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Comparative effects of nano elemental selenium and sodium selenite on selenium retention in broiler chickens

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ABSTRACT

Two experiments were performed to explore the selenium retention of Nano elemental selenium (Nano-Se) in Arbor Acre male broiler chickens as compared with sodium selenite. A 2×4 factorial arrangement with 0.15, 0.30, 0.60 and 1.20 mg/kg dietary Se from Nano-Se or sodium selenite added to a maize–soybean meal diet was conducted to study the effects of Se source and level on growth performance, serum glutathione peroxidase (GSH-Px) activity, Se concentration in serum and tissue. Furthermore, selenium retention of Nano-Se and selenite was determined in chicks by the oral or intravenous administration of the radiolabeled Se and the *in vivo* ligated intestinal loop procedure. As for selenite, average daily gain (ADG), gain/feed and survival ratio reached a plateau at the Se concentration of 0.15–0.30 mg/kg and then declined as supplemental selenite increased. As for Nano-Se, ADG, gain/feed and survival ratio reached a plateau at the Se concentration of 0.15–1.20 mg/kg. Survival ratio, ADG and gain/feed increased quadratically ($P<0.05$) as dietary selenite increased ($P<0.05$), and increased linearly and quadratically ($P<0.05$) as dietary Nano-Se increased ($P<0.05$). Selenium concentrations in serum, liver and breast muscle increased linearly and quadratically ($P<0.05$) as the dietary Se level increased for either Se source, but the magnitude of increase was substantially greater ($P<0.05$) when Nano-Se was fed. Retention of the orally or intravenously administered ^{75}Se showed that the percentages of Nano-Se in the whole body and liver tissue were much higher ($P<0.05$) than those of selenite. Intestinal transport of ^{75}Se from ligated loop to body showed that the transfer of Nano-Se from the intestinal lumen to the body was higher ($P<0.05$) than that of selenite, while the intestinal retention of Nano-Se was lower ($P<0.05$) than that of selenite. The results showed that the range between optimal and toxic dietary levels of Nano-Se was wider than that of sodium selenite, and Nano-Se was more efficiently retained in the body than sodium selenite.

1. Introduction

Selenium (Se) has been recognized as an essential dietary nutrient. Most of the soils in China are marginal to deficient in Se. It is common practice to supplement broiler diets with Se. The Se supplement that primarily has been used in animal diets is the inorganic form, sodium selenite, which has a very narrow margin between its nutritional dosage and its toxicity (Wolffram et al., 1986). Nano elemental selenium (Nano-Se), which is bright red, highly stable, soluble and of nano defined

Abbreviations: ADFI, average daily feed intake; ADG, average daily gain; GSH-Px, glutathione peroxidase; Nano-Se, nano elemental selenium; SEM, standard error of the mean.

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size in the redox state of zero (Se^0), has been manufactured for use in nutritional supplements and developed for applications in medical therapy (Zhang et al., 2001; Gao et al., 2002). It has been reported that Nano-Se have a higher efficiency in upregulating selenoenzymes and exhibit less toxicity than selenite (Zhang et al., 2001, 2005; Jia et al., 2005; Wang et al., 2007).

Nano-materials exhibit novel properties, such as great specific surface area, high surface activity, a lot of surface active centers and high catalytic efficiency (Gao and Hiroshi, 2005). Due to the advantage of size effect and high surface reactivity, nanoparticle has been already used in pharmaceutical applications to increasing the bioavailability of drugs and targeting therapeutic agents to particular organs (Florance et al., 1995; Davda and Labhasetwar, 2002). It has been reported that nanoparticle showed new characteristics of transport and uptake and exhibited higher absorption efficiencies (Davda and Labhasetwar, 2002; Chithrani and Chan, 2007; Zha et al., 2008; Liao et al., 2010). However, there is little data on intestinal absorption and Se retention of Nano-Se.

The present study focused on the Se retention of Nano-Se in broiler chicks in comparison to sodium selenite. A 2×4 factorial arrangement with 0.15, 0.30, 0.60 and 1.20 mg/kg dietary Se from Nano-Se or sodium selenite added to a maize–soybean meal basal diet was conducted. The effects of dietary Se source and level on growth performance, serum glutathione peroxidase (GSH-Px) activity, Se concentration in serum and tissue of broilers were studied. Furthermore, Se retention of Nano-Se and sodium selenite was determined in chicks both by the oral or intravenous administration of the radiolabeled selenium and the *in vivo* ligated intestinal loop procedure.

2. Materials and methods

2.1. Selenium sources

Nano-Se and [^{75}Se]–Nano-Se was synthesized by reducing selenite in an environment containing bovine serum albumin (BSA), which is able to adhere to Se atoms and control the size of their aggregation according to Zhang et al. (2001). One milliliter of 25 mM sodium selenite was mixed with 4 mL of 25 mM GSH containing 15 mg of BSA for the Nano-Se preparations. The pH of the mixture was adjusted to 7.2 with 1.0 M sodium hydroxide, forming red elemental Se and oxidized GSH. The red suspension was dialyzed against double-distilled water for 96 h, with the water being changed every 24 h to separate the oxidized GSH from the Nano-Se. The final suspension containing Nano-Se and BSA was lyophilized and stored at room temperature. The size of the red elemental Se was 20–80 nm using a Mastersizer particle size and zeta potential analyzer (Malvern Instruments, Malvern, UK), with the average size being 60 nm. Sodium selenite was purchased from Shanghai reagent Co. Ltd (Shanghai, China). [^{75}Se]–Na_2SeO_3 was provided by Chinese Isotope Corporation (Beijing, China).

2.2. Animal and experimental procedures

Three experiments were performed to explore the Se retention of Nano-Se in broiler chicks as compared to sodium selenite. All procedures were approved by the Institutional Animal Care and Use Committee of Zhejing University.

2.2.1. Experiment 1. The effects of dietary Se source and level on growth performance, serum GSH-Px activity, Se concentration in serum and tissue of broilers

A total of 810 Arbor Acre male broiler chickens, 1 d of age, were allotted to a randomized complete block design in a 2×4 factorial arrangement. Chicks were fed diets containing sodium selenite or Nano-Se, each at 0.15, 0.30, 0.60 or 1.20 mg/kg Se (as fed). A basal diet without added Se was a ninth treatment group. Basal diet was formulated to meet nutrient requirements according to the NRC (1994) except Se (Tables 1 and 2). Diets were fed from 1 to 49 d including starter (1–21 d), grower (21–42 d) and finisher (42–49 d). The chicks were raised in wooden cages (120 cm×120 cm×50 cm, length×width×height), equipped with nipple waterers and tube feeders. There were 15 chicks per cage, and six cages were used for each treatment. All chicks were given *ad libitum* access to feed and water. Temperature was maintained at 32 °C for the first week and then gradually reduced according to normal management practices, until a temperature of 23 °C was achieved. During the first week, 24 h of light were provided with a reduction to 20 h afterwards. Chicks were weighed individually at 1 and 49 d of age to determine average daily gain (ADG). Feed consumed on cage basis was recorded daily. Average daily feed intake (ADFI) and gain/feed were calculated. At the 49th day of the feeding trial, 18 chicks per treatment (3 per cage) were slaughtered by severing the jugular vein. Serum, liver, kidney and breast muscle (*pectoralis major*) were collected, immediately processed in liquid nitrogen and then stored at −70 °C.

2.2.2. Experiment 2. Retention of radiolabeled selenium after oral or intravenous administration

After hatching, the Arbor Acre male chicks were fed a starter diet (Table 1) supplemented with 0.15 mg/kg Se as sodium selenite for 3 weeks. The animals used in the following experiments were 3-week-old Arbor Acre male chicks.

The retention of selenium by oral or intravenous administration of the radiolabeled selenium compounds was conducted according to the method of Humaloja and Mykkanen (1986). In the experiment on Se retention of oral isotopes administration, twelve chicks were allotted to two groups of six chicks each and orally administered 20 kBq [^{75}Se]–Nano-Se or [^{75}Se]–Na_2SeO_3 in 1 mL of solution containing 0.02 mmol/L Se (Nano-Se or sodium selenite) and 0.15 mmol/L NaCl, pH 6.5.