

## The Importance of Arsenic, Vanadium, Cobalt and Strontium in Poultry, A Review

Review Article

B. Navidshad<sup>1\*</sup> and M. Mohammadrezaei<sup>1</sup><sup>1</sup> Department of Animal Science, University of Mohaghegh Ardabili, Ardabil, Iran

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\*Correspondence E-mail: [bnavidshad@uma.ac.ir](mailto:bnavidshad@uma.ac.ir)

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### ABSTRACT

Any deficiency in trace element content of commercial poultry diets will decrease their performance. To prevent this situation it is necessary to supplement trace minerals in poultry diets to allow the modern birds to reach their genetic potential. The NRC publication as the most famous reference for livestock and poultry nutrients requirement has no recommendation for some less needed trace mineral such as arsenic, vanadium, cobalt and strontium. This deficiency is seen in commercial mineral supplements too which in some situations could result in a reduction in animals productivity. This review has summarized the new finding on the important role of arsenic, vanadium and cobalt in poultry.

**KEY WORDS** arsenic, cobalt, vanadium, poultry, strontium.

### INTRODUCTION

The modern poultry production experienced a huge development in recent decades. In the middle of 2000 s, the body weight of a commercial broiler chicken reached 2 kg in 5 weeks, down from 9 weeks in 1970 s. The nutrients requirements for broilers have still been thought to be the same level as those recommended by the NRC (1994), some of which for trace minerals are based on information as far back as the 1950 s. Although most of the increase in body weight via genetic improvement has been an indirect response to selection for appetite, increased body growth has resulted in skeletal problems, which may be related to poor mineral nutrition. It is thus reasonable to consider the current NRC recommendation as unsuitable for the needs of the modern bird. Actually, the industry is using trace mineral supplements in feed formulation to reduce the deficiency risk. However, for some trace minerals such as arsenic, vanadium, cobalt and strontium, no recommendation has suggested in NRC (1994) and common

mineral supplement may not supply adequate amounts of these less attractive elements. The present review tries to summarize the scientific finding on the essential role of these elements in commercial poultry industry.

#### Arsenic

Arsenic (As) is a trace mineral found in the environment, both from natural occurrence and from anthropogenic activity and it is also present in groundwater, soil, and numerous plants. This trace mineral displays different valences (-3, 0, +3, +5) which result in formation of broad variety of arsenic compounds with different chemical characteristics (EFSA, 2005). It has been reported that trivalent arsenic compounds have a greater toxicity than the pentavalent forms, particularly at high doses (Uthus and Seaborn, 1996). Arsenic is found both in inorganic and organic compounds, with different physical and chemical properties. The organic forms of arsenic have very low toxicity relative to the organic sources; however, most of the collected data from food and feed in the framework of official food con-

tol are usually reported as total arsenic without distinguishing the various arsenic species (EFSA, 2009). Arsenic is present mainly (99%) in the organic forms of arsenocholine and arsenobetaine in most of the marine animals and organisms, which is virtually non-toxic (EFSA, 2005).

There could be a marked difference in bioavailability of inorganic and organic source of arsenic. Inorganic compounds of arsenic, present in drinking water, are rapidly and completely (about 95%) absorbed after ingestion by rats, mice and poultry (EFSA, 2005). Nonetheless, the solubility of the arsenical compounds determines the rate of absorption of ingested inorganic arsenic source, with high water soluble compounds being greatly absorbed (Uthus and Seaborn, 1996).

However, many studies with hamsters, rats and chickens have proved that arsenic is sort of an essential nutrient (Anke, 1986; Uthus, 1992; Uthus, 1994), but the physiological role of this trace mineral has not been clearly verified and the essential nature of arsenic in poultry has not yet demonstrated (Nielsen, 1991). Some of these studies have suggested a physiological role in methionine metabolism for arsenic, by affecting the methylation of molecules whose functions are influenced by methyl incorporation (Nielsen, 1991; Uthus, 2003; Fowler *et al.* 2007; NRC, 2005).

Since the mid-1940's the organic arsenic source have been used as feed additives to improve performance and control diseases in poultry in various countries (EFSA, 2009). For example, roxarsone (3-nitro-4-hydroxyphenylarsonic acid) is incorporated in broiler chickens diet to promote growth rate and improve weight gain and feed efficiency and also as a mean to control coccidial intestinal parasites (Van Rysse, 2008). Additionally, phenylarsonic acid, arsanilic acid, 4-nitrophenylarsonic acid and 4-ureidophenylarsonic acid are also being used in many countries for in favor of all the above-mentioned reasons (EFSA, 2005). Organic arsenic compounds that are used as feed additives in pigs and poultry diets can cause intoxication in these animals, when the concentration of arsenic compounds falls 2 to 10 times higher than the essential dose, which is usually 100 mg/kg complete feed (MVM, 2008). According to NRC (2005), poultry and rats are relatively sensitive to inorganic arsenic compared to other species.

Despite the apparent deficiency signs and beneficial effects for arsenic compounds reported in several animal studies, the NRC (2005) does not consider arsenic as a generally essential nutrient. Decreased S-adenosyl-methionine (SAM), and increased S-adenosyl-homocysteine (SAH) concentrations in the liver, and a decreased SAM/SAH ratio are the most reported and consistent symptoms of arsenic deprivation in rats and mice (Uthus, 2003).

The transportation of inorganic arsenic in edible tissues of mammals and birds is generally low, and, thus, foods derived from these tissues contribute only insignificantly to the possible intoxication of human. Consequently, the amount of inor-

ganic arsenic present in food determines the potential adverse effects of arsenic to animal and human health. The maximum content of arsenic in complete feed has been set by the European Union at 2 mg/kg feed (with 12% moisture) for all animal species except fish (European Union, 2003).

Since, arsenic is regarded as one of the toxic mineral elements, harmful to animals' health; feeds should continuously be monitored to ensure that concentrations of this toxic mineral element are below the maximum level set by the European Union (Bampidis *et al.* 2013).

### Vanadium

Vanadium (V) is widely distributed in the earth's crust. It occurs naturally in the form of about 70 minerals but does not occur as metallic vanadium (Curran and Burch, 1967). In its compounds, it forms different oxidation states, the most common being +3, +4 and +5. The major source of exposure to vanadium for all species of animals is feed. Despite, the very low concentrations of vanadium that can lead to toxicosis, it is also recommended as an essential element for poultry diets at very low concentrations. Yuan *et al.* (2016) reported that 10 and 15 mg/kg vanadium in diet negatively affected the albumen quality, eggshell color, and caused antioxidant stress in the liver of laying hens. An important concern is the vanadium content in rock phosphates that are used as a phosphorus source in poultry diets (NRC, 1994; EFSA, 2004). The concentration of vanadium in sources of phosphorus may vary at different deposit locations and has been reported to be as high as 6000 mg/kg in some deposits (Henry and Miles, 2006).

Vanadium deficiency signs have been observed in laying hens under experimental conditions (Davis *et al.* 1999). EFSA (2004) did not consider vanadium as an essential element for animals. However, it has been shown that vanadium might play a role in the regulation of some enzymes, such as the Na<sup>+</sup>/K<sup>+</sup>-exchanging ATPase, phosphoryl-transfer enzymes, adenylate cyclase and protein kinases. This might imply a role of vanadium in hormone, glucose, lipid and bone metabolism. Adverse effects of dietary vanadium in poultry have been reported by many researchers over the past 35 years, including several toxic effects in laying hens. High concentrations of vanadium in phosphorus sources are detrimental to performance and are of major concern in poultry feeds. Berg *et al.* (1963) are known as the first researchers to report that high concentrations of vanadium in laying hens diet results in a decline in egg interior quality. Later on, other researchers (Benabdeljelil and Jensen, 1990; Davis *et al.* 1999; Bressman *et al.* 2002) also reported similar findings. Bressman *et al.* (2002) concluded that all dietary concentration of vanadium (20, 40 and 60 mg/kg diet) resulted in a significant increase in excreta moisture and decreased feed consumption, egg fertility, hatchability, and egg production. Also, they reported that dietary vanadium was unaffected on embryo malposition, but

when dietary concentration of vanadium was increased (60 mg/kg diet) embryonic. Additionally, Wang *et al.* (2009) suggested that low concentration of vanadium (20 mg/kg diet) could improve the structures of digestive glands in chickens, but more than 40 mg/kg could affect their development and 80 mg/kg could damage the structures.

According to some reports mentioned above, it could be concluded that presence of up to 20 mg/kg of vanadium in breeders and layers hens' diet, can reduce their performance while these concentration of vanadium on broiler chicken, can improve structures of digestive glands.

### Cobalt

Vitamin B<sub>12</sub> belongs to a specific group of cobalt (Co)-containing corrinoids with specific biological activity in animals. The tag vitamin B<sub>12</sub> is restricted to the suggested biochemical nomenclature for the form of cobalamin. Cobalamin is not synthesized in plants; it is only synthesized by certain bacteria, fungi, and algae (Green, 2005). Vitamin B<sub>12</sub> is an essential factor of several enzyme systems in animal's body. This vitamin plays a central role in methylation, energy metabolism, cell division and functions of the immune system (EFSA, 2009; McDowell, 1999; Underwood and Suttle, 1999). Vitamin B<sub>12</sub> also has a key role in the formation of red blood cells and is necessary for reactions of isomerases and methyltransferases (Banerjee and Ragsdale, 2003).

Both inorganic and organic forms sources of cobalt such as oxides, acetates, sulphates, carbonates, nitrates, chlorides and glucoheptonates can be used as cobalt supplements in animal nutrition. However in the United States, only cobalt oxide, cobalt acetate, cobalt sulphate, cobalt choline citrate complex, cobalt gluconate, cobalt glucoheptonate, cobalt carbonate, cobalt chloride, cobalt proteinate, cobalt choline citrate complex, cobalt glucoheptonate, cobalt amino acid complex, cobalt amino acid chelate are allowed to be used in animal diets (AAFCO, 2010). In the European Union, also various cobalt compounds are presently authorized as feed additives (EFSA, 2010). Information on cobalt absorption from the gut, especially in poultry are rather scarce. In general, different factors may affect the absorption such as amount and solubility of the cobalt compound, presence of amino acids and sulphhydryl groups in the diet and the iron status of the animal (Lison, 2007).

Some strain of poultry are capable of synthesizing vitamin B<sub>12</sub> by using cobalt inside the ceca, but this level of vitamin is below the requirements, and it must be supplemented (Halle and Ebrahem, 2011). In monogastric animals such as pig and poultry, cobalt is not regarded as an essential trace mineral, although it may be as much as 4% of the composition of the molecule of vitamin B<sub>12</sub>. Literature concerning cobalt supplementation for chickens is scarce, particularly for laying hens (NRC, 1994).

In general, the common signs of vitamin B<sub>12</sub> deficiency in broiler that received cobalt (up to 40 µg/kg diet) are reduction in body weight gain, feed intake and feed conversion (Halle and Ebrahem, 2011). In this regard, Halle and Ebrahem (2011) concluded that supplementation of vitamin B<sub>12</sub> (20 µg/kg diet) was sufficient to compensate the deficiencies on feed intake and growing performance. In addition, an exclusive supplementation of cobalt to the broiler feed improved growth performance in a small scale, while the supplementation of vitamin B<sub>12</sub> with cobalt did not have any additive effect on performance of broilers. Kato *et al.* (2003) also suggested that vitamin B<sub>12</sub> supplementation was important for commercial laying hens on the second cycle of production, but not cobalt supplementation.

Furthermore, there is no consensus about cobalt supplementation in poultry diets. In practice, the industries of mineral supplement add, on an average, 0.29 g of cobalt per ton of feed. Considering the high price of organic sources of cobalt, adding it may represent an additional cost for poultry production. Besides, environmental issues have also to be considered, since cobalt may become a pollutant if used inadequately or when it is not really needed.

### Strontium

The biochemistry and physiology of vitamin D and strontium (Sr) are uniquely integrated following similar metabolic pathways of intestinal absorption, bone deposition, and renal reabsorption. Vitamin D<sub>3</sub> is an essential nutrient for bone growth and maintenance and has a critical role in biological pathways such as calcium and phosphorus homeostasis, cellular differentiation, proliferation and immune function (Holick, 2004).

Strontium accumulates in bone with 99% of strontium in a vertebrate animal found in bone (Dahl *et al.* 2001). At low dose levels of supplementation (316-634 mg/kg per day Sr<sup>2+</sup>), strontium has been shown to stimulate bone formation by increasing the number of bone osteoblast cells and while at the same time inhibiting bone resorption by inhibiting the action of bone osteoclast cells, leading to an increase in bone volume with no deleterious effect on bone mineralization (Ferraro *et al.* 1983; Marie *et al.* 1985; Grynepas and Marie, 1990; Dahl *et al.* 2001; Marie *et al.* 2001). In summary, strontium has both an anabolic and an anti-resorptive effect on bone (Isaac *et al.* 2011). Interestingly, among the trace elements found in bone strontium is the only element correlated with bone compression strength (Browning and Cowieson, 2015).

Browning and Cowieson (2015) concluded, as confirmed by several physiological parameters, the supplementation of strontium (500 mg/kg diet) significantly improved egg production and improved feed efficiency, and also their data confirmed a unique interrelationship between vitamin D<sub>3</sub> and strontium. Further investigation needs to be undertaken to refine the optimum strontium level required to maximize hen

performance. The nature of the relationship between vitamin D<sub>3</sub> and strontium also requires further exploration, particularly at the intercellular level.

## CONCLUSION

Arsenic is always regarded as a toxic mineral element, and feeds should continuously be monitored to ensure that concentrations of arsenic are below toxic levels. It seems that dietary vanadium concentrations up to 20 mg/kg of vanadium in breeders and layers hens' diet can reduce their performance while these concentrations of vanadium on broiler chicken, can improve structures of digestive glands. There is no consensus about cobalt supplementation in poultry diets. In practice, the industries of mineral supplement add, on an average, 0.29 g of cobalt per ton of feed. Supplementation of strontium (500 mg/kg diet) significantly improved egg production and improved feed efficiency, and also a unique interrelationship between vitamin D<sub>3</sub> and strontium has reported. Further investigation needs to be undertaken to refine the optimum strontium level required to maximize hen performance. The nature of the relationship between vitamin D<sub>3</sub> and strontium also requires further exploration, particularly at the intercellular level.

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