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Can different concentration of chelated and inorganic trace minerals (Zn, Se and Cr) be an effective supplement for better production performance and carcass traits in broilers?

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Abstract
Poultry is the fastest growing livestock sector in the developing countries. The global poultry sector is expected to continue to grow, as demand for poultry meat is driven by growing needs, population, rising incomes and urbanization. The present experiment was conducted to investigate the effect of inorganic and chelated trace minerals supplementation on production performance and carcass traits in broilers. A total of 216 broilers randomly divided into twelve groups and each group consisting of 18 broilers in 3 replicates. T1 group was kept as control. T2, T3 and T4 group was supplemented with zinc (40 mg/kg of feed) inorganic, chelated and 50% chelated form respectively. T5, T6 and T7 groups was supplemented with selenium (0.3 mg/kg of feed) from inorganic, chelated and 50% chelated form respectively. T8, T9 and T10 groups was supplemented with chromium (2 mg/kg of feed) from inorganic, chelated form and 50% chelated form respectively. T11 and T12 group was supplemented with combination of all 3 minerals from inorganic and chelated form respectively. Significant difference ($p<0.05$) was observed in body weight gain between all the groups as compared to control group. The maximum body weight gain was attained in T12 group, supplemented with combination of chelated form of Zn, Se and Cr whereas, minimum body weight gain was attained in T1 (control group). Significant difference ($p<0.05$) in total feed intake (g) was observed in T12 group as compared to control group. Maximum feed intake was observed for T12 group and minimum feed intake was observed for T7 group. The FER differed significantly ($p<0.05$) for all the treatment groups as compared to T1 group. Significant difference ($p<0.05$) was observed in dressed weight (%) and drawn weight (%) in T12 as compared to T1 group. Eviscerated weight (%), organ (liver, heart gizzard, giblets and pancreas) weight (% live wt.) and percent processing loss (blood, feather and head) differed non significantly between all the groups. In the present investigation chelated Zn, Se and Cr supplementation showed better body weight gain, which could lead to increased production performance and minimum mortality in broilers.

Keywords: Broilers, body weight gain, feed intake, carcass trait, mortality and chelated trace minerals

Introduction
The genetic advancement continuously elevated the broiler growth potential and broiler can attain mature body weight by consuming less feed in shorter period of time (Mckay, 2009) [28]. Broilers is having higher metabolic rate that makes them more prone to stress which can alter their immunity, productivity, health or even cause death (Echeverry *et al*., 2016) [10].
Conventionally, inorganic trace minerals zinc (Zn), chromium (Cr) and selenium (Se) are used in chicken diet, because they are cost- effective and readily available, but are relatively inferior to chelated trace minerals due to poor bioavailability (Virden *et al*., 2004) [47]. In the gastro-intestinal tract, the inorganic minerals chelate with phytic acid complex and reduce their rate of absorption and consequently affect the tissue uptake of minerals. In contrast, chelated minerals are devoid of free divalent cations for chelation in the intestinal lumen with phytic acid and hence they are differently metabolized facilitating enhanced absorption. OTM's are highly bioavailable because they have higher retention rate in the body as compared with inorganic trace minerals (ITMs) and acted as a performance enhancer (Nollet *et al.*, 2007) [30].
Chelated trace minerals are environment-friendly because of their lower excretion rate and it remains long time in the gut consequently improves the growth performance. Chelated minerals could be advantageously incorporated in diet at lower level than the inorganic sources for realizing higher mineral bio availability and lower excretion to the environmental

(Aksu *et al.*, 2010) [3]. Excessive use of inorganic trace mineral can result in a detrimental effect on the environment because of their low retention rate and are excreted with the feces (Lukasz *et al.*, 2017) [26].

Supplementation of combined chelated trace mineral in broilers diets has multiple beneficial effects. Zinc is an important nutrient that facilitates body biological functions as a catalyst in many enzymes and hormone system that are associated with growth (Salim *et al*., 2008) [40]. Chromium is an essential element required for carbohydrate, fat and protein metabolism. It increases growth rate, feed efficiency and improves carcass quality in broilers (Mayada *et al*., 2017) [27].

Therefore, in present study, use of chelated and inorganic form of Zn, Cr and Se in poultry diets was attempted on production performance and carcass traits in broilers.

Materials and methods

The research was carried out in the Department of Veterinary Physiology and Biochemistry, College of Veterinary Science and Animal Husbandry, N.D.V.S.U., Jabalpur (M.P.). A total of 216 broilers randomly divided into twelve groups and each group consisting of 18 broilers in 3 replicates. The experimental design presented below.

Experimental design

Groups	Replicates	No. of Broilers	Treatments
T1 (n=18)	T1 R1 T1 R2 T1 R3	6 6 6	Basal diet
T2 (n=18)	T2 R1 T2 R2 T2R3	6 6 6	Basal diet + Inorganic zinc @ 40 mg/kg of feed
T3 (n=18)	T3 R1 T3 R2 T3R3	6 6 6	Basal diet + Chelated zinc @ 40 mg/kg of feed
T4 (n=18)	T4 R1 T4 R2 T4R3	6 6 6	Basal diet + Chelated zinc @ 20 mg/kg of feed
T5 (n=18)	T5 R1 T5 R2 T5 R3	6 6 6	Basal diet + Inorganic selenium @ 0.30 mg/kg of feed
T6 (n=18)	T6 R1 T6 R2 T6 R3	6 6 6	Basal diet + Chelated selenium @ 0.30 mg/kg of feed
T7 (n=18)	T7 R1 T7 R2 T7 R3	6 6 6	Basal diet + Organic selenium @ 0.15 mg/kg of feed
T8 (n=18)	T8 R1 T8 R2 T8 R3	6 6 6	Basal diet + Inorganic chromium @ 2 mg/kg of feed
T9 (n=18)	T9 R1 T9 R2 T9 R3	6 6 6	Basal diet + Chelated chromium @ 2 mg/kg of feed
T10 (n=18)	T10 R1 T10 R2 T10 R3	6 6 6	Basal diet + Chelated chromium @ 1 mg/kg of feed
T11 (n=18)	T11 R1 T11 R2 T11 R3	6 6 6	Basal diet + Inorganic zinc @ 40 mg/kg of feed + Inorganic selenium @ 0.30 mg/kg of feed + Inorganic chromium @ 2 mg/kg of feed
T12 (n=18)	T12 R1 T12 R2 T12 R3	6 6 6	Basal diet + Chelated zinc @ 40 mg/kg of feed + Chelated selenium @ 0.30 mg/kg of feed + Chelated chromium @ 2 mg/kg of feed

Diets were formulated as per NRC (1994) [31] specifications. Feed-grade sulphate salts of Mn, Zn, Fe and Cu were used, while Se and Cr were in the form of selenite (sodium selenite) and dichromate (potassium dichromate), respectively, in the control diet (CD). Chelated form of Se (0.30 mg/kg), Cr (2 mg/kg) or Zn (40 mg/kg) was supplemented in treatment groups. The chelated forms of Se, Zn and Cr (Sel-Plex 2000, Bioplex zinc and Biochrome, respectively) were generous gift from Alltech Biotechnology Pvt. Ltd., Bengaluru, India. Concentrations of Zn, Se and Cr in the above chelated trace mineral premixes were 15, 0.2 and 0.1 %, respectively (Table 01).

Table 1: Ingredients and composition of broiler ration

Ingredients	Starter %	Finisher %
Maize	43.36	57.30
Soybean meal	43.90	33.10
Soybean oil	08.74	05.61
Common Salt	00.40	00.40
DL- Methionine	0.185	0.175
Di-Calcium Phosphate	01.80	01.80
Limestone Powder	01.37	01.37
Supplements (Vitamins supplement and feed additives)	0.245	0.245

*Trace mineral Premix: Mn-55,I-0.4, Fe-56 and Cu-4kg-1
** Vitamin premix: Vitamin A-8250 IU, Vitamin D_3- 1200 IU, Vitamin k-1mg, Vitamin E-40 IU, Vitamin B1-2mg, Vitamin B_2-4mg, Vitamin B_{12}-10mg, Percent of values specified by NRC, 1994, *** Calculated

Broilers were kept in closed ventilated system for 35 days during the experimental period. Production performance parameters such as Body weight was recorded individually at weekly intervals till 5 weeks of age by weighing all the birds in each treatment group using electronic weighing balance in the morning hours before feeding. Feed intake was recorded by weighing the offered feed and residual feed on weekly basis. Weekly feed consumption of broilers was recorded replicate wise till the end of week. The feed consumed was determined by subtracting the residual feed from total feed offered during each of the period. Feed efficiency ratio was calculated on the basis of body weight gain and feed intake in weekly of the experiment. FER was calculated using following formula.

FER = Body weight gain (g) / Feed consumption (g)

Performance index was calculated as per the formula proposed by Bird (1955) [9]. PI = Body weight gain (g) X FER

Mortality was recorded on daily basis and the mortality rate was calculated for the period from 0 to 5 weeks.

Carcass traits parameters

Two broilers from each replicate were sacrificed on completion of experiment. Broilers were kept off-feed for twelve hours before sacrifice. Before sacrifice, each broiler was weighed then by giving severe cut to the jugular vein. They were allowed bleeding completely. For complete bleeding, birds were hanged in inverted position on the iron rails. After complete bleeding weight was recorded accordingly. Weight of the broilers was again recorded after manual defeathering using hot water (50-55^0 C).

Dressing weight = Live weight –weight loss as blood, feather, head, shank and wing tip

After recording the dressed weight, a horizontal cut was applied posterior to keel bone. Breast was pushed forward to expose the viscera which were then pulled out. Weight of carcass recorded again. Various visceral organs like proventriculus, liver, heart, spleen, gizzard and pancreas was weighed. The eviscerated weight was recorded as follows:

Eviscerated weight = Dressed weight - weight of viscera

Drawn weight = Eviscerated weight+ weight of giblet (liver, heart and gizzard)

Various processing losses such as blood, head, feather, shank, fat and wing tip were recorded during the study.

Results and discussion

Body weight

The mean body weight (g) of broilers has been presented in Table 02. In the present study, significant difference ($p<0.01$) was observed in body weight gain among all the groups on day 35. The maximum body weight was found in T12 (combination of chelated Zn, Se and Cr) While, the minimum body weight was found in T1 group (Control). It may be due to the use of chelated minerals which can improve intestinal absorption of trace elements as they reduce interference from agents that form insoluble complexes with the ionic trace elements and thereby enhancing their bioavailability and body weight gain.

Present findings are in agreement with the results of Kroliczewska *et al.* (2005) [21] reported that supplementation of 500 µg/kg Cr significantly increased body weight and body weight gain as compared to the dose of 300 µg/kg Cr and control diet. Abdallah *et al.* (2009) [2] found that 100 per cent organic Zn supplemented chicks were higher in body weight than 50 per cent organic Zn fed group. Abbas *et al.* (2010) [1] found that increased body weight gain in broilers supplemented with 50 % each of Zn, Mn and Cu in chelated form as compared to group fed with 100% of these minerals from inorganic sources. Tawfeek *et al.* (2014) [45] reported that weight gain was significantly increased ($p<0.001$) with the addition of Cr and vitamins C+E ($p<0.01$) while showed non-significant improvement with Zn + Se supplement. Saleh *et al.* (2018) [39] reported that body weight was significantly increased ($p<0.05$) in 50 mg Zn- methionine supplemented group as compared with control group.

Rama Rao *et al.* (2016) [37] reported that supplementation of Se, Cr and Zn as organic form significantly increased ($p<0.05$) body mass gain as compared to those fed the control diet. Among the trace minerals supplemented groups, the growth was significantly ($p<0.05$) higher in broilers fed with Se as compared to those fed Zn or Cr.

The present findings were in non-agreement with the results obtained by Rama Rao *et al.* (2013) [36] who observed non-significant difference in body weight of Vanaraja chicks fed with reduced levels of chelated trace minerals (Zn, Mn, Cu, Fe, I, Se and Cr). Echeverry *et al.* (2016) [10] also reported that body weight was not different in chelated trace mineral treatments compared to control (p>0.05). Pacheco *et al.* (2017) [33] also reported that chelated Zn and inorganic Zn had non-significant effects on the body weight.

Feed intake

Feed intake (g/bird/day) of broilers has been presented in Table 3. Significant higher ($p<0.05$) total feed intake (Kg) was observed in T12 group as compare to control group (T1). Maximum feed intake was observed for T12 group and minimum feed intake was observed for T7 group.

The present findings are in agreement with the results of Rahaman *et al.* (2008) [34] reported that Ross broilers fed with zinc- methionine (40, 80 and 120 mg/kg) showed significantly higher feed intake as compared to inorganic source fed

groups. Naghieh *et al*. (2010) [29] found that improved cumulative weight gain was observed with diet supplemented with Chromium Picolinate in heat stress birds. Similar results were also reported by Hamidi *et al*. (2016) [14].
The results obtained in the present study were contradictory to the findings of Iqbal *et al.* (2011) [17] reported that feed intake of broiler chickens were not influenced significantly by supplementation of Zn from inorganic and organic sources at different concentration of 40 and 80 mg/kg. Rossi *et al.* (2007) [38] reported that basal diet containing 60 ppm Zn from an inorganic source (Bioplex) in Ross broilers and by adding graded level of 0, 15, 30, 45 and 60 ppm of dietary organic Zn had non-significant effect on feed consumption. Hudson *et al.* (2005) [16] revealed that broiler fed with diets having added Zn from either inorganic or chelated source had no significant effect on feed intake. Abdallah *et al.* (2009) [2] observed that diets supplemented with the chelated form of Zn, Cu, Mn and Fe at 50 or 100 per cent of total requirements of broilers had non-significant difference in feed consumption.
Sunder *et al.* (2013) [43] also found that feed intake was not significantly affected by feeding OTM and ITM in broilers. Baloch *et al.* (2017) [6] reported that OTM supplementation did not significantly affect feed intake in broilers. Yaqoob *et al.* (2020) [48] reported that the overall (1-12 wk) feed intake was not affected by dietary treatments when inorganic trace minerals were replaced by complexed glycinates in broiler breeders which was dissimilar to present findings.

Feed efficiency ratio (FER) and Performance index (PI)
Feed efficiency ratio and performance index has been presented in Table 4. FER and PI were also significantly (p<0.05) different for the all treatment groups as compared to control group. Maximum FER and PI were observed in T12 group whereas, minimum FER and PI was observed for T1 group. The better feed efficiency and PI is due to increased body weight gain and feed intake in broilers.
The present observations are in agreement with the findings of Lee *et al*. (2003) [23] reported that Cr as Cr Pic increased feed efficiency in 0 to 3wks broilers. Kroliczewska *et al*. (2005) [21] reported Cr yeast (500 µg/kg) supplementation improve the feed efficiency (p<0.05) in broilers. Samanta *et al*. (2008) [41] reported 0.5 mg/kg of Cr to improve the feed intake and FCR. Similarly, increased feed efficiency and body weight gain was reported in broilers diet supplemented with Se-enriched yeast (Krstic *et al*., 2012) [22].
In disagreement to present findings, Edens *et al.* (2001) [11] reported non-significant differences in feed efficiency, when broilers were fed with diets containing 0.20 ppm Se from sodium selenite or selenium yeast. Ellen *et al.* (2012) [13] found non-significant difference in feed efficiency by supplementing diets with amino acid chelates copper, zinc, manganese and iron.

Table 2: Mean body weight (g) of broilers birds at different intervals

Period/Treatment	Day 1	Day 7	Day 14	Day 21	Day 28	Day 35	Body wt. gain
T1	53.49 ± 0.06	182.28^{f} ± 2.03	454.11^{d} ± 07.29	847.38^{c} ± 20.79	1359.05^{b} ±34.94	2017.11 ± 30.93	1964.0^{e} ± 38.10
T2	53.29 ± 0.11	184.00^{ef} ± 2.04	458.11^{cd} ± 08.45	908.16^{abc} ± 23.10	1441.16^{ab} ± 28.93	2097.38 ± 39.10	2045.0^{bcd} ± 09.52
T3	53.44 ± 0.03	191.11^{cd} ± 1.68	472.11^{bcd} ± 08.69	924.16^{bc} ± 16.02	1463.33^{a} ± 32.75	2150.11 ± 35.33	2097.0^{b} ± 14.43
T4	53.45 ± 0.10	189.72^{cde} ± 2.78	464.50^{cd} ± 13.42	888.11^{bc} ± 27.02	1443.11^{ab} ± 28.61	2141.44 ± 43.79	2088.0^{bc} ± 16.16
T5	53.42 ± 0.06	182.77^{ef} ± 2.72	463.88^{bcd} ± 08.71	909.27^{abc} ±17.67	1448.22^{ab} ± 38.98	2061.00 ± 27.11	2008.0^{de} ± 05.60
T6	53.35 ± 0.05	199.11^{ab} ± 1.46	493.16^{ab} ± 08.81	939.33^{ab} ± 18.68	1484.00^{a} ± 22.53	2090.00 ± 51.72	2037.0^{bcde} ± 29.15
T7	53.32 ± 0.10	193.22^{bc} ± 1.39	489.11^{acd} ± 08.54	931.22^{ab} ± 19.22	1481.38^{a} ± 30.50	2071.33 ± 41.35	2018.0^{cde} ± 34.64
T8	53.47 ± 0.09	187.72^{cdef} ± 3.10	478.16^{abcd} ±09.55	895.00^{abc} ± 21.18	1413.38^{a} ± 31.84	2069.05 ± 54.36	2016.0^{cde} ± 21.36
T9	53.33 ± 0.11	185.50^{efg} ± 2.46	481.77^{abcd} ±08.98	912.22^{bc} ± 17.04	1456.00^{ab} ± 29.62	2117.16 ± 48.66	2065.0^{bcd} ± 10.10
T10	53.40 ± 0.06	193.50^{bc} ± 3.33	484.44^{abcd} ±08.63	907.44^{abc} ± 13.14	1452.22^{ab} ± 29.92	2073.16 ± 53.06	2020.0^{bcde} ± 23.38
T11	53.33 ± 0.11	189.33^{cde} ± 2.86	461.44^{cd} ± 09.40	923.00^{ab} ± 21.51	1458.11^{ab} ± 31.65	2121.00 ± 40.38	2068.0^{bcd} ± 12.12
T12	53.44 ± 0.03	202.11^{a} ± 1.67	506.16^{a}± 12.63	960.11^{a} ± 22.42	1510.33^{a} ± 28.78	2279.46 ± 58.16	2226.0^{a}± 34.70

Means bearing different superscripts within same column differ significantly (p<0.05).

Table 3: Feed intake (g/bird/day) of broilers at weekly intervals

Week/Treatment	1st	2nd	3rd	4th	5th	Total feed intake (g)
T1	22.31 ± 0.68	53.28 ± 2.61	68.63 ± 1.80	87.26 ± 3.06	121.23 ± 3.23	2495.0^{b}± 48.56
T2	22.81± 0.98	54.27 ± 2.66	70.36 ± 2.67	88.38 ± 2.42	122.50 ± 2.86	2585.0^{ab}± 19.94
T3	24.26 ± 0.48	55.79 ± 1.82	70.54 ± 1.95	90.23 ± 3.15	123.06 ± 1.99	2586.0^{ab} ± 22.47
T4	23.32 ± 1.13	57.67 ± 1.60	71.07 ± 2.03	91.12 ± 2.59	124.51± 2.25	2568.0^{ab} ± 16.67
T5	21.92 ± 1.73	54.69 ± 4.78	69.21 ± 1.83	89.38 ± 4.63	123.36 ± 2.91	2510.0^{ab} ± 24.24
T6	24.40 ± 2.11	57.50 ± 4.38	70.59 ± 1.53	91.15 ± 3.75	124.14 ±1.79	2482.0^{b} ± 10.20
T7	23.18 ± 1.04	57.91± 1.89	71.76 ± 1.84	92.39 ±1.36	123.75 ± 3.81	2481.0^{b} ± 08.81
T8	23.01 ± 1.66	54.66 ± 2.80	69.71 ± 1.15	90.43 ± 2.58	122.38 ± 1.52	2525.0^{ab} ± 38.21
T9	24.04 ± 1.81	56.88 ± 1.59	72.06 ± 0.86	91.83 ± 2.03	125.37± 2.71	2571.0^{ab} ± 23.20
T10	24.54 ± 0.53	58.30 ± 1.81	72.03 ± 1.61	92.10±0.84	124.17± 3.22	2598.0^{ab} ± 31.05
T11	23.06 ± 1.21	56.45 ± 2.06	70.63 ± 1.61	90.72 ± 4.24	123.75 ± 1.48	2553.0^{ab} ± 16.32
T12	24.78 ± 1.09	58.73 ± 4.00	73.52 ± 0.99	95.43 ± 1.76	128.23 ± 1.39	2662.0^{a} ± 26.43

Means bearing different superscripts within same column differ significantly (p<0.05).

Table 4: Production performance of broilers

Parameter/Treatment	Wt. gain (g)	FI (g)	FER	PI
T1	$1964.0^{e} \pm 38.10$	$2495.0^{b} \pm 48.56$	$0.78^{b} \pm 0.02$	$1560.0^{d} \pm 84.99$
T2	$2045.0^{bcd} \pm 9.52$	$2585.0^{ab} \pm 19.94$	$0.79^{ab} \pm 0.01$	$1618.0^{bcd} \pm 27.21$
T3	$2097.0^{b} \pm 14.43$	$2586.0^{ab} \pm 22.47$	$0.81^{ab} \pm 0.01$	$1701.0^{b} \pm 28.04$
T4	$2088.0^{bc} \pm 16.16$	$2568.0^{ab} \pm 16.67$	$0.81^{ab} \pm 0.01$	$1698.0^{b} \pm 32.87$
T5	$2008.0^{de} \pm 05.60$	$2510.0^{ab} \pm 24.24$	$0.80^{ab} \pm 0.00$	$1608.0^{bcd} \pm 18.10$
T6	$2037.0^{bcde} \pm 29.15$	$2482.0^{ab} \pm 10.20$	$0.82^{ab} \pm 0.02$	$1673.0^{bcd} \pm 21.87$
T7	$2018.0^{cde} \pm 34.64$	$2481.0^{ab} \pm 8.81$	$0.81^{ab} \pm 0.01$	$1642.0^{bcd} \pm 13.42$
T8	$2016.0^{cde} \pm 21.36$	$2525.0^{ab} \pm 38.21$	$0.80^{ab} \pm 0.01$	$1610.0^{bcd} \pm 33.72$
T9	$2065.0^{bcd} \pm 10.10$	$2571.0^{ab} \pm 23.20$	$0.80^{ab} \pm 0.01$	$1659.0^{bcd} \pm 26.80$
T10	$2020.0^{bcde} \pm 23.38$	$2598.0^{ab} \pm 31.05$	$0.77^{ab} \pm 0.01$	$1570.0^{cd} \pm 18.41$
T11	$2068.0^{bcd} \pm 12.12$	$2553.0^{ab} \pm 16.32$	$0.80^{ab} \pm 0.01$	$1676.0^{bc} \pm 19.08$
T12	$2226.0^{a} \pm 34.70$	$2662.0^{a} \pm 26.43$	$0.83^{a} \pm 0.01$	$1863.0^{a} \pm 53.61$

Means bearing different superscripts within same column differ significantly ($p<0.05$).

Mortality

In all the treatment as well as in control group of broilers, no mortality (%) was recorded during entire experimental period. The present findings were in agreement with Jackson *et al.* (2008) [18], found that Cr Pic and Cr yeast supplementation decreased mortality in broilers. Tawfeek *et al.* (2014) [48] reported that supplementation of antioxidants improved the viability and decreased the mortality to the degree that no deaths occurred in the Zn + Se and Cr supplemented group. Echeverry *et al.* (2016) [10] also reported that mortality in the OTM treatment group was 20% lower as compared to control. Contrary to present findings, Osama *et al.* (2012) [32] found that mortality was not related to the dietary treatments of organic zinc.

Carcass traits parameters

Carcass traits of broilers in terms of carcass yield, organ weights and processing losses have been presented in following Tables 5, 6 and 7. Effects of varying levels of inorganic and chelated trace minerals supplementation on the percent carcass yield of broilers have been presented in Tables 5. In the present study, significant difference ($p<0.05$) in terms of dressed and drawn weight (%) was observed between T12 and T1. Maximum dressed and drawn weight (%) was observed for T12 group and minimum was observed for T1 group. Non-significant difference (p>0.05) in terms of eviscerated weight (%) was observed among all the groups. Maximum eviscerated weight (%) was observed for T12 group and minimum eviscerated weight (%) was observed for T1 group. This might be due to synergistic effect of chelated trace minerals possessing growth promoting properties which in turn resulted in improvement of dressed, eviscerated and drawn weight in broilers.

Growth performance and carcass characteristics are the main parameters which normally used to evaluate the broiler performance. The success of higher broiler performance has been successfully achieved through genetic improvement which demands better management and appropriate nutrition, especially in trace element nutrition. It is well established that dietary requirement of trace minerals are negligible; however, it is important to note that these negligible element are important for broiler enzyme system, metabolism, growth and reproduction (Berger and Cunha, 2006) [8].

The present observations are in agreement with the findings of Tronina *et al.* (2007) [46] stated that organic Zn could increase dressing percentage of broilers. Huang *et al.* (2016) [15] reported that chromium addition increased dressing percentage of broiler chickens exposed to heat stress in comparison with control group.

Contrary to present findings, Anandhi *et al.* (2006) [4] reported that organic chromium supplementation in broilers had no significant effects on carcass yield. Rossi *et al.* (2007) [39] and Anil *et al.* (2012) [5] reported that carcass yields were not influenced by the addition of dietary chelated Zn and different levels of inorganic Zn were fed to broilers. Liu *et al.* (2011) [25] reported that dietary Zn levels and sources did not influence the carcass traits of broilers. Tavares *et al.* (2014) [44] reported that there was no effect of organic trace mineral supplementation on carcass yield in broilers. Khatun *et al.* (2019) [20] reported that dressing percentage (DP) did not show any significant difference among the dietary groups supplemented OTM as compared to control diet supplemented with ITMs.

Table 5: Effect of inorganic and chelated trace mineral supplementation on carcass yield (% live weight) in broilers

Weight/ Treatment	Dressed weight (%)	Eviscerated weight (%)	Drawn weight (%)
T1	$79.65^{b} \pm 1.66$	69.42 ± 2.24	$73.71^{b} \pm 1.97$
T2	$80.95^{ab} \pm 1.17$	70.27 ± 1.46	$74.78^{b} \pm 1.44$
T3	$81.45^{ab} \pm 0.66$	69.98 ± 1.71	$74.71^{b} \pm 1.50$
T4	$82.15^{ab} \pm 1.10$	72.56 ± 1.66	$77.2^{ab} \pm 0.93$
T5	$80.87^{ab} \pm 1.20$	69.84 ± 1.81	$74.16^{b} \pm 1.33$
T6	$82.47^{ab} \pm 1.00$	73.47 ± 1.28	$78.33^{ab} \pm 0.53$
T7	$82.61^{ab} \pm 1.73$	72.44 ± 2.62	$77.3^{ab} \pm 1.98$
T8	$82.78^{ab} \pm 1.78$	72.72 ± 3.07	$77.08^{ab} \pm 2.17$
T9	$83.65^{ab} \pm 1.41$	72.49 ± 2.30	$77.42^{ab} \pm 1.65$
T10	$83.36^{ab} \pm 0.38$	73.34 ± 0.55	$77.77^{ab} \pm 1.10$
T11	$82.03^{ab} \pm 2.16$	71.77 ± 3.27	$76.39^{ab} \pm 2.51$
T12	$84.39^{a} \pm 0.12$	75.38 ± 1.39	$80.26^{a} \pm 0.65$

Means bearing different superscripts within same column differ significantly ($p<0.05$).

Organs weight of broilers

Effects of varying levels of inorganic and chelated trace minerals supplementation on the percent organ weight of broilers have been presented in Tables 6. In the present study, non-significant difference (*p*<0.05) in terms of liver, heart, gizzard, giblets and pancreas weight (%live wt.) was observed among all the treatment groups. Maximum weight of liver gizzard giblets and pancreas (% live weight) was observed in broilers in T12 group and minimum weight was observed in T1 group. Maximum weight of heart (% live weight) was observed in broilers in T6 group and minimum weight was observed in T1 group.

The present observations are in agreement with the findings of Liu *et al.* (2011) [25], who reported that broiler supplemented with organic trace mineral diet had non-significant effect on the organ weight percentage. Tronina *et al*. (2007) [49] reported that liver and heart weights were not significantly different between the supplemented group and the control group. Bao *et al*. (2007) [7] reported that organic trace mineral supplementation had no significant effect on liver, gizzard and giblet weight. The heart weight was numerically higher in ITM group compared with others organic minerals groups. Zhao *et al.* (2010) [49] have also shown that chelated trace mineral had no significant effects on giblet weight. Rajalekshmi *et al.* (2014) [35] reported that the relative weights of liver, heart, gizzard and giblet were not influenced (p>0.05) by the supplementation of chromium in the diet. Savari *et al.* (2015) [45] concluded that there was no influence of ZnO on carcass traits. El-Kholy *et al.* (2017) [12] reported that supplemental Cr had non-significant impacts on carcass traits of growing quails as compared with untreated group. Khatun *et al.* (2019) [20] reported that feeding organic trace mineral had non-significant effect on liver, gizzard and giblet weight, which is similar to present findings.

In disagreement to present findings, Lien *et al.* (1999) [24] reported dietary supplementation of 800 μg Cr kg–1 diet, as chromium picolinate, significantly increased liver percent in broiler fed diets containing 800, 1600 and 3200 μg Cr kg–1. Jahanian *et al.* (2015) [19] reported that increasing Zn supplemental levels from 40 to 80 mg/kg from both inorganic and organic Zn sources increased liver weight percentage.

Table 6: Effect of inorganic and chelated trace mineral supplementation on organ weight (% live weight) in broilers

Organ wt./Treatment	Liver (%)	Heart (%)	Gizzard (%)	Giblets (%)	Pancreas (%)
T1	1.78 ± 0.16	0.59 ± 0.05	1.79 ± 0.26	4.22 ± 0.34	0.21± 0.01
T2	1.89 ± 0.07	0.65 ± 0.02	1.97 ± 0.06	4.51 ± 0.02	0.22± 0.01
T3	2.13 ± 0.19	0.66 ± 0.01	1.93 ± 0.03	4.72 ± 0.21	0.23± 0.01
T4	1.93 ± 0.34	0.75 ± 0.09	1.95 ± 0.24	4.65 ± 0.72	0.23± 0.01
T5	1.85 ± 0.19	0.61 ± 0.07	1.87 ± 0.22	4.32 ± 0.48	0.22 ± 0.01
T6	2.09 ± 0.21	0.76 ± 0.15	2.04 ± 0.40	4.89 ± 0.75	0.23 ± 0.01
T7	2.08 ± 0.29	0.69 ± 0.09	2.11 ± 0.27	4.86 ± 0.64	0.23 ± 0.01
T8	1.89 ± 0.34	0.60 ± 0.12	1.87 ± 0.36	4.35 ± 0.82	0.22 ± 0.01
T9	1.99 ± 0.28	0.61 ± 0.10	2.09 ± 0.27	4.88 ± 0.65	0.23 ± 0.01
T10	1.96 ± 0.36	0.63 ± 0.09	1.85 ± 0.14	4.38 ± 0.45	0.23 ± 0.01
T11	1.94 ± 0.37	0.60 ± 0.01	2.08 ± 0.37	4.62 ± 0.75	0.24 ± 0.01
T12	2.14 ± 0.29	0.65 ± 0.07	2.33 ± 0.38	4.93 ± 0.74	0.25 ± 0.01

Processing losses of broilers

Effects of varying levels of inorganic and chelated trace minerals supplementation on the processing losses of broilers have been presented in Table 7. Processing losses in terms of blood (% live weight) was maximum in T1 group followed by T3 group and minimum in T7 group. Processing losses in terms of feather (% live weight) was maximum in T2 group followed by T1 group and minimum in T12 group. Processing losses in terms of head (% live weight) was maximum in T11 group followed by T8 group and minimum in T2 group. Processing losses in terms of shank and wing tip (% live weight) was maximum in T1 group followed byT6 group and minimum in T12 group.

Table 7: Effect of inorganic and chelated trace mineral supplementation on processing loss (% live weight) in broilers

Treatment	Blood (%)	Feather (%)	Head (%)	Shank and Wingtip (%)
T1	5.31 ± 0.11	6.03 ± 0.13	3.04 ± 0.33	6.05^{a} ± 0.69
T2	5.15 ± 0.14	6.18 ± 0.13	2.25 ± 0.47	5.46^{ab} ± 0.97
T3	5.21± 0.19	5.66 ± 0.01	2.49 ± 0.17	5.19^{ab} ± 0.30
T4	4.76 ± 0.33	5.69 ± 0.61	2.48 ± 0.04	4.92^{ab} ± 0.13
T5	4.85 ± 0.10	5.79 ± 0.61	2.60 ± 0.12	5.89^{ab} ± 0.85
T6	3.82 ± 0.34	4.90 ± 0.31	2.87 ± 0.05	5.91^{ab} ± 0.26
T7	3.78 ± 0.23	4.73 ± 0.39	3.03 ± 0.44	5.85^{ab} ± 0.67
T8	3.83 ± 0.18	4.83 ± 0.39	3.18 ± 0.48	5.37^{ab} ± 0.77
T9	4.21± 0.28	5.11± 0.79	2.78 ± 0.10	4.25^{b} ± 0.24
T10	5.13 ± 0.32	4.33 ± 0.01	2.62 ± 0.03	4.56^{ab} ± 0.62
T11	4.65 ± 0.78	5.59 ± 0.63	3.37 ± 0.16	4.35^{b} ± 0.60
T12	4.21± 0.51	4.24 ± 0.30	3.03 ± 0.34	4.13^{b} ± 0.08

Means bearing different superscripts within same column differ significantly (*p*<0.05).

In the present study, non-significant difference (p>0.05) in terms of blood, feather and head (% live weight) was observed among all the treatment groups. Significant difference (*p*<0.05) were observed in terms of shank and wingtip loss (% live weight). The maximum shank and wingtip loss (% live weight) was observed in T1 group and minimum shank and wingtip loss (% live weight) was observed in T12 group followed by T11 and T9 groups.

Supplementation of chelated trace minerals reduces the various processing losses parameters in experimental broilers.

Conclusions

Effects of different concentration of chelated and inorganic trace minerals (Zn, Se and Cr) supplementation on production performance and carcass traits in broilers. Significant difference ($p<0.05$) was observed in body weight gain between all the groups as compared to control group. The maximum body weight gain was attained in T12 group, supplemented with combination of chelated form of Zn, Se and Cr whereas, minimum body weight gain was attained in T1 (control group). Significant difference ($p<0.05$) in total feed intake (g) was observed in T12 group as compared to control group. Maximum feed intake was observed for T12 group and minimum feed intake was observed for T7 group. The FER differed significantly ($p<0.05$) for all the treatment groups as compared to T1 group. Significant difference ($p<0.05$) was observed in dressed weight (%) and drawn weight (%) in T12 as compared to T1 group. Eviscerated weight (%), organ (liver, heart gizzard, giblets and pancreas) weight (% live wt.) and percent processing loss (blood, feather and head) differed non significantly between all the groups. In the present investigation chelated Zn, Se and Cr supplementation showed better body weight gain, which could lead to increased production performance and minimum mortality in broilers

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References

1. Abbas AG, Ali RF, Majid T, Mohammad MG. Effects of organic chelates of zinc, manganese and copper in comparison to their inorganic sources on performance of broiler chickens. Journal of Animal and Plant Science. 2010; 6(2):630-636.
2. Abdallah AG, El-Husseiny OM, Abdel-Latif KO. Influence of some dietary organic mineral supplementations on broiler performance. International Journal of Poultry Science. 2009; 8(3):291-298.
3. Aksu D, Aksu T, Ozsoy B, Baytok E. The effects of replacing inorganic with a lower level of organically complexed minerals (Cu, Zn and Mn) in broiler diets on lipid peroxidation and antioxidant. Asian-Australasian Journal of Animal Science. 2010; 23:1066-1072.
4. Anandhi M, Mathivanan R, Vishwanathan K, Mohan B. Dietary inclusion of organic chromium on production and carcass characteristics of broilers. International Journal of Poultry Science. 2006; 5:880-884.
5. Anil KC, Ramana JV, Rama PJ, Sudheer SD, Satyanarayana RPVV. Influence of zinc sulphate and zinc-methionine dietary supplementation on carcass characteristics and feed efficiency of broilers. Annual Journals of Biological Research. 2012; 3(8):4215-4221.
6. Baloch Z, Yasmeen N, Pasha TN. Effect of replacing inorganic with organic trace minerals on growth performance, carcass characteristics and chemical composition of broiler thigh meat. African Journal of Agricultural Research. 2017; 12(18):1570-1575.
7. BaoYM, Choct M, Lji PA, Bruerton K. Effect of organically complexed copper, iron, manganese and zinc on broiler performance, mineral excretion and accumulation in tissues. Journal of Applied Poultry Research. 2007; 16:448-455.
8. Berger LL, Cunha TJ. Trace minerals. *In*: Cunha, T.J. (ed), Salt and trace minerals for livestock, poultry and other animals. Salt Institute, 2006; Alexandria.
9. Bird H R. Performance index of growing chickens. Poultry Science. 1995; 34:1163-1164.
10. Echeverry H, Yitbarek A, Munyaka P, Alizadeh M, Cleaver A, Camelo-Jaimes G *et al*. Organic trace mineral supplementation enhances local and systemic innate immune responses and modulates oxidative stress in broiler chickens. Poultry Science. 2016; 95:518-527.
11. Edens FW, Parkhurst CR, Havenstein GB, Sefton AE. Housing and selenium influences on feathering on broilers. Journal of Applied Poultry Research, 2001; 10:128-134.
12. El-Kholy MS, El-Hindawy MM, Alagawany M, El-Hack MEA, El-Gawad SA, El-Sayed AEH *et al*. Dietary supplementation of chromium can alleviate negative impacts of heat stress on performance, carcass yield and some blood hematology and chemistry indices of growing Japanese quail. Biological Trace Element Research. 2017; 10:1007-17
13. Ellen BB, Florinia ME, Amado AA, Sonia PA, Edwin SL. Effects of supplementing diets with amino acid chelates of copper, zinc, manganese and iron on the performance of broilers. Philippine Journal of Veterinary and Animal Science. 2012; 38(1):1-10.
14. Hamidi O, Mohammad C, Hasan G, Ali AS, Hassan MK. Effects of chromium (iii) picolinate and chromium (iii) picolinate nanoparticles supplementation on growth performance, organs weight and immune function in cyclic heat stressed broiler chickens. Kafkas Universitesi Veteriner Fakultesi Dergisi. 2016; 22(3):373-380.
15. Huang Y, Yang J, Xiao F, Lloyd K, Lin X. Effects of supplemental chromium source and concentration on growth performance, carcass traits and meat quality of broilers under heat stress conditions. Biological Trace Element Research. 2016; 170:216-223.
16. Hudson BP, Dozier WA, Wilson JL. Broiler live performance response to dietary zinc source and the influence of zinc supplementation in broiler breeder diets. Animal Feed Science and Technology. 2005; 118:329-335.
17. Iqbal S, Deo C, Mandal AB, Tyagi PK, Wachat VB. Response of feeding different sources and concentrations of zinc and copper on performance of broiler chickens. Indian Journal of Poultry Science. 2011; 46(3):330-336.
18. Jackson AR, Powell S, Johnston S, Shelton JL, Bidner TD, Valdez FR *et al*. The effect of chromium propionate on growth performance and carcass traits in broilers. Journal of Applied Poultry Research. 2008; 17**:**476-481.
19. Jahanian R, Rasouli E. Effects of dietary substitution of zinc-methionine for inorganic zinc sources on growth performance, tissue zinc accumulation and some blood parameters in broiler chicks. Journal of Animal Physiology and Animal Nature. 2015; 99(1):50-58.
20. Khatun A, Chowdhury SD, Roy BC, Dey B, Haque A, Chandran B. Comparative effects of inorganic and three forms of organic trace minerals on growth performance, carcass traits, immunity and profitability of broilers. Journal of Advanced Veterinary and Animal Research. 2019; 6(1):66-73.
21. Kroliczewska BB, Zawadzki W, Dobrzanski Z, Kaczmarekoliwa A. Changes in selected serum parameters of broiler chicken fed supplemental chromium. Journal of Animal Physiology and Animal Nutrition. 2005; 88(11):393-400.

22. Krstic B, Jokic Z, Pavlovic Z, Zivkovic D. Options for the production of selenized chicken meat. Biological Trace Element Research. 2012; 146:68-72.
23. LeeDN, WuFY, ChengYH, LinRS, WuPC. Effects of dietary chromium picolinate supplementation on growth performance, feed efficiency and immune responses of broilers. Asian-Australian Journal of Animal Science. 2003; 16:227-233.
24. Lien TF, Horng YM, Yang KH. Performance, serum characteristics, carcass traits and lipid metabolism of broilers as affected by supplement of chromium picolinate. British Poultry Science. 1999; 40:357-363.
25. Liu ZH, Lu L, Li SF, Zhang LY, Xi L, Zhang KY. Effects of supplemental zinc source and level on growth performance, carcass traits, and meat quality of broilers. Poultry Science. 2011; 90(8):1782-1790.
26. Lukasz J, Agnieszka M, Zbigniew G, Malgorzata K, Marcin K. The effect of feed supplementation with zinc chelate and zinc sulphate on selected humoral and cell-mediated immune parameters and cytokine concentration in broiler chickens. Research Veterinary Science. 2017; 112:59-65.
27. Mayada F, Mahmoud A, El-HackM, Arif M, Ayasan T, Dhama K *et al*. Role of chromium in poultry nutrition and health: beneficial applications and toxic effects. International Journal of Pharmacology. 2017; 13(10):907-915.
28. McKay JC. The genetics of modern commercial poultry. Biology of breeding poultry ref.7. Centre for Agriculture and Biosciences International (CABI) Wallingford UK, 2009, 3-9.
29. Naghieh A, Toghyani M, Gheisari AA, Saeed SE, Mirzazade H. Effect of different sources of chromium on performance and immune responses of broiler chicks. Journal of Animal and Veterinary Advances. 2010; 9:354-358.
30. Nollet L, Vanderklis JD, Lensing M, Spring P. The effect of replacing inorganic with organic trace minerals in broiler diets on productive performance and mineral excretion. Journal of Applied Poultry Research. 2007; 16(4):592-597.
31. NRC. Nutrient Requirement of Poultry (9th Rev. Edn.) National Research Council, National Academy Press, Washington, DC, 1994, 20418.
32. Osama ME, Hashish SM, Ali RA, Arafa SA, Abd El Samee LD *et al*. Effects of feeding organic zinc, manganese and copper on broiler growth, carcass characteristics, bone quality and mineral content in bone, liver and excreta. International Journal of Poultry Science. 2012; 11(6):368-377.
33. Pacheco BHCI, Nakagi VSI, Kobashigawa EH, Faria DEI. Dietary levels of zinc and manganese on the performance of broilers between 1 to 42 Days. Brazilian Journal of Poultry Science. 2017; 19(2):171-178.
34. Rahman J, Hasan NM, Abbas R. Improved broiler chick performance by dietary supplementation of organic zinc sources. Asian-Australasian Journal of Animal Science. 2008; 21(9):1348-1354.
35. Rajalekshmi M, Sugumar C, Chirakkal H, Ramarao SV. Influence of chromium propionate on the carcass characteristics and immune response of commercial broiler birds under normal rearing conditions. Poultry Science. 2014, 93:574-580.
36. Rama RaoSV, Prakash B, Kumari K, Raju MVLN, Panda AK. Effect of supplementing different concentrations of organic trace minerals on performance, antioxidant activity and bone mineralization in Vanaraja chickens developed for free range farming. Tropical Animal Health and Production. 2013; 45(6):1447-1451.
37. Rama Rao SV, Prakash B, Raju MVLN, Panda AK, Kumari RK, Reddy EPK. Effect of supplementing organic forms of zinc, selenium and chromium on performance, anti-oxidant and immune responses in broiler chicken reared in tropical summer. Biological Trace Element Research. 2016; 172(2):511-520.
38. Rossi P, Rutz F, Anciuti MA, Rech JL, Zauk NHF. Influence of graded levels of organic zinc on growth performance and carcass traits of broilers. Journal of Applied Poultry Research. 2007; 16:219-225.
39. Saleh AA, Ragab MM, Enas AMA, Abudabos AM, Ebeid TA. Effect of dietary zinc-methionine supplementation on growth performance, nutrient utilization, antioxidative properties and immune response in broiler chickens under high ambient temperature. Journal of Applied Animal Research. 2018; 46(1):820-827.
40. Salim HM, Jo C, Lee BD. Zinc in broiler feeding and nutrition. Avian Biological Research. 2008 1:5-18.
41. Samanta S, Haldar S, BahadurV, Ghosh T. Chromium picolinate can ameliorate the negative effects of heat stress and enhance performance, carcass and meat traits in broiler chickens by reducing the circulatory cortisol level. Journal of the Science of Food and Agriculture. 2008; 88:787-796.
42. Sarvari BG, Seyedi AH, Shahryar HA, Sarikhan M, Ghavidel SZ. Effects of dietary zinc oxide and a blend of organic acids on broiler live performance, carcass traits and serum parameters. Brazilian Journal of Poultry Science. 2015; 17:39-46.
43. Sunder GS, KumarCV, Panda AK, Raju MVLN, Rama Rao SV. Effect of supplemental organic Zn and Mn on broiler performance, bone measures, tissue mineral uptake and immune response at 35 days of age. Current Research in Poultry Science. 2013; 3(1):1-11.
44. Tavares T, Mourao JL, Kay Z. The effect of replacing inorganic trace minerals with organic bioplex® and sel-plex® on the performance and meat quality of broilers. Journal of Applied Animal Nutrition. 2014; 2(10):1-7.
45. Tawfeek SS, Hassanin KMA, Youssef IMI. The effect of dietary supplementation of some antioxidants on performance, oxidative stress and blood parameters in broilers under natural summer conditions. Journal of World's Poultry Research. 2014; 4(1):10-19.
46. Tronina W, Kinal S, Lubojemska B. Effect of various forms of zinc applied in concentrate mixtures for broiler chickens on its bioavailability as well as meat composition and quality. Polish Journal of Food Nutrition Science. 2007; 57(4):577-581.
47. Virden WS, Yeatman JB, Barber SJ, Willeford KO, Ward TL, Fakler TM *et al*. Immune system and cardiac functions of progeny chicks from dams fed diets differing in zinc and manganese level and source. Poultry Science. 2004; 83:344-351.
48. Yaqoob MU, Wang G, Sun W, Pei X, Liu L, Tao W *et al*. Effects of inorganic trace minerals replaced by complexed glycinates on reproductive performance, blood profiles and antioxidant status in broiler breeders. Poultry Science. 2020; 99(5):2718-2726
49. Zhao J, Shirley RB, Vazquez-Anon M, Dibner JJ, Richards JD, Fisher P *et al*. Effects of chelated of trace minerals on growth performance, breast meat yield and footpad health in commercial meat broilers. Journal of Applied Poultry Research. 2010; 19:365-372.