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ESTIMATION OF THE RELATIVE BIOAVAILABILITY OF SEVERAL ZINC SOURCES FOR BROILERS WHEN FED A CONVENTIONAL DIET

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Abstract: An experiment was conducted with 312 day-old male broiler chicks in grower phase(8-28d) to estimate the biological availability of four sources Zinc (Zn), Zinc sulfate($ZnSO_4.H_2O$), two sources of Zinc oxide(ZnO FG1 and ZnO FG2) and Bioplex Zn. Zinc sulfate ($ZnSO_4.H_2O$) was used as the standard in the bioavailability assay. Chicks were allotted randomly to 13 dietary treatments with 6 birds per replicate and 4 replicates per treatment, that included an unsupplemented corn-soybean meal basal diet (25.50 mg of Zn/kg of DM), or the basal diet supplemented with 100, 150 or 200 mg/kg of DM as either $ZnSO_4.H_2O$ (33 % Zn), Zinc oxide FG1(72%Zn), Zinc oxide FG2 (75%Zn) or Bioplex Zn (15% Zn). Dietary Zn level and source had no effect ($P>0.05$) of feed intake or body weight gain of chicks during first and second weeks of experimental periods, but feed conversion ratio in the first and second week and feed intake, body weight gain or feed conversion ratio in third week and total experimental periods were significant difference between treatments ($P<0.05$). The relative biological availability values using body weight gain were estimated to be 59, 99 or 45 for three levels of Zinc oxide FG1, 64, 78 or 31 for three levels of Zinc oxide FG2 and 151, 200 or 147 for three levels of Bioplex Zn, respectively. From the standpoint of bioavailability, Bioplex Zn was more available to broiler chicks than Zn from other sources and can be used by the feed industry as sources of supplemental Zn for broiler chickens.

Key words: Zinc, Bioavailability, Chicks, Performance

Introduction

Zinc is an essential trace element that is required for growth, bone development, feathering, enzyme structure and function, and appetite for all avian species, Zinc is commonly added as a supplement to all formulated poultry diets.

Because many natural feed ingredients are marginally deficient in Zn (*Falchuk and Vallee, 1985; Kaim and Schwederski, 1994*). The current (NRC,1994) zinc requirement for broilers is 40 mg/kg, that based upon research conducted more than 40 yr ago with animals of markedly different productive potential than those that exist today, also this requirement is based on only a few research reports, most of which were carried out using purified or semipurified diets with growth as the only requirement criterion (*Roberson and Schaible, 1958; Zeigler et al., 1961; Emmert and Baker, 1995*). Dietary Supplementation by inorganic trace minerals have traditionally provided with sufficient amounts of each mineral to support normal growth, health, and reproduction. However, genetic improvements continually change the commercial broiler strains, and nutritionists start to question if currently used trace mineral levels and sources will be suitable in the future when feeding these faster-growing and highly productive birds for meat and eggs (*Nollet et al., 2008*). Considerable confusion exists concerning bioavailability of Zn in various Zn supplements for chickens and pigs. Using weight gain as a response variable, *Edwards (1959)* reported that Zn from analytical grade (AG) and technical grade ZnO as well as Zn metal powder was 100% bioavailable for young chicks relative to AG $ZnSO_4.7H_2O$. The next year, *Roberson and Schaible (1960),* also using chick weight gain as the response variable, reported that ZnO was as bioavailable as ZnSO4, but they did not clearly identify either compound. *Miller et al. (1981)* compared AG ZnO to Zn metal dust in pigs fed a corn-soybean meal diet. *Wedekind and Baker (1990)* reported relative bioavailability (RBV) values for chicks fed feed-grade (FG) Waelz-processed ZnO of 61% (weight gain) and 44% (total tibia Zn) compared with FG $ZnSO_4.H_2O$ (100%). *Wedekind et al. (1994)* concluded, based on bone Zn accumulation in pigs, that FG ZnO was only approximately 68% as bioavailable as FG ZnSO4.H2O. Edwards et al. (1998) evaluated two byproducts of the galvanizing industry, Fe-ZnSO4.H2Oand Zn-FeSO4 .H2O, and found both to be as bioavailable, based on weight gain and total tibia Zn, as FG $ZnSO_4.H_2O$. Many experiments have been conducted during the last 50 yr to estimate the bioavailability of Zn in supplemental sources and dietary ingredients; however, there are considerable confusion concerning bioavailability of this nutritionally trace element in various supplements for chickens and pigs. Using weight gain as a response variable, *Edwards (1959)* reported that Zn from analytical grade and technical grade ZnO as well as Zn metal powder was 100% bioavailable for young chicks relative to analytical grade ZnSO4.7H2O. Some researchers (*Spears, 1989;Wedekind et al., 1992*) have reported greater bio-efficacy for organic Zn sources than that observed for inorganic forms, including Zn oxide and Zn sulfate; consequently, organic forms of the trace element have been used with increasing pattern by the feed industry. An enhanced bioavailability of a mineral source could reduce the amount of a mineral that is added to a diet to meet mineral nutritional requirements, which would reduce the amount of mineral excreted by birds (*Cheng et al., 1998*). The use of organic complexes of trace element, such as Zn-lysine (ZnLys) and Zn methionine (ZnMet), has received more attention because of The data reported by *Wedekind et al. (1992)* indicated that, for chicks fed corn-soybean meal diets, Zn from a Zn methionine complex was 206% bioavailable relative to a ZnSO4.H2O standard (i.e. 100%), where ZnO provided only 61% bioavailable Zn. There are conflicting data reported regarding the relative efficacy of different organic versus inorganic Zn sources in enhancing broiler performance. The research presented herein, therefore, aimed to compare bio-efficacy of various inorganic and organic Zn compounds in the light of their effects on the performance of broiler chicks fed corn-soybean meal diets.

Materials and Methods

Birds, treatments and managing program

This study was conducted in the poultry research farm of Tabriz University (Tabriz, Iran). A total of 312 day-old Ross308 male broiler chicks were randomly allotted to four pen replicates of six birds for each of 13 dietary treatments such that each pen had a similar initial weight and weight distribution.

Table 1: Composition of the basal diets

Ingredients (%)	(8-28d)
Corn	55.90
Corn Starch	0.05
Soybean meal	36.60
Soybean oil	3.60
Di-Calcium phosphate	1.50
Caco3	1.35
Salt	0.25
DL-methionine	0.15
L-lysine	0.10
Vitamin premix[a]	0.25
Zn free mineral premix[b]	0.25
Nutrient composition	
Metabolizable energy (Kcal/kg)	3000
Crude protein(%)	21.00
Calcium	0.95
Available Phosphorus(%)	0.44
Lysine (%)	1.19
Methionine (%)	0.49
Zinc (mg/kg)	25.50

a:Supplied per kg diet: 11,025 I.U. vitamin A, 3,528 I.U. vitamin D3, 33 I.U. vitamin E, 0.91 mg; vitamin K, 2 mg thiamin, 8 mg riboflavin, 55 mg niacin, 18 mg Ca pantothenate, 5 mg vitamin ;B6, 0.221 mg biotin, 1 mg folic acid,478 mg choline, 28 µg vitamin B12

b:Zinc-free mineral premix. Provided per kilogram of diet: Mn (fromMnSO4 H2O), 60 mg; Fe (from FeSO4 7H2O), 50 mg; Cu (from CuSO4 5H2O), 6 mg; I (from Ca (IO3)2 H2O), 1 mg; Se, 0.20 mg.

The basal corn-soybean meal diets (Table 1) containing 25.50 mg Zn/kg as fed basis (by analysis) were formulated to meet or exceed nutritional requirements of broiler chicks (NRC, 1994) grower stages from 8-28 d. Dietary treatments included the basal diet or basal diet supplemented with 100, 150, or 200 mg/kg added Zn as feed-grade Zn sulfate , Zn oxide feed- grade1, Zn oxide feed- grade2 and Bioplex Zn (as organically Zn compounds). The basal diets were formulated using Zn-free mineral premix, so that contained minimum amount of zinc. A single batch of basal feed was mixed and divided into 13 aliquots according to the experimental treatment, Each Zn source was mixed with cornstarch to the same weight and mixed with each aliquot of the basal diet. All of the diets were calculated to contain equal concentrations of methionine, lysine and other nutrients except of Zn. Chicks were housed in the cage pens which placed at thermostatically-controlled room. Chicks were maintained on a 24 h constant lighting regimen and had free access to feed and tap water containing no detectable Zn in all times. Feed and water were provided using plastic instruments to minimize environmental Zn contamination.

Chemical analysis

Prior to formulating the diets, the ingredients and Zn sources used were analyzed for crude protein, ether extract, crude fiber, and ash content according to standard procedures (AOAC,1995). Zinc concentrations in Zn sources, diets and water were determined by atomic absorption spectrophotometery (Perkin Elmer, Precisely A Analyst 200, Absorption spectrophotometer).

Data collection

Body weight, body weight gain, feed conversion ratio and Zn intake were recorded weekly and overall experimental period. Relative bioavailability values were estimated by a slope ratio techniques from regression of weight gain on Zn intake with ZnSO4.H2O as the standard source at 100% *(Finney,1978, Littell et al., 1997*). Because feed intake differences among treatments could affect Zn intake, regressions were calculated using dietary Zn intake (based on Zn assays of diets) as the independent variable rather than added Zn concentrations (*Wedekind et al., 1992, Li et al.,2004*).

Statistical analysis

Pen means data were subjected to ANOVA procedures of SAS, PC version 6.12 (1999), appropriate for completely randomized designs. Regression equations for the $ZnSO_4.H_2O$ standard curves were derived using Minitab 10. Weight gain was regressed on supplemental Zn intake from ZnSO4.H2O, and Zn bio-availabilities in the test sources of Zn were determined using standard-curve methodology .Relative bioavailability estimates were calculated for each of the four replicate pens that were fed each experimental Zn source. Duncan's multiple range tests (*Duncan, 1955*) was used to separate treatment means at p<0.05 significant level.

Results and discussion

Chemical characteristics of mineral sources are presented in Tables 2. The Zinc sources studied herein (zinc sulfate, Zinc oxide FG1, Zinc oxide FG2 and Bioplex Zn) were determined to be containing 32, 72, 75 and 15% zinc as fed basis, respectively.

Table 2. Characterization of zinc sources under investigation

Zn source[a]	Zn level, %[b]	Color
$ZnSO_4.H_2O$(FG)	33	White
ZnO(FG 1)	72	White
ZnO(FG 1)	75	White
Bioplex Zn[c]	15	Yellow

a FG: feed grade.
b Determined from atomic absorption spectrophotometery.
c Supplied by Alltech Biotechnology

The effects of source and supplemental zinc level on performance parameters are shown in Table 3. The Zn source and concentration did not affect Feed intake (FI) or weight gain (WG), in the first or second week and body weight (BW) in 14 d,21d and 28d ($P>0.05$) but feed conversion ratio(FCR) in all experimental periods, Feed intake (FI) or weight gain (WG) in the third week and overall trial periods were, significantly ($p<0.05$) affected by zinc sources (Table 3). In the first week of trials, the best FCR was observed in the 100 ppm levels of Bioplex Zn, 200 ppm levels of Zn oxide FG1 and 150 ppm levels of Zinc sulfate. In the second weeks, all of zinc sources in different levels had significant effects on FCR, but the lowest FCR was observed in 150 ppm levels of Bioplex Zn in diet. In the third week, the highest feed intakes were assigned to chicks fed on Zinc oxide FG1 supplemented diets with 150 ppm. The lowest feed intakes were attributed to Bioplex Zn supplemented with 150 ppm. The highest weight gain were shown in the 200 ppm of Zn sulfate, 150 ppm of Zinc oxide FG1 and Zinc oxide FG2($P<0.05$). FCR in different Zn sources except 200 ppm of Zinc oxide FG2 had significant difference with basal unsupplemented diet ($P<0.05$). In the entire experimental periods, the lowest and highest FI were observed in the 150 ppm of Zinc sulfate and 150 ppm of Zinc oxide FG1, respectively ($P<0.05$). Regardless WG only 150 ppm of Zinc oxide FG1 had significant difference rather than basal unsupplemented diet ($P<0.05$). The better FCR was observed in all experimental treatments except 200 ppm levels of Zinc oxide FG2 in comparing with basal unsupplemented diet ($P<0.05$) (Table 3).

Table 3. Effect of zinc source and dietary zinc concentration on growth performance of broilers fed with conventional corn- soybean meal diets

Zinc source	Added Zn,ppm	d 8-14			BW 14d	d 15-21			BW 21d	d 22-28			d 8-28			BW 28d
		FI	WG	FCR		FI	WG	FCR		FI	WG	FCR	FI	WG	FCR	
Control	0	270.75	177.83	1.52^{b}	317.16	393.99	204.95	1.92^{a}	522.11	580.25^{abc}	311.50^{ab}	1.86^{c}	976.24^{ab}	694.28^{a}	1.40^{c}	833.61
Sulfate	100	253.54	178.99	1.41^{a}	314.74	412.83	239.12	1.72^{b}	553.86	571.74^{abc}	331.70^{abc}	1.72^{ab}	998.08^{ab}	749.82^{ab}	1.33^{a}	885.57
	150	243.16	172.99	1.40^{a}	320.03	385.66	218.78	1.76^{b}	538.82	526.29^{a}	316.49^{ab}	1.66^{a}	945.32^{a}	708.28^{ab}	1.33^{ab}	855.31
	200	251.16	176.87	1.42^{a}	329.87	408.45	229.33	1.78^{b}	559.20	605.64^{ab}	354.28^{c}	1.70^{ab}	1013.91^{ab}	760.49^{ab}	1.33^{a}	913.49
Oxide FG1	100	254.79	176.37	1.44^{ab}	314.47	408.35	229.45	1.78^{b}	543.93	585.20^{abc}	343.33^{bc}	1.70^{ab}	1006.48^{ab}	749.15^{ab}	1.34^{ab}	887.26
	150	275.33	192.45	1.43^{ab}	335.24	430.24	237.45	1.81^{b}	572.69	613.45^{c}	354.87^{c}	1.72^{ab}	1060.45^{b}	784.78^{b}	1.35^{ab}	927.56
	200	256.12	186.29	1.38^{a}	321.12	426.83	235.12	1.81^{b}	556.24	562.46^{abc}	323.66^{abc}	1.73^{ab}	1006.62^{ab}	745.07^{ab}	1.35^{ab}	879.90
Oxide FG2	100	250.58	173.08	1.44^{ab}	314.15	357.79	201.37	1.77^{b}	515.52	589.95^{bc}	342.37^{bc}	1.72^{ab}	950.74^{ab}	716.82^{ab}	1.32^{a}	857.89
	150	255.79	175.58	1.45^{ab}	315.16	400.45	230.66	1.73^{b}	545.82	604.66^{bc}	358.41^{c}	1.68^{a}	1014.66^{ab}	764.66^{ab}	1.32^{a}	904.24
	200	264.79	182.29	1.45^{ab}	312.57	420.03	231.40	1.81^{b}	543.98	548.25^{ab}	303.50^{a}	1.80^{bc}	988.32^{ab}	717.36^{ab}	1.37^{bc}	847.48
Bioplex	100	266.29	187.25	1.42^{a}	319.37	418.99	232.37	1.80^{b}	551.74	560.75^{abc}	333.25^{abc}	1.68^{a}	1018.53^{ab}	752.87^{ab}	1.35^{ab}	884.99
	150	254.00	173.08	1.46^{ab}	279.58	378.62	221.87	1.70^{b}	501.45	546.12^{ab}	327.75^{abc}	1.66^{a}	960.37^{ab}	772.99^{ab}	1.32^{a}	829.20
	200	246.16	170.12	1.44^{ab}	302.08	381.29	219.33	1.74^{b}	521.41	567.75^{abc}	326.58^{abc}	1.73^{ab}	954.03^{ab}	716.03^{ab}	1.33^{a}	847.99
Sig.*		ns	ns	*	ns	ns	ns	*	ns	*	*	*	*	*	*	ns
SEM**		2.71	2.10	0.007	4.70	60.03	3.35	0.011	7.02	5.67	3.42	0.011	9.20	6.67	0.004	8.75

FCR: Feed Conversion Ratio; BW:Body Weight. FI: Average daily feed Intake. BWG: Body Weight Gain

In the same colum differently superscripted are significantly ($P<0.05$) different.

* ns: nonsignificant **Std.Error Mean

As presented in Table 4, the relative biological availability values using body weight gain as criteria were estimated to be 59, 99 or 45 for three levels of Zinc oxide FG1, 64, 78 or 31 for three levels of Zinc oxide FG2 and 151, 200 or 147 for three levels of Bioplex Zn, respectively. The highest RBV of different Zinc sources was observed in the 150 ppm levels of these sources when used in diets.

Table4. Estimated relative Zn bioavailability values of weight gain(g/21d) on dietary zinc sources intake (mg/21d) (Zn from $ZnSO_4.H_2O$ set at 100%)[a]

Zinc source	Added Zn,ppm	Regression equation[b]	RBV(%)[c]	R^2
	100	Y= 135+8.87X	100	0.86
Sulfate	150	Y=239+5.81X	100	0.93
	200	Y=-79.7+8.16X	100	0.98
	100	Y=154+5.25X	59	0.86
Oxide FG1	150	Y=-35+5.15X	99	0.91
	200	Y=37.5+3.75X	45	0.99
	100	Y=124+5.69X	64	0.91
Oxide FG2	150	Y=95+4.54X	78	0.94
	200	Y=265+2.52X	31	0.53
	100	Y= 37.3+13.4X	151	0.96
Bioplex	150	Y=55+11.6X	200	0.94
	200	Y=-57.2+12X	147	0.98

aData are means of four pens of six male chicks fed the experimental diets for 21d (d 8 to d 28 posthatching); average initial weight was 92 g.

bStandard curve for weight gain (Y, in g/21 d) regressed on supplemental Zn intake (X, in mg/21 d) from different zinc sources.

cRelative bioavailability (RBV) was calculated from the standard curve regressions, setting RBV of Zn in the ZnSO4.H2O standard at 100%.

Supplementation of Zn to the basal diet at graded levels had no significant influence on body weight gain and feed intake at 3week of age (Table 3). This was in agreement with the findings of *Burrell et al. (2004)* who found that a practical diet of maize-soybean meal containing 30 ppm of Zn was adequate to support optimum performance during the initial 3 week of age. Similarly, others (*Stahl, et al., 1986*) reported that a basal diet containing 37 ppm of Zn was optimum for realizing good growth in chicks and additional supplementation had no added advantage. In another study with male broiler chicks, little effect was found on body weight, feed efficiency, or livability with supplementation of Zn up to 6 week of age because the basal diet contained 44 ppm of Zn. The present study also indicated that the Zn content available in cornsoybean diet (25.50 ppm) was adequate to sustain growth and other related parameters at par with those supplemented with Zn up to 4 week of age. Obviously, this level was lower than that recommended by NRC (1994) (40 ppm) for broiler chicks. The absence of any difference in performance between groups fed diets with or without supplemental Zn could be due to slower rate of Zn utilization, necessitating no further replenishment in diets *(Collins and Moran, 1999)*. The lack of increase in feed intake or body weight gain with added Zn in this phase indicates that the amount of the element in the non-supplemented basal diet was adequate for growth specially until 21 day of life despite of the fact that NRC *(1994)* suggested that 40 mg/kg as the requirement for broiler chicks. The contribution of Zn from the remaining yolk sac and easier permeability of the still developing gastrointestinal tract may have contributed to this observation (*Cao et al., 2002)*. Also the lack of responses in feed intake and weight gain to added Zn levels up to 100 ppm, probably due to increased synthesis of intestinal metallothionein. Zinc intake has been shown to induce intestinal metallothionein synthesis *(Sandoval et al., 1997)*. Increased synthesis of this zinc binding protein is associated with reduced zinc absorption. This protein will influence the regulation of Zn absorption and possibly the response of broiler chicks to supplemental levels of zinc from different sources. But the improvements effects of adding different zinc sources of FCR in week3 and total experimental periods indicated that the using of this supplement might be suitable in practical diet of broilers in grower phase. Bioavailability of trace minerals is defined as the proportion of the ingested element that is absorbed, transported to its site of action, and converted to a physiologically active form *(Ammerman et al., 1995)*. Thus, bioavailability implies not only absorption but also utilization of the mineral for a specific function. However, it is difficult to quantitatively evaluate the actual utilization of an element with a response criterion of sufficient sensitivity to determine statistical differences with a small population of animals *(Li et al., 2005)*. The old experiments designed to assay the bioavailability of Zn usually used purified diets supplemented with low concentrations of Zn and growth performance and tibia Zn concentration as the response criteria (*Edwards, 1959; Wedekind and Baker, 1990*). But, the estimate determined in a purified diet might not be applicable to practical diets because of the absence of phytate and fiber (*Wedekind et al., 1992)*. Therefore, the later experiments were designed to use a corn-soybean meal diet with a short-term, high-supplemental Zn to determine relative bioavailability based on weight gain as a simple assay factor *(Cao et al., 1996, 2000; Sandoval et al., 1997)*. The method offers several advantages in assessing Zn bioavailability such as: minimizing the effect of decreased feed intake and also the applicability of the results to commercial conditions, the diet is less expensive than semi-purified or purified diets, the diet more palatable, therefore enabling maximum genetic growth potential and the extrapolative value of the results is good, because the conventional soybean meal diet is like to that used in commercial conditions

(*Wedekind et al.,1992*). Based on those findings, a practical corn soybean meal diet (25.50 mg of Zn/kg) and 4 supplemental Zn concentrations (0, 100, 150, 200 mg Zn/kg) were chosen in our study. In this experimental design, finding a criterion that responds in a linear manner to dietary added Zn intake is most difficult and important. Weight gains is one method to measure utilization but is generally a fairly unresponsive criterion for many mineral elements (*Luo et al., 2007*). In the present study, bioavailability estimates of Zn from the tested sources were based on weight gains (Table 4) the best relative bioavailability value (RBV) was observed in 150 mg of Zn/kg of basal diet in different Zinc sources relative to Zinc sulfate as a standards. Also three levels of the Bioplex Zn had higher RBV than other Zinc sources. The lower bioavailability observed for Zn oxide sources compared to Zn sulfate in the studies reported herein is in agreement with *Wedekind and Baker (1990).* The feeding study performed by *Leeson (2003)* showed that the bioavailability of proteinated forms of elements supplemented to the diet for broilers was at least by 30% higher than that of inorganic forms of elements. The greater bioefficacy of ZnMet and/or ZnLys relative to sulfate or oxide forms suggests that the metabolism of these Zn complexes differs from metabolism of Zn supplied by inorganic Zn sources. These results would suggest that the major differences in Zn bioavailability among different Zn sources can be attributed to differences in absorption, and that once absorbed, differences in Zn utilization among sources reflect differences in net utilization. These differences in utilization may reflect differences in endogenous Zn loss, which has been shown to increase due to homeostatic mechanisms with increasing Zn absorption *(Weigand and Kirchgessner, 1980).* In poultry and swine nutrition, it is difficult to avoid the presence of phytates as they are the main storage forms of P in seeds. Diets based on corn and soybean meal generally contain between 2.0 and 2.5 g phytic P / kg. Zinc content in feed components from plant origin is positively correlated to the phytic P content, with ~10 mg of Zn to 1 g phytic P **(***Revy et al., 2003***).** It is suggested that Zn from organic sources is protected by the ligand from reacting with feed antagonists, such as phytate to form insoluble complexes. Zinc from organic sources is absorbed by the intestinal cells as an ion, or it is also suggested that Zn is absorbed intact thanks to a second absorption pathway related to the ligand. Also a review of Zn bio-availability data *(Ledoux, 2005; Wedekind et al., 1992)* indicates that in most studies, organic mineral sources were at least as available as the standard inorganic sources, and in some cases were more available. One of the hypothesized reasons for increased bioavailability of organic minerals is that this form of mineral is protected form unwanted interactions in the gastrointestinal tract. Conversely, some reports have shown no influences of complexing with an organic ligand (protein, methionine, or lysine) on mineral (Zn and Mn) bioavailability (*Aoyagi and Baker,1993; Pimental, et. al., 1991;Baker and Halpin,1987*).The discrepancy of the results in different experiments might be relate to the difference in the age of the chicks when feeding high Zn commenced, duration of feeding, dietary Zn concentration, and previous body stores.

Conclusion

The results of this study showed that in corn soybean meal diets the highest RBV of different zinc sources were observed in 150ppm concentration, and Bioplex Zn was more bio-availabile than zinc sulfate or zinc oxide in practical diets.

Procena relativne biološke dostupnosti nekoliko izvora cinka u ishrani brojlera konvencionalnom obrokom

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Rezime

Ogled je izveden sa brojlerskim pilićima muškog pola, u fazi porasta (8-28d) u cilju procene biološke dostupnosti četiri izvora cinka (Zn), cink sulfat ($ZnSO_4.H_2O$), dva izvora cink oksida (ZnO FG_1 i ZnO FG_2) i Bioplex Zn. Cink sulfat ($ZnSO_4.H_2O$) je korišćen kao standard u ispitivanju biološke dostupnosti. Pilići su nasumično podeljeni u 13 prehrambenih tretmana sa po 6 grla po ponavljanju i 4 ponavljanja po tretmanu, koji je uključivao obrok na bazi kukuruza i sojine sačme (25.50 mg Zn / kg SM), ili osnovni obrok dopunjen sa 100, 150 ili 200 mg / kg SM bilo kao $ZnSO_4.H_2O$ (33 % Zn), cink oksid FG1(72% Zn), cink oksid FG2(75% Zn) ili Bioplex Zn(15% Zn). Nivo Zn u obroku kao i izvor nisu imali uticaj ($P>0.05$) na unos hrane ili prirast brojlera tokom prve i druge nedelje eksperimentalnog perioda, ali kod parametara konverzija hrane u prvoj i drugoj nedelji ogleda, kao i unosa hrane, prirasta i konverzije u trećoj nedelji, kao i u celom ogledu, utvrđene su signifikante razlike između tretmana ($P<0.05$). Vrednosti relativne biološke dostupnosti koristeći prirast telesne mase su sledeće - 59, 99 odnosno 45 za tri nivoa cink oksida FG1, 64, 78 odnosno 31 za tri nivoa cink oksida FG2 i 151, 200 odnosno 147 za tri nivoa Bioplex Zn, respektivno. Sa stanovišta biološke dostupnosti, Bioplex Zn je bio dostupniji brojlerima nego Zn iz drugih izvora i može se koristiti u industriji stočne hrane kao izvor dodatnog Zn za brojlerske piliće.

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