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Nutrient utilization and carcass traits in broiler chickens as affected by nano-chromium supplementation

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ABSTRACT

The present study was carried out to perceive the effects of dietary supplementation of nano-chromium on nutrient utilization and carcass traits in broiler chickens. For this, 120 unsexed day-old broiler chickens were procured and randomly allocated into four different treatment groups with three replicates in each. The control group (T_0) was fed with a standard basal diet as per BIS (2007). Treatment groups T_1, T_2, and T_3 were fed the basal diet with 400, 800, and 1600 ppb levels of nano-chromium, respectively for six weeks. Dry matter, crude protein, and total carbohydrate metabolizability were significantly improved in treatment groups T_2 and T_3; while organic matter and ether extract retention were found significantly higher in treatment groups T_1, T_2, and T_3 when compared with a control group. There was no significant difference in the yield of cut-up parts (% live body weight). The supplementation of nano-chromium did not bring any significant changes in processing loss i.e. blood, feather, head, and shank, but abdominal fat was significantly reduced with increasing levels of nano-chromium. Hence, it can be concluded that dietary supplementation of 1600 ppb nano-chromium in the diet of broiler chicken improved nutrient utilization and lowered abdominal fat in broiler chicken.

Keywords: Abdominal fat, Cut-up parts, Nano-chromium, Nutrient metabolizability

Chromium has been identified as a cardinal trace mineral that plays a pivotal role in carbohydrate and lipid metabolism, along with protein synthesis (Sahin *et al*. 2010). More specifically, it is thought to facilitate the activation of insulin through the glucose tolerance factor (Schwarz and Mertz 1959). Supplementation of different forms of chromium in the diet of broiler chickens has significantly increased the utilization of dry matter, organic matter, crude protein and ether extract (Amatya *et al*. 2004). Chromium nanoparticles could boost bioavailability as well as absorption rate than other native chromium picolinate (CrPic) and $CrCl_3$ form in both livestock and poultry nutrition due to their novel properties such as great specific surface area, high catalytic efficiency and strong adsorbing ability (Zha *et al*. 2008, Lien *et al*. 2009). Beneficial effects of chromium nanoparticles on growth performance, body composition, and retention of chromium in tissues in selected muscles along with enhanced chromium digestibility and absorption were also noticed in rats (Zha *et al*. 2007, Lien *et al*. 2009). Supplementation of nano-chromium picolinate improved chromium and calcium accumulation in the liver and eggs; and also showed to improve zinc and manganese retention in laying chickens (Sirirat *et al*. 2012).

It has potent hypocholesterolemic and antioxidant properties and has a useful impact on feed utilization, immune response, lean carcass quality, growth performance, and quality of egg (Farag *et al*. 2017). The potential applications of nano-particles (NPs) for increasing meat quantity and quality by decreasing disease overload can help the poultry industry (Anwar *et al*. 2019). The metabolic ability of crude protein and ether extracts was significantly increased in treatment groups of *C. catla* fingerlings which were fed 2 mg/kg and 1.5 mg/kg of nano-chromium, respectively (Hussain *et al*. 2019). However, the vast majority of the research on chromium in poultry has only documented the effects of inorganic chromium as $CrCl_3$ or organic chromium as chromium picolinate. This implies that the effect of nano-chromium on broiler performance, nutrient metabolizability, and carcass traits still needs to be explored. Therefore, the purpose of this research was to evaluate the effect of nano-chromium on nutrient metabolizability and carcass traits in poultry.

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MATERIALS AND METHODS

Ethical statement of animal experiments: The procedures related to management and care of birds used in this experiments, and the procedures followed during the trial were aproved by the ‘Institutional Animal Ethics

Committee (IAEC) (registration no: 330/GO/Re/SL/01/CPCSEA) GBPUA & T, Pantnagar, Uttarakhand.

Table 1. Ingredient and chemical composition (% DMB) of basal diets fed to the commercial broiler chickens during experiment (0–42 d)

Ingredient	Pre-starter (0-7 d)	Starter (8-21d)	Finisher (22-42 d)
Yellow Maize (%)	51.25	52.25	55.5
Deoiled soybean (%)	29.25	28.75	26.25
GNC-solvent extracted (%)	10.60	9.50	7.75
Rice polish (%)	5.00	4.50	4.25
Dicalcium Phosphate (%)	1.00	1.00	1.00
Vegetable oil (%)	1.879	2.98	4.345
Lysine (%)	0.15	0.14	0.13
DL-methionine (%)	0.30	0.30	0.30
Choline Chloride (%)	0.05	0.05	0.05
Hepatocare (%)	0.10	0.10	0.10
Mineral mixture (%)	0.20	0.20	0.20
Common salt (%)	0.15	0.15	0.15
Vitamin Premix (%)	0.025	0.025	0.025
Coccidiostats (%)	0.05	0.05	0.05
Total (%)	100.00	100.00	100.00
Chemical composition (% DMB)			
Organic Matter (%)	90.95	91.63	92.94
Crude Protein (%)	22.39	21.76	20.29
Ether Extract (%)	4.47	7.07	7.18
Crude Fibre (%)	4.41	4.34	4.29
Nitrogen Free Extract (%)	59.68	58.46	61.18
Total Ash (%)	9.05	8.37	7.06
Metabolisable Energy (kcal/kg) (calculated)	2975.08	3011.13	3113.53

DMB, Dry matter basis.

Experimental birds, design and dietary treatments: The nutrient utilization and carcass traits in broiler chickens (n=120, day-old Vencobb) fed diets with or without supplementation of nano-chromium were assessed during the winter season (November 2020 to January 2021). Four dietary treatments, i.e. T_0, T_1, T_2, and T_3 were prepared by supplementing nano-chromium at the levels of 0, 400, 800, and 1600 ppb, respectively in pre-starter (0-7d), starter (8-21d) and finisher (22-42 d) diets to meet the nutrient requirements of broiler chicken as per recommendations of BIS (2007) (Table 1). All the experimental birds were individually weighed and randomly allocated using completely randomized design into four different treatment groups each with three replicates (30 birds per treatment) and reared for 42 days under a battery cage system at Instructional Poultry Farm (IPF), GBPUA&T, Pantnagar, Uttarakhand. The broiler chickens were provided *ad lib.* feed and water. The nano-chromium powder required for the trial was procured from Nano Research Element, New Delhi. The distribution of chicks was made in such a way that average body weight was similar for all experimental groups. Nutrient utilization and carcass traits were observed.

Estimation of nutrient utilization: To estimate nutrient retention, six chicks from each treatment designated for metabolic trial were kept in metabolic cages for 5 days, i.e. 2 days adaptation period followed by 3 days collection period. The experimental diets and fresh drinking water were made available *ad lib*. During the collection period, a weighed amount of feed was offered daily to all broiler chickens in the morning and the leftover feed was weighed the next morning at the same time. The daily feed intake and excreta voided were recorded and the weighed amount of excreta samples were placed in a hot air oven at 70°C for 48 h for estimation of dry matter, organic matter, and ether extract. However, for nitrogen estimation, weighed amount of fresh samples of excreta were preserved by adding 5 ml of 25% sulphuric acid (v/v) in wide-mouthed glass bottles with tightly closed lid and were estimated using the Micro-Kjeldahl method. For this purpose, 2 g of sample was taken in a Kjeldahl digestion flask and added with 4-5 g of digestion mixture (K_2SO_4 and $CuSO_4$ in a 9:1 ratio) and 25 ml of concentrated sulphuric acid was added. The mixture was digested till a blue/green transparent liquid was obtained. The digested mixture after cooling was transferred to a volumetric flask and the final volume was made up to 100 ml by adding distilled water. 25 ml aliquot of digested mixture was distilled in the presence of an excess of 40% sodium hydroxide in micro Kjeldahl's distillation aparatus (KELPLUS NITROGEN ANALYZER) and distillate was collected in 2% boric acid (w/v) solution containing 2-3 drops of Tashiro's indicator (10 ml of each 0.1% methyl red and 0.1% bromocresol green to 1000 ml of 2% boric acid solution). Simultaneously, a blank without a sample was similarly digested and distillated which was titrated against standard N/10 H_2SO_4. The percentage of nitrogen content present in the sample was determined as described below:

$$\text{Nitrogen}(\%) = \frac{{}^{T}\text{difference} \times N_{H2SO4}\ ) \times 0.014 \times V}{\text{Aliquot taken} \times \text{weight of sample taken (g)})} \times 100$$

Where, ^{T}difference, Sample titre-Blank titre (ml); N_{H2SO4}, Normality of H_2SO_4; V, Volume made up (ml).

The crude protein (CP) per cent in sample was calculated by multiplying nitrogen per cent with the factor 6.25.

The nutrient utilization was calculated by using the following formula:

$$\text{Nutrient utilization (\%)} = \frac{\text{(Nutrient intake - Nutrients excreted)}}{\text{(Nutrient intake)}} \times 100$$

The representative samples of experimental broiler pre-starter, starter, and finisher feeds as well as excreta obtained during the metabolic trial were collected and proximate analysis was conducted on the samples collected, using the standard procedures (AOAC 2000).

Determination of total carbohydrates: Total carbohydrate content in the sample was derived by deducting the total of crude protein, ether extract, and total ash per cent from 100.

Table 2. Nutrient utilization (%) in broiler chickens as affected by nano-chromium supplementation

Attribute	Treatments/ groups				
	T_0	T_1	T_2	T_3	SEM
Dry matter	73.98±0.23^{b}	74.72±0.55^{b}	77.43±0.32^{a}	77.59±0.56^{a}	0.50
Organic matter	75.28±0.38^{b}	79.64±0.58^{a}	79.66±0.90^{a}	79.79±0.54^{a}	0.29
Crude Protein	73.13±1.00^{c}	75.49±0.64^{bc}	78.17±0.89^{ab}	82.22±1.22^{a}	0.78
Ether Extract	74.34±0.60^{cd}	79.27±1.06^{ab}	82.46±0.93^{a}	83.36±1.09^{a}	0.75
Total Carbohydrate	71.60±0.68^{b}	74.05±0.94^{ab}	76.98±0.71^{a}	77.26±0.83^{a}	0.91

T_0, control; T_1, basal diet+400ppb nano-chromium; T_2, basal diet+800ppb nano-chromium; T_3, basal diet+1600ppb nano-chromium. Means with different superscripts $^{(a, b, c, d)}$ in a row differ significantly (p≤ 0.05) from each other.

Total carbohydrates (%) (On DM basis)= 100 – (CP% + EE% + Ash%)

Where, CP, Crude protein; EE, Ether extract.

Carcass traits: At the end of the trial (42 d), two birds were randomly selected from each pen (replication) and kept off feed overnight before slaughter, but drinking water was offered to them. The selected chickens were euthanized and directly taken to perform the following measurements: cut-up part yields (breast, thigh, drumsticks, back, neck and wing), and processing loss in terms of blood, feather, head, and shank were recorded and expressed as % of live weight. Abdominal fat located in the abdominal cavity, surrounding the intestines and around the heart, was separated, weighed, and expressed as % of the live body weight.

Statistical analysis: Statistical analysis of data obtained for nutrient utilization and carcass traits during the experiment was carried out by the apropriate method of analysis described by Snedecor and Cochran (1994) using the SPSS software (IBM SPSS Statistics 22) package. The variance ratio (F-values) was recorded as significant at 5% (p≤0.05) probability. Duncan's New Multiple Range Test (Duncan's Range Test) as modified by Kramer (1957), was used to test the significance of mean differences. The results are shown as means (±SE) and differences were considered significant with p≤0.05.

RESULTS AND DISCUSSION

Data obtained for the nutrient utilization and carcass traits in the entire experimental period (1-42 d) are reported in Table 2 and 3, respectively. The average values of dry matter utilization were significantly (p≤0.05) increased in treatment groups T_2 and T_3 which were supplemented with 800 and 1600 ppb nano-chromium, respectively when compared with the control group and T_1 group (400 ppb nano-Cr). There was significantly no difference (p≥0.05) between the control group and the T_1 group. Numerically similar values for dry matter utilization were found in T_2 and T_3 groups. Organic matter and ether extract metabolizability were significantly (p≤0.05) increased in all treatment groups when compared with control group T_0. There was no significant (p≥0.05) effect on organic matter and ether extract utilization among T_1, T_2 and T_3 treatment groups. Crude protein utilization was significantly (p≤0.05) increased in T_2 and T_3 groups in comparison to the control group. Crude protein metabolizability was statistically similar between the control group and T_1 group, T_1 and T_2, and T_2 and T_3 treatment groups. In relation to total carbohydrate utilization, there was significantly (p≤0.05) increased values in T_2 and T_3 groups from the control group while statistically similar to the T_1 treatment group. Our results are consistence with previous studies of Sahin

Table 3. Cut up parts, processing losses and abdominal fat (% live weight) of broiler chickens as affected by nano-chromium supplementation

Cut-up parts (% live weight)					
Parameter	T_0	T_1	T_2	T_3	SEM
Neck	3.23±0.09	3.28±0.08	3.34±0.06	3.19±0.16	0.11
Wing	7.53±0.17	7.44±0.15	7.41±0.14	7.39±0.15	0.84
Back	14.61±0.18	14.66±0.13	14.71±0.09	14.72±0.14	0.13
Breast	18.69±0.38	18.78±0.29	19.79±0.21	18.71±0.21	0.28
Thigh	10.11±0.27	10.45±0.32	10.75±0.29	10.36±0.20	0.29
Drumstick	8.21±0.36	6.86±0.22	7.45±0.36	7.78±0.27	0.31
Processing losses and abdominal fat (% live weight)					
Blood loss	3.36±0.18	3.16±0.16	3.13±0.10	3.29±0.12	0.148
Feather	5.58±0.12	5.73±0.09	5.05±0.27	5.18±0.19	0.17
Head	2.74±0.14	2.78±0.16	2.64±0.11	2.65±0.22	0.171
Shank	2.98±0.11	3.13±0.11	3.24±0.17	3.10±0.11	0.11
Abdominal fat	2.10±0.05^{a}	1.97±0.06^{abc}	1.78±0.04^{c}	1.83±0.05^{bc}	0.45

T_0, control; T_1, basal diet+400ppb nano-chromium; T_2, basal diet+800ppb nano-chromium; T_3, basal diet+1600ppb nano-chromium. Means with different superscripts $^{(a, b, c, d)}$ in a row differ significantly (p≤ 0.05) from each other.

and Sahin (2001) who observed that nutrient utilization in terms of dry matter, organic matter, crude protein, crude fat, crude fibre, and nitrogen-free extract was improved linearly ($p<0.01$) as well as quadratically ($p<0.01$) through dietary inclusion of chromium in the form of chromium picolinate in layer chickens under cold conditions ($p<0.01$). Similarly, Amatya *et al*. (2004) observed significantly increased utilization of dry matter, organic matter, crude protein, and ether extract with the addition of chromium in the form of potassium chromate, chromium chloride and chromium yeast in the diet of broiler chickens. Alike, Ahmed *et al*. (2005) concluded that crude protein and total carbohydrate utilization increased ($p<0.05$) when 0.2 mg chromium was suplemented with 50 mg ascorbic acid in broiler chickens ration. In the same way, Hussain *et al*. (2019) observed that the metabolisability of crude protein and ether extracts was significantly increased in treatment groups of *C. catla* fingerlings which were fed 2 mg/kg and 1.5 mg/kg of nano-chromium, respectively. The better nutrient utilization in the broiler chickens fed different levels of nano-chromium was possibly due to the role of chromium in the stimulation and regulation of insulin secretion that improved the anabolic processes. Chromium also acts as an anti-oxidative agent and protects pancreatic tissue that leads to increased pancreatic secretion including digestive enzymes and thereby improved nutrient metabolizability.

There was no alteration in average values for cut-up parts (neck, wing, back, breast, thigh, and drumstick) and processing loss (blood, feather, head, and shank) in treatment groups due to dietary supplementation of nano-chromium (Table 3). Moreover, the abdominal fat percentage was significantly ($p\leq0.05$) reduced in nano-chromium supplemented (T_2 and T_3 treatment) groups in comparison to the control group. Abdominal fat percentage was statistically ($p\geq0.05$) similar in the control and T_1 groups. There was no significant ($p\geq0.05$) difference among nano-chromium supplemented groups. The outcomes of the current study are in agreement with Haq *et al*. (2018) who carried out an experiment to assess the effect of supplementation of chromium yeast alone and in combination with 250 mg ascorbic acid or 250 mg vitamin E for designer broiler chicken meat and observed that chromium yeast alone did not affect dressing percentage, breast and thigh yield percentage. Similarly, Kashyap *et al*. (2018) did not spot significant difference in the carcass characteristics such as per cent processing shrinkage, dressing percentage, relative eviscerated weight, per cent giblet weight, and cut-up-parts, viz. thigh, drumstick, breast, back and neck among the treatment groups suplemented with chromium picolinate in coloured chicken. Likewise, study of Kulkari *et al*. (2018) revealed that dietary supplementation of chromium picolinate in broiler chicken did not affect cut-up parts, viz. breast, back, drumstick, thigh, and neck. Similarly, Arif *et al*. (2019) did not observe significant ($p>0.05$) differences in live weight, dressing percentage, eviscerated weight, breast weight, and legs with shank weight through Cr propionate supplementation. In addition, El-Kelawy (2019) recorded significantly reduced abdominal fat, whereas, visceral organs weight were not affected due to dietary supplementation of the organic form of chromium in broiler chickens. Likewise, Dosoky *et al.* (2020) did not find a significant difference in carcass yield, but a significant reduction in abdominal fat, bursa, and heart by dietary inclusion of chromium methionine in Japanese quail. Significant depreciation in abdominal fat in our study may be due to nano-chromium supplementation leading to increased glucose up-take by tissues through enhancement of insulin sensitivity that governs no extra glucose left in blood for lipogenesis in broiler chickens. Another possible reason is that chromium promotes lipid hydrolysis along with a decrease of the enzymes such as fatty acid synthetase, acetyl-CoA carboxylase, hormone-sensitive lipase, and lipoprotein lipase activity which are essential in fat metabolism, transportation, and fatty acids storage in broiler chickens. It is concluded that nano-chromium, which is product of nanotechnology, can be supplemented to the broiler diet at the level of 1600 ppb for better utilization of nutrients along with significant deprivation in abdominal fat which may have an implication for producing designer meat in broiler chicken.

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