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Selenium bioavailability from shrimps (*Penaeus vannamei Boone*) and its effect on the metabolism of phospholipid and cholesterol ester

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ARTICLE INFO

Article history:
Received 20 July 2013
Received in revised form
8 September 2013
Accepted 12 October 2013
Available online 7 November 2013

Keywords:
Bioavailability
Metabolism
Penaeus vannamei Boone
Phospholipid
Cholesterol ester
Selenium

ABSTRACT

We evaluated selenium bioavailability from shrimps, and its effect on the metabolism of phospholipid (PL) and cholesterol ester (CE) using a mouse model. Experimental mice were categorized into 4 groups received different doses of Se from shrimps for 4 consecutive weeks. It was calculated that the bioavailability of Se from shrimps was ~86–88% based on the apparent absorption. Comparing with control group, Se content in tissues and Glutathione peroxidase (GPx) activities in liver and blood increased significantly from selenium supplemented groups. The lipidomics analysis showed that there was no difference in detectable total species of PLs and CE in intestine samples, but the total content and the relative percentage of PLs and CE increased proportionally to the dose of Se intake. The results indicate that selenium supplementation lead to an increase in tissue Se concentration and GPx activity as well as changes in intestine PLs and CE, species and abundance of individual lipid fractions.

1. Introduction

Selenium (Se) is an essential trace element for both human and animals, and it has an important nutritional and biological role in living systems. Selenium functions as a redox centre which is best-known for the reduction of hydrogen peroxide, converting lipid and phospholipid to harmless products and protecting membrane cells from free radicals during oxidation by the family of selenium-dependent glutathione peroxidase (Kieliszek & Blazekak, 2013; Rayman, 2000, 2004). There is evidence that Se-deficiency can have adverse consequences for disease susceptibility such as: Keshan disease, myocardial infarction (Salvini, Diet, & Hennekens, 1995), and cardiovascular disease (Tanguy, Grauzam, Leiris, & Boucher, 2012). An adequate intake of Se has many potential health benefits, including protective against cardiovascular

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Abbreviations: CE, cholesterol ester; GPx, glutathione peroxidase; ICP, inductively coupled with plasma; NLS, neutral loss scan; PC, phosphatidyl choline; PE, phosphatidyl ethanolamine; PIS, precursor ion scan; PL, phospholipid; PS, phosphatidyl serine; Se, selenium

1756-4646/$ - see front matter
http://dx.doi.org/10.1016/j.jff.2013.10.005

disease (Alissa, Bahijri, & Ferns, 2003), enhancement in immune responses (Hawkes, Kelley, & Taylor, 2001; Hoffman & Berry, 2008), improvement of thyroid health, and reduction in cancer risk (Clark, Combs, Turnbull, & Slate, 1996; Clark, Dalkin, & Krongard, 1998; Whanger, 2004).

There is a narrow range between the beneficial and toxic levels of selenium (Kieliszek & Blazekak, 2013; Rayman, 2002). US Food and Nutrition Board and European Scientific Committee for Food have recommended dietary allowance and the tolerable upper intake values (Thiry, Ruttens, Temmerman, Schneider, & Pussemier, 2012). However, the recommended value for supplementation of selenium did not take into account the occurrence and composition of selenium presented in food (Amoako, Uden, & Tyson, 2009). The beneficial or toxic effect of Se is not only dose-dependent, but also relates to the chemicals forms and its bioavailability which depends on the form of occurrence and food composition (Kieliszek & Blazekak, 2013; Thiry et al., 2012). It is generally believed that organic Se compounds are better and safer than inorganic one (Moghadaszadeh & Beggs, 2006). The bioavailability of Se is defined as the fraction of an ingested element that is absorbed through the intestinal barrier and that passed into the bloodstream or an organ used for normal physiological functions (Ruby, Schoof, Brattin, & Goldade, 1999). The analysis of Se retention levels in tissues and the activity of GPx (Glutathione peroxidase) in livers are good ways to determine the bioavailability of Se (Finley, 2006; Pedrero & Madrid, 2009). Detection Se values in urine and feces is the principal way to test Se excretion in humans and animals (Kobayashi, Ogra, Ishiwata, & Takayama, 2002).

Lipids as the fundamental components of biological membranes play multiple important roles in biological systems (Tocher, Bendiksen, Campbell, & Bell, 2008). The major classes of phospholipids found in mammalian cell membrane include phosphatidyl choline (PC), phosphatidyl ethanolamine (PE), phosphatidyl inositol (PI), phosphatidyl serine (PS), phosphatidyl glycerol (PG) and phosphatidyl acid (PA) (Bou Khalil, Hou, Zhou, & Elisma, 2010; Fahy, Subramaniam, Brown, & Glass, 2005). Phospholipids play an important role in central nervous system as an essential membrane constituent (Zia & Islam, 2000). Selenocystein-containing proteins (Briqelius-Flohe & Flohe, 2003), (such as GPx), plasma selenoprotein and selenoprotein P (SeP) (Takebe, Yarimizu, Saito, & Hayashi, 2002) serve as a major player in reduction of lipid hydroperoxides. Selenium functions as an antioxidant in membrane lipids due to activation of unsaturation fatty acid mainly in PC through elevating levels of linoleic (C18:2) and linolenic acids (C18:3) (Certík, Breierová, Oláhová, Šajbidor, et al., 2013).

Increasing evidence of the health benefits of supplemental Se to appropriate levels is resulting in a greater interest in Se-containing foods (Finley, 2006). Selenium deficiency and selenium accumulated to a toxic level (Sooking, Davis, & Soller Dias Da Silva, 2013) could lead to many diseases. Shrimps, which contain selenium 0.25 ± 0.02 mg/kg in fresh and 1.20 ± 0.09 mg/kg in dried, are a good source for dietary Se supplementation (Bügel, Sandstrom, & Larsen, 2001) The aim of this study was to investigate safety and bioavailability of selenium from shrimps and establish the optimal intakes, and the effect of different dose of selenium on the metabolism of phospholipid and cholesterol ester by using a lipidomics approach.

2. Materials and methods

This study was approved by the Institutional Animal Care and use Committee of Zhejiang Gongshang University, and procedures were conducted in compliance with the animal-use guidelines.

2.1. Diet preparation

A low selenium semisynthetic diet produced by the Zhejiang Academy of Medical Science Animal Experimentation Centre and described in Table 1. The composition of dried shrimps is shown in Table 2 and content of phospholipid and cholesterol ester in shrimps are shown in Table 3. The Se supplemented diet was prepared by adding dried shrimps (contain selenium 1.20 mg/kg) to the powder of basal diet to bring the total Se level to 10, 40, 80 μg/kg, during the adapting period, 6 g diet was taken during adapting time and the average body was 30 g after adapting time. 6 g mixed diet was mixture with 0.05, 0.20, 0.40 g died shrimps plus 5.95, 5.80 and 5.60 g for groups I–III, respectively. Each mixed diet was analyzed for Se and macro-nutrient before it was provided to mice and showed in Table 4. With low phospholipid and cholesterol ester content in shrimps and low content of shrimps in diets, the influences of metabolism of PLs and CE from diet intake were low.

2.2. Experimental design

Twenty ICR mice (initially weighting 17.61 ± 0.96 g, $n = 20$) were supplied by Animal Experimental Centre, Zhejiang Academy of Medical Sciences. Shrimps were newly caught and purchased from a local market (Cuiyuan, Hangzhou, China).

ICR mice were fed with the basal diet to deplete them of Se for a week and randomly categorized into 4 groups (5 in each group). The mice (during a study period of 28 days) were fed either with a common basal diet (group control), formulated to contain all nutrients required, or with a diet supplemented with three different Se doses groups (groups I–III) received diet with supplemented Se 2, 8, 16 μg/kg body weight from shrimps, respectively. Deionized water was offered by Milli-Q (Millipore, USA) with 18.2 MΩ cm with no selenium detected. The selenium and macro-nutrient content of the diet with shrimps were analysis in four groups and shown in Table 4.

Animals were fed the respective diets for 4 consecutive weeks. All mice were housed individually in stainless steel cages in a room maintained at a temperature of 21–23 °C and 50–60% relative humidity with a 12-h/12-h light–dark schedule. The mice were free to access to deionized water. During the study, all mice were examined daily for changes in body weight and food intake. Make sure that 6 g mixed diet was taken every day for each mice. No mortality was occurred during the experiment.