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Review article

Selenium in sow nutrition

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ABSTRACT

Selenium (Se) is shown to be an essential element for sow nutrition and a great deal of information has been accumulated for the last two decades indicating that dietary form of Se is a major determinant of its efficiency. Indeed, there are two major Se sources for pigs, namely inorganic selenium (mainly selenite or selenate) and organic selenium in the form of selenomethionine (SeMet; mainly as Se-yeast or SeMet preparations). The aim of the review is to update existing information about Se roles in sow nutrition with a specific emphasis to the oxidative stress and possibilities of decreasing negative consequences of the stresses by using dietary Se supplementation in an optimal form. It has been clearly shown that organic selenium has many important advantages in sow nutrition in comparison to traditional sodium selenite. The aforementioned benefits of organic selenium for sow include: better Se status of sows, especially in the case of advanced parities; improved antioxidant defences of sows; increased Se concentration in colostrum and milk and improved antioxidant status of colostrum and milk; improved Se transfer via placenta; improved Se status of foetus and development of pig embryos. It was proven that replacement of sodium selenite by organic Se in the sow's diet improved Se status of newly born piglets characterised by increased Se concentrations in tissues and whole body. In particular, increased Se concentration in piglet muscles could be considered as an important storage form of Se to be used in stress conditions. Furthermore, organic Se in sow's diet (versus sodium selenite) provides better Se status and antioxidant status of weaning piglets, as well as improves thyroid metabolism and increases activities of major digestive enzymes in piglet pancreas at time of weaning. However, most of the commercially relevant parameters (growth rate, mortality, FCR, etc.) were not affected. Only in two most recent publications in which sodium selenite was replaced by pure organic Se source in the sows diet, there were significant improvements in weaning litter weight and average weight of progeny piglets and daily weight gain of piglet from birth to weaning. Indeed, additional well-designed organic Se trials with big numbers of sows in commercial conditions are needed to explore a full potential of organic Se in sow nutrition.

Abbreviations: CAT, catalase; GSH-Px, glutathione peroxidase; GST, glutathione transferase; HMSeBA, 2-hydroxy-4-methylselenobutanoic acid; MDA, malondialdehyde; Nrf2, nuclear factor-erythroid-2-related factor 2; ROS, reactive oxygen species; SOD, superoxide dismutase; SeCys, selenocysteine; SeMet, selenomethionine; SS, sodium selenite; SY, selenium-yeast; T-AOC, total antioxidant capability.

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1. Introduction

Effect of oxidative stress in animal reproduction has been extensively studied recently. In our previous review (Surai and Fisinin, 2015a) we characterised the antioxidant system of the boar spermatozoa and described the role of Se in the antioxidant defences and maintenance of boar reproduction. Roles of oxidative stress and protective functions of antioxidants, in particular selenium in sow nutrition is difficult to overestimate. Recently a hypothesis of programming by oxidative stress has been developed (Luo et al., 2006) suggesting that oxidative stress in dams can have long-lasting consequences for the progeny. The authors suggested that mechanisms of oxidative stress programming might be through directly modulating gene expression or indirectly through the effects of certain oxidised molecules. In fact, oxidative stress can be modified during gestation and early postnatal periods by dietary antioxidants and selenium is considered to be a major player in the antioxidant systems of the body (Surai, 2006). The aim of the review is to update existing information about Se roles in sow nutrition with a specific emphasis to the oxidative stress and possibilities of decreasing negative consequences of the stresses by using dietary Se supplementation in an optimal form.

2. Oxidative stress and female reproduction

There is a great body of evidence to indicate that the antioxidant-prooxidant balance is an important regulator of the mammalian reproductive functions, such as ovarian follicular development, ovulation, fertilisation, luteal steroidogenesis, endometrium receptivity and shedding, embryonic development, implantation and early placental growth and development (Al-Gubory et al., 2010). It is well known that reactive oxygen species (ROS) have a dual role in the female reproductive tract: they serve as key signal molecules in physiological processes but can also be considered important elements in pathological processes (Rizzo et al., 2012). Indeed, oxidative stress plays a central role in the pathophysiology of many different disorders, including complications of gestation (Burton and Jauniaux, 2011). In fact, gestation is considered to be a state of oxidative stress arising from increased placental mitochondrial activity and production of ROS. Furthermore, the placenta also produces ROS which have pronounced effects on placental function including trophoblast proliferation and differentiation and vascular reactivity (Myatt and Cui, 2004). Therefore, the antioxidant defence system is shown to be extremely important in animal reproduction (Surai, 2006; Surai and Fisinin, 2015a,b).

3. Antioxidant system of the body and selenium

During evolution living organisms have developed specific antioxidant protective mechanisms to deal with ROS. Therefore it is only the presence of oxidation–reduction controlled mechanisms in living organisms enable them to survive in an oxygen-rich environment (Halliwell, 2012). These mechanisms are described by the general term “antioxidant systems”. They are diverse and responsible for the protection of cells from the actions of free radicals. These systems include (Surai, 2006, 2015; Surai and Fisinin, 2015a,b):

- natural fat-soluble antioxidants (vitamin E, carotenoids, ubiquinones, etc.);
- water-soluble antioxidants (ascorbic acid, uric acid, carnitine, taurine, etc.);
- antioxidant enzymes: superoxide dismutase (SOD), glutathione peroxidase (GSH-Px) and catalase (CAT);
- thiol redox system consisting of the glutathione system (glutathione/glutathione reductase/glutathione peroxidase) and a thioredoxin system (thioredoxin/thioredoxin peroxidase (peroxiredoxin)/thioredoxin reductase).

Antioxidant system of the living cell includes three major levels of defence (Surai, 2002, 2006).

The first level of defence is responsible for prevention of free radical formation by detoxifying free radicals (e.g. superoxide) or by inactivating catalysts and consists of three antioxidant enzymes namely SOD, GSH-Px and CAT plus metal-binding proteins. Transition metal ions accelerate the decomposition of lipid hydroperoxides into cytotoxic products such as aldehydes, alkoxyl radicals and peroxyl radicals. Therefore, metal-binding proteins (transferrin, lactoferrin, haptoglobin, hemopexin, metallothionein, ceruloplasmin, ferritin, albumin, myoglobin, etc.) belong to the first level of defence. Unfortunately, this