Vol. 12 · March 2013
Print ISSN 2012-3981 • Online ISSN 2244-0445
doi: http://dx.doi.org/10.7719/jpair.v12i1.212

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by AJA Registrars, Inc.

Effects of Different levels of Zinc in the Performance and Meat Zinc Contents of Broilers

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ABSTRACT

Zinc is one of the most deficient microminerals. For poultry, NRC (1994) recommended 40 ppm only but, commercial feeds contain more than 100 ppm resulting to toxicity. Zinc oxide is commonly used inorganic forticant but, its safety is questionable compared to organic counterpart. Generally, the study aimed to determine the effects of different levels of zinc oxide and zinc methionine in the performance of broilers and their meat content at 36 and 42 days. To address the latter, two experiments (experiment 1, zinc oxide and experiment 2, zinc methionine) were conducted and gathered data were analysed using ANOVA. Results showed that in both experiments, the performance and meat zinc contents were not affected but, the parts were affected showing highest zinc content in the liver, followed by the thigh and legs, and the wings. Lowest amount was noted in the breast. Fortification, up to 36 days of feeding was found to be enough. In fortification programs, it is recommended to use organic minerals.

Keywords **-** Animal Nutrition, Fortification, Meat, Zinc, Philippines

INTRODUCTION

Zinc is the most ubiquitous and metabolically active of all the trace minerals in the body. It is a co-factor or activator of more than 200 enzymes, participates in all major biochemical pathways and plays multiple roles in the perpetuation and expression of gene including transcription of DNA, translation of RNA and cell division. In addition, it facilitates the folding of proteins into three-dimensional configurations called "zinc fingers" that enable them to carry out their biological activity (Klasing1998; Holtz and Brown, 2004).

The US National Research Council (NRC) in 1994 set 40 mg/kg as the minimum requirement for zinc in poultry, but commercial feeds contain more than 100 mg/kg regardless of the kind. However, the concentrations of zinc being used in the feed industry also vary. Zinc oxide as one of the commonly used inorganic form and usually prepared in much higher concentration compared to their organic counterpart. Its feed grade has 72-81% zinc while its analytical grade is 79.6% (Wedekind and Baker, 1990). The organic or chelated zinc contains as low as 16% zinc only.

In food fortification programs, feed grade zinc oxide is commonly utilized as forticant (Shrimpton *et al.* 2005). Since it is inorganic, its relative safety is questionable because of the possibility of either acute or chronic toxicity (Reilly, 2004). In addition, like other inorganic forms of zinc, zinc oxide is less bioavailable. It can be antagonized by other substances in the system like phytate and eventually excreted. This is one of the probable reasons why inorganic minerals are prepared in much higher concentration. Although counteracted by antagonists, the assumption is that a small amount of the inorganic mineral may still be left to carry out its function.

Because of these controversies, organic or chelated minerals were launched in the market. Some are using amino acids as ligand aside from the usual metal ions since the utilization of which will add up to the protein content of the diet. In this study, the ligand of the organic zinc is HMBTA (2-hydroxy-4-(methylthio) butanoic acid) which is considered as an organic acid and not an amino acid. In the body, it is converted to L- methionine making it a methionine precursor (Yi *et al.*, 2007).

NRC (1994) recommends only 40 ppm of zinc in poultry diet regardless of its kind. Since zinc has antagonistic, acute or chronic toxicity effect, feed manufacturers and food fortifiers should be properly guided. In order to deal with this problem, the present study was done to determine the optimum level/s of either inorganic (in the form of zinc oxide) or organic (in the form of zinc methionine) zinc that would serve as a guide for food and feed manufacturers particularly for commercial chicken production.

OBJECTIVES OF THE STUDY

Generally, the study aimed to determine the effects of the different levels of zinc oxide and zinc methionine on the performance and meat zinc contents of broilers. Specifically, it aimed to:

1. determine the effects of zinc on production parameters such as feed intake, body weight, body weight gain and feed conversion efficiency.
2. determine the effects of zinc on the zinc contents of the different meat cuts at 36 and 42 days of harvest.
3. compare the meat zinc contents at 36 and 42 days of harvest.

MATERIALS AND METHODS

Acquisition of Test Materials

Two zinc preparations were used in the study. Zinc oxide containing 81.4% zinc and zinc methionine containing 16% zinc with purity of ninety nine percent (99%) and one hundred percent (100%), respectively. Other feed ingredients like corn, soybean meal, soybean protein concentrate, fishmeal, etc were purchased and stored in a refrigerated (4°C) stock room until they were used in mixing the diets.

Experiment 1. Zinc oxide

A total of two hundred thirty (230) day-old straight run Cobb broiler chicks were randomly distributed into four treatments following a Completely Randomized Design (CRD) in 8 stainless cages with 16 birds per cage.

Each treatment was replicated twice and, the dietary treatments were as followed:

Treatment	Description
Treatment 1	Control diet, without additional zinc oxide
Treatment 2	Diet with 40 ppm zinc oxide (32.23 ppm zinc)
Treatment 3	Diet with 80 ppm zinc oxide (64.47 ppm zinc)
Treatment 4	Diet with 120 ppm zinc oxide (96.70ppm zinc)

Experimental Diets

The broiler booster, starter and finisher diets (Table 1) were formulated following the NRC's (1994) recommendation to contain 22.89%, 20.14% and 18.23% crude protein (CP) and 3000 metabolizable energy (ME kcal/kg), respectively.

Feeding Trial

The day-old broiler chicks were brooded in a stainless cage measuring 114.3 x 114.3 cm for three (3) weeks. Chicks were fed booster feed for twenty (20) days and from 21 to 28 days, starter feeds was offered. Similarly, the birds were also transferred to eight (8) floor cages measuring 1.5 x 0.5 meters on the 22nd day. On the 29th and 42 day, finisher feeds was offered. Feeds and water was made available to the birds at all times.

Table 1. Ingredient composition (%) and calculated nutrient content of the basal diet

Ingredients	Booster	Starter	Finisher
Corn	61.1	64.5	54.4
Soybean meal	28.0	27.5	28.3
Soybean protein	5.0	2.8	28.3
Wheat bran			6.9
Limestone	1.5	1.5	1.3
Continued..			
Calcium phosphate	1.4	1.3	1.0
Salt	0.2	0.2	0.2
Vitamin premix[1]	0.1	0.1	0.1
Mineral premix[2]	0.1	0.1	0.1
Methionine	0.2	0.1	0.1
Choline chloride	0.1	0.1	0.1
Soybean oil	2.2	1.8	7.4
Calculated Nutrient Content			
Crude protein (%)	22.89	20.14	18.23
Metabolizable energy(Kcal/kg)	3005.00	3004.00	3003.00
Lysine (%)	1.20	1.00	0.94
Zn(ppm)[3]	35.16	36.36	38.32

[1] Vitamin premix provided the following per kg of diet: Vitamin A: 5000 IU; Vitamin D 500 IU; Vitamin E: 20 IU; Vitamin K1: 1 mg; Thiamin: 1.8 mg; Riboflavin 5.4 mg; Niacin: 27 mg; Vitamin B: 4.2 mg; Vitamin B12: 0.03 mg; Folic acid: 0.55 mg; Biotin: 0.16 mg; Ca pantothenate: 10 mg

[2] Trace mineral premix supplied the following per kg of diet: $CuSO_4.5H_2O$ 34.9 mg, $MnSO_4.H_2O$ 207.2 mg, Na_2SeO_3 0.4 mg, and $FeSO_4.7H2O$ 442.5 mg.

[3]The computed zinc contents of the basal diets obtained from the different zinc contents of the ingredients. Zinc oxide (81.4% zinc) or zinc methionine (16% zinc) was added at 40 ppm, 80 ppm and 120 ppm in the different treatments to contain 32.23 ppm, 64.47 ppm and 96.70 ppm for Treatments 2, 3 and 4 of Experiment 1, respectively. For Experiment 2, the computed values were only 6.4, 12.8, and 19.2 ppm for Treatments 2, 3 and 4, respectively.

To compute the production performance of the broilers such as feed intake, body weight, body weight gain and feed conversion efficiency, daily recording was observed. To determine the zinc contents of the birds at thirty six (36) and forty two (42) days, three to four birds from each replicate were obtained to determine the zinc contents of the different prime cuts namely: thigh and legs, wings, breast, and liver.

Parameters Gathered

Production parameters

*Initial body weight and body weight gain***.** The average initial body weight for each replicate and each treatment was determined by dividing the total group weight by the number of birds in each lot. The average cumulative body weight during the booster, starter and finisher periods were obtained by subtracting the initial weight from their corresponding body weights on the growth stages mentioned.

Feed intake. The amount of feeds given each day from day 1 until the harvest was recorded and the amount of leftover feeds weighed every three (3) days were used as subtrahend to the total amount of feeds offered to birds for a period of three (3) days. However, the total feed intake was presented on a weekly basis.

*Feed conversion efficiency***.** The average cumulative feed efficiency of the birds in each replicate was calculated by dividing the average cumulative feed consumption by their respective average body weight gain.

Zinc contents of meat

The zinc contents of the different meat prime cuts were obtained at ages thirty six (36) and forty two (42) days and were analyzed for zinc content using atomic absorption spectrometer (Perkin Elmer 2000).

Experiment 2. Zinc methionine

Experimental Design and Birds

The experimental design, number of birds used and replications were similar to that in Experiment 1 except for the source of zinc. The four (4) treatments are as follows:

Treatment	Description
Treatment 1	Control diet, without additional zinc
Treatment 2	Diet with 40 ppm zinc methionine (6.4 ppm zinc)
Treatment 3	Diet with 80 ppm zinc methionine (12.8 ppm zinc)
Treatment 4	Diet with 120 ppm zinc methionine (19.2 ppm zinc)

Treatment 1 in this experiment utilized the same control group used in Experiment 1.

Experimental Diet

Ingredient composition and nutrient content of diets were the same as that in Experiment 1 except that Zinc methionine was used instead of Zn Oxide. Since the zinc content of zinc methionine was 16%, and the purity was 100% with the inclusion of 40 mg, 80 mg, and 120 mg of zinc methionine, the additional zinc content of the diets were 6.4 ppm for Treatment 2, 12.8 ppm for Treatment 3 and 19.2 ppm for Treatment 4.

Feeding Trial

Same procedural management was followed as in Experiment 1.

Parameters Gathered

All data gathered in this experiment were similar to that in Experiment

RESULTS AND DISCUSSIONS

Experiment 1. Zinc oxide

Production performance

Table 2 presents the cumulative production performance of broilers fed diets with different levels of zinc oxide. Results showed no significant differences on the feed intake, body weight, body weight gain as well as feed efficiency.

Table 2. Cumulative production performance of broilers fed diets with different levels of zinc oxide

Parameters	Treatment			
	1	2	3	4
Feed intake(g) ^{ns}				
20 days	839.0	892.0	942.0	872.0
28 days	1845.0	2061.0	2346.0	2057.0
42 days	3661.0	4015.0	4196.0	3855.0
Body weight(g) ^{ns}				
Initial	44.0	43.1	42.7	41.8
20 days	539.0	638.0	646.0	547.0
28 days	1039.0	1083.0	1120.0	1052.0
42 days	2159.0	2053.0	2342.0	2122.0
Body weight gain(g) ^{ns}				
20 days	495.0	595.0	605.0	505.0
28 days	995.0	1040.0	1078.0	1010.0
42 days	2115.0	2010.0	2300.0	2080.0
FCR ^{ns}				
20 days	1.71	1.51	1.56	1.74
28 days	1.86	1.98	2.17	1.94
42 days	1.74	1.99	1.82	1.88

ns- not significantly different (P>0.05).

Zinc dose ranging from 32.23 to 96.70 ppm zinc oxide did not influence the feed intake of the birds. Holtz and Brown (2004) also observed a decrease in food intake in the early stage of zinc depletion. In humans, the onset of observed anorexia is still unknown but, there is a suggestion of alteration in amino acid transport and in metabolism through the blood-brain barrier as well as the, the synthesis of certain neurotransmitters which affect appetite. Browning *et al.* (1998) had a hypothesis regarding the effect of zinc deficiency in inducing anorexia. They claimed that there was a decrease in the concentration of a potent appetite stimulant known as neuropeptide Y (NPY). On the contrary, Lee *et al.* (1998) found that, NPY system appears to be intact postsynaptically. It is possible that zinc deficiency impairs the processing of the NPY, losing its affinity for its receptors and an eventual decreased in food intake.

In the present study, the dosage of zinc oxide used did not affect the body weight or the body weight gain of the broilers as shown in Table 2. The findings of the present study were contrary to the findings of Carlson (2004) who found an improvement of 7.85% in ADG of early weaned pigs (<21 d) and 8.3% for pigs weaned after 22 days. Fuller *et al.* (1960) as cited by Carlson (2004) hypothesized that the growth response after feeding the animal with 2,000 to 3,000 ppm of zinc oxide maybe due to the antimicrobial action of the mineral and its ability to reduce the turnover of the intestinal cells, leaving more nutrients available for absorption. *E.coli, the* primary cause of post weaning scours in piglets, is one of the most sensitive bacteria to zinc oxide (Owusu-Aseidu *et al.*, 2003). In this study, inclusion of 120 ppm did not show superiority when it comes to antibacterial action because all treatments appeared to have similar results. This is contrary to the findings of Nys *et al.* (1999) as cited by Reilly (2004) with zinc sulphate at a rate of 25 to 45 ppm. Favourable result was attained in terms of feed intake and body weight gain after feeding the chicks with zinc sulphate. There was an improvement in the two parameters measured after supplementing the diet with 25 to 45 ppm of dietary zinc but, beyond that level, no effect was noted.

The two dosages used (64.47 - 96.7 ppm) in the study was higher than the inclusion of 45 ppm (Nys *et al.,* 1999) and 55 ppm (Young *et al.,* 1958) to achieve normal growth in chicken particularly between 10 to 21 days. Generally, the study agrees to the statement of Wedekind *et al.* (1992) that zinc dietary concentrations of 45 to 95 ppm and 117 and 867 ppm had no effect on growth of 22 day -old chicks.

Birds fed a ration without zinc performed comparably with those fed with varying concentration of zinc oxide. This can be attributed to the adjustment in the fractional zinc absorption in response to levels of dietary intake. In human, it was found out that reduction of zinc intake to a very low level would increase absorption by 25 to 93%. However, doubling the zinc intake reduced fractional intake to 21%. Generally, the lower the zinc intake, the higher the rate of fractional zinc absorption (Reilly, 2004). Since there was no significant difference in the FCR, it shows that the control group are more efficient in converting a kilogram of feeds to a kilogram gain in body weight than the other groups. The negative zinc balance mentioned by Reilly (2004) due to inadequate dietary zinc intake especially if it is prolonged was not observed in the present study probably because forty two (42) days were not yet too long for the birds to manifest such effect.

Meat Zinc Content

Table 3 shows the zinc content of the different meat parts at days 36 and 42. It appeared that there is no significant difference between treatments in both collection periods but, it showed variation in zinc content at different parts.

Table 3. Meat zinc (ppm) content of broilers fed zinc oxide

Treatment[ns]	Meat parts				Mean
	Thigh and legs	Wings	Breast	Liver	
Day 36					
1	42.6[a]	50.0[a]	28.7[b]	93.5[c]	53.7
2	55.3[a]	49.7[a]	37.0[b]	96.0[b]	59.5
3	41.1[a]	52.8[a]	29.1[b]	102.4[c]	56.4
4	51.2[a]	45.9[a]	31.2[b]	89.0[c]	54.3
	57.9[a]	45.6[a]	27.8[b]	90.0[c]	
Day 42					
1	57.9[a]	45.6[a]	27.8[b]	90.0[c]	55.3
2	55.6[a]	43.3[a]	36.7[b]	101.5[c]	59.3
3	54.0[a]	50.9[a]	33.1[b]	88.1[c]	56.5
4	66.0[a]	51.2[a]	29.8[b]	83.0[c]	57.5

Means with different superscripts within the same row are significantly different from each other at ($P< 0.05$).

ns- not significantly different at ($P>0.05$)

If there is an increased in dietary intake, there will be a corresponding increase in endogenous fecal zinc (EFZ) and decrease in absorption (Reilly, 2004). There is a possibility then that those treatments that have received 80 and 120 ppm of zinc just resulted to the circumstance mentioned. The homeostatic mechanism of maintaining zinc in the body is not yet enough to replace the zinc losses in the integument such as the hair and nails, in the semen and menstrual blood (McAnena, 2004). Note that there is no storage pool or nutritional reserve that has been identified in zinc so; humans are relatively dependent upon a constant renewed supply of the metal (Strain and Cashman, 2002). It is therefore, imperative to determine the dosage enough to meet the need of zinc oxide inclusion in the diet since there was no difference noted among treatments. The results also show that an inclusion of 40 ppm or a total of 32.23 ppm of zinc oxide in a corn soy ration is enough to fortify chicken meat either harvested at 36 or 42 days.

As previously mentioned, there was a significant difference in the zinc contents of the meat parts showing the liver to be consistently higher in both collection periods compared to other meat parts. The thigh and legs and wings manifested the same amount of zinc. Lowest zinc content was noted in the breast.

Reilly (2004) considered food fortification to have the potential to be a cost-effective and sustainable method for improving dietary zinc intakes on a national level in countries where zinc deficiency is endemic. The procedure is expected to be acceptable to consumers since it can be introduced without changes in existing food consumption practices. Rosado (2003) enumerated some of the considerations in the selection of suitable food vehicle in food fortification which include; it should be centrally processed, commonly used and contains minimum components which could interfere with zinc bioavailability. With these criteria, it shows that chicken meat meet al.l the requirements to be a good food vehicle considering that most people from all walks of life and religious beliefs consume chicken. Note that chicken meat and meat products are important sources of both protein and lipids including the minerals it contains.

The pooled mean zinc content at 36 and 42 days of harvest regardless of treatments are shown in Table 4. It shows that at 36 day of harvest, the liver manifested the highest zinc content of 95.22 ppm followed by 49. 6 ppm in the wings, 47.55 in the thigh and legs and the least was noted in the breast with 31.5 ppm. Note that all of the nutrients pass through the liver through its vascular function of storing and filtering blood. It has also metabolic functions concerned with the majority of the metabolic systems of the body, and also involve in the secretory and excretory functions that are responsible for forming the bile that flows through the bile ducts into the GIT tract (Guyton and Hall, 1998). With these functions of the liver, it is then possible that the highest concentration of zinc can be derived from this organ.

Unlike other chicken meat parts, the breast is generally less influenced by all the diets used. This has been proven by the current study for it shows that the zinc content of the breast meat regardless of the mineral inclusion were generally lower. On the other hand, the thigh and legs and wing parts generally have high zinc contents next to the liver. It had been observed that these parts, with the skin attached to them are fatty/ oily in nature before the samples were ashed compared to that of the breast. The exact mechanism of zinc deposition on these parts is not yet fully understood. One of the probabilities is that the fatty/oily substance derived from the skin contains a lot of zinc. In addition, since these are very movable organs and possibly synthesize a lot of protein, the content of zinc is alos possibly high because the mineral is involved in the proper folding of proteins. Note that one of the manifestations of zinc deficiency is a skin problem both in animals and humans.

At day 42, the same observations on the amount of zinc in each meat part were also noted. It reveals in Table 3 that at day 42, the thigh and legs contain more zinc than the wings with 58.4 ppm and 47.8 ppm, respectively. However, statistically, they are still comparable. Meanwhile, the liver had the highest zinc of 90.65 ppm and the lowest was that of the breast with 31.9ppm. Since statistical analysis revealed that there is no difference between the meat parts at days 36 and 42 as revealed in Table 4, this shows that generally, 36 day feeding period is enough to feed the chickens with zinc oxide. In a number of current fortification programmes, zinc oxide is commonly used because it is relatively easily absorbed, no organoleptic qualities which may affect the taste or colour of the carrier food. It is cheap but, the bioavailability is low (Reilly, 2004).

Table 4. Mean zinc content of broilers fed zinc oxide
(pooled from 36 and 42 days, in ppm)

Time of collection	Meat parts [ns]				Total zinc content (ppm)
	Thigh and legs	Wings	Breast	Liver	
Meat at 36 days	47.6	49.6	31.5	95.2	55.97
Meat at 42 days	58.4	47.8	31.9	90.65	57.19

ns- not significantly different (P> 0.05)

Based on the result of the study shown in the table above, the thigh and legs and wings have high zinc contents. This is very important because these chicken parts are being served in many food establishments worldwide thus, the goal of fortification then can be successful.

Experiment 2. Zinc Methionine

Table 5 shows the cumulative production performance of broilers fed with different levels of zinc methionine. Like the previous experiment, the different inclusion rates of zinc methionine in the ration did not affect the production performance of the broilers in terms of feed intake, body weight, body weight gain and FCR.

Table 5. The cumulative production performance of broilers fed diets with different levels of zinc methionine

Parameters	Treatment			
	1	2	3	4
Feed intake(g) ^{ns}				
20 days	839.0	926.0	854.0	876.0
28 days	1845.0	1922.0	1956.0	1903.0
42 days	3661.0	3866.0	4092.0	3730.0
Body weight(g) ^{ns}				
Initial	44.0	41.9	43.5	43.7
20 days	539.0	572.0	548.0	549.0
28 days	1039.0	1098.0	1048.0	969.0
42 days	2159.0	2052.0	2108.0	2064.0
Body weight gain(g)^{ns}				
20 days	495.0	530.0	505.0	504.0
28 days	995.0	1056.0	1007.0	925.0
42 days	2115.0	2011.0	2065.0	2020.0
Feed Conversion Efficiency				
20 days	1.74	1.74	1.68	1.75
28 days	1.86	1.82	1.95	2.00
42 days	1.75	1.92	1.98	1.83

ns-not significantly different (P>0.05).

In this study, the levels of zinc used were far lower than the 40 ppm recommendation of NRC (1994), 45 ppm of Nys *et al.* (1999) as cited by Reilly (2004) and 55 ppm of Young *et al.* (1958) that claimed to cause normal growth in chicken. The present study utilized 16% zinc in the form of zinc methionine.

The similar results of Treatment 1 with other treatments in the performances mentioned can be attributed to the adjustment in the fractional zinc absorption in response to levels of dietary levels as mentioned in the previous experiment that in general, the lower the intake, the higher rate of fractional zinc absorption or vice versa (Reilly, 2004).

The body weight and weight gain of broilers fed zinc methionine can be associated to the hypothesis made by Fuller *et al.* (1960) as cited by Carlson (2005) that growth response is due to the antimicrobial action of the mineral and its ability to reduce the turnover of the intestinal cells thus leaving more nutrients available for absorption. Richards *et al.* (2006) studied the effect of zinc methionine using nucleotide analog (BrdU) that would permanently label the DNA at the first day of life of the intestinal cells of broilers. Seven days later, it was found out that those birds that were not given supplemental zinc have few positively stained cells in the intestine which mean that all of the absorptive cells died whereas those that received 40 ppm zinc methionine showed many positively stained cells indicating reduction in the rate of cellular turnover. Summers (1991) and Cantl *et al.* (1996) as cited by Richards *et al.* (2006) stated that the gut tissues require approximately 30% of the total energy in a broiler diet and, much of that used just to repopulate absorptive cells of the small intestine. If intestinal cell turn over will be slowed by feeding zinc adequate diet, there will be a reduction in the nutritional requirements of gut resulting in more free energy and nutrients for growth.

In addition to the antimicrobial effect of zinc, the other factors that would enhance growth are the provision of more nutrients available for absorption that would reduce intestinal turnover and the methionine content of zinc methionine that adds additional protein (Yi *et al.* 2007). Carlson (2004) and other researchers found out that when they used organic zinc in nursery pig diets post-weaning, the ligand binding or source has little effect on growth improvement with an average increase of 3.1% only. Carlson (2004) also cited that there are numerous researchers that show pigs fed lower concentrations of organic zinc forms have similar growth stimulation as fed 3,000 ppm Zn as ZnO (Ward *et al.*, 1996; de Rodas *et al.*, 1999; Mullan and Souza, 2003). On the other hand, McCalla *et al.* (1999) reported that lower concentrations of organic zinc from a Zn amino acid complex did not support the same growth performance response as nursery pigs fed 3,000 ppm zinc oxide up to 34-d post weaning. Carlson *et al.* (2004) further cited the statement of de Rodas *et al.* (1999) that the growth performance response seems to be dependent on the complexity of the overall diet formulation for the nursery pigs. In the present study, the FCR were almost within the standard range for broilers although it shows that zinc methionine did not influence the said parameter.

Meat Zinc Content

Table 6 presents the zinc contents of broilers fed zinc methionine at days 36 and 42. Just like the previous experiment, no significant difference was noted in the amount of zinc in the different treatments although Treatment 3 manifested the highest numerical content of zinc. It reflects that an additional 12.8 ppm, of zinc methionine in a corn-soy diet will be enough to fortify chicken meat in a period as short as 36 days. This result agrees to the many claims that organic mineral particularly zinc is highly bioavailable (Fremaut, 2003) and equates more closely to that of amino acid with 90-95% (Leeson, 2004). The meat parts showed differences reflecting highest zinc content in the liver, followed by the thigh and legs and wings. The lowest amount was noted in the breast.

At day 42, it shows that 12.8 ppm of zinc methionine is not enough to maintain the high concentration of zinc in the liver and wings although there was a little bit increased in the zinc content of the thigh and legs and breast. This can be attributed to the possible increased in the endogenous excretion of the trace element which is considered as inevitable, obligatory losses that are in turn attributed to the maintenance of metabolism especially if the dietary supply is deficient or just adequate. Probably, 12.8 ppm of zinc methionine is just enough until 36 days to meet the zinc requirement of the animal. The presence of high zinc content in the thigh and legs of Treatment 4 at 42 days is not yet fully known although, the association of the skin and its zinc content can be considered.

Table 6. Meat zinc (ppm) content of broilers fed zinc methionine

Treatment	Meat parts				Mean
	Thigh and legs	Wings	Breast	Liver	
Day 36					
T 1	42.6[a]	50.0[b]	28.7[c]	93.5[d]	54.5
T2	55.3[a]	42.9[b]	29.8[c]	85.4[d]	52.4
T3	41.1[a]	46.9[b]	30.6[c]	98.4[d]	57.3
T4	51.2[a]	46.2[b]	28.2[c]	97.0[d]	54.4
Day42					
T1	57.9[a]	45.6[b]	27.8[c]	90.0[d]	55.3
T2	61.3[a]	45.0[b]	37.2[c]	75.8[d]	54.7
T3	56.9[a]	45.1[b]	27.6[c]	96.8[d]	58.0
T4	64.7[a]	41.5[b]	35.6[c]	107.7[d]	60.9

Means with different superscripts within the same row are significantly different from each other at ($P<0.05$).

It shows that in order to meet the requirements of the chicken up to 42 days and increase the zinc content of the meat, an additional 6.4 ppm of zinc methionine or a total of 19.2 ppm is needed in a corn-soy diet.

Table 7 revealed that fortification up to 36 days is enough in broilers the zinc content of the meat at 36 days are comparable to those of 42 days. Although there is no difference in the zinc content between treatments, it can be depicted from Treatment 3 that an inclusion rate of 12.8 ppm of zinc methionine is just enough to meet the metabolic needs of the body but would not allow more zinc deposition in the meat as compared if it 19.2 ppm.

Table 7. Mean zinc content of meat (pooled from 36 and 42 days, in ppm) of broilers fed zinc methionine

Time of collection ^{ns}	Meat parts				Total zinc content (ppm)
	Thigh and legs	Wings	Breast	Liver	
Mean at 36 days	47.6	46.5	29.3	93.6	57.2
Mean at 42 days	60.2	44.3	32.0	92.6	55.9

ns –not significantly different at (P>0.05).

Reilly, (2004) stated that to increase zinc intake, there should be dietary diversification and modification and one of which is by eating meat rich in zinc. What makes it possible for the zinc methionine to be added in the ration at a much lower inclusion rate is that, the methionine itself is a promoter for zinc absorption. The methionine is a low molecular weight organic substance (Reilly, 2004) that can pass readily through the intestine with ease.

CONCLUSIONS

Based on the results of the study, the following are therefore, concluded:

The production performances of broilers were not affected by different levels of zinc oxide and zinc methionine. At 36 and 42 days of harvest, the different levels of zinc oxide did not affect the amount of meat zinc. However, the meat parts were affected showing higher concentration in the liver, similar concentration in the wings, in the thigh and legs and the least amount was noted in the breast. The zinc contents of the meat parts were similar at 36 and 42 days of harvest. For broilers fed zinc methionine, they manifested the same observations as those birds received zinc oxide at 36 and 42 days of harvest. On the meat parts, the zinc content of the thigh and legs was higher than that of the wings. The zinc contents of the pooled zinc content of meat parts at 36 and 42 days were also similar.

RECOMMENDATIONS

Based on the conclusions of the study, the following are therefore recommended:

1. Animal nutritionists should consider the form of zinc to be used in the formulation of rations for broilers. A ration which requires a much lesser inclusion in the diet but will give the same performance expected is recommended as observed in Experiment 2.
2. Feed broilers with zinc fortified feeds for 36 days only.

ACKNOWLEDGEMENTS

Profound gratitude is hereby extended to the Commission on Higher Education, SEARCA, and National Taiwan University for supporting this study.

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