Biological Functions of Selenomethionine and Its Application in Laying Hen Production: Postprint

Authors: Meng Tiantian, Liu Yilin, Zhang Bin, Wu Xin, Yin Yulong

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Abstract

Selenomethionine (SeMet) is the most bioavailable organic selenium compound, which not only exhibits higher absorption and utilization efficiency than inorganic selenium, but also possesses biological functions such as enhancing immune function and anti-stress capacity. SeMet can significantly increase egg selenium content, improve egg quality, and enhance antioxidant capacity, immune function, and stress resistance in organisms. This paper reviews the absorption and metabolism of SeMet, its biological functions, and the current status of its application in laying hen production, aiming to provide a theoretical basis for the application of SeMet in laying hen production and for further research.

Full Text

Biological Functions of Selenomethionine and Its Application in Laying Hen Production

MENG Tiantian[1], LIU Yilin[2], ZHANG Bin[1], WU Xin[1,2]*, YIN Yulong[1,2]

[1]Hunan Co-Innovation Center of Safety Animal Production, College of Animal Science and Technology, Hunan Agricultural University, Changsha 410128, China
[2]Institute of Subtropical Agriculture, Chinese Academy of Sciences, Key Laboratory of Agro-Ecological Processes in Subtropical Region, Hunan Provincial Engineering Research Center of Healthy Livestock, Changsha 410125, China

Abstract: Selenomethionine (SeMet) is the organic selenium compound with the highest bioavailability, offering superior absorption and utilization compared to inorganic selenium while providing biological functions such as enhancing immunity and anti-stress capacity. SeMet can significantly increase egg selenium content, improve egg quality, and enhance antioxidant capacity, immune function, and stress resistance in laying hens. This review synthesizes current

research on the absorption and metabolism of SeMet, its biological functions, and its application in laying hen production, aiming to provide a theoretical foundation for the practical application and further investigation of SeMet in the poultry industry.

Keywords: selenomethionine; laying hens; biological functions; production; application

1. Overview of SeMet

Selenium is an essential trace element for organisms, with both deficiency and excess causing serious harm. Initially classified as toxic due to adverse effects at high concentrations, selenium deficiency was later shown to significantly reduce laying rate and hatchability in hens, necessitating appropriate dietary supplementation. Current selenium supplements for poultry include inorganic forms such as selenate and sodium selenite (SS), and organic forms like selenomethionine (SeMet). Inorganic selenium suffers from low bioavailability, potential antagonism with other minerals, poor selenium deposition and storage, and susceptibility to oxidation of selenite ions, making it less effective and potentially hazardous to animals and the environment. Organic selenium, by contrast, offers higher absorption efficiency, lower toxicity, and superior effects on antioxidant capacity, stress resistance, and immune function. L-SeMet can form a biological selenium pool in the body after meeting physiological requirements, preventing short-term selenium deficiency. Consequently, SeMet-based organic selenium has gained increasing attention in animal production.

SeMet is a naturally occurring organic selenium compound found in plants and feed grains, representing the most bioavailable organic selenide. Structurally similar to methionine (Met), SeMet is formed when sulfur in Met is replaced by selenium [Figure 1: see original paper]. It exists in three forms: the L-type, D-enantiomer, and synthetically produced DL-racemate (a 50:50 mixture of D- and L-forms). L-SeMet is the natural form found in nature and constitutes 70–76% of total selenium in selenium yeast. Due to its low toxicity and natural presence in food, SeMet is an ideal selenium supplement, with documented benefits of dietary L-SeMet and selenium yeast supplementation compared to SS.

2.1 Absorption and Transport Mechanisms

Inorganic selenium is primarily absorbed through simple diffusion with low efficiency, whereas SeMet is absorbed in the ileum via a sodium ion (Na^+)-dependent neutral amino acid transport system. Because SeMet shares this carrier-mediated, Na^+-dependent transport mechanism with Met, high Met concentrations can inhibit its absorption. Following intestinal absorption, inorganic selenium mainly exists as glutathione peroxidase (GPX), while organic selenium in the form of SeMet is deposited in tissue proteins.

Selenium transport proteins play a crucial role in SeMet absorption and transport. Proteins such as $b^{0,+}$rBAT, B^0, and PAT1 on the intestinal brush border serve as transporters for most neutral amino acids, exhibiting Na^+ dependence and facilitating absorption. SeMet and selenocysteine (SeCys) are primarily absorbed via the $b^{0,+}$rBAT system, with SeMet sharing absorption pathways with Met under certain conditions, providing valuable insights for future selenium transporter research.

Monogastric animals demonstrate high absorption and utilization efficiency for SeMet. Studies show that selenium absorption from selenium yeast is significantly higher than from SS in laying hens. In finishing pigs, both SeMet and SS increase selenium content in serum, muscle, liver, pancreas, and kidney, with SeMet yielding significantly higher levels in muscle, liver, and pancreas. Similar results have been reported in broiler chickens, where both DL-SeMet and L-SeMet groups showed significantly higher selenium content in serum and tissues compared to SS.

SeMet undergoes two primary metabolic pathways in vivo [Figure 2: see original paper]. First, absorbed SeMet can non-specifically incorporate into general tissue proteins in place of Met, serving as a biological selenium pool that can be mobilized during selenium deficiency. Free SeMet in the amino acid pool can either incorporate into tissue proteins or be degraded, with incorporation being reversible but degradation irreversible. The balance between incorporation and degradation depends on dietary Met content. Second, SeMet metabolized to SeCys can be degraded to selenide in the liver, which can then be converted to selenophosphate for synthesis of SeCys-containing selenoproteins or methylated to dimethylselenol or trimethylselenium ions for urinary excretion. In contrast, selenate and selenite are directly converted to selenide for selenoprotein synthesis or excretion.

3.1 Antioxidant Properties of SeMet

Selenium' s most important biological function is its antioxidant activity. As a core component of GPX, selenium enables the enzyme to scavenge lipid radicals in cell membranes, preventing oxidative membrane damage caused by accumulation of superoxide anions (O^-), hydroperoxides (ROOH), and hydrogen peroxide (H_2O_2), thereby maintaining cell integrity. Beyond GPX-1, which directly acts on H_2O_2, GPX-4 plays a critical role in ROOH scavenging. Selenium deficiency reduces GPX activity, leading to free radical accumulation, cell and mitochondrial membrane damage, elevated reactive oxygen species levels, and enhanced oxidative stress. Other selenoenzymes and selenoproteins also contribute significantly to the antioxidant system. For instance, thioredoxin reductases (TR-1 and TR-2) are essential for regenerating reduced thioredoxin (TRX), which maintains intracellular redox balance, while selenoprotein P functions as both a selenium transporter and an antioxidant.

Early studies demonstrated that both SS and selenium yeast significantly increase serum GPX activity in finishing pigs, with SS showing higher activity at 0.1 mg/kg supplementation but equivalent activity at 0.3 mg/kg. Recent research indicates that at 0.3 mg/kg selenium, SeMet formulations increase plasma GPX activity, catalase activity, and total antioxidant capacity while reducing malondialdehyde content in plasma, liver, and muscle. Selenium yeast has been shown to increase serum GPX activity in laying hens and enhance GPX activity and GPX-1 gene expression in liver and spleen of broiler chickens. These findings demonstrate that SeMet-based organic selenium significantly enhances antioxidant function.

3.2 SeMet and Immunity

Selenium modulates immune function primarily through selenoproteins such as GPX-1, GPX-4, TR-1, and TR-2 by enhancing macrophage and natural killer cell activity and promoting T and B lymphocyte proliferation, thereby strengthening non-specific, cellular, and humoral immunity. Adhesion molecules recruit neutrophils and T lymphocytes to inflammatory sites by activating nuclear factor- B (NF- B) through cytokines like IL-1β, TNF-α, and IL-6, exacerbating inflammation. Selenium supplementation with SS dose-dependently inhibits TNF-α-induced adhesion molecule expression, suggesting that selenium may suppress inflammation by inhibiting protein kinase-mediated phosphorylation of I Bα through GPX, thereby preventing NF- B release and activation. Recent studies also show that selenium significantly reduces lipopolysaccharide-induced expression of pro-inflammatory genes TNF-α and cyclooxygenase-2 by inhibiting the mitogen-activated protein kinase pathway.

Dietary supplementation with 0.3 mg/kg SS has been shown to increase concentrations of ascorbic acid, retinol, and α-tocopherol in serum and γ-interferon in serum and thymus of laying hens. Compared to SS, selenium yeast significantly increases serum immunoglobulin (Ig) G and IgM levels in male broilers, lymphocyte rosette formation rate and spleen and bursal indices in chicks, and serum IgG, IgA, IgM, and complement 3 levels in piglets. These results indicate that SeMet-based organic selenium significantly enhances immune function.

3.3 SeMet and Anti-stress Effects

Selenium yeast serves as a biological selenium pool that releases SeMet during stress to provide selenium for GPX and other selenoenzyme synthesis, protecting tissues and organs from oxygen radical-induced damage, thus demonstrating higher biological efficacy than SS. Studies show that selenium yeast supplementation results in significantly higher spleen selenium content compared to SS, indicating that SeMet deposition in immune organs can intervene in lipid peroxidation, protect against stimulus-induced cytotoxicity, maintain cellular homeostasis in damaged tissues, and enhance stress resistance. Under heat stress conditions, SeMet-based organic selenium improves growth performance and antioxidant capacity in broiler chickens, mitigating adverse effects of high temperature stress.

4.1 Effects of SeMet on Selenium Deposition in Eggs

Dietary selenium supplementation significantly increases egg selenium content, with SeMet-based organic selenium depositing more readily into eggs than inorganic forms. Adding 0.3 mg/kg selenium from selenium yeast and SS to laying hen diets increased egg selenium content by 4.8-fold and 2.8-fold, respectively. While research confirms that selenium yeast increases egg selenium content, comparisons between SeMet formulations and selenium yeast remain controversial. Some studies report that SeMet formulations deposit more readily into eggs than selenium yeast, with egg selenium content increasing significantly with dietary SeMet levels, while others report contradictory results, possibly due to differences in SeMet content between products. Additionally, feeding SeMet-based organic selenium results in higher selenium deposition in egg albumen because, under certain conditions, SeMet shares metabolic pathways with Met and can directly deposit in albumen, whereas SS must first be metabolized to selenide in the liver, incorporated into selenoproteins, and then deposited in albumen.

Selenoprotein P reflects selenium homeostasis and is most abundantly expressed in the liver. Egg selenium concentration correlates significantly with liver selenium concentration in hens. Furthermore, supplementing a basal diet containing 0.3 mg/kg SS with 1.0, 2.4, or 5.1 mg/kg selenium yeast resulted in linear increases in egg selenium content, with organic selenium levels up to 3–6 mg/kg showing no toxic effects. Selenium yeast can also synergize with Met to significantly increase muscle selenium content in progeny chicks.

4.2 Effects of SeMet on Egg Quality

SeMet-based organic selenium improves egg quality in laying hens. Supplementation with 0.25 and 0.5 mg/kg selenium yeast slows the decline in Haugh units during storage, extending shelf life. Compared to SS, selenium yeast significantly enhances shell strength while reducing albumen height and Haugh units. Other studies report that both selenium yeast and SeMet formulations significantly increase yolk color during days 60–90 of treatment, with selenium yeast showing superior effects, though the SeMet group had significantly higher soft and broken egg rates and a trend toward reduced shell thickness.

In summary, compared to inorganic selenium salts, lower levels of SeMet supplementation can improve antioxidant capacity, immune function, stress resistance, egg selenium content, and egg quality in laying hens. However, the complexity of biological fermentation makes it difficult to maintain stable SeMet content and chemical forms during large-scale production, hindering wider application. Production costs also represent a key limiting factor. Therefore, further research into SeMet production processes, quality control, effects in different animal species, and underlying mechanisms will promote its practical application in animal production.

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