



Concentration of Micronutrients, Specifically Copper and Molybdenum, in Different Parts of the Honey Bee Body and Varroa Mite

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10.18805/ag.DF-761

ABSTRACT

Background: Minerals are essential bioelements that participate in numerous physiological and metabolic processes in animals. Among these, copper (Cu) and molybdenum (Mo) are critical trace elements that regulate enzymatic activity, protein metabolism and respiration. In honey bees (*Apis mellifera*), copper is a key component of hemocyanin, the respiratory metalloprotein that substitutes for hemoglobin, while molybdenum is involved in the activity of enzymes such as xanthine oxidase and aldehyde oxidase. Both elements are chemically antagonistic, with molybdenum capable of inhibiting copper accumulation in tissues. Understanding the distribution of these micronutrients in different body parts of bees and in their ectoparasite, Varroa destructor, is important for assessing nutrient dynamics between host and parasite and for the overall health of bee colonies.

Methods: The study was conducted in apiaries of the southern Tyumen region from 2020 to 2025. Samples of dead bees and mites (200-300 g) were collected from comparable colonies. Bee bodies were carefully dissected into individual fragments including head, thorax, abdomen, wings and legs. Concentrations of copper and molybdenum in each fragment and in the bodies of Varroa destructor mites were measured using spectral analysis after dry mineralization, following GOST 26929-86 standards.

Result: The concentrations of copper and molybdenum varied significantly among different bee body parts. Molybdenum was highest in bee heads (8.02 ± 0.32 mg/kg) and absent in legs and wings, whereas copper was most concentrated in the abdomen (6.26 ± 1.37 mg/kg), likely due to the fat body tissue's mineral accumulation properties. In Varroa mites, copper and molybdenum concentrations reflected those in the bee abdomen, consistent with their feeding on the fat body. These findings demonstrate differential accumulation patterns of trace elements in bees and their parasites, highlighting the role of anatomical specialization in micronutrient distribution.

Key words: Copper, Honey bees, Micronutrients, Molybdenum, Trace element distribution, Varroa destructor.

INTRODUCTION

Minerals are essential structural and functional components of animal organisms and are present in organs, tissues and biological fluids in the form of macroelements and microelements. These elements are collectively referred to as bioelements, as they are directly involved in the regulation of biochemical, physiological and metabolic processes that ensure normal growth, development and homeostasis of animals (Hille, 2013; Shishkina *et al.*, 2016). Mineral elements participate in enzyme activation, hormone synthesis, redox reactions and the maintenance of osmotic balance and acid-base equilibrium, thereby playing a fundamental role in the adaptation of organisms to environmental conditions.

Among the numerous microelements required for normal physiological functioning, molybdenum (Mo) and copper (Cu) occupy a special position due to their involvement in key enzymatic and metabolic pathways. Molybdenum is a chemical element of group VI of the periodic table of D. I. Mendeleev and is widely distributed in the environment, occurring in nature primarily in the form of sulfide and oxide compounds (Barashkov *et al.*, 2001; Shishkina *et al.*, 2015). In animal organisms, molybdenum enters predominantly through dietary intake and is

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How to cite this article: Pashayan, S.A., Gazaryan, A., Abramyan, V.V. and Stoliarov, S.G. (2026). Concentration of Micronutrients, Specifically Copper and Molybdenum, in Different Parts of the Honey Bee Body and Varroa Mite. *Agricultural Science Digest*. 1-4. doi: 10.18805/ag.DF-761.

Submitted: 03-06-2025 **Accepted:** 30-12-2025 **Online:** 14-02-2026

absorbed in the gastrointestinal tract, after which it is transported to various organs and tissues, where it exerts its biological effects.

As a vital bioelement, molybdenum is a constituent of several molybdoenzymes that catalyze essential redox reactions. These include xanthine oxidase, aldehyde

oxidase and sulfite oxidase, enzymes that play a decisive role in purine metabolism, detoxification of aldehydes and sulfur-containing amino acid metabolism, respectively (Hille, 2013; Lutsenko, 2010). Through the regulation of these enzymatic systems, molybdenum contributes to protein turnover, energy metabolism and the elimination of toxic metabolic by-products. In addition, molybdenum has been shown to stimulate enzymatic systems involved in the synthesis of ascorbic acid and to support normal tissue respiration, processes that are critically important for cellular proliferation, differentiation and resistance to oxidative stress (Barashkov *et al.*, 2001; Lutsenko, 2010; Shishkina *et al.*, 2016).

Copper is a chemical element of group XI of the fourth period of the periodic table and is one of the most biologically significant trace elements for living organisms. It is an integral component of numerous metalloproteins and enzymes, including cytochrome c oxidase, superoxide dismutase and tyrosinase. In warm-blooded animals, copper is present in the blood and distributed throughout all tissues, with particularly high concentrations found in the liver and spleen, which serve as major depots for this element. Copper plays a key role in hematopoiesis and hemoglobin synthesis, ensuring efficient oxygen transport and cellular respiration (Barashkov *et al.*, 2001; Suttle, 2012).

Furthermore, copper acts as a powerful catalyst in oxidation-reduction reactions and is involved in the metabolism of iron and ascorbic acid. It contributes to a wide range of physiological processes, including pigmentation, osteogenesis, formation of myelin sheaths in the nervous system and the synthesis of structural proteins such as collagen and elastin. Through these mechanisms, copper influences the strength of connective tissues, the functioning of the nervous system, immune defense and the reproductive capacity of animals (Shishkina *et al.*, 2015; Suttle, 2012).

In insects, the biological role of copper has specific physiological features associated with their mode of respiration. In many arthropods, including honey bees (*Apis mellifera*), the hemolymph lacks erythrocytes and hemoglobin, which are characteristic of higher animals. Instead, oxygen transport and respiratory gas exchange are carried out by hemocyanin, a copper-containing respiratory pigment. Hemocyanin is a metalloprotein freely dissolved in the plasma of the hemolymph and contains two copper atoms in its active center, which reversibly bind a single oxygen molecule (O_2). This mechanism ensures effective oxygen transport and release under varying physiological conditions (Zhelyazkova and Salkova, 2014; Van der Steen *et al.*, 2015).

An important physiological aspect of mineral metabolism is the antagonistic relationship between molybdenum and copper. Excessive intake of molybdenum can disrupt copper absorption and utilization, leading to functional copper deficiency and associated metabolic disorders. This antagonism is of particular relevance in

insects and other invertebrates, where trace element balance directly affects metabolic efficiency, immunity and resistance to environmental stressors.

In this context, the determination of molybdenum and copper concentrations in individual body compartments of honey bees (*Apis mellifera*) and in the parasitic mite *Varroa destructor*, which exerts a significant negative impact on bee health and colony productivity, represents an important and timely research objective. Studying the distribution and interaction of these antagonistic microelements in both the host and the parasite may provide new insights into mineral metabolism, host-parasite relationships and potential approaches to improving honey bee resistance and survival.

MATERIALS AND METHODS

Research to determine the concentration of copper and molybdenum in individual parts of honey bees' body and *Varroa destructor* L. mite's organism was carried out in apiaries in the south of the Tyumen region, at the Department of Anatomy and Physiology of the Northern Trans-Ural State Agricultural University and in the laboratory of the Institute of Soil Science and Agrochemistry in 2020-2025.

The objects of the study were honey bees *Apis mellifera* and *Varroa destructor* mites. 200-300 g samples of dead bees and mites were taken from analogous families. The bodies of the bees were carefully dissected into individual fragments, then the presence of trace elements of copper and molybdenum was determined using the method of spectral analysis in individual fragments of the body of bees (heads, thoraxes, abdomens, wings, legs) and the body of mites, using the method of dry mineralization in accordance with GOST 26929-86.

RESULTS AND DISCUSSION

As a result of the conducted work, it turned out that the concentration of copper and molybdenum bioelements in individual parts of the bees' body was within different limits. The maximum value of molybdenum was recorded in the head samples -8.02 ± 0.32 mg/kg. In breast samples, the concentration of this element was 2.46 ± 0.17 mg/kg, in abdomen samples -1.32 ± 0.15 mg/kg. No molybdenum was found in samples of legs and wings. In the mites' body, the average amount of this element was 1.28 ± 0.07 mg/kg (Fig 1).

The concentration of copper in the samples varied from 3.23 ± 0.73 mg/kg to 6.26 ± 1.37 mg/kg. The maximum value of this micronutrient was recorded in the abdomen -6.26 ± 1.37 mg/kg, the minimum value in the heads -3.23 ± 0.73 mg/kg, in the thorax the average amount of copper was found to be 5.18 ± 1.73 mg/kg, in the legs -3.55 ± 0.4 mg/kg, in the wings -4.12 ± 1.12 mg/kg. In the mites' body, the concentration of this element was 4.43 ± 0.47 mg/g. (Fig 2, 3, 4, 5, 6).

The ratio of molybdenum and copper, these chemically antagonistic elements, in certain parts of the body of *Apis*

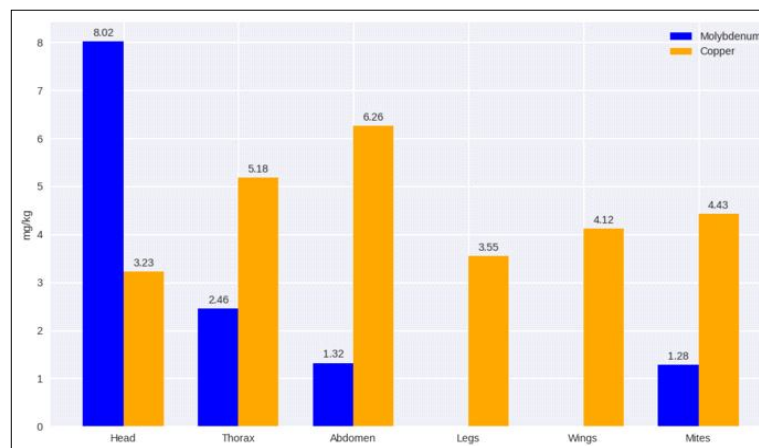


Fig 1: Copper and molybdenum concentration in individual parts of bees' body and mites' organism (mg/kg).



Fig 2: Bee heads.



Fig 5: Bee wings.



Fig 3: Bee thorax.



Fig 6: Bee legs.



Fig 4: Bee abdomens.

mellifera bees and in the body of Varroa destructor mites was as follows (Fig 1). As can be seen from this figure, in the heads of bees the concentration of molybdenum was at a higher level than in other fragments -8.02 mg/kg, copper, on the contrary, was at the lowest level -3.23 mg/kg. In thorax, the concentration of molybdenum is lower than in heads -2.46 mg/kg and the concentration of copper is higher -5.183 mg/kg. In the abdomens, the amount of molybdenum is significantly lower -1.32 mg/kg, than in the heads and thorax and copper, on the contrary, is higher -6.267 mg/kg. It should be added that molybdenum was not detected in the samples of bee legs and wings; the

Table 1: Concentrations of copper and molybdenum in different parts of the honey bee body and Varroa mite (mg/kg; mean±SE).

Body part/mite	Molybdenum (mg/kg)	Copper (mg/kg)
Heads	8.02±0.32	3.23±0.73
Thoraces	2.46±0.17	5.18±1.73
Abdomens	1.32±0.15	6.26±1.37
Wings	Not detected	4.12±1.12
Legs	Not detected	3.55±0.40
Mites	1.28±0.07	4.43±0.47

amount of copper was respectively 3.556 mg/kg and 4.12 mg/kg. In the mites' body, the concentration of molybdenum was 1.28 mg/kg, copper -4.43 mg/kg (Table 1).

CONCLUSION

Molybdenum is the chemical antagonist of copper. This means that it can inhibit the accumulation of copper in living tissues and organisms. Analysis of the results obtained indicates that the concentration of copper and molybdenum in individual parts of the bee body varies widely. Moreover, the higher accumulation of molybdenum was determined in the samples of fragments of the heads of bees, where a very low concentration of copper was observed, compared to other parts of the bees' body.

The maximum copper concentration was observed in samples of abdomen fragments. This is most likely due to the fact that in the abdomen of the bee there is a fat body, which exhibits the cumulative properties of fat substances, including copper. Mites, as ectoparasites, live and feed on the body of honey bees; they are mainly found on the abdomen and consume fat body of insects, especially in winter. Therefore, the concentration of copper and molybdenum in the body of these parasites depends on the amount of these elements in the abdomen samples.

ACKNOWLEDGEMENT

The present study was supported by FGBOU HE State Agrarian University of the Northern Trans-Urals.

Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

All procedures involving honey bees and mites were approved by the Committee of Experimental Animal Care and handling techniques were approved by the University Animal Care Committee.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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