)	89.58±6.25(43)	89.58±6.25(43)	89.58±6.25(43)
T_4- Organic sources of Zn & Se (X)	95.83±2.40(46)	85.41±9.84(41)	72.91±12.44(35)	72.91±12.44(35)	72.91±12.44(35)	72.91±12.44(35)
T_5 - Nano sources of Zn & Se (½ X)	83.33±4.81(40)	83.33±4.81(40)	62.50±4.16(29)	58.33±5.89(28)	58.33±5.89(28)	58.33±5.89(28)
T_6 - Nano sources of Zn & Se (¼ X)	95.83±4.16(46)	93.75±6.25(45)	87.50±5.37(42)	85.41±6.25(41)	85.41±6.25(41)	85.41±6.25(41)
F value	2.120[NS]	0.653[NS]	1.692[NS]	1.567[NS]	1.567[NS]	1.638[NS]

Figures in the parenthesis indicate number of live chicks
[NS] Not significant

Table 7: Effect of in feed supplementation of various forms of zinc and selenium on the on the production cost, European Economic Factor (EEF)# and Average daily gain (g) of Japanese quail on 35 d (Mean±SE)

Treatment	Feed cost (Rs./kg)	No. of live birds	Cost of Production (Rs. / bird)	EEF#	Average daily gain (g)
T_1-No supplemental Zn & Se (Negative control)	49.00	33	54.48±5.42	13.13±2.19	6.09±0.14
T_2 - Inorganic Zn & Se (Positive control; X)	49.05	36	47.35±1.58	15.79±2.01	6.15±0.12
T_3 - Enhanced inorganic Zn & Se (2X)	49.10	43	42.63±0.55	16.74±1.05	5.64±0.12
T_4 - Organic sources of Zn & Se (X)	49.10	35	48.55±3.52	13.92±2.37	5.80±0.12
T_5 - Nano sources of Zn & Se (½X)	49.15	28	54.26±2.43	10.74±1.47	5.89±0.13
T_6 - Nano sources of Zn & Se (¼ X)	49.08	41	45.22±1.56	16.17±2.05	5.82±0.09

#EEF = [Livability (35 d) × Average body weight (kg; 35 d) / Mean Age (35 d) × FCR on 35 d] × 100; Cost of Production=Total of all input cost/ JQ sold; Production cost (per JQ) was calculated from the chick cost (Rs.7 /chick), feed cost, miscellaneous cost (Litter material, labour cost, medicine and electricity, etc.; Rs. 3 per JQ purchased)

Table 8: Effect of in feed supplementation of various forms of zinc and selenium on dressing parameters of Japanese quail at 6 weeks of age (Mean ± SE); n=6

Treatment	Live weight (g)	Blood loss (%)	Dressing yield# (%)	Eviscerated yield (%)
T_1-No supplemental Zn & Se (Negative control)	255.67±16.71	3.66±0.29	76.96±0.46	57.67^{b}±1.40
T_2 - Inorganic Zn & Se (Positive control; X)	255.33±12.29	3.30±0.23	75.95±0.69	59.13^{ab}±0.89
T_3 - Enhanced inorganic Zn & Se (2X)	240.33±11.33	3.07±0.19	77.37±0.94	59.46^{ab}±1.20
T_4 - Organic sources of Zn & Se (X)	255.33±10.95	3.28±0.24	75.24±0.68	56.14^{b}±1.35
T_5 - Nano sources of Zn & Se (½ X)	241.00±12.66	2.87±0.20	77.08±0.52	61.80^{a}±1.22
T_6 - Nano sources of Zn & Se (¼ X)	232.33±4.48	2.74±0.18	76.53±0.60	61.87^{a}±0.89
F value	0.724^{NS}	2.099^{NS}	1.418^{NS}	3.700^{*}

#without blood, feathers, skin, head and feet, NSNot Significant, *Significant (p≤0.05)
Means in columns not sharing a common superscript differ significantly (p≤0.05)

performance and lower cost of production noticed in the groups fed with enhanced level of inorganic (T_3) and 25 per cent of nano minerals (T_6), which might be due to role of Zn and Se in the various metabolic process, enzyme metabolism, immunomodulatory effect and higher livability in Japanese quail.

Carcass characteristics and meat proximate principles

Carcass traits such as live weight, blood loss and dressing yield did not show any significant differences among the treatments. The per cent eviscerated yield of Japanese quails supplemented with nano Zn and Se had a significantly (p≤0.05) higher eviscerated yield. It is in agreement with the findings of Petrovic *et al.* (2010), who found that groups given trace elements in proteinate form or highly bioavailable form even at lower levels (50% in Cu, 20% in Fe, Zn, Mn and Se) had the same impact on eviscerated yield. Alian *et al.* (2020) observed similar results while evaluating the influence of nano selenium *vs*. other selenium sources on carcass characteristics in Ross 308 broilers who reported that groups fed with 0.3 mg/kg nano selenium had the highest dressing percentage. Varun *et al.* (2018) also studied the influence of replacing the inorganic Zn (40 ppm) with Zn nanoparticle (20 ppm) in the diet of commercial broilers and reported a comparable result on carcass traits. Results of the present work are also in agreement with Bhanja and Verma (2021) who have reviewed various nano mineral application in the poultry diet and indicated the suitability of feeding the same at low concentration for obtaining better growth performance and meat quality.

Proximate principles of meat such as moisture, crude protein and crude fat (ether extractives) had a non-significant ($p \geq 0.05$) difference among the groups. Similar findings were also reported by Winiarska-Mieczan *et al.* (2021) who found that non-significant impact was observed due to different levels of glycinates made with Zn, Cu and Fe in the diet on the content of moisture, crude ash, crude protein and crude fat or on the pH of broiler-chicken thigh meat.

CONCLUSION

The study revealed that enhanced level of inorganic Zn and Se and lower level (25 percent) of the same in nano forms could be of benefit in terms of better overall performance and lower cost of production.

ACKNOWLEDGEMENTS

The authors are thankful to the Tamil Nadu Veterinary and Animal Sciences University, Chennai-51 for providing all facilities to carry out this study.

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