Using maternal transfer to deliver the power of selenium to offspring

Since its discovery over 200 years ago, it has been well demonstrated that selenium (Se) plays a critical role in oxidative stress, reproductive performance, immune function and growth development. In general, plant-based raw materials (for example, corn, soybean, wheat) do not meet the Se requirements of modern breeder birds, necessitating supplementation.

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Plant-soil interactions have a major influence on plant Se content. Changes to climate and soil organic carbon content are predicted to lead to further decreases in soil Se concentrations and exacerbate deficiencies in raw materials used for animal production. Therefore, supplementation to achieve adequate Se levels in breeder diets will be a continued strategy to improve reproduction performance, fertility, and hatchability.

While many factors ultimately affect offspring quality, there are important roles that breeder Se nutrition plays in hatchery outcomes and chick development. Se is involved in rooster reproductive tissue development, spermatogenesis, and male fertility. Further, maternal nutrition and its effect on the offspring have received more attention in poultry in recent years.

Research shows that boosting breeder hen Se status through feeding a high quality mineral source results in Se being available for embryo development and the support of post-hatch chick health. Interestingly, the Se source in breeder diets has been shown to impact developing embryos and positively influence the hatching process and day-old chick quality.

Table 1. Influence of selenium source (Sel-Plex vs. selenite) on distribution of normal, dead and abnormal spermatozoa in commercial Hubbard broiler breeder at 32 and 42 weeks of age.

Selenium source	Spermatozoal category (%)	32 weeks of age	42 weeks of age
Sel-Plex	Normal	98.01^{a,x}	97.65^{a,x}
	Dead	0.42^{b,x}	0.56^{b,x}
	Abnormal midpiece	0.51^{b,x}	0.76^{b,x}
	Corkscrew head	0.40^{b,x}	0.58^{b,x}
	Other	0.24^{b,x}	0.41^{b,x}
Sodium selenite	Normal	91.93^{b,x}	85.39^{b,y}
	Dead	1.31^{a,y}	1.94^{a,x}
	Abnormal midpiece	3.78^{a,y}	6.21^{a,x}
	Corkscrew head	1.33^{a,y}	3.19^{a,x}
	Other	1.96^{a,y}	3.22^{a,x}

^{a,b} Within weeks of age, comparison of the influence of Sel-Plex to sodium selenite on specific spermatozoal categories, means with unlike superscripts differ significantly ($p \leq 0.05$)
^{x,y} Comparison of the influence of age on specific spermatozoal categories, means with unlike superscripts differ significantly ($p \leq 0.05$)

Organic selenium improves semen quality

Rooster sperm quality plays a critical role in the fertility performance of reproductive hens. The level of polyunsaturated fatty acids (PUFAs) within sperm can lead to lipid peroxidation and oxidative damage during storage.

Selenium plays an essential role in antioxidative function, and sperm from roosters fed a high quality source may be superior during and after storage.

Edens et al. (2009) investigated the effect of Se source on semen production and sperm quality. They showed that Se-supplemented roosters produced semen at 19 weeks, seven weeks earlier than the Se-deficient group. Testes were poorly developed in the Se-deficient group, while the addition of 0.2mg/kg Se from yeast (Sel-Plex, Alltech Inc) resulted in greater relative testes weight by 115.07% and 9.57% compared with Se-deficient and selenite groups, respectively. Spermatozoa morphology was also improved with the addition of Sel-Plex. Spermatozoa abnormalities were 42.1%, 10.6% and 1.3% in the Se-deficient, selenite and Sel-Plex groups, respectively.

The long-term addition of Sel-Plex maintained the normal spermatozoa at 97.65%, while the selenite group only achieved 85.39% at 42 weeks of age (Table 1).

Perivitelline sperm holes in the egg are a quantitative indicator of sperm's ability to reach the ovum and thus sperm quality.

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After insemination, sperm from roosters fed Sel-Plex had higher spermatozoa penetration of the egg vitelline layer than the selenite group. The number of perivitelline sperm holes was 12.3, 32.5 and 25.1 for the control, Sel-Plex and selenite groups, respectively, after 2-7 days of insemination.

It would appear that the form of Se fed to roosters impacted the rooster semen quality. One of the explanations for this observation may be the enhanced control of the oxidative environment through the Se-dependent antioxidative enzyme glutathione peroxidase (GSH-Px).

Overall, the supplementation of Sel-Plex in rooster diets has been shown to be beneficial for testes maturity, sperm morphology and, as a result, breeder fertility.

Pathway/function[a]	Sodium selenite	Sel-Plex
Selenoproteins	⟷	↑
Protein synthesis	↓ Translation, initiation of translation and translation of RNA ↓ Metabolism of protein ↓ Protein biosynthesis ↓ Degradation and catabolism of protein ↓ Expression of protein	↑ Protein synthesis/biosynthesis ↑ Metabolism of proteins
Oxidative phosphorylation	↓ Complexes I-IV subunits ↓ ATP: polyphosphate kinase ↓ Proton exporting ATPase, proton exporting two-sector ATPase	↑ Complexes 1, III and IV subunits ↑ Proton exporting ATPase, protein exporting two-sector ATPase
Ubiquinone	⟷	↑ Ubiquinone biosynthesis

[a]pathways and functions identified by Ingenuity Pathway Analysis Software

Table 2. Overview of select transcriptional changes in the oviduct of sodium selenite-supplemented (SS) or Sel-Plex-supplemented (SP) hens. Changes reported are compared to the control (selenium-deficient) hens: up-regulated, ↑; down-regulated, ↓; and not-affected, ⟷.

Breeder reproductive performance

The process of laying eggs is a major stressor for breeder and layer birds. This process, combined with the environment, management and the required vaccine schedules, ensures that breeder hens are in need of a strong antioxidative system to deal with these various on-farm challenges.

When compared with traditional inorganic Se forms, such as selenite, Se yeast has a higher bioavailability and Se uptake.

Organic Se from the Se yeast can be utilised to synthesise selenoproteins more easily, and the excess Se can be stored in a protein pool.

In contrast, the inorganic selenite is poorly absorbed, and most excess Se is excreted through urine and faeces.

Renema et al. (2004) evaluated the effect Se source has on reproductive performance in broiler breeders. They found that using Sel-Plex to replace all the selenite in feed could produce five extra eggs from 24-58 weeks of age.

Correspondingly, six more settable eggs

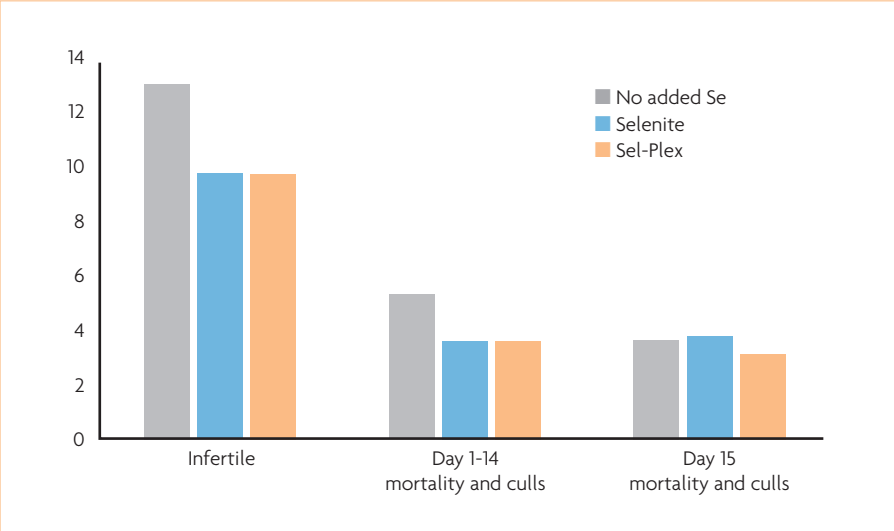

Fig. 1. Effect of different selenium sources on embryo mortality and culls.

were produced with Sel-Plex when replacing selenite. In the late laying period (49-58 weeks), Sel-Plex showed more benefits in production than selenite, with a hen-housed rate of 68% compared to 61% in the selenite group.

Research conducted by AMR in 2010 evaluated different inclusion rates of Sel-Plex on breeder reproduction. In agreement with previous research, supplementation of 0.1 or 0.2mg/kg Se from Sel-Plex significantly increased fertility and hatchability in two different broiler breeder strains studied. Fertility and hatchability were improved by 2.94% and 3.54%, respectively, compared to a control without Sel-Plex. Those improvements were concluded to have been due to the feeding of the highly bioavailable Se yeast. This inference was supported by the higher Se deposition in various tissues of the breeder birds.

Compared with inorganic selenite, the Se content in the liver, pancreas and breast muscles was increased by 16-24% with Sel-Plex, which clearly indicates that the Se from Sel-Plex can be deposited in tissue more effectively and that more Se is available when breeders are faced with production stress.

With advancing technology and detection methods combined with traditional biochemical indicators, it is possible to explore the potential mechanism of nutrient effects on animals through gene microarray analysis. A 2011 study employed those very techniques in broiler breeder birds. The results found that supplementing Sel-Plex resulted in a 14% higher Se content in the oviduct compared with the feeding of selenite. When gene expression was investigated, 2,106 (1,961 down-regulated, 145 up-regulated) genes were differentially expressed in sodium selenite hens and 947 (639 down-regulated, 308 up-regulated) in Sel-Plex hens.

Gene expression analysis revealed that the addition of Sel-Plex in breeder diets up-regulated translation of genes encoding for energy production, protein synthesis and protein metabolism in the oviduct more than sodium selenite (Table 2). Genes that modulate energy production and up-regulated by Sel-Plex, but not sodium selenite, included those encoding several subunits of the mitochondrial respiratory complexes, ubiquinone production and ribosomal subunits.

A decrease in transcripts of genes involved in respiratory complexes, ATP synthesis, protein translation and metabolism were observed in the breeder oviduct with sodium selenite. Those gene expression differences may partially explain the benefits of Sel-Plex in breeder reproductive performance.

Egg quality

Due to the reproductive process of poultry, all of the nutrients deposited by a hen into an egg must support embryonic development and energy expenditure during the entire hatching phase. Considering the high level of PUFAs contained within eggs, optimal antioxidation status of embryos is required to ensure egg quality. Studies show a positive relationship between egg weight and hatched bird weight, so it is also vital to pay attention to this egg quality metric in breeder productions.

A 10-week experiment found that replacing inorganic Se with Sel-Plex in broiler breeder diets could increase egg weight by 0.83g (0.3mg/kg sodium selenite: 56.70g; 0.3mg/kg Sel-Plex: 57.53g).

At the same time, Se content was increased in both the albumen and yolk with Sel-Plex compared to selenite.

Higher Se deposition in eggs leads to higher GSH-Px (a key antioxidant) activity in the albumen and yolk. Stronger antioxidative capacity could provide more protection to eggs during storage and incubation, thereby lowering embryo mortality.

Embryo mortality

Nutrients in eggs play a crucial role in early embryonic development. Embryo mortality in the first 14 days is considered to be related to nutrient deficiency in eggs. Inorganic selenite is poorly absorbed in the intestine; thus, less is available for transfer from hen to egg to embryo. Moreover, the antioxidative capacity of selenite is limited in its ability to mitigate oxidative stress during incubation. Fig. 1 shows a reduction of infertile eggs when Se was added to breeder diets. During the first 14 days of incubation, embryonic mortality was found to be 5.33% with the non-supplemented diet, compared to 3.72% (selenite) and 3.52% (Sel-Plex). Similarly, the lowest embryo mortality from incubation day 15 to hatch was observed in the group with Sel-Plex.

Day-old chick quality

Selenoprotein P (SEPP1) contains multiple selenocysteine residues and is a good indicator of Se status in animals. It has been well evaluated that SEPP1 can improve antioxidant capacity within animal systems. It is interesting to observe that the SEPP1 concentration in the cecum, liver and kidney was higher in both breeder and their day-old chicks with the addition of Se yeast. Higher SEPP1 concentration means more Se is transported throughout the body, especially within the liver, which is the main tissue to take up Se synthesise into SEPP1.

Consistently higher egg weight and day-old chick body weight with the addition of Sel-Plex in lieu of inorganic selenite has been observed. More importantly, body weight and chick length uniformity were improved by 8% and 11%, respectively, with Sel-Plex compared to selenite.

Conclusion

It has been widely and well established within published literature and commercial practice that Se is an essential trace mineral in breeder nutrition. It plays a vital role in rooster semen development and quality, breeder reproduction performance, egg quality, the hatching process and day-old chick quality.

Numerous peer-reviewed research trials over the last two decades have consistently shown that organic Se supplementation, in the form of Sel-Plex, results in a higher Se deposition in breeder tissue and eggs. Optimal Se content in eggs can help with embryonic development and improve chick quality and uniformity.

These effects of Sel-Plex are not only beneficial to breeders but their offspring as well. ■

References are available from the author on request