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Effects of supplementation of manganese with or without phytase on growth performance, carcass traits, muscle and tibia composition, and immunity in broiler chickens

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ABSTRACT

An experiment was conducted to study the effect of Mn and phytase supplementation on performance, carcass traits, and immunity in broiler chickens. A total of 350 one-day-old unsexed broiler chickens were randomly allotted to 7 dietary treatments (5 replicate pens of 10 chicks per pen) in a $1+3\times2$ factorial arrangement with 3 concentrations of supplemental Mn and with or without phytase addition. The control diet represented a basal diet with no supplemental Mn and phytase. The basal diet was supplemented with Mn at 50, 75, and 100 mg/kg diet and microbial phytase was added at a dose of 500 FTU/kg. Average daily gain, feed intake, and feed conversion ratio were similar among the treatments. During the starter, grower, and finisher periods, 5, 7.5, and 17.5% of the broiler chickens, respectively, developed leg abnormalities in the control diet, which were not observed in the treatment groups. The serum concentrations of glucose, total cholesterol, Ca, and P were not affected by supplemental Mn and phytase or their interaction. Antibody titer against Newcastle virus disease vaccine on 16 d and 32 d of the feeding trial (10 d after vaccination) were increased ($P<0.05$) by Mn or phytase supplementation, but the antibody titer was not affected by the Mn and phytase interaction. Carcass traits such as hot carcass weight, eviscerated carcass weight, dressing percentage, breast, leg, frame, and giblet were not altered by Mn or phytase or both supplementation. Abdominal fat content was decreased ($P<0.05$) by high concentrations of Mn supplementation (75 and 100 mg/kg), but not by phytase addition. Chemical composition (moisture, protein, ash, and fat) in thigh and breast muscle, and total ash, Ca, and P concentrations in tibia at 42 d were similar among the dietary treatments. Thus, supplementation of Mn at 75–100 mg/kg to a basal corn-soybean diet could be beneficial for improving immunity and decreasing fat deposition, and phytase supplementation could also improve immunity measures in broiler chickens.

1. Introduction

Mn is an essential trace mineral and Mn requirements in avian species are higher than that of mammals. This is because chicks absorb Mn less efficiently than do mammals (Halpin et al., 1986; Turk et al., 1982). The absorption efficacy of Mn from inorganic Mn-sulphate was estimated to be 1.71% for corn-soybean diets to 2.40% for pure casein-dextrose diets fed to chicks (Halpin et al., 1986), and the bioavailability of Mn is highly variable depending upon the Mn sources (Li et al., 2004). The NRC (1994) recommends 60 mg Mn/kg diet for broiler chickens. This requirement is based on research conducted at least 20 years ago with broiler chickens of genetic characteristics that differ from existing genetic traits today. The evaluation of the dietary Mn requirement is based on some specific performance indices such as average daily gain (ADG) and leg abnormalities (Lu et al., 2007). However, other indices for Mn requirements may be more representative, such as immune function. Mn is required for Mn-superoxide dismutase (MnSOD) enzyme function, which has been shown to contribute to the integrity of macrophases and heterophils, virulence to pathogenic microorganisms, and antibody production (Cook-Mills and Fraker, 1993; Cox et al., 2003; Lynch and Kuramitsu, 2000). Re-evaluation of the Mn requirement in broiler chickens using more specific and sensitive indices such as MnSOD activity has been advocated (Li et al., 2004; Lu et al., 2007; Suttle, 2010). Based on ADG and incidences of leg abnormality along with heart MnSOD activity, and tissue Mn concentrations, Luo et al. (1991) recommended 120 mg Mn/kg corn-soybean meal basal diets in broiler chickens.

Poultry industry faces environmental challenges such excess nutrient and mineral excretion, and gas emission. Commercial practice of feeding Mn above the recommended requirement (e.g.,

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NRC, 1994) results in excretion of high level of this element in excreta (Inal et al., 2001; Wang et al., 2008), which may cause environmental pollution (Powers and Angel, 2008). In addition, supplementation of high concentration of a mineral affects the bioavalibility of other minerals masking the advantages of the mineral supplementation (Collins and Moran, 1999). Reports show that high concentrations of Mn in diets may depress Cu concentrations in tibia and liver (Gajula et al., 2011) and decrease immunity by unbalancing trace mineral concentrations in lymphoid organs of broiler chickens (Liu et al., 2012). The strategy for reducing Mn excretion is to supplement microbial phytase to diets, which hydrolyses phytic acid to inositol and improved the absorption of Mn (Mohanna and Nya, 1999). Indeed, phytase supplementation increased tibia Mn concentration of broiler chickens fed on a corn-soybean based diet (Singh et al., 2003; Sunder et al., 2006).

Another major concern for the modern day poultry industry as well as consumers of chicken meat is excessive fat deposition in chicken meat (Choct et al., 2000; Fouad and El-Senousey, 2014). In response to concern of health-conscious consumers, current research aims at reducing excessive fat deposition in broiler chickens without affecting growth performance by dietary means. Supplementation of Mn decreased abdominal fat deposition in broilers (Lu et al., 2007; Sands and Smith, 1999) by decreasing the activity of lipoprotein lipase of abdominal fat (Mersmann, 1998).

Efficacy of phytase supplementation in maize-soybean based diets on P and Ca utilization has been studied thoroughly. There are several studies showing significant interaction effects between phytase and other minerals such as Ca, P, and Zn on intake, growth and mineral content in tibia and plasma (e.g., Paiva et al., 2014; Qian et al., 1996; Sebastian et al., 1996). However, the interaction effects of phytase and Mn on growth performance, carcass traits, and immunity in broiler chickens are limited. It was hypothesized that phytase and Mn addition in a basal diet could affect some response variables associated with Mn in broiler chickens. Therefore, the objective of this study was to determine the effects of graded doses of Mn supplementation in a diet based on maize-soybean with or without addition of phytase on growth performance, immune response, carcass traits, and meat composition in broiler chickens.

Table 1
Ingredients and chemical composition of diets.[1]

Item	Starter (0 to 10 d)	Grower (10 to 22 d)	Finisher (22 to 42 d)
Ingredient (%)			
Maize	57.3	61.1	62.8
Soyabean meal	38.0	33.0	31.0
Rice bran oil	0.8	2.0	2.5
Dicalcium phosphate	2.0	1.9	1.8
Limestone powder	1.0	1.0	1.0
Common salt	0.22	0.22	0.22
L-Lys.HCl	0.08	0.11	0.08
DL-Met	0.14	0.16	0.13
Sodium bicarbonate	0.20	0.20	0.20
Toxin binder	0.05	0.05	0.05
Bacitracin methylene disalicylate	0.04	0.04	0.04
Cocciodistate	0.05	0.05	0.05
Trace minerals[a]	0.03	0.05	0.05
Vitamins[b]	0.05	0.05	0.05
Choline chloride	0.04	0.04	0.04
Energy and nutrient composition			
Metabolizable energy (Mcal/kg)[c]	2.91	3.02	3.06
Crude protein (%)[d]	22.4	20.6	20.0
Ether extract (%)[d]	3.23	4.34	5.03
Crude fiber (%)[d]	3.75	3.41	3.33
Lys (%)[c]	1.31	1.20	1.12
Met (%)[c]	0.51	0.50	0.46
Ca (%)[d]	1.06	0.96	0.92
Available P (%)[c]	0.50	0.48	0.45
Mn (mg/kg)[d]	26.4	24.7	23.3

[1] For phytase diets, a small increase of 0.4 to 0.5% of maize grain with a decrease of 0.4 to 0.5% of dicalcium phosphate, limestone powder, soybean meal, and rice bran oil was made with similar calculated concentrations of crude protein and metabolizable energy. These slight changes in ingredient composition would result in minor changes in other nutrient composition.

[a] Supplied per kilogram of diet: Cu, 4.0 mg; Zn, 75 mg; Fe, 20 mg; and I, 0.35 mg.

[b] Supplied per kilogram of diet: vitamin A, 13,000 IU; vitamin D_3, 2,500 IU; vitamin E, 30 IU; vitamin K, 3 mg; vitamin B_1, 4 mg; vitamin B_2, 9 mg; vitamin B6, 4 mg; vitamin B_{12}, 20 μg; biotin, 0.15 mg; foilc acid, 2 mg; niacin, 45 mg; and pantothenic acid, 15 mg.

[c] Calculated value.

[d] Analyzed value.

2. Materials and methods

2.1. Broiler chicken management and diet

The experiment was conducted following the ethical guidelines of animal care and use of this institute. A total of 350 one-day-old unsexed broiler chickens (Vencobb 400 breed, Venkys, Pune, Maharashtra) were purchased from local hatchery and brought to the poultry shed 6 h post-hatch. Immediately after arrival, they were weighed and randomly allotted to 1–7 treatments (5 replicate pens of 10 chicks per pen). Broiler chickens were maintained in a deep litter system made up of husks and sawdust. The treatment diets were offered from d 2. Continuous illumination was given for first 15 d. A dark period of 1 and 3 h during night was provided from d 16–25 and d 26–35, respectively, to reduce the activity of broiler chickens. The broiler chickens were vaccinated against Newcastle (ND) disease at d 6 and 22, and infectious bursal disease at d 12.

The broiler chickens were allowed ad libitum access to the experimental diets in mash form and water containing no detectable amount of Mn. The starter (d 0–10), grower (d 10–22) and finisher (d 22–42) diet (Table 1) were formulated using maize grain and soyabean meal. Seven dietary treatments were designed in a 3×2 factorial arrangement with 3 concentrations of supplemental Mn and with or without phytase addition plus one control diet. The control diet represented a corn-soybean meal-based basal diet with no supplemental Mn or phytase. The control diet contained approximately 25 mg Mn/kg diet, and was supplemented with Mn at 50, 75, and 100 mg/kg diet using $MnSO_4$, and a commercial microbial phytase was added at a dose of 500 FTU/kg. When phytase was added to the diets, the amounts of incorporation of limestone powder and dicalcium phosphate were adjusted accounting 0.16 g available P and 0.2 total Ca per 100 FTU phytase/kg (Kornegay, 2001). Thus, the phytase diet contained 0.1% less Ca and 0.08% less available P compared with non-phytase diet. For phytase diets, a small increase of 0.4–0.5% of maize grain with a decrease of 0.4–0.5% of dicalcium phosphate, limestone powder, soybean meal, and rice bran oil was made with similar calculated concentrations of crude protein and metabolizable energy in diets. These slight changes in ingredient composition would result in insignificant differences in other nutrient composition.

2.2. Performance traits and incidence of leg abnormalities

Initial body weights of the broiler chickens were recorded at the start, and replicate-wise body weight and feed intake was recorded at weekly intervals. Average daily gain (ADG), average daily feed intake (ADFI), and feed conversion ratio (FCR) were calculated from body weights and feed intake data. Leg