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

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Abstract

Selenomethionine (SeMet) is the organic selenium compound with the highest bioavailability, which not only exhibits higher absorption and utilization rates than inorganic selenium, but also possesses biological functions such as enhancing organism immunity and strengthening anti-stress capabilities. SeMet can significantly increase egg selenium content, improve egg quality, and enhance organism antioxidant, immune, and stress capacities. This article 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

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Abstract

Selenomethionine (SeMet) represents the organic selenium compound with the highest bioavailability, offering superior absorption and utilization compared to inorganic selenium while conferring important biological functions such as

enhanced immunity and improved stress resistance. SeMet can significantly increase egg selenium content, improve egg quality, and bolster antioxidant capacity, immune function, and stress tolerance in laying hens. This review synthesizes current research on the absorption and metabolism of SeMet, its biological functions, and its practical applications in egg production, providing a theoretical foundation for further research and expanded use of SeMet in the poultry industry.

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

Selenium is an essential trace element for organisms, with both deficiency and excess causing serious harm to animals. Initially classified as toxic due to its detrimental effects at high concentrations, selenium was later recognized as critical for poultry, as deficiency markedly reduces laying rate and hatchability. Consequently, diets must be supplemented with appropriate selenium levels to meet physiological requirements. Current poultry selenium supplements primarily fall into two categories: 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. These limitations prevent optimal selenium supplementation and may pose potential hazards to animals and environmental pollution risks. 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 recurrence. Consequently, SeMet-based organic selenium has garnered increasing attention in animal production. This article reviews the absorption, metabolism, biological functions, and current applications of SeMet in laying hen production.

1. Overview of SeMet

SeMet is a naturally occurring organic selenium compound found in plants and feed grains, representing the most bioavailable organic selenium source. Structurally analogous to methionine (Met), SeMet is formed when sulfur in Met is replaced by selenium [Figure 1: see original paper]. Three forms exist: the L-isomer, D-enantiomer, and synthetically produced DL-racemate. L-SeMet is the naturally occurring form in nature and constitutes the primary selenium species in yeast selenium, accounting for 70%–76% of total selenium in selenium-enriched yeast. Like other amino acids, SeMet exists as D- and L-isomers, with synthetic products being DL-mixtures (50% each). Dietary supplementation with L-SeMet and selenium yeast has demonstrated clear advantages over SS. Due to its low toxicity and natural occurrence in foods, SeMet represents an ideal selenium supplement.

2.1 Absorption and Transport Mechanisms

Inorganic selenium is primarily absorbed through simple diffusion with relatively low efficiency. In contrast, SeMet is absorbed in the ileum via a sodium ion (Na^+)-dependent neutral amino acid transport system. Because SeMet shares this Na^+-dependent, carrier-mediated transport mechanism with Met, high Met concentrations can inhibit its absorption. Following intestinal absorption, inorganic selenium predominantly exists as glutathione peroxidase (GPX), whereas organic selenium mainly deposits in tissue proteins. Selenium transport proteins play crucial roles in SeMet absorption and translocation. 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 important absorptive functions. SeMet and selenocysteine (SeCys) are primarily absorbed through the b^0,$^+$rBAT system, with SeMet sharing Met absorption pathways under certain conditions, providing valuable insights for future selenium transporter research.

Monogastric animals efficiently absorb and utilize SeMet. Studies show that selenium absorption from selenium yeast is significantly higher in laying hens compared to SS. In finishing pigs, both SeMet and SS supplementation increase selenium content in serum, muscle, liver, pancreas, and kidney, with SeMet yielding significantly higher selenium levels in muscle, liver, and pancreas than SS. Similar results demonstrate that SeMet supplementation significantly elevates selenium concentrations in plasma, liver, and longissimus dorsi muscle of finishing pigs. Research on different SeMet isomers in broilers reveals that both DL-SeMet and L-SeMet groups exhibit significantly higher selenium levels in serum and tissues compared to SS, along with increased serum triiodothyronine content.

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, forming a biological selenium pool that can be mobilized during selenium deficiency. Studies show that selenium yeast supplementation significantly increases total blood selenium and the proportion of SeMet in total selenium in lambs, while enhancing erythrocyte GPX activity compared to SS. Free SeMet in the amino acid pool can either incorporate into tissue proteins or undergo degradation, with protein incorporation being reversible while degradation is irreversible. The balance between incorporation and degradation depends on dietary Met content. Second, SeMet metabolized to SeCys can be degraded in the liver to selenide, which may be converted to selenophosphate for synthesis of SeCys-containing selenoproteins or methylated to dimethylselenol or trimethylselenonium for urinary excretion. In contrast, selenate and selenite are directly converted to selenide for selenoprotein synthesis or urinary excretion.

3.1 Antioxidant Properties of SeMet

Selenium' s most crucial biological function is its antioxidant activity. As the primary component of GPX active centers, selenium enables GPX to scavenge lipid radicals in cell membranes, preventing oxidative membrane damage from accumulated superoxide anions (O^-), hydroperoxides (ROOH), and hydrogen peroxide (H_2O_2), thereby maintaining cellular integrity. Beyond GPX-1, which directly acts on H_2O_2, GPX-4 plays a key role in ROOH scavenging. Selenium deficiency reduces GPX activity, leading to free radical accumulation, cellular and mitochondrial membrane disruption, elevated reactive oxygen species, 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 transport protein 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 preparations increase plasma GPX activity, catalase activity, and total antioxidant capacity while elevating GPX activity in liver and muscle and reducing malondialdehyde content in plasma, liver, and muscle compared to SS. Selenium yeast enhances serum GPX activity in laying hens and increases GPX activity and GPX-1 gene expression in liver and spleen of broilers. These findings demonstrate that SeMet-based organic selenium significantly enhances antioxidant function.

3.2 SeMet and Immunity

Selenium modulates immune function primarily through selenoproteins including GPX-1, GPX-4, TR-1, and TR-2, enhancing macrophage and natural killer cell activity while promoting T and B lymphocyte activation and proliferation, thereby strengthening non-specific, cellular, and humoral immunity. Adhesion molecules recruit neutrophils and T lymphocytes from periphery to inflammatory sites, activating nuclear factor- B (NF- B) through cytokines IL-1β, TNF-α, and IL-6 production, which amplifies inflammatory responses. Selenium supplementation significantly inhibits TNF-α-induced adhesion molecule expression in a dose-dependent manner, suggesting that selenium may suppress inflammation by inhibiting I Bα phosphorylation via GPX, thereby preventing NF- B release and activation. Recent findings also show selenium significantly reduces lipopolysaccharide-induced expression of major pro-inflammatory genes TNF-α and cyclooxygenase-2 by inhibiting the mitogen-activated protein kinase pathway.

Dietary supplementation with 0.3 mg/kg SS significantly increases ascorbic acid, retinol, and α-tocopherol concentrations in laying hen serum and γ-interferon levels in serum and thymus. Compared to SS, selenium yeast significantly ele-

vates serum immunoglobulin (Ig) G and IgM in male broilers, increases lymphocyte rosette formation rate and spleen and bursal indices in chicks, and enhances serum IgG, IgA, IgM, and complement 3 levels in piglets. These results indicate that SeMet-based organic selenium markedly enhances immune function.

3.3 SeMet and Stress Resistance

Selenium yeast serves as a biological selenium pool that releases SeMet during stress, providing selenium for GPX and other selenoenzyme synthesis to protect tissues and organs from oxygen radical damage, thus exhibiting significantly higher biological value than SS. Studies show that selenium yeast supplementation yields significantly higher spleen selenium content in laying hens than SS, demonstrating that SeMet can protect and improve cellular homeostasis in stress-induced damaged tissues by depositing in immune organs and intervening in cellular lipid peroxidation, thereby enhancing stress resistance. Under heat stress conditions, SeMet-based organic selenium improves growth performance and antioxidant capacity in broilers, mitigating adverse effects of high temperature stress.

4.1 Effects of SeMet on Egg Selenium Deposition

Dietary selenium supplementation significantly increases egg selenium content, with organic selenium primarily in the form of SeMet depositing more readily into eggs than inorganic forms. Adding 0.3 mg/kg selenium from yeast or SS to laying hen diets increases egg selenium content by 4.8-fold and 2.8-fold, respectively. Pavlović et al. confirmed that selenium yeast enhances egg selenium content. However, controversy remains regarding selenium deposition efficiency between SeMet preparations and selenium yeast. Some studies indicate SeMet preparations deposit more readily into eggs than selenium yeast, with egg selenium content increasing dramatically with dietary SeMet levels, while others report contradictory results, possibly due to varying SeMet contents in different products. Additionally, feeding organic selenium primarily as SeMet deposits more selenium in egg albumen because, under certain conditions, SeMet and Met share metabolic pathways, allowing direct deposition 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, with highest expression in the liver. Egg selenium concentration correlates significantly with maternal liver selenium concentration. Furthermore, Bennett et al. added 1.0, 2.4, or 5.1 mg/kg selenium yeast to a basal diet containing 0.3 mg/kg SS and observed linear increases in egg selenium content with dietary selenium level, with organic selenium levels up to 3–6 mg/kg showing no toxic effects on hens. Wang et al. found that at certain concentrations, selenium yeast synergizes with Met to significantly increase muscle selenium content in progeny chicks from supplemented breeder hens.

4.2 Effects of SeMet on Egg Quality

Organic selenium primarily in the form of SeMet improves egg quality. Studies show that adding 0.25 and 0.5 mg/kg selenium yeast to laying hen diets slows Haugh unit decline during storage, extending egg freshness. Compared to SS, selenium yeast significantly enhances shell strength while reducing albumen height and Haugh units. Other research indicates that both selenium yeast and SeMet preparations significantly increase yolk color during days 60–90 of treatment, with selenium yeast showing superior effects, though the SeMet group exhibited significantly higher soft/broken egg rates and a trend toward reduced shell thickness.

In summary, compared to inorganic selenium salts, lower supplementation levels of SeMet 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 broader application. Production costs also represent a key limiting factor for commercial adoption. Therefore, further research into SeMet production processes, quality control methods, and its effects and mechanisms across different animal species will facilitate expanded application in animal production.

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