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# VANADIUM IN POULTRY NUTRITION

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## Abstract

Vanadium (V) is essential element for poultry nutrition. Relatively low level of V (< 10 μg/kg of feed) is known to reduce both growth in chicks and Haugh unit value of eggs. The National Research Council (NRC) recommends the presence of very low levels of V in poultry diets, with the maximum tolerance level (MTL) being 10 mg/kg. Excessive vanadium in poultry diets has been shown to be detrimental to egg production, interior quality of eggs (albumen height), body weight and feed consumption. There is little information on the content of V in feedstuffs. Phosphates are known to be the cause of excessive V in various types of poultry diets. The objective of this study was to obtain information about the content of vanadium in phosphates and poultry feed. The samples were prepared by microwave wet digestion. Content of V was determined by the method of coupled plasma with mass spectrometry on the Agilent ICP-MS 7700. The concentrations of vanadium determined in the examined samples were above the minimum recommended levels for poultry feed, still not exceeding the maximum tolerable values.

**Keywords**: vanadium, phosphates, poultry feed

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# VANADIJUM U ISHRANI ŽIVINE

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## Kratak sadržaj:

Vanadijum (V) je esencijalni element u ishrani živine. Relativno niski nivoi V (< 10 mg) smanjuju porast pilića i vrednosti Haugh-ovih jedinica jaja. The National Research Council (NRC) preporučuje veoma niske nivoe V u hrani za živinu, pri čemu je za maksimalni nivo tolerancije utvrđena vrednost od 10 mg/kg. Višak vanadijuma u ishrani živine ispoljava štetne efekte u proizvodnji jaja, negativno utiče na unutrašnji kvalitet jaja, telesnu masu živine i efikasnost iskorišćavanja hrane. Podaci o sadržaju V u hrani i hranivima za životinje su oskudni, ali zna se da fosfatna mineralna hraniva često sadrže visoke koncentracije ovog elementa. Cilj ovog istraživanja je bio da se dobiju informacije o sadržaju vanadijuma u hranivima i hrani za živinu. Uzorci hrane za životinje su pripremljeni mikrotalasnom digestijom, a sadržaj V je određen metodom indukovano kuplovane plazme sa masenom spektrometrijom (ICP-MS). Koncentracije vanadijuma u ispitivanim uzorcima bile su iznad minimalnih preporučenih nivoa u ishrani živine, ali nisu prelazile maksimalne tolerantne vrednosti za živinu za ovaj element.

**Ključne reči:** vanadijum, fosfati, hrana za živinu

## INTRODUCTION

Inorganic elements find in the Earth's crust are often referred to as minerals. The essential minerals/elements are those that have well-defined biochemical functions and must be in the diet of verterbrates for optimal health and productivity (NRC, 2005). In spite of relatively small share of minerals in poultry feed their role in normal metabolism is highly important. The deficiency or excess of particular minerals can result in immune system disorders and impairment of overall health status as well as consequent decrease of production performance. Microelement requirements are relatively low and daily amounts range from a microgram to one milligram. Accumulation of excessive amounts of microelements higher than those required for normal metabolic activity can induce intoxication symptoms. Some minerals are essential for health and productivity of animals and have well-defined nutritional and biochemical roles. Many other minerals naturally occur at trace levels in feed and tissues of animals but they are not typically suspected to play a useful nutritional purpose (NRC, 2005).

Vanadium is an essential element in various enzymes in algae, bacteria, fungi, and lichens (Nielsen, 2000). This mineral has high number of oxidative states (from -1 to +5). This fact makes it multifunctional element in the body and likely contributes to its ability to have effects at relatively low levels (NRC, 2005).

There are conflicting reports as to essentiality of V for animals. Vanadium deficiency has first been described in rats. In chickens fed rations containing less than 10 μg V/kg, poor growth and reduced development of feathers of the tail and wing was observed. Vanadium deficiency in laying hens often results in poorer albumin quality and hatchability loss. Data on natural vanadium deficiency are still scarce; however, it was established that it can occur if vanadium content in feed mixes is below nutritional requirements of poultry. Vanadium plays a role in lipid metabolism; its deficiency in feed can be associated with decreased levels of blood and bone iron, which can result in abnormal bone development (Puls, 1990).

Studies indicate that vanadium is absorbed from digestive tract at an efficiency rate of 1% or less. Absorbed vanadium is excreted by the kidneys with a minor amount excreted in the faeces (NRC, 2005). Vanadium content in chicken liver ranges 0.018-0.038 mg/kg, in kidneys 0.101-0.180 mg/kg, bones 1.3-6.3 mg/kg and in egg yolk 0.002-0.003 mg/kg dry matter. Somewhat lower vanadium levels were established in all organs in ducks.

Relatively high amounts of vanadium are found in fish-based products. Vanadium in high concentrations can be found in phosphates originating from South Africa, Russia, the United States, Finland and China (NRC, 2005).

The toxicity of vanadium has been investigated more intensively in relation to its presence in phosphates at high concentrations, in the form of calcium orthovanadate. Maximum tolerable level for vanadium in poultry is set at 10 mg V/kg (NRC, 1994), whereas toxicity level is 100-800 mg/kg feed. NRC (2005) suggested the maximum tolerable dietary level (MTL) for poultry being 50 mg V/kg. More recent research indicates that poultry can tolerate up to 25 mg V/kg diet and possibly even up to 50 mg V/kg diet without significant decreases in weight gain and health. MTL depends on the valence of vanadium source (toxicity tends to increase as the valence increases), chemical form of vanadium source, the period of dosing the length of exposure, and size of the dose.

Bones and kidneys are major target organs for vanadium, but oral intake of vanadium leads to its increased content in liver and magnum. Enzyme inhibition and cell damage is considered the most likely mechanism of vanadium toxicity. Vanadium action competes with ions of Ca, Mn, Zn and Fe for ligand-binding sites and interacts with phosphate ions for a range of metabolic processes. Peroxy-form of vanadium often mimic insulin actions in different cell types (Fantus et al., 1989). Selenium given as a selenite can synergistically potentiate vanadyl-induced cell damage (Zwolak, 2015).

The relevant available literature data provide limited information on the content of vanadium in foods, and therefore the aim of this study was to obtain information on the content of vanadium in phosphates and poultry feed.

## MATERIAL AND METHODS

In the present study, we examined 10 samples of phosphates (monocalcium phosphate (MCP), monoammonium phosphate (MAP) of domestic producers and imported origin, 5 samples of imported fish meal and 10 samples of complete poultry feed of domestic producers). The samples (1g) were prepared applying the microwave (Ethos, Lab station Microwave, Milestone), digestion method with the use of the mixture $H_2O_2/HNO_3$ (1:4, v/v). The samples were transferred to 50 ml volumetric flasks and diluted with deionized water. Analyses of vanadium were conducted by ICP-MS 7700 mass spectrometer (Agilent Technologies).

Statistical analysis was performed by the STATISTICA 12 software package, version 16.0. Data were grouped according to tissue and presented as mean ± standard error, minimum and maximum values.

## RESULTS AND DISCUSSION

Average values and minimum and maximum values of vanadium obtained in this study are summarized in Table 1. The concentrations of vanadium determined in the examined samples of complete feed for poultry (chickens and layers) were above the minimum recommended levels for poultry feed, still not exceeding the maximum tolerable values (Table 1).

**Table 1.** Vanadium concentrations (mg/kg) in poultry feed, feed phosphates and fish meal

| Sample | Origin | V (mg/kg) | |
|---|---|---|---|
| | | Average ± SD | Min-Max |
| Complete feed for chickens | domestic | 0.641 ± 0.103 | 0.568 - 0.713 |
| Complete feed for layers | domestic | 0.484 ± 0.307 | 0.137 - 0.844 |
| Phosphates | domestic | 22.86 ± 26.36 | 1.650 - 68.6 |
| Phosphates (MCP) | imported | 30.37 ± 14.82 | 18.10 - 46.84 |
| Phosphates (MAP) | imported | 19.65 ± 0.212 | 19.50 - 19.80 |
| Fish meal | imported | 0.161 ± 0.076 | 0.042 - 0.225 |

Imported monocalcium phosphates were the most V-contaminated feed ingredient (average value 30.37 mgV/kg). Lower levels of V were found in the domestic MCP (22.86 mg/kg), while monoammonium phosphates were the least contaminated (19.65 mgV/kg). The lowest average concentration of V was measured in fish meal (average value 0.161 mg/kg) and the highest level of this element was measured in MCP of domestic origin (68.6 mg/kg).

The results were compared with results from other authors (Table 2). The relevant available literature data provide only limited information on the content of vanadium in feed. Our results for V concentrations are markedly lower as compared with other investigations (Table 2). Since the origin of phosphates was not taken into account during data interpretation in the cited studies (Table 2), the vanadium levels could not be directly compared with our research. Phosphates with high vanadium content usually originate from Rocky Mountains (USA) with vanadium concentrations reaching even over 6000 mg/kg. The use of these phosphates adds 120 mg of vanadium per kg of feed (Henry and Miles, 2001).

**Table 2.** Vanadium concentrations (mg/kg) according to various authors

| V (mg/kg) according to various authors | | |
|---|---|---|
| **V (mg/kg)** min - max | Reference | Samples |
| 47 -796 | Sullivan et al. (1994) | Monocalcium phosphate |
| < 20 - 164 | Sullivan et al. (1994) | Dicalcium phosphate |
| 45 - 185 | Sullivan et al. (1994) | Thermochemically produced defluorinated phosphate |
| 2 - 1210 | Limma et al. (1995) | Dicalcium phosphate dyhidrate |

The use of phosphates with high vanadium content can occur in conditions of increased price of phosphates on global market, thus less expensive phosphates of poor quality will be brought to the animal feed market causing consequent vanadium-contamination of feed. In conditions of increased price of phosphates, phytase is recommended to the purpose of better use up of plant phosphorus and reducing phosphate supplementation in feed mixes (Miles and Henry, 2004; Živkov Baloš, 2011).

Under the influence of high doses of vanadium, the internal quality of the egg is reduced, probably as a consequence of the weakening of the magnitude of the magnum during the egg formation. Poorer quality of the egg white has been observed in laying hens fed diets containing 6 mg V from DKP/kg feed, whereas a dose of some 28 mg V from DKP/kg feed resulted in a drop of egg production (Sell et al., 1982). Kubena and Philips (1982) reported that 50 mg V from calcium orthovanadate/kg feed did not cause mortality in laying hens after 28-day research period, whereas 100 mg V from calcium orthovanadate/kg feed resulted in an increase of mortality for 56%. According to the results of Miles and Henry (2004) laying hens fed feed-mixes supplemented with 10 mg V/kg feed had poorer albumin quality than birds from the control group (fed diet without vanadium supplementation). The quality of albumen has continued to drop during consequent two days after changing the feed and removing excess vanadium from hens' diet to reach the albumin quality of laying hens from the control group as late as after six days. Odabaşi et al. (2006) reported that feeding hens with diet supplemented with 15 mg V from ammonium-monovanadate/kg feed had adverse effects on eggshell pigmentation.

Detrimental effects of excess vanadium in feed can be alleviated by adding dietary cottonseed meal and vitamin C (Ousterhout and Berg, 1981; Whitehead and Keller, 2003; Odabaşi et al., 2006) or combination of vitamin C, vitamin E or β-carotene (Miles et al., 1997). Henry and Miles (2001) suggested that feed known to contain phosphates with high vanadium content should be supplemented with potentially harmful amounts of copper (400 ppm) and mercury (100 ppm) in order to reduce detrimental impact of excess vanadium. Puls (1990) reported the following: 6 mg V/kg feed negatively affects the albumen quality and growth rate of poultry; levels higher than 40 mg V/kg decrease egg hatchability and body weight of laying hens; levels higher than 80 mg V/kg result in intensive molting, whereas levels above 100 mg V/kg increase the mortality rate.

Phytase can play a role also in the sphere of manure management since feeds with high vanadium content increase faecal moisture for 10%, which may pose problems in manure manipulation on poultry farms especially in view of controlling the number of flies that correlates with the manure moisture content (Henry and Miles, 2001).

## CONCLUSIONS

Based on data presented in this paper the biological role of vanadium in normal metabolism during production of poultry is very important. Essential role of V in poultry nutrition is still under investigation, while toxicity was relatively well established a long time ago. Even though some feeds might represent potential source of harmful amounts of vanadium, the combination of relevant quality control programs in animal feed industry as well as application of good production practices and adequate education of nutritionists can substantially reduce the risks associated with poultry feed contamination. Future studies and additional research are needed to define essentiality and toxicity of vanadium for poultry and possible interaction with other nutrients in the feed.

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