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Comparative effects of zinc oxide, zinc oxide nanoparticle and zinc-methionine on hatchability and reproductive variables in male Japanese quail

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ABSTRACT

The objective was to examine the effect of different dietary zinc sources on reproduction of male Japanese quail. A total of 512 quail chicks (day-old) were divided into four groups with four replications for a period of 42 days. After this period, excess chicks were removed to attain the ratio of one male to three females and 16 quail in each subgroup. At 52 to 60 d of age, the eggs were collected and incubated. The basal diet (control) contained no zinc and the other three experimental diets were supplemented with 25 and 50 mg/kg zinc from zinc oxide (ZnO), zinc oxide nanoparticles (ZnONP) and zinc-methionine (Zn-Met) for 1 to 35 and 36 to 60 days, respectively. On day 42, two males from each replicate were euthanized. Males from the ZnO and Zn-Met treatments had an increase ($P < 0.05$) in seminiferous tubule diameters (STD) and germinal epithelium thickness (GET) compared with the control and ZnONP treatments. Cloacal gland index (CGI) was greatest ($P < 0.05$) for the Zn-Met compared with the other groups. Testosterone concentration was greater ($P < 0.05$) in the ZnO and Zn-Met compared with the other groups. Addition of Zn-Met to the diet enhanced ($P < 0.05$) fertility, hatchability and hatched chick weight compared with the other groups. Early and late embryonic death was greater ($P < 0.05$) in the control and ZnONP groups, respectively, compared with the other groups. This study indicated that supplementing diets with the Zn-Met source improves male Japanese quail reproductive performance and hatchability traits while zinc oxide nanoparticles have detrimental effects on male Japanese quail reproduction and reduces hatchability.

1. Introduction

Supplying day-old chicks by breeding companies is an important aspect of the success in the poultry production chain (King'ori, 2011). Fertility and hatchability of eggs are the two most significant economic factors of reproduction affecting the number of chicks that can be marketed from a breeding flock (Narinc et al., 2013). Reproductive performance of a poultry breeder is influenced by genetic and environmental factors, such as nutritional status (Brillard, 2003). It was reported that heritability of fertility and hatchability of eggs in poultry are less than optimal and require a complicated genetic improvement program (Wolc et al., 2009). It, therefore, is of primary interest to incorporate procedures in breeding flocks that can modify environmental effects and influence

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these traits.

Nutrition has an important role in modulation of reproductive responses. Zinc is an important factor in maintaining desirable reproductive functions of poultry (Gallo et al., 2003, 2005). The effects of Zn deficiency on embryo development and breeder performance have been well documented and include male sexual dysfunctions, decreased testicular weights, smaller diameters of seminiferous tubules (Egwurugwu et al., 2013), poor egg production, reduced eggshell strength, decreased fertility, poor hatchability of eggs, embryonic malformations, weak chicks with poor feathering and high mortality (Kidd, 2003; Oliveira et al., 2015). Nutritionists realize that both the amount and the source of microelements have important roles in diet formulations and optimizing production, product quality, health status of birds and economic returns (Attia et al., 2010). In general, a greater amount of dietary zinc is added to reduce the incidence of zinc deficiency and allow birds to reach their genetic growth potential under commercial conditions (Zhao et al., 2010). The reason is the poor availability of zinc in plant feed ingredients and conventional inorganic zinc sources (Lukić et al., 2009). Diets containing large amounts of zinc contribute to an environmental concern due to the excretion of excess zinc in the feces (Bao et al., 2007; Aksu et al., 2011). Furthermore, greater than optimal amounts of dietary Zn can interfere with bioavailability of other minerals, such as iron, copper and cadmium, and increase cost of feed (Suttle, 2010).

One way to overcome the problems associated with poor bioavailability of zinc can be a change from inorganic to organic sources of zinc supplementation (Jahanian et al., 2008). Inclusion of lesser amounts of organically bound Zn in diets with greater bio-efficacy (e.g., zinc-methionine) might maximize Zn bioavailability (Jahanian et al., 2008). In addition, there has been a considerable interest in replacing inorganic trace minerals with nanoparticles that can meet the requirements of animals and simultaneously improve bioavailability of the metals for animals (Sekhon, 2014). Nanoparticles, which involve at least one dimension that is reduced to a nanometric scale, have altered electrical, mechanical and biological features (Sekhon, 2014) and have been identified as important factors influencing particle uptake at sites where agents are biological active (Delie, 1998).

The reports pertaining to zinc supplementation and the effects on male quail fertility and hatchability of eggs in Japanese quail breeders are limited. Consequently, this study investigated the effects of different zinc source (nano, organic and inorganic) supplementations on some important reproductive traits and hatchability of eggs of Japanese quail breeders.

2. Materials and methods

This experiment was conducted with 512 one-day old Japanese quail chicks. The quail were housed at University of Guilan, Faculty of Agricultural Sciences, Education Research and Practice Farm, South Rasht, Iran. Animal care and experimental procedures and protocols were approved by the veterinary organization of Iran. The birds were divided into four groups and four subgroups. The quail were fed a basal diet based on corn and soybean meal, formulated for two phases of production including the first (1–35 days) and the second (36 to 60 days) phases according to National Research Council (NRC, 1994), except for Zn (Table 1). The control group's diets were not supplemented with zinc. Diets of the other groups were supplemented with zinc oxide (ZnO), zinc oxide nanoparticles (ZnONP, Nanosany Co.; purity: 99.9%; and average particle size: 10–30 nm) and zinc methionine (Zn-Met, Sanadam-e-pars and Yasna mehr Co., Iran). The amount of dietary zinc was 25 and 50 mg/kg of diet for the first and second periods of the experiment, respectively. The quail had free access to water and feed. Daily photoperiod was 16 h during the laying period.

Table 1
Composition and analysis of experimental basal diet fed to Japanese quail during growth and pubertal periods.

Ingredient profiles	Growth period (%)	Pubertal period (%)
Corn	48.3	56.6
Soybean meal	45	33.17
Vegetable Oil	3.2	2.5
Limestone	1.2	5.6
Dicalcium phosphate	1.2	1.16
Common salt	0.33	0.33
Vitamin premix[a]	0.25	0.25
Mineral premix[b]	0.25	0.25
DL-methionine	0.17	0.14
L-Lysine	0.1	0
Total	100.00	100.0
Calculated values		
ME (kcal/kg)	2900	2900
Crude protein (%)	24	20
Calcium (%)	0.85	2.5
Av. phosphorus (%)	0.38	0.35
Lysine (%)	1.35	1.00
Methionine + Cysteine (%)	0.8	0.75

[a] Vitamin premix in provided the following per kilogram of basal diet: A, 9000 IU; D_3, 2000 IU; E, 18 IU; K_3, 2 mg; B_1, 1.8 mg; B_2, 6.6 mg; B_3, 30 mg; B_6, 3 mg; B_7, 0.1 mg; B_{12}, 0.015 mg; choline chloride, 500 mg; Folic acid, 1 mg.

[b] Zinc-free trace mineral premix provided the following in milligrams per kilogram of basal diet: selenium, 0.2; manganese, 60; iron, 120 (60 for pubertal period); iodine, 0.3; copper, 5.