



# BOOK OF ABSTRACTS

## XIX International Conference of the Julian Aleksandrowicz Polish Magnesium Society

“Magnesium and other bioelements in medical, chemical, and natural sciences”



**October 16–18, 2025**

Potocki Palace in Będlewo  
(near Poznań)

Julian Aleksandrowicz Polish Magnesium Society  
Adam Mickiewicz University in Poznań  
Poznań University of Medical Sciences  
Poznań University of Life Sciences



POZNAŃ  
UNIVERSITY  
OF LIFE SCIENCES

**Publishing editors**

Bogna Gryszczyńska  
Anetta Hanć  
Katarzyna Przygocka-Cyna

**Reviewer**

Maria Iskra

**Typesetting**

Krzysztof Strzyżewski

**Cover designer**

Julia Frąckowiak

**ISBN: 978-83-62783-21-2**

Adam Mickiewicz University, Faculty of Chemistry  
8 Uniwersytetu Poznańskiego Street, 61-614 Poznań, Poland

The editors are not responsible for the content of abstracts.

## Honorary and Scientific Committee Organizers

Conference organized under the honorary patronage of:



Her Magnificence the Rector of  
Adam Mickiewicz University in Poznań  
*Prof. dr hab. Bogumiła Kaniewska*



His Magnificence the Rector of the  
Poznań University of Medical Sciences  
*Prof. dr hab. Zbigniew Krasiński*



His Magnificence the Rector of the  
Poznań University of Life Sciences  
*Prof. dr hab. Krzysztof Szoszkiewicz*

## Organizers

Julian Aleksandrowicz

Polish Society for Magnesium Research

Wielkopolska Branch of the Polish Magnesium Society

## Scientific Committee

- Prof. Maria Iskra (UM Poznań) – *Chairwoman of the Conference Scientific Committee*
- Prof. Danuta Barańkiewicz (UAM Poznań)
- Prof. Przemysław Barłóg (UP Poznań)
- PhD, DSc Marzena S. Brodowska, Assoc. Prof. (UP Lublin) – *President of the Polish Magnesium Society (PTMag)*
- PhD, DSc Magdalena Budzyń (UM Poznań)
- Prof. MD Dariusz Chlubek (PUM Szczecin)
- Prof. Jean Diatta (UP Poznań)
- PhD, DSc Dariusz Dobrzyński, Assoc. Prof. (UW Warszawa)
- PhD, DSc Bogna Grysczyńska (UM Poznań)
- Prof. Witold Grzebisz (UP Poznań)
- PhD, DSc Anetta Hanć, Assoc. Prof. (UAM Poznań)
- Prof. Izabella Jackowska (UP Lublin)
- Prof. Beata Krasnodębska-Ostręga (UW Warszawa)
- PhD, DSc Sławomir Krzebietke, Assoc. Prof. (UWM Olsztyn) – *Editor-in-Chief of the Journal of Elementology*
- Prof. Andrzej Lewenstam (AAU Turku, Finland, AGH Kraków)
- Prof. Wojciech Lipiński (KSChR Warszawa)
- Prof. Magdalena Maj-Żurawska (UW Warszawa)
- Prof. Andrzej Mazur (CHU Clermont-Ferrand, France)
- Prof. MD Oliver Micke (Franziskus Hospital Bielefeld, Germany) – *President of German Society of Magnesium Research*
- Prof. Anna Nogalska (UWM Olsztyn)
- PhD, DSc Jarosław Potarzycki, Assoc. Prof. (UP Poznań)
- PhD, DSc Katarzyna Przygocka-Cyna, Assoc. Prof. (UP Poznań)
- Prof. Joanna Suliburska (UP Poznań)
- PhD, DSc Witold Szczepaniak, Assoc. Prof. (UP Poznań)
- MSc Tadeusz Wojtaszek (Kraków)
- Prof. Federica Wolf (UCSC Rome, Italy) – *President of Inter. Society for the Development of Research on Magnesium*
- PhD, DSc Elżbieta Wszelaczyńska, Assoc. Prof. (PB Bydgoszcz)
- Prof. Mirosław Wyszowski (UWM Olsztyn)

## ***Organizing Committee:***

PhD, DSc Anetta Hanć, Assoc. Prof. (UAM) – *Chairwoman of the Committee*  
PhD, DSc Anna Boguszevska-Czubara, Assoc. Prof. (UM Lublin) – *PTMag Treasurer*  
PhD Maria Biber (UP Poznań)  
PhD, DSc Bogna Gryszczyńska (UM Poznań)  
PhD Joanna Grupińska (UM Poznań)  
PhD Magdalena Kasprzak (UM Poznań)  
PhD, DSc Izabela Komorowicz (UAM Poznań)  
PhD, DSc Remigiusz Łukowiak (UP Poznań)  
PhD, DSc Katarzyna Przygocka-Cyna, Assoc. Prof. (UP Poznań)  
PhD, DSc Adam Sajnóg (UAM Poznań)  
PhD Krzysztof Strzyżewski (UM Poznań)

## ***Partners and Sponsors***



# ABSTRACTS

# MEASURING LITHIUM AND MAGNESIUM IN BIOLIQUIDS USING ION SENSORS: FROM CONCEPT TO THE FIRST COMMERCIAL BLOOD ANALYZER

**Andrzej LEWENSTAM<sup>a-d</sup>, Magdalena MAJ-ŻURAWSKA<sup>d</sup>, Krzysztof DOŁOWY<sup>e</sup>**

<sup>a</sup> AGH University of Krakow, Faculty of Materials Science and Ceramics, 30-059 Cracow, Poland,

<sup>b</sup> Åbo Akademi University, Center for Process Analytical Chemistry and Sensor Technology  
'ProSens' 20500 Åbo-Turku, Finland

<sup>c</sup> Thermo Fisher Scientific, Helsinki-Waltham, Finland-USA

<sup>d</sup> University of Warsaw, Biological and Chemical Research Centre, Faculty of Chemistry,  
Zwirki i Wigury, 02-089 Warsaw, Poland

<sup>e</sup> University of Life Sciences, Department of Physics and Biophysics,  
Institute of Biology, 02-776 Warsaw, Poland  
e-mail address: [alewenst@agh.edu.pl](mailto:alewenst@agh.edu.pl)

Electrochemical sensors have been central to both research and clinical diagnostics for decades. Their prevalent use in clinical diagnostics for measuring the main blood serum electrolytes - sodium, potassium, chloride, and pH - is driven by the high selectivity, fast response time, durability, and cost-effectiveness of dedicated ion sensors. The ability to deliver rapid and accurate electrolyte measurements has made the ion-sensors indispensable tools in emergency diagnostics, critical care, and health monitoring. The aim to increase the list of parameters for lithium and magnesium, occurred to be as attractive and non trivial because of overlapping demands of seemingly independent sectors of science (physical chemistry, solution chemistry, electrochemistry), sensor technology (material science and engineering), metrology (novel electronic circuit boards), computer sciences (data mining, machine discovery), and compliance to clinical chemistry requirements (reference materials and methods, report requirements).

With experience bridging academia and industry, the lecture will highlight numerous challenges related to the research, development, and implementation of ion sensors for new parameters, using the case of ionized lithium and ionized magnesium. The lecture will trace the development of the first-ever automated measurement of ionized lithium and magnesium, from its inception to a commercial product, clinical analyser *Microlyte 6*. The pivotal role of data-driven algorithms and modelling techniques in creating integrated workflows for clinical instrumentation will be explored and exposed. This information is typically non-disclosed, considered proprietary, is at the forefront of innovation, as it is embedded within instrument software, calibration and readout algorithms and methods, and guided by reference materials and methods established by international recommendations, including those from the International Federation of Clinical Chemistry (IFCC) or the European Union in vitro diagnostics regulations. The lecture offers insights into this lesser-

known area, demonstrating how it is possible to harmonize the non-ideal properties of the  $\text{Li}^+$  and  $\text{Mg}^{2+}$  sensors, variable compositions of blood samples, and IFCC reference methods. In fact, it would deliver information on how rapid, reliable, and certified reporting of clinical results, specifically the determination of active concentrations of free lithium and magnesium ions in blood, is achieved and has been achieved, thereby highlighting the aspects of every research activity aimed at developing an innovative, knowledge-based commercial product.

# CALCIUM AND MAGNESIUM - CRITICAL NUTRIENTS FOR NITROGEN USE EFFICIENCY

**Witold GRZEBISZ, Przemysław BARŁÓG, Remigiusz ŁUKOWIAK**

*Department of Agricultural Chemistry and Environmental Biogeochemistry,  
Poznan University of Life Sciences, Wojska Polskiego 28, 60–637 Poznan, Poland;  
e-mail address: [witold.grzebisz@up.poznan.pl](mailto:witold.grzebisz@up.poznan.pl)*

Nitrogen, or more precisely, nitrate nitrogen (N-NO<sub>3</sub>), is a major nutrient that drivers plant growth dynamics, the formation of yield omponents, and ultimately determines yield. The efficiency of N utilization (uptake and utilization) by plants depends on numerous environmental, nutritional, and agronomic factors [1,2]. Among the nutrients, calcium (Ca) and magnesium (Mg) deserve special attention. Both are alkaline earth elements, positively charged and with an oxidation state of 2<sup>+</sup>. However, ions of both these elements differ significantly in their physicochemical properties, which leads to a specific effect on soil properties and on the physiological processes in crop plants [3]. As a result of these differences, calcium dominates in the soil sorption exchangeable complex (CEC), and the Ca:Mg ratio is about 3:1 in sandy soils and 4:1 in clay soils. Both elements, occurring in the form of carbonates, are subject to global geochemical transformation, called the carbonate cycle [4].

Plants absorb both nutrients in ionic form in the so-called transpiration water stream. The difference between them is that Ca is not remobilized from older to younger organs, which is an inherent characteristic of Mg. Hence, visual symptoms of Ca deficiency appear on growing points, while Mg deficiency appears on older leaves. This fundamental difference in intraplant transport results in extremely low (Nutrient Harvest Index, NuHI) for Ca and moderate for Mg. The increase of CaHI over MgHI is an indirect indicators of stress conditions occurred during the formation of yield components or during seed/grain filling [5].

The basic functions of Ca in crop plants, responsible for growth and yield formation, include [6]:

- 1) Formation of the root system architecture; essential for the process of cell division of the root meristem; growth of the root in the juvenile phase.
- 2) Reducing the impact of toxic aluminium (Al<sup>3+</sup>) on plant growth.
- 3) Plant tissue formation; a component of the middle lamella of a cell; a critical nutrient for legumes and crucifers;
- 4) Regulation of the daily movement of stomata, in conjunction with K<sup>+</sup> and the Cl<sup>-</sup>;

- 5) Formation of root nodules in legumes (peas, field beans, lupins, vetches) and forage legumes (clovers, alfalfa);
- 6) Regulation of plant hormonal status.

Calcium, together with the plant's organic components, co-creates mechanical tissues, thus providing a mechanical barrier to fungal growth in the plant's covering tissue [7]. In climate zones with frequent droughts, the calcium signaling function is noteworthy, as it becomes active when stress factors, both abiotic and biological, occur. The water deficiency observed in the plant's above-ground shoots is a symptom of an already advanced state of water deficiency within the plant [5;8].

The production role of magnesium is due to its several basic functions, namely [9]:

1. Photosynthesis; The intensity of this process primarily depends on the plant's nutritional status with this nutrient and nitrogen. Mg deficiency leads to a reduction in the amount of bound CO<sub>2</sub> and disruption of the yield formation processes.
2. Plant crop mineral uptake; Mg and phosphorus deficiency slows the uptake and transport of minerals in the plant, especially phosphorus and nitrate nitrogen.
3. Carbohydrate synthesis; Mg nutrition in plants determines the yield and quality of agricultural crops, such as protein content (cereals), sucrose (sugar beets), and starch (cereals, potatoes).
4. Transport of assimilates from vegetative parts to: (i) reserve organs (roots, tubers), (ii) generative parts (seeds, grain).
5. Mg content in agricultural main producers, vegetables, fruits, and feeds, including hay.

The nutritional status of crop plants, including both the discussed nutrients, is critical for plant N management [9]. Nutrient uptake determines the development of the root system (phosphorus, potassium), which in turn determines N-NO<sub>3</sub> uptake. Any deficiency or imbalance in Ca and Mg uptake affects nitrogen use efficiency. These relationships cannot be precisely defined but can be controlled through soil fertility management.

#### References:

- [1] W. Grzebisz, R. Łukowiak, *Agronomy*, **2021**, *11*, 419.
- [2] P. Barłóg, W. Grzebisz, Łukowiak, *Plants*, **2022**, *11*, 1855.
- [3] R. Reid, J. Hayes, *Inter. Rev. Cytol.*, **2003**, *229*, 73–114.
- [4] A. Ridgwell, R.E. Zeebe, *Earth Planetary Sci. Lett.*, *234*(3-4), 299–315.
- [5] W. Grzebisz, W. Zielewicz, K. Przygocka-Cyna, *Agronomy*, **2023**, *13*, 66.
- [6] Ph. J. White, *Ann. Bot.*, **2003**, *92*, 4, 487–511.
- [7] D. Lecourieux, R. Ranyeva, A. Pugin, *New. Phytol.*, **2006**, *171*(2), 249–269.
- [8] K. Thor, *Front. Plant Sci.*, **2019**, *10*, 440.
- [9] W. Grzebisz, *Plant Soil*, **2013**, *368*, 23–39.

# FROM AMPUTATION TO INNOVATION: MAGNESIUM IN VASCULAR MEDICINE

**Andrzej JAWIEN**

*Department of Vascular, Endovascular Surgery, Angiology and Phlebology,  
Poznan University of Medical Sciences, 61-701 Poznan, Poland  
e-mail address: [ajawien@ump.edu.pl](mailto:ajawien@ump.edu.pl)*

Chronic limb ischemia remains one of the most serious challenges in modern vascular surgery and the leading cause of amputations in Poland. Every amputation is not only a dramatic event for the patient and their family but also a major social and economic burden. In seeking ways to prevent or delay this outcome, attention is increasingly directed not only towards surgical techniques but also towards seemingly simple trace elements.

Magnesium has long been associated with muscle and cardiac function, yet growing epidemiological evidence (e.g., ARIC, NHANES) indicates that low serum magnesium levels and insufficient dietary intake are linked with a higher risk of chronic limb ischemia. This suggests that magnesium is involved in inflammation, endothelial dysfunction, and vascular calcification—key mechanisms in the progression of atherosclerosis.

At the same time, magnesium has become a focus of technological innovation. Biodegradable magnesium alloy stents, initially tested in cardiology (e.g., Magmaris, JDBM), combine the strength of metal with the ability to be completely absorbed by the body once their function is fulfilled. New generations show favorable biocompatibility, promote faster re-endothelialization, and reduce chronic inflammatory response. In the future, such devices may also be applied to peripheral arteries—where, too often today, amputation remains the only option.

From amputation to innovation, the journey of magnesium shows its potential both as a marker of vascular risk and as a foundation for novel bioresorbable endovascular solutions to save limbs.

# BIOSTYMULATION FOR ADAPTING TO CLIMATE CHANGE

**Marzena S. BRODOWSKA**

*University of Life Sciences in Lublin, Department of Agricultural and Environmental Chemistry,  
Lublin, Poland*

*e-mail address: [marzena.brodowska@up.lublin.pl](mailto:marzena.brodowska@up.lublin.pl)*

Limiting mineral fertilization, withdrawing many active substances from plant protection products, reducing the use of pesticides resulting from the assumptions of the European Green Deal and the Common Agricultural Policy forces the search for solutions that are aimed not only at using the genetic yield potential of plants and thus obtaining high yields characterized by good quality parameters, but also at improving the condition of plants, among others through increasing their resistance to stress factors. One such solution is the use of biostimulating preparations.

According to the definition of the European Biostimulant Producers Association (EBIC), biostimulants are substances and/or microorganisms whose function, when applied to plants or the rhizosphere, is to stimulate natural processes that promote/improve the absorption or utilization of nutrients, tolerance to abiotic stresses, quality or yield of the crop, regardless of the presence of the ingredients. The introduction of biostimulating substances to the market results from the need for new solutions that will maximize yields, both in terms of quantity and quality, in unfavorable climatic conditions.

When a stress factor occurs, plants try to overcome it by redirecting biochemical processes to fighting stress, not to their development. This leads to reduced yield and lower quality. The development of the plant root system is limited, which results in a reduction in the absorption of minerals by plants. Transport in the plant is limited, the photosynthesis process is disrupted, protein production is limited, which leads to a reduction in plant yield. The later stress occurs on the plantation, the greater the chance of protecting the expected yield. That is why it is so important to build the natural resistance of plants to stress factors, which will protect the plant and focus on building biomass.

Biostimulants do not replace fertilizers, but are used to supplement them. The use of biostimulants is particularly effective when growing plants in unfavorable environmental conditions. Biostimulants used in plant cultivation are compounds containing active substances of natural or synthetic origin. Recently, biostimulating substances produced on the basis of marine algae extracts, chitosan, amino acids, humic and humic acids, silicon and titanium have been used in agricultural, horticultural and vegetable crops. Soil and foliar application of biostimulating substances, combined with an appropriate plant fertilization strategy, can significantly prevent the reduction of crop yields in unfavorable environmental conditions.

# **MAGNESIUM AND THE HEART: ARE THE ANTIARRHYTHMIC PROPERTIES THE ONLY ONES?**

**Tomasz URBANOWICZ**

*Cardiac Surgery and Transplantology Department, Poznan University of Medical Sciences, Długa ½ Street,  
Poznan, 61-848, Poland*

Magnesium is an essential mineral with critical functions in cellular electrophysiology and myocardial stability. Its established role as an antiarrhythmic agent—particularly in treating torsades de pointes and digitalis-induced arrhythmias—has led to its routine use in acute cardiac care. The broader cardioprotective effect of this macroelement is highlighted, including its involvement in vascular tone regulation, essential role in endothelial function, followed by its impact on myocardial energy metabolism, and modulatory role in inflammatory and oxidative pathways.

Previous studies indicated the associations between low magnesium levels and increased risks of hypertension, atherosclerosis, heart failure, and sudden cardiac death. Moreover, magnesium's function as a physiological calcium antagonist contributes to its vasodilatory and antihypertensive properties. These multifaceted actions suggest that magnesium deficiency may be an underrecognized contributor to cardiovascular morbidity and mortality. Recognizing and addressing subclinical magnesium deficiency could offer a low-cost, low-risk intervention with broad therapeutic implications in cardiovascular medicine.

Elevated magnesium levels, often resulting from renal insufficiency or excessive supplementation, can lead to hypotension, bradycardia, atrioventricular conduction disturbances, and even cardiac arrest in severe cases.

In conclusion, the importance of maintaining magnesium homeostasis, as both deficiency and excess pose significant risks to cardiovascular health.

# MODIFYING MG-DOPED MATERIALS FOR POTENTIAL USES IN HARD COAL COMBUSTION THROUGH CHEMICAL LOOPING

**Ewelina KSEPKO, Rafal LYSOWSKI**

*Wroclaw University of Science and Technology,  
Department of Engineering and Technology of Chemical Processes, Wroclaw, Poland  
e-mail address: [ewelina.ksepko@pwr.edu.pl](mailto:ewelina.ksepko@pwr.edu.pl)*

A promising chemical looping combustion technique could enable carbon dioxide neutrality in energy production. It produces a stream suitable for sequestration and greatly decreases nitrogen oxide emissions. This is achieved when an oxygen carrier (OC), a medium that transfers oxygen between the fuel and air reactors during combustion, is used. The OC should have suitable oxygen transport capacity, high reactivity with fuel, and adequate mechanical strength.

This work employs a family of Mg and Cu co-doped spinel oxygen carriers for coal combustion. X-ray powder diffraction (XRD), Energy-dispersive spectroscopy (EDS), and Inductively coupled plasma-Optical emission spectrometry (ICP-OES) analyses focused heavily on their structural properties and confirmed their qualities.

The OCs' reactivity toward selected fuel was evaluated using a thermogravimetric analyser coupled with a quadrupole mass spectrometer (TGA-QMS). XRD analysis proved their good regeneration ability and potential for reuse.

In summary, the research has demonstrated that applying mixed metal oxides through chemical looping could be a potential pathway to achieving net carbon dioxide neutrality during power production from coal.

Acknowledgment:

*The work was financed by the National Science Centre, Poland, Project No. 2020/37/B/ST5/01259.*

# **MAGNESIUM IN DIABETES MELLITUS AND APPLICATION OF MULTICollectOR MASS SPECTROMETRY AND LASER ABLATION IN THE STUDY OF MAGNESIUM ISOTOPES FRACTIONATION PHENOMENON DURING TRANSPORT THROUGH AN ION-SELECTIVE MEMBRANE**

**Andrii TUPYS<sup>a</sup>, Magdalena MAJ-ŻURAWSKA<sup>a</sup>, Adriana PALINSKA-SAAD<sup>a</sup>, Jakub KARASINSKI<sup>a</sup>, Ludwik HALICZ<sup>a,b</sup>, Agata JAGIELSKA<sup>a</sup>, Barbara WAGNER<sup>a</sup>, Andrzej LEWENSTAM<sup>c</sup>, Ewa BULSKA<sup>a</sup>**

<sup>a</sup>*University of Warsaw, Biological and Chemical Research Centre, Faculty of Chemistry, Zwirki i Wigury 101, 02-089 Warsaw, Poland*

<sup>b</sup>*Geological Survey of Israel, 32 Y. Leybowitz st., 9692100 Jerusalem, Israel*

<sup>c</sup>*AGH University of Krakow, Faculty of Materials Science and Ceramics, Al. Mickiewicza 30, 30-059 Crakow, Poland*

*e-mail address: [m.maj-zurawska@uw.edu.pl](mailto:m.maj-zurawska@uw.edu.pl)*

Diabetes mellitus, the illness which has been known since ancient times, is one of the most common diseases of people nowadays. It appears that magnesium status of organism is crucial for this illness. Total magnesium concentrations in blood serum do not differ in healthy people and in diseased ones. However, magnesium is removed from the ill people with urine in significantly more amount than from healthy ones. It has been found that ionized magnesium concentration in blood serum is significantly lowered in ill people. In addition, magnesium isotopes fractionation has been investigated in blood serum of ill people. The serum Mg isotopic composition of diabetes mellitus type I patients was significantly lighter than the serum Mg isotopic composition of the reference population.[1] Therefore, it seems that serum Mg isotope signature could provide valuable information for clinical purposes.

The aim of this work was to study the process of magnesium ions transport through a membrane selective for magnesium. For this purpose, multicollector inductively coupled plasma mass spectrometry (MC-ICP-MS) and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) techniques were used. A system with an ion-selective membrane containing a magnesium ionophore (ETH 5220), a lipophilic salt (potassium tetrakis(*p*-chlorophenyl)borate), plasticizers (chloroparaffin, *o*-nitrophenyl phenyl ether), and a polymeric matrix (polyvinyl chloride), which separates the magnesium salt solution from the solution containing calcium salt, was constructed. Elemental and isotopic analyses of the solutions on both sides of the membrane, as well as the membrane surface itself, were conducted.

Changes in magnesium and calcium concentrations in the solutions bathing both sides of the membrane confirmed that ions of these metals are transported from one side of the membrane to the other. It was hypothesized that, similarly to the kinetic factors in chemical reactions, the lighter isotopes are favoured in transmembrane transport by this factor. Consequently, when magnesium ion passes through the membrane, the solution after passage becomes enriched in the lighter isotope  $^{24}\text{Mg}$ . Supporting this assumption, the MC-ICP-MS technique, used to measure the Mg isotope ratio at the membrane passage, indicated the Mg isotopic fractionation ( $\delta^{26}\text{Mg}$ ) up to -1.5‰ relative to the initial solution. Obtained results proved the ability of isotope ratio measurements to evaluate the diffusion process of magnesium through this kind of membranes [2].

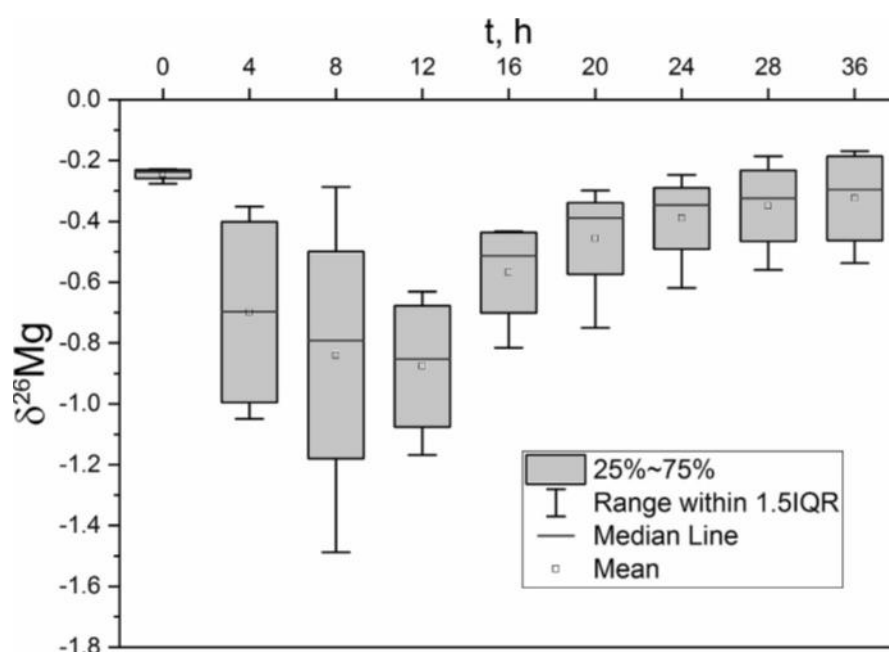


Fig.1. Dependence of Mg isotopic fractionation on the time of solution contact with a membrane for the set membranes ( $n=4$ ). Results for each sample of all membranes are presented as mean values of 3 measurements

#### References:

- [1] R. Grigoryan, M. Costas-Rodrigues, S. Van Laecke, M. Speekaert, B. Lapauw, F. Vanhaecke, *J. Anal. At. Spectrom.*, **2019**, 34, 1514-1521
- [2] A. Tupys, M. Maj-Żurawska, A. Palińska-Saadi, J. Karasiński, L. Halicz, A. Jagielska, B. Wagner, A. Lewenstam, E. Bulska, *Spectrochim. Acta PartB: Atomic Spectroscopy*, **2025** 228, 107182 (DOI: 10.1016/j.sab.2025.10782)

#### Acknowledgements:

*This research was financially supported by the National Science Centre (NCN, Poland) under research project MINIATURA 6 no. 2022/ 06/X/ST4/00343 and by the National Science Centre (NCN, Poland) under research project PRELUDIUM 20 no. 2021/41/N/ST4/03218.*

# MAGNESIUM - A NUTRIENT RESPONSIBLE FOR THE EFFECTIVENESS OF NITROGEN IN PLANT FERTILIZATION

**Jarosław POTARZYCKI, Marcin POTRAWIAK, Łukasz BINIEK,  
Bartosz RIDIGER**

*Department of Agricultural Chemistry and Environmental Biogeochemistry,  
Poznan University of Life Sciences, Wojska Polskiego 28, 60-637 Poznan, Poland  
e-mail address: [jpotarzycki@gmail.com](mailto:jpotarzycki@gmail.com)*

Nitrogen efficiency is one of the most important criteria for assessing fertilization strategies, related to the volume and profitability of production (economic aspect) and the safety of the agroecosystem (ecological aspect). Nitrogen management is still ineffective, and the applied nitrogen doses are insufficiently utilized by plants. Nitrogen utilization from fertilizers (NU) is inversely proportional to the availability of soil nitrogen, ranging from 30 to 55% [1,2,3]. NU can reach the level of 70% and more, provided that available diagnostic tools are used to determine the current nitrogen resources in the plant/soil/fertilizer system, taking into account the dynamics of nitrate uptake by plants during the growing season [4,5,6]. Therefore, it is important to control nitrogen transformations, at least on three levels. The first concerns the ability of plants to take up nitrogen, which is a function of the availability of the nutrient in the soil and the activity of the root system. The second is related to the control of the current assimilation measured by the physiological effectiveness of nitrogen. The realization of the yield potential of maize will be possible after meeting the third criterion. This condition is related to the remobilization process, which involves the transfer of assimilates from leaves and stems/culms to developing generative organs. This is important not only for yield but also for quality. Each stage of nitrogen conversion into usable yield depends on the magnesium supply of plants and the balance of other nutrients. At the Poznań University of Life Sciences, multi-year experiments in this area were conducted using various crop plants. The most important results of these studies include: (1) soil application of a multi-component fertilizer increased the NU from ammonium nitrate from 78 to 92% in maize. However, the yield-forming response of plants depended on the fertilizer dose and was greater when lower amounts of the nutrient were applied (80 versus 140 kg N/ha); (2) in an experiment with corn in degraded soil, the use of N+CaMg (in one granule) increased agronomic and physiological nitrogen efficiency especially in conditions with limited level of N fertilization. N and Mg content in sub-cob leaf (BBCH 65) and DRIS indices for these nutrients were defined as yield predictors; (3) in maize cultivation Partial Factor Productivity of Fertilizer Nitrogen (PFPN<sub>f</sub>) reached the highest value after

combined application of potassium fertilizer with magnesium, magnesium sulphate (into the soil and foliar at the 5-leaf stage).

(4) the presence of Mg in the fertilizer dose increases the physiological activity of leaves during flowering, measured by the SPAD index. This index can be considered a predictor of yield; (5) the increase in yield of winter wheat resulted from the extended transfer of N from vegetative wheat parts to grain. Mg applied to wheat, irrespective of the method (soil and foliar fertilization), increased the efficiency of the N taken up by the crop; (6) a condition necessary for yield formation results from the size of the inorganic N pools in the soil/wheat system during the pre-flowering period of wheat growth. The sufficient condition of yield formation environmental concerns (water and thermal stresses) and agronomic factors, for example, magnesium use; (7) the share of nitrogen translocated from vegetative organs to grains during harvest, depending on the magnesium application system, was at the level of 69-73%. Application of magnesium at a dose of 25 kg Mg·ha<sup>-1</sup> led to a significant increase in agronomic efficiency (EA), efficiency index (We) and nitrogen use from fertilizers (UN). Foliar application, apart from its effect on EA, We and UN, also shaped the physiological efficiency of nitrogen (EF), with the first date of the application being crucial;

Overall, magnesium has proven to be an important element in controlling nitrogen management – the most important and, at the same time, ecologically hazardous nutrient. Recommending a possible reduction in nitrogen doses (after balancing with magnesium) leads to improved production profitability and reduced nitrogen dispersion into the environment.

#### References:

- [1] K. G. Cassman, A. Dobermann, D. T. Walters, *Nitrogen-use efficiency and Nitrogen Management*, **2002**, Agroecosystems, *Journal of the Human Environment*, 31(2): 132-140.
- [2] A. Halvorson, F. C. Schweissing, M.E. Bartolo, C. A. Reule, *Corn response to nitrogen fertilization in a soil with high residual nitrogen*, **2005**, *Agron. J.*, 97: 1222-1229.
- [3] A. Liimatainen, A. Sairanen, S. Jaakkola, T. Kokkonen, K. Kuoppala, T. Jokiniemi, P. S. A. Makela, *Yield, quality and nitrogen use of forage maize under different nitrogen application rates in two boreal locations*, **2022**, *Agronomy*, 12, 887.
- [4] L.K. Sharma, S. K. Bali, *A review of methods to improve nitrogen use efficiency in agriculture*, **2018**, *Sustainability*, 10, 51.
- [5] J. Potarzycki, *Effect of magnesium or zinc supplementation at the background of nitrogen rate on nitrogen management by maize canopy cultivated in monoculture*, **2011**, *Plant Soil Environ.*, 57(1): 19-25.
- [6] J. Potarzycki, W. Grzebisz, W. Szczepaniak, *Magnesium Fertilization Systems as a Fertilizing Factor Increasing the Nitrogen Use Efficiency in Winter Wheat (Triticum aestivum L.)*, **2022**, *Plants* 11, 2600.

# IMPACTS OF MAGNESIUM (Mg) ON CROP PHYSIOLOGY AND QUALITY

**Setareh Jamali JAGHDANI<sup>a</sup>, Jóska GERENDÁS<sup>a</sup>**

*<sup>a</sup> KS Minerals & Agriculture GmbH, Bertha-von-Suttner-Strasse 7, Kassel 34131, Germany*

Magnesium (Mg), often called the "forgotten element," is central to chlorophyll and plays a vital role in photosynthesis and CO<sub>2</sub> fixation within chloroplasts. Due to its high demand in these processes, photosynthesis and key enzymes like ATP synthase and ribulose-1,5-bisphosphate carboxylase/oxygenase (Rubisco) are particularly sensitive to Mg availability. Low Mg levels may also affect photoprotective mechanisms such as non-photochemical quenching (NPQ). While Mg deficiency is known to impair carbon fixation by Rubisco across various species, its impact on light reactions and photoprotection varies, likely due to species-specific sensitivity to highlight intensity.

In our study, we examined Mg deficiency in wheat, sunflower, barley, and spinach—crops with differing tolerance to light stress—focusing on CO<sub>2</sub> assimilation, photosynthetic efficiency, and photoprotection. Results showed that Mg deficiency significantly reduced CO<sub>2</sub> assimilation in all crops except wheat, mainly due to decreased activity of enzymes like Rubisco and Rubisco activase.

Chlorophyll fluorescence analysis revealed that photochemical quenching (qP) remained stable in sunflower, wheat, and spinach but declined in barley, indicating more closed reaction centers and reduced electron transport. Electron transport rate (ETR) dropped in sunflower and barley, suggesting damage to the photosynthetic electron transport chain. Furthermore, maximum quantum efficiency (Fv/Fm) decreased in sunflower, barley, and wheat, pointing to damage in the photosynthetic apparatus and possible photoinhibition of photosystem II due to oxidative stress.

Apart from its pivotal role in photosynthesis Mg – together with K – is also critical for phloem loading and hence translocation of photosynthates, as seen in spinach and French bean. This impaired assimilate translocation led to an accumulation of soluble sugars and starch in leaves and reduced root growth, with far-reaching consequences for nutrient uptake and water. The latter gains importance in the era of global change. The importance of Mg for assimilate translocation has also far-reaching implications for yield formation and produce/product quality. A literature survey confirms that increasing Mg supply increases the crop quality, particularly when grown on Mg-deficient sites and when the formation of quality trait under consideration is dependent on Mg-driven assimilate translocation within

the plant (sugar content of sugar beet, starch content of cereal grain). It is also concluded that Mg doses beyond those required for maximum yield rarely induce a further improvement of produce quality. Hence, in an agricultural setting farmers are advised focusing on Mg as a nutrient important for assimilate translocation and hence yield formation. Apart, the Mg content itself can also be regarded as a quality trait in view of its significance in animal in human nutrition. However, with regard to food quality farmers are usually not rewarded when producing crops with a higher Mg content.

Contrary to the synergistic role of Mg and K in phloem loading and assimilate translocation, these two cations exert a strong antagonism regarding nutrient uptake by the root. This is mostly referred to the existence of several high-affinity K transport systems, while Mg uptake is mostly associated with less specific transport systems (cation channels) operating at roots. These are prone to cation antagonisms, resulting in K-induced Mg-deficiency. The reverse effect, a Mg-induced K deficiency, is not observed under field conditions.

# APPLICATIONS OF METAL IONS IN BIOMATERIALS

**Radosław MRÓWCZYŃSKI**

*Faculty of Chemistry, Adam Mickiewicz University, Poznań  
e-mail address: [radoslaw.mrowczynski@amu.edu.pl](mailto:radoslaw.mrowczynski@amu.edu.pl)*

Metal oxides, particularly those of iron, manganese, copper, and silver, currently form the foundation for the development of modern biomaterials and therapeutic nanoplatforms. Owing to their magnetic, redox-active, and photothermal properties, they enable simultaneous diagnosis and therapy within the framework of the theranostics concept.

A special class is represented by iron oxides ( $\text{Fe}_3\text{O}_4$ ,  $\gamma\text{-Fe}_2\text{O}_3$ ) and their complexes, which have long been used as contrast materials in magnetic resonance imaging (MRI). Their high chemical stability, low toxicity, and the possibility of surface functionalization with polymers or biological ligands make them an excellent basis for designing smart biomaterials responsive to external stimuli (e.g., magnetic field, light, or pH).

The incorporation of manganese ions ( $\text{Mn}^{2+}$ ) into biomaterials not only enhances MRI contrast through a paramagnetic effect, but also imparts redox-active properties that help neutralize reactive oxygen species (ROS) in inflammatory environments. Copper ions ( $\text{Cu}^{2+}$ ), apart from their well-known antibacterial activity, participate in cuproptosis — a regulated form of cell death with promising therapeutic potential in oncology. Iron ions can induce ferroptosis, while silver ions ( $\text{Ag}^+$ ) act as powerful antimicrobial agents, commonly used in protective implant coatings and bioactive dressings.

The integration of metal ions with biomaterials leads to the formation of multifunctional hybrid systems capable of performing diagnostic (MRI, CT, optical imaging), therapeutic (photothermal, redox, antibacterial), and regenerative (osteogenic and angiogenic stimulation) functions simultaneously.

The lecture will discuss synthetic strategies and surface-engineering approaches for macro- and nanoscale biomedical platforms based on iron, copper, and manganese oxides, as well as their integration with bioactive coatings containing Ag, Cu, Mn, and Au ions, enabling synergistic effects in the diagnosis and therapy of cancer and in biomedical engineering.

# USE OF PBET (PHYSIOLOGICALLY BASED EXTRACTION TEST) FOR ASSESSING THE RELEASE AND POTENTIAL ABSORPTION OF MINERAL ELEMENTS OF CLAYS AVAILABLE IN THE POLISH MARKET

**Jean DIATTA**

*Poznań University of Life Sciences, Agronomy, Horticulture and Biotechnology, Poznań, Poland  
e-mail address: [jean.diatta@up.poznan.pl](mailto:jean.diatta@up.poznan.pl)*

Clays are a natural component of soil being a involved in many healthcare products (Argillotherapy) [1] and in cosmetics, as well as dietary supplements (Geophagy) [2]. The use of clays in medicine and cosmetics has attracted the attention of many physicians and cosmetologists [3]. Therefore, their chemical composition and the rate of release and absorption of minerals in humans, should be investigated.

The main goal was to use the PBET (Physiologically Based Extraction Test) [4] to assess the release rate and potential absorption of mineral elements from clays available on the Polish market. The concept of this study was based on the assumption, that mineral components of clays are released when applied externally (as face masks) or internally (orally). Furthermore, these amounts were compared to nutritional standards (*Dietary Reference Intakes - DRI*).

The research involves 22 clays (white, yellow, blue, pink, red, green, and black) commonly available on the Polish market. It includes a range of chemical tests, like pH in water, electrical conductivity (EC), and cation exchange capacity (CEC) (Test with 1M CH<sub>3</sub>COONH<sub>4</sub>, pH 7.0). Detailed tests include extraction of macro (Ca, Mg, K, Na) and trace elements (Cu, Zn, Fe, Mn, Pb and Cd) using PBET (solution of 0.40 M glycine i.e. aminoacetic acid). The pH was adjusted to 2.5 or 5.5 using a solution of 1 M HCl dm<sup>-3</sup>). The PBET test at pH 2.5 was used to simulate oral (internal) use of clays, and at pH 5.5 when applied externally (as face masks). The data obtained will be used for calculating the simulated absorption of mineral elements.

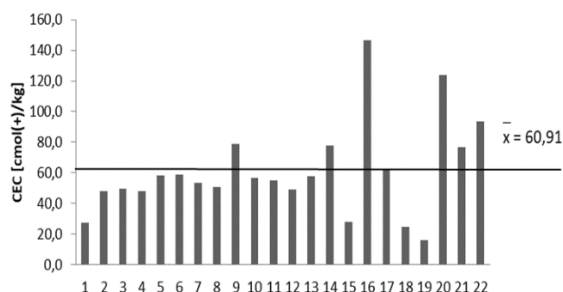
Several parameters should be considered [5] in evaluating the potential absorption of minerals from the tested clays, as follows:

$$D = C \frac{WK}{MC} * \frac{CK}{T}$$

where,

**D** – rate of mineral elements intake [mg \* (kg body weight \* day)<sup>-1</sup>]; **C** – content of mineral elements in tested clay [mg \* kg<sup>-1</sup>]; **WK** – length of contact with the tested clay [mg clay \* day<sup>-1</sup>]; **CK** – frequency of contact with clay [hours, days, years]; **MC** – body weight [15 kg for children under 6 years; 70 kg for adults]; **T** – average time, it is usually assumed 6 (70 years) \* 350 days the year.

The cation exchange capacity (CEC), (Fig. 1) reveals a wide scatter of data with min. = 16.0 cmol<sub>(+)</sub>/kg, max. = 146.4 cmol<sub>(+)</sub>/kg; whereas only 32% of the clays exceeded the mean value ( $\bar{x}$  = 60.91 cmol<sub>(+)</sub>/kg). The release of mineral elements is strictly controlled by these properties.



Graph 1: Cation exchange capacity (CEC) values of the tested clays

The amount of a mineral element dissolved in a PBET solution is a determinant of its potential absorption by the human digestive system. Applying clays, both orally (internally) and externally (as face masks), can be an effective way to replenish element deficiencies in the human body. This was particularly true for Ca, Mg, Fe, and Zn (Table 1), and least for K, Cu, and Mn.

Table 1: PBET (pH 2.5) extracted Ca and Zn and their potential intakes accordingly to age

| Statistical description<br>(n = 22) | Ca                                     |                              |                      | Zn                                     |                              |                      |
|-------------------------------------|----------------------------------------|------------------------------|----------------------|----------------------------------------|------------------------------|----------------------|
|                                     | PBET (pH = 2.5)<br>mg kg <sup>-1</sup> | μg/day/kg body weight (b.w.) |                      | PBET (pH = 2.5)<br>mg kg <sup>-1</sup> | μg/day/kg body weight (b.w.) |                      |
|                                     |                                        | Children 1-6<br>years        | Adults - 70<br>years |                                        | Children 1-6<br>years        | Adults - 70<br>years |
| Min.                                | 670.0                                  | 2.68                         | 1.91                 | 6.58                                   | 0.026                        | 0.019                |
| Max.                                | 11560.0                                | 46.24                        | 33.03                | 81.20                                  | 0.325                        | 0.232                |
| <u>Mean</u>                         | <b>4326.1</b>                          | <b>17.30</b>                 | <b>12.36</b>         | <b>26.23</b>                           | <b>0.105</b>                 | <b>0.075</b>         |
| Median                              | 3027.5                                 | 12.11                        | 8.65                 | 19.54                                  | 0.078                        | 0.056                |
| Standard deviation                  | 3129.7                                 | 12.52                        | 8.94                 | 19.99                                  | 0.080                        | 0.057                |

The applied PBET test (Physiologically Based Extraction Test) proved to be useful for describing the rate of release of macro- and microelements from the tested clays.

#### References:

- [1] V. Ihadjadene, *L'Argile à l'hôpital. Utilisation de l'argile dans un service de soins hospitaliers*, **2012**, Formation Hippocratus, 30 p.
- [2] W. A. Price, Nutrition and physical degeneration, *Price-Pottenger Nutrition Foundation*, **2006**, 524 p.
- [3] S.A. Lafi and M.R. Al-Dulaimy, *Acad. J. Biolog. Sci.* **2011**, 3(1): 75-78.
- [4] M.V. Ruby, A. Davis, R. Schoof, S. Eberle, and C.M. Sellstone, *Environ. Sci. Technol.*, **1996**, 30(2): 422-430.
- [5] M. Biesiada, A. Janeczek, M. Biesiada, M. Muszyńska-Graca, B. Dąbkowska, B. Malec, E. Gałkowska, *Instytut Medycyny Pracy i Zdrowia Środowiskowego*, **2006**, 72p.

# **TO SOFTEN WATER OR NOT TO SOFTEN? ...THAT IS THE QUESTION! PRESENTATION OF TEST RESULTS FOR DRINKING WATER AND WATER AFTER ADDITIONAL TREATMENT PROCESSES, PERFORMED AT THE SALUBRIS LABORATORY.**

**Agnieszka WICHŁACZ-BELLUCCI<sup>a</sup>**

*<sup>a</sup> SALUBRIS SP. Z O.O. Laboratorium ul. Poznańska 2, 63-004 Tulce, Poland  
e-mail address: [aga@wichlacz.net](mailto:aga@wichlacz.net)*

Over the last few years, there has been a continuous increase in the demand for water and drinking water testing by residents for their private needs. The results of these analyses conducted by the SALUBRIS Laboratory will be presented.

While the desire of private wells and water supply owners to carry out water treatment is entirely justified, the treatment of water from municipal or rural networks, is surprising. Treating underground water for drinking purposes primarily involves removing iron and manganese compounds. Microbiological purity monitoring is also crucial. It is increasingly common for water, in addition to iron and manganese removal, to be further softened or osmosis-treated. In the case of municipal or rural water, softening filters are primarily installed. As a result, the water is almost completely devoid of minerals, mainly magnesium and calcium, that are valuable to human health. The scale of this phenomenon is becoming dangerously large.

Difficult questions arise: what reality does this represent for a society that consumes such water ? What health consequences could this have?

The impact of deionized water consumption on human health has been previously described in the literature [1]. The usefulness of research on the impact of mineral-free water consumption on mineral balance in the human body has been demonstrated and further research is needed.

## References:

[1] M. Drobnik, T. Latour, *Roczn., PZH*, **2002**, 53, NR 2, 187.195 Influence of the deionized water on the wholesomeness of the population.

# THE CONTENT OF SELECTED MACRO- AND MICROELEMENTS IN DIFFERENT BEETROOT CULTIVARS (*BETA VULGARIS* L.) DEPENDING ON THE LEVEL OF SOIL FERTILIZATION WITH SELENIUM

**Michał MAJEWSKI<sup>a</sup>, Anetta HANĆ<sup>b</sup>, Joanna MAJKOWSKA-GADOMSKA<sup>c</sup> and Anna FRANCKE<sup>c</sup>**

<sup>a</sup> *University of Warmia and Mazury, Faculty of Medicine, Department of Pharmacology and Toxicology, Olsztyn, Poland*

<sup>b</sup> *Adam Mickiewicz University, Faculty of Chemistry, Department of Trace Analysis, Poznań, Poland*

<sup>c</sup> *University of Warmia and Mazury, Faculty of Agriculture and Forestry, Department of Agroecosystems and Horticulture, Olsztyn, Poland*

*e-mail address: [michal.majewski@uwm.edu.pl](mailto:michal.majewski@uwm.edu.pl)*

The nutritional values and biological activity of vegetables are dependent on genetic and environmental factors, and later the method of food processing. Beetroot is a well-known vegetable of nutritional values and culinary taste. Moreover, beetroot, like other root vegetables, can accumulate environmental substances present in the soil.

We analyzed the influence of different cultivars of beetroot on the impact of soil fertilization with selenium (Se) preparation (AminoSelenit) on the concentration of the selected macro and microelements in this vegetable. This provide some information on how to prepare a daily diet to examine the influence of experimental supplementation in a rat model with metabolic disorders and vascular dysfunction.

Beetroot (Baldor, Wodan, Anello and Avalanche) were harvested on a soil with 1 – no added Se, 2 – Se added preparation 1.5 l/ha, and 3 – 3.0 l/ha Se. Beetroot was dried, powdered and examined by inductively coupled plasma mass spectrometry (ICP-MS) [1].

The highest concentration of examined macro- and microelements was found in Wodan, contrary to Baldor which was identified as the one with the smallest amount, with some exceptions as to Cu and Pb (Figure 1).

The concentration of Se didn't increase in beetroots according to the dose of Se inclusion in soil (Figure 2).

Together with Se addition into the soil the concentration of chosen macro- and microelements (Cr, Fe, Ni, Zn, As, Sb, Pb, and less with Cu) decreased in beetroot, and this was observed in a most significant way in Wodan (data not presented).

Different dependent variables were observed between the soil Se concentration and chosen macro and micro elements determined in beetroot. It seems reasonable to choose Wodan and Baldor for the further studies on metabolic disorders in a rat model.

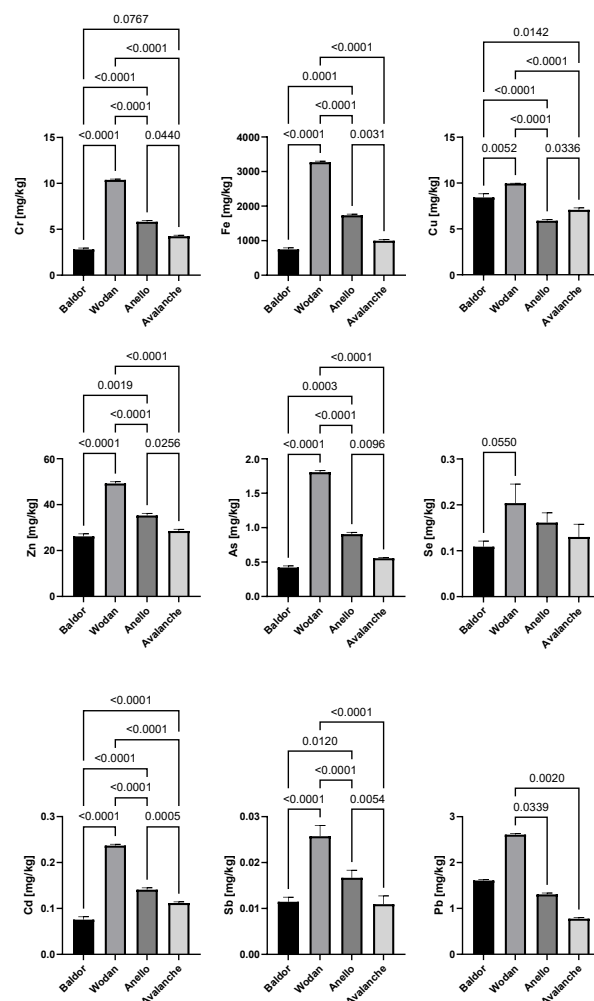


Figure 1. The content of selected macro and micro elements in Baldor, Wodan, Anello and Avalanche cultivars with the inclusion of varying levels of soil fertilization with selenium.

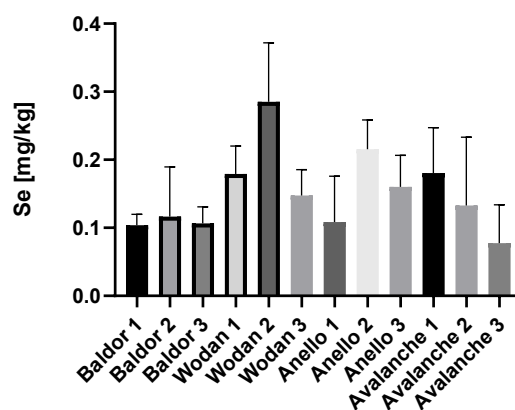


Figure 2. Selenium concentration in Baldor, Wodan, Anello and Avalanche cultivars with the inclusion of varying levels of soil fertilization with selenium.

#### References:

[1] K. Kitala-Tańska, , A. Hanć, , J. Juśkiewicz, , M. Majewski, *Nutrients*, **2024**, 16(19), 3230.

# THE IMPACT OF SALICYLATE TREATMENT ON MAGNESIUM CONCENTRATION IN MATERNAL-FETAL TISSUES IN PREECLAMPTIC RATS

**Rafsan CHOLIK, Joanna SULIBURSKA**

*Department of Human Nutrition and Dietetics, Poznan University of Life Sciences, Poznan, Poland  
e-mail address: [rafsan.cholik@up.poznan.pl](mailto:rafsan.cholik@up.poznan.pl)*

Preeclampsia is one of the most concerning complications associated with pregnancy and is characterized by the development of hypertension and proteinuria in pregnant women. Although the etiology of preeclampsia remains a topic of discussion, both clinical and pathological research indicate that preeclampsia might affect the concentration of minerals in the body, including magnesium. This study aimed to investigate whether salicylate treatment affects magnesium levels in maternal and fetal tissues of preeclamptic rats. Four groups of twelve-week-old female Sprague Dawley rats were selected: healthy rats (CH, n=8), preeclamptic rats (CP, n=8), preeclamptic rats treated with natural salicylates (HSP, n=8), and preeclamptic rats treated with aspirin (HAP, n=8). In the rat model of preeclampsia, NG-nitro-L-arginine-methyl-ester (L-NAME) was used. A non-invasive blood pressure device named CODA (Kent Scientific) was used to assess the systolic (Sys) and diastolic (Dia) blood pressure on gestational day (GD) 6 and GD 18. Daily food intake was measured. Rats were decapitated at 19 GD, final body mass was measured, and their tissues and blood were taken. Magnesium concentration was measured in amniotic fluid (AF), serum, fetus, and placenta. The level of magnesium (Mg) in tissues was assessed using flame atomic spectrometry (ZA 3000 Hitachi) after mineralization in a microwave digestion system (Mars 2 TM System; CEM Corporation). Statistical analysis was performed using Statistica 13.3.

Daily food intake and final body mass were comparable between groups. Preeclamptic rats had elevated systolic and diastolic blood pressure compared to the healthy group. Magnesium concentration in the placenta was significantly higher in treated preeclamptic groups (HSP and HAP) compared to the control preeclamptic and healthy groups (CP and CH). While, magnesium content in the fetus, amniotic fluid, and serum was comparable across groups.

In conclusion, salicylate treatment does not change the blood pressure in preeclamptic rats; however increases magnesium concentration in the placenta.

*This study was funded by NCN (grant no 2021/43/B/NZ9/00177).*

# THE CONTENT OF MAGNESIUM AND OTHER BIOELEMENTS IN ORGANICALLY AND CONVENTIONALLY GROWN SOYBEANS

**Katarzyna PUŻYŃSKA<sup>a</sup>, Stanisław PUŻYŃSKI<sup>b</sup>**

<sup>a</sup> *University of Agriculture in Krakow, Department of Agroecology and Crop Production, Faculty of Agriculture and Economics, Mickiewicza 21, 31-120 Krakow, Poland*

<sup>b</sup> *Independent scientist, Poland*

*e-mail address: [katarzyna.puzynska@urk.edu.pl](mailto:katarzyna.puzynska@urk.edu.pl); [spuzynski@wp.pl](mailto:spuzynski@wp.pl)*

*Key words:* soybean; organic system, conventional system, bioelements

Soybean (*Glycine max* L. Merr.) is becoming increasingly widely cultivated in Poland due to the availability of varieties with varying growing season lengths, which allows it to be grown almost nationwide. Increased production of certified seed and farmers' cultivation skills, subsidies for the cultivation of large-seeded legumes and seed, and the inclusion of soybean in the environmental schemes are contributing to the increase in soybean cultivation areas.

Globally, soybean is one of the oldest and most important crops. It ranks first in terms of the area cultivated among legumes, and second only to wheat. Its cultivated area is similar to that of corn and rice, and has increased significantly since the elimination of animal protein from concentrated feeds in the form of meat and meat-and-bone meal following the outbreak of mad cow disease more than a decade ago. The largest amounts of soybean are grown in the USA, Brazil, and Argentina, while in Poland, the trend continues upward. According to the Polish Soybean Association, in 2025, the area under soybean cultivation in Poland reached a record 98.100 hectares.

Soybeans are valued for their high protein content (30-40 percent) and quality, with a very favorable amino acid composition. They also contain an average of 20 percent oil, with a high content of beneficial essential unsaturated fatty acids (EFAs). They are also a rich source of lecithin, vitamins, and minerals. This makes soybean meal the main protein component of concentrated feed, while the seeds are a valuable raw material for the food industry. They are used for feed, food, and industrial purposes. Soybeans are a very good source of magnesium, iron, zinc, copper, manganese, molybdenum, calcium, phosphorus, potassium, and sodium.

Reducing energy consumption and increasing the energy efficiency of crop cultivation technologies is becoming a priority. Increasing soybean sowings allows for greater environmental protection by allowing for the elimination of nitrogen fertilization from soybean cultivation practices, which also prevents soil degradation. Soybeans live in

symbiosis with the soil bacteria *Bradyrhizobium japonicum* (Kirchner) Jordan. These bacteria fix atmospheric nitrogen (N<sub>2</sub>), which can be utilized by the plant. This interaction is beneficial for both the plant and the soil environment.

The aim of this study was to test the feasibility of soybean cultivation in an organic farming system and to compare the content of magnesium and other bioelements in soybean seeds grown under different farming systems. Organic and conventional systems were compared. An additional research factor was the selection of the soybean variety. The analysis of the research results was based on a field experiment conducted at the Experimental Station of the Department of Agroecology and Crop Production at the University of Agriculture in Krakow. Using the collected material from 2023-2024, an analysis of the impact of research factors on the content of bioelements was conducted. Statistical analysis showed that the content of bioelements varied over the years of the study, depending on the influence of research factors. The management system and variety significantly modified the content of bioelements in soybean seeds.

# EVALUATION OF THE YIELD FORMATION AND NUTRITION REACTION OF TWO VARIETIES OF WINTER WHEAT TO INCREASING LEVELS OF NITROGEN FERTILIZATION

**Witold SZCZEPANIAK<sup>a</sup>, Michał KULWICKI<sup>b</sup>, Katarzyna PRZYGOCKA-CYNA<sup>a</sup>,  
Maria BIBER<sup>a</sup>, Agnieszka ANDRZEJEWSKA<sup>a</sup>**

<sup>a</sup> Department of Agricultural Chemistry and Environmental Biogeochemistry,  
Poznan University of Life Science, Wojska Polskiego 28, 60-637 Poznan, Poland

<sup>b</sup> Syngenta Polska, Szamocka 8, 01-748 Warszawa, Poland  
e-mail address: [witold.szczepaniak@up.poznan.pl](mailto:witold.szczepaniak@up.poznan.pl)

In Poland, wheat varieties can be classified into one of five grain quality groups: E, A, B, C and K. It is assumed that quality varieties (A) have a lower yield potential than bread-making varieties (B) [4]. Fertilization of cereals with nitrogen, i.e. the main yield-forming component, should be carried out according to the realistic yield that is possible to obtain under farming conditions, taking into account the quality characteristics of the cultivated varieties [1, 2, 3].

The aim of the study was to assess the yield-forming and nutritional response of two winter wheat cultivars to the increasing level of nitrogen fertilization. A strict two-factor field experiment was established on fertile soil, which belongs to the II quality class, in a split-block system in 2018-2021 in the town of Borówno in the "Złoty Kłos" seed farm, located in the Kujawsko-Pomorskie Voivodeship. The factors of the experiment were: 1) Varieties (O): Arktis and KWS Emil; 2) Nitrogen (N) doses: 0, 40, 80, 120, 160, 200 and 240 kg N ha<sup>-1</sup>. Arktis wheat is a quality variety - A, while KWS Emil is a bread-making variety - B. Nitrogen in the form of ammonium nitrate was sown at three different times: 1) before the start of spring vegetation, but not earlier than March 1st - up to a dose of 80 kg N ha<sup>-1</sup>, 2) at the stage of the end of tillering/beginning of stem elongation (BBCH 29-31) - up to a dose of 160 kg N ha<sup>-1</sup>; 3) at the flag leaf stage (BBCH 39) - up to a dose of 240 kg N ha<sup>-1</sup>. The grain yield was assessed by harvesting with a combine harvester from an area of 160 m<sup>2</sup>, while plants for the assessment of nutrient content (N, P, K, Mg, Ca) at the BBCH 65 stage were taken from 0.5 m<sup>2</sup>. The results were subjected to the analysis of variance for factorial experiments in the Statistica 13® software. The differences between the levels of experimental factors were determined on the basis of Tuckey's post-hoc test.

The statistical analysis showed that both the grain yield and the nutrient content of plants at BBCH 65 stage were shaped by the weather conditions in individual years of the study, as well as by the factors tested in the experiment. At the same time, the analyzed cultivars did not differ in the content of phosphorus in leaves and phosphorus and magnesium in the

stalks. On the other hand, nitrogen doses did not determine the phosphorus content in leaves and ears.

The highest grain yield was obtained in 2020 ( $9.099 \text{ t ha}^{-1}$ ), when a favorable amount and distribution of rainfall during the flowering and grain pouring period was recorded. On the other hand, yields in the first and third year of the study were similar, however significantly lower than in the second year (on average by  $1.5 \text{ t ha}^{-1}$ ). The conducted research confirmed the higher potential of bread-making varieties (B) compared to the quality varieties (A). In the experiment, the KWS Emil cultivar obtained a yield higher by  $1.933 \text{ t ha}^{-1}$  compared to the Arktis cultivar. The analysis of nitrogen fertilization showed that the highest yield in the experiment ( $8.729 \text{ t ha}^{-1}$ ), which was obtained on the plot fertilized with  $200 \text{ kg N ha}^{-1}$ , differed only from those obtained on the plots fertilized within the range of  $0\text{-}80 \text{ kg N ha}^{-1}$ . However, compared to the plot fertilized with  $120 \text{ kg N ha}^{-1}$  it was higher by only  $0.118 \text{ t ha}^{-1}$ , i.e., by 1.4%. This indicates the high fertility of the site where the experiment was conducted. The relationship between grain yield and nitrogen doses for both varieties is best described by second-order polynomial equations, which show that the Arktis variety would reach its maximum yield at 190, while the KWS Emil variety at  $181 \text{ kg N ha}^{-1}$ . Therefore, despite the significant difference in yields, both varieties are characterized by a similar yield-forming response to nitrogen doses.

The analysis of the nutritional status of plants in the flowering phase showed a higher concentration of the studied components in the organs of the Arktis cultivar, apart from the content of nitrogen and potassium in the leaves and magnesium and calcium in the ears. At the same time, the correlation matrix showed positive relationships between grain yield and the content of nitrogen, magnesium and calcium in leaves, phosphorus in stalks and phosphorus, magnesium and calcium in ears in the case of a quality cultivar. In the case of the bread-making variety, however, grain yield was correlated with the nitrogen content in the leaves and the phosphorus and potassium content in the ears. At the same time, it was shown that the increase in the level of nitrogen fertilization generally contributed to the improvement of plant nutrition, both with nitrogen and other tested macronutrients.

#### References:

- [1] S.E.D. Faizy, S.A. Mashali, S.M. Youssef, S.M. Elmahdy. Study of Wheat Response to Nitrogen Fertilization, Micronutrients and their Effects on Some Soil Available Macronutrients. *J. Sus. Agric. Sci.*, **2017**, Vol. 43, No.1, pp. 55-64.
- [2] W. Grzebisz. Technologie nawożenia roślin uprawnych - fizjologia plonowania. Tom 2. Zboża i kukurydza. *PWRiL*, **2012**, Poznań, 280 s.
- [3] W. Grzebisz. Nawożenie Roślin Uprawnych. Tom 1. Podstawy Nawożenia. *PWRiL*, **2015**, Warszawa, 428.
- [4] [www.coboru.gov.pl](http://www.coboru.gov.pl) - 10.07.202

# DYNAMICS OF ELEMENTS IN SOIL – A MATHEMATICAL APPROACH AT CAPTURING THE CHANGES IN PHOSPHORUS FORMS

**Stanisław W. BIBER<sup>a, b</sup>, Jarosław POTARZYCKI<sup>c</sup>, Maria BIBER<sup>c</sup>,  
Katarzyna PRZYGOCKA-CYNA<sup>c</sup>**

<sup>a</sup> School of Mathematics and Physics, University of Surrey, Guildford, GU2 7XH, United Kingdom

<sup>b</sup> School of Engineering Mathematics, University of Bristol, Bristol BS8 1TW, United Kingdom

<sup>c</sup> Department of Agricultural Chemistry and Environmental Biogeochemistry, Poznan University of Life Science, Wojska Polskiego 28, 60-637 Poznan, Poland

*e-mail address: [s.biber@surrey.ac.uk](mailto:s.biber@surrey.ac.uk)*

Mathematical modelling is a powerful tool reaching far beyond (but not excluding) statistical analysis of data. Research has seen application of mathematical models to engineering, physics, biology, medicine, chemistry or economics, to name a few. Apart from making predictions, mathematical models allow for analysis leading to informed data collection, experiment design, optimisation of procedures or exploration of otherwise unknown mechanisms. Beyond the most common purpose of predicting outcomes, mathematical modelling is often used to inform data collection, explain underlying mechanisms or highlight intricacies of the studied systems [1].

We utilise mathematical approaches to study the changes between labile and non-labile forms of phosphorus in soil. We present a simple and intuitive mathematical model for changes between different forms of phosphorus based on common model used for the studies of infectious diseases [2].

In examining the model, we utilise data collected over 60 days in different regimes of phosphorus fertilisation (including control sample), with sampling performed every 10 days to measure the levels of phosphorus in the soil.

This model is a proof-of-concept approach demonstrating how interventions (such as fertilisation) can be guided by a studied mathematical model. Although using the data from phosphorus only, this simple model can be easily adjusted to other elements, such as magnesium. The model should guide further data collection protocols, and once finely tuned and parametrised, should lead to an optimisation of fertilisation processes. Although this work considers simple mechanisms only, further constraints can be imposed, leading to more accurate models in the future.

[1] J. M. Epstein, *J. Artif. Soc. Soc. Simul.*, **2008**, Why model?, 11, (4).

[2] W. O. Kermack, A. G. McKendrick, *Proc. R. Soc. A.*, **1927**, A contribution to the mathematical theory of epidemics, 115 (772), 700-721

# THE IMPACT OF LONG-TERM DIVERSIFIED SOIL USE ON THE CONTENT OF TRACE ELEMENTS AND THEIR DISTRIBUTION WITH SOIL DEPTH

**Agnieszka ANDRZEJEWSKA-JUSKOWIAK<sup>a</sup>, Zuzanna SAWINSKA<sup>a</sup>, Andrzej BLECHARCZYK<sup>a</sup>**

*<sup>a</sup> Poznań University of Life Sciences, Faculty of Agronomy, Horticulture and Biotechnology, Poznań, Poland  
e-mail address: [agnieszka.andrzejewska@up.poznan.pl](mailto:agnieszka.andrzejewska@up.poznan.pl)*

It has been assumed that the long-term impact of a diversified soil use system (SUS) due to continuous application of manure and/or mineral fertilizers (NPK) significantly changes the content and distribution of available trace elements (nutrients and bioavailable heavy metals) in the soil. This hypothesis was verified in 2022 i.e., based on the 75<sup>th</sup> year long-term experiment founded at the Brody Experimental Station by the Poznań University of Life Sciences, Poland (52° 26' N, 16° 18' E, 92 m a.s.l.), Poland. The experiment was established on soil formed from loamy sand, classified as Albic Luvisols (Neocambic).

The experiment consisted of a seven-course crop rotation: potato–spring barley–winter triticale–alfalfa–alfalfa–winter wheat–winter rye and monocultures of these crops plus black fallow. The studies were carried out on three separate fields: black fallow (BF), winter wheat grown in monoculture (WW-MO), and in crop rotation (WW-CR). Each of these experimental objects consists of five fertilizer variants (FVs) fertilized in the same way every year: absolute control (AC)—variant without fertilizers for 75 years; farmyard manure (30 t ha<sup>-1</sup>) — FM; mineral fertilizers (using 90 kg N ha<sup>-1</sup>, 26 kg P ha<sup>-1</sup>, and 100 kg K ha<sup>-1</sup>) — NPK; mixed variant — NPK+FM; mineral fertilizers plus lime (1 t CaO ha<sup>-1</sup> year<sup>-1</sup>) — NPK+L. The content of trace elements was determined in three soil layers: 0.0–0.3 m, 0.3–0.6 m, and 0.6–0.9 m.

The general state of soil fertility was determined based on four indicators, namely the soil texture, electrical conductivity (EC), soil reaction (pH), and organic carbon content (C<sub>org</sub>, humus). The consequences of eluviation/illuviation processes were clearly noted in the experiment, regardless of the SUS. The increase in sand content, which dominated, had a greater impact on silt than on the clay content. The value of R<sup>2</sup> (coefficient of determination) in BF was 0.95 and 0.43 for Si and Cl; in WW-MO, it was 0.79 and 0.47; in WW-CR, respectively. The downward trend in Cl distribution with soil depth was strongest for NPK+FM (CV = 76%) and the stable and high clay content in the entire soil profile was recorded in NPK+L.

The content of  $C_{org}$  was the key factor determining the content and vertical distribution of trace elements in the soil. Its content decreased in the following order: WW-CR ( $13.2 \pm 5.8$ )  $\geq$  WW-MO ( $12.3 \pm 6.9$ )  $>$  BF ( $6.6 \pm 2.8 \text{ g} \cdot \text{kg}^{-1}$ ). The large variability resulted from a distribution trend with soil depth, which increased as follows:  $MO \geq CR > BF$ . FVs with FM had the highest  $C_{org}$  content. NPK, regardless of the long-term SUS, had the lowest content. The Humus Stability (Saturation) Index values for the examined FVs amounted to  $8 \pm 2$  on average for BF. In winter wheat grown in monoculture, the average HSI was  $13 \pm 4.2$ , whereas in crop rotation, this index reached  $15 \pm 3$ . It was found that the  $C_{org}$  content in the topsoil of  $10.5\text{--}11 \text{ g kg}^{-1}$  was sufficient to reach the humus saturation status. The required range of  $C_{org}$  content in layer B was  $7.5\text{--}8.5 \text{ g kg}^{-1}$ ; in C, it was  $5\text{--}6 \text{ g kg}^{-1}$ .

Among the elements studied, the key one impacting the content of both micronutrients and heavy metals was iron (Fe). Its average content in the entire soil profile was in the medium availability class and decreased in the order  $BF (239 \pm 109 \text{ mg kg}^{-1}) \geq WW-MO (217 \pm 58) \geq WW-CR (203 \pm 62 \text{ mg kg}^{-1})$ . As a rule, it showed a decreasing trend with soil depth. The content of  $C_{org}$  significantly determined the content of all elements examined, with the exception of Ni. At the same time, the stability of  $C_{org}$ -Fe associations decreased in the following order: BF (Linear,  $R^2 = 0.66$ )  $>$  WW-CR (Quadratic,  $R^2 = 0.62$ )  $>$  WW-MO (L, ns.). The strongest dependency between both soil characteristics was found in the non-cropped soil. The opposite tendency was found for the remaining elements, the content of which was consistent with the content of  $C_{org}$ , which was the highest in CR. The strongest impact of Fe, modified by the SUS, was found for Zn, Pb, and Cd. Despite the differences observed between SUSs, fertilization variants, and soil layers, the content of Fe and Mn was in the medium class, while Zn and Cu were in the high class of availability. The content of Ni was the highest for NPK+FM in WW-CR. The content of Pb was weakly affected by the long-term SUS but showed a strong tendency for accumulation in the topsoil layer. The content of Cd was the highest in BF, where it exceeded the threshold of  $0.27 \text{ mg} \cdot \text{kg}^{-1}$ . The long-term diversified SUS makes it possible to indicate the directions of humus accumulation and its distribution in the soil. It turned out to be a key factor, but in cooperation with Fe, it determined the content of micronutrients and bioavailable heavy metals in the soil.

#### References:

[[1] A. Blecharczyk, D. Zawada, Z. Sawińska, I. Małecka-Jankowiak, W. Waniorek, Impact of crop sequence and fertilization on yield of winter wheat. *Fragm. Agron.*, **2019**, 36(4), 27–35.

- [2] A.E. Johnston, P.R. Poulton, The importance of long-term experiments in agriculture: Their management to ensure continued crop production and soil fertility: The Rothamsted experience. *Eur. J. Soil Sci.*, **2018**, *69*, 113–125.
- [3] M.K. Kostrzevska, M. Jastrzębska, M. Marks, W.P. Jastrzębski, Long-term crop rotation and continuous cropping effects on soil chemical properties. *J. Elem.*, **2022**, *27(2)*, 335–349.
- [4] H.Q. Viet, Influence of 96 years of mineral and organic fertilization on selected soil properties: a case of study from long-term experiments in Skierniewice, Central Poland. *Soil Sci. An.*, **2023**, *74(1)*, 161945.
- [5] Y. Šimon, M. Madaras, M. Mayerová, E. Kunzová, Soil organic carbon dynamics in the long-term experiments with contrasting crop rotations. *Agriculture*, **2014**, *14*, 818.
- [6] T. Kautz, W. Amelung, F. Ewert, Th. Gaiser, R. Horn, R. Jahn, M. Javaux, A. Kemna, Y. Kuzyakova, J.-Ch. Munch, S. Pätzold, S. Peth, H.W. Scherer, M. Schlöter, H.; Schneider, J. Vanderborght, D. Vetterlein, A. Walter, G.L.B. Wiesenberger, U. Köpke, Nutrient acquisition from arable subsoils in temperate climates: A review. *Soil Biol. Biochem.*, **2013**, *57*, 1003–1022.
- [7] A. Mehlich, Mehlich 3 soil test extractant: A modification of Mehlich 2 extractant. *Com. Soil Sci. Plant. Anal.*, **1984**, *15*, 1409–1416.
- [8] J. Zbiral, Determination of plant-available micronutrients by the Mehlich 3 soil extractant—A proposal of critical values. *Plant Soil Environ.*, **2016**, *62*, 527–531.
- [9] St. Maly, J. Zbiral, E. Čížmárová, Is Mehlich 3 soil extraction a suitable screening method for determination of some risk elements? *Plant, Soil Environ.*, **2021**, *67(9)*, 499–506.
- [10] W. Szychalski, W. Grzebisz, J. Diatta, D. Kostarev, Humus stock degradation and its impact on the phosphorus forms in arable soils – a case of Ukrainian Forest-Steppe Zone. *Chem. Spec. Bioav.*, **2018**, *30(1)*, 33–46.

# CHEMICAL METROLOGY – AN IMPORTANT TOOL TO OBTAIN VALID ANALYTICAL RESULTS

**Adam Sajnog**

*Department of Trace Analysis, Adam Mickiewicz University, Poznań, Uniwersytetu Poznańskiego 8,  
61-614, Poznań, Poland  
e-mail address: [adam.sajnog@amu.edu.pl](mailto:adam.sajnog@amu.edu.pl)*

The reliable determination of trace elements in biological, environmental, and clinical samples is of fundamental importance for both research and decision-making in public health, environmental monitoring, and food safety. Ensuring that analytical results are not only accurate but also comparable across laboratories and over time requires a clear understanding of the principles of chemical metrology. This lecture will focus on the conceptual framework and practical implications of chemical metrology, highlighting its three essential pillars: validation of analytical methods, estimation of measurement uncertainty, and demonstration of metrological traceability. Method validation ensures that analytical procedures are fit for purpose, covering parameters such as selectivity, sensitivity, linearity, limits of detection, and robustness. The estimation of measurement uncertainty provides quantitative information about the reliability of results, allowing for meaningful interpretation in regulatory and clinical contexts. Metrological traceability, established through the use of reference measurement procedures and certified reference materials (CRMs), ensures that results are linked to international standards, thus enabling comparability of the results. The lecture will also illustrate how CRMs play a critical role in studies of both essential (e.g., Fe, Zn, Se) and toxic elements (e.g., Pb, Cd, Hg, As) in diverse matrices such as blood, tissues, soils, and waters. Examples will be provided to demonstrate how instrumental techniques, including inductively coupled plasma mass spectrometry (ICP-MS), can deliver reliable data when combined with rigorous metrological principles. By integrating theoretical aspects with practical case studies, the presentation aims to underline the necessity of applying metrological concepts to trace element analysis, ultimately ensuring that analytical results are valid and useful for scientific, regulatory, and clinical purposes.

## References:

- [1] A. Sajnog, E. Koko, D. Kayzer, D. Barańkiewicz, *Sci. Rep.*, **2021**, *11*, 20683.
- [2] A. Sajnog, A. Hanć, D. Barańkiewicz, *Talanta*, **2018**, *182*, 92-110

# DOES THE CONCENTRATION OF MAGNESIUM AND CALCIUM IN THE BLOOD SERUM OF WOMEN WITH BREAST CANCER CHANGE DURING DISEASE TREATMENT?

**Joanna GRUPIŃSKA<sup>a, b</sup>, Dominik DZIENISZEWSKI<sup>c</sup>, Elżbieta KAJA<sup>a</sup>,  
Bogna GRYSZCZYŃSKA<sup>a</sup>, Maria ISKRA<sup>a</sup>, Zbigniew KRASIŃSKI<sup>d</sup>,  
Dorota FORMANOWICZ<sup>a</sup>, Magdalena BUDZYŃ<sup>a</sup>**

<sup>a</sup> Chair and Department of Medical Chemistry and Laboratory Medicine, Poznan University of Medical Sciences, Poznań, Poland; <https://ror.org/02zbb2597>

<sup>b</sup> Greater Poland Cancer Centre, Hospital Pharmacy, Poznań, Poland;

<sup>c</sup> Student Scientific Society, Molecular and Biochemical Basis of Diseases; Poznan University of Medical Sciences, Poznań, Poland; <https://ror.org/02zbb2597>

<sup>d</sup> Department of Vascular, Endovascular Surgery, Angiology and Phlebology, Poznan University of Medical Sciences, 60-701 Poznań, Poland; <https://ror.org/02zbb2597>  
e-mail address: [jgrupinska@ump.edu.pl](mailto:jgrupinska@ump.edu.pl)

**Purpose:** Magnesium deficiency may promote tumor growth and metastasis, hence the need to monitor and possibly normalize its level during treatment is emphasized. Therefore, our study aimed to assess the effect of a six-week adjuvant chemotherapy on serum magnesium, calcium and Ca/Mg ratio in patients with breast cancer.

**Material and methods:** The study included a group of 80 women with breast cancer who underwent surgical treatment and were qualified for adjuvant chemotherapy in the AC regimen (doxorubicin and cyclophosphamide). Serum magnesium and calcium levels were determined spectrophotometrically. Serum hs-CRP was measured using the immunoenzymatic method (ELISA).

**Results:** In the postoperative period, decreased serum magnesium and increased calcium and Ca/Mg ratio were observed in breast cancer women compared to healthy controls. After six weeks of AC chemotherapy, magnesium levels increased significantly, reaching a lower reference value. The same trend was noticed for the Ca/Mg ratio, which increased slightly but remained higher than in the control group. No differences in calcium levels were observed during chemotherapy. In patients with higher values of hs-CRP after treatment, decreased serum magnesium level was observed.

**Conclusions:** Our study showed that the postoperative period is associated with magnesium deficiency in breast cancer patients. However, AC chemotherapy tends to normalize its concentration. During treatment, low magnesium concentration was associated with increased hs-CRP levels. This finding confirms that magnesium deficiency may induce inflammation, which has been implicated in tumor growth and metastasis. However, further research is needed explain the role of magnesium in tumor development clearly.

# HEALTH-PROMOTING PROPERTIES OF BASIL WASTE: EVALUATION OF CHLOROPHYLL, CAROTENOID AND ANTIOXIDANT POTENTIAL

**Jarosław POBEREŻNY<sup>a</sup>, Elżbieta WSZELACZYŃSKA<sup>a</sup>,  
Katarzyna BRAŹKIEWICZ<sup>a</sup>**

<sup>a</sup> Department of Agronomy and Food Processing, Faculty of Agriculture and Biotechnology,  
Bydgoszcz University of Science and Technology, 7 Kaliskiego St.,  
85-796 Bydgoszcz, Poland  
e-mail address: [poberezny@pbs.edu.pl](mailto:poberezny@pbs.edu.pl)

Herbs have long been used for various purposes, m.in. in medicine, as a food additive or as an additive to cosmetics. Thanks to their natural origin and biologically active properties, medicinal plants are still widely used in modern phytotherapy and dietetics. One of the interesting representatives of this group is common basil (*Ocimum basilicum* L.), which acts as an herb. It is characterized by a high content of antioxidant compounds, necessary for the proper functioning of the human body. Basil leaves are used in practice, but the stems can also be a valuable source of biologically active substances. The health-promoting properties of this plant are mainly due to compounds belonging to the group of polyphenols and natural pigments that have strong antioxidant properties.

The raw material for the research consisted of fresh and frozen leaves and stems of common basil obtained from a processing plant – ‘RUN Chłodnia Sp. z o.o.’ in Włocławek, Kuyavian-Pomeranian Voivodeship.

The aim of the study was to determine the usefulness of the health-promoting value of waste (stems) obtained in the process of production of frozen basil (*Ocimum basilicum* L.). For this purpose, the content of plant pigments (total carotenoids, chlorophyll a and b and total - [4]) and antioxidant properties (FRAP - [1]) were determined. A SHIMADZU UV-1800, UV-Vis (Spectral Photometer System, Japonia) spectrophotometer was used to determine the quality characteristics of basil leaves and waste.

Basil is a rich source of chlorophyll and carotenoid pigments. In fresh basil leaves and stems, the content of pigments was respectively: total carotenoids – 135.6 i 32.8 mg kg<sup>-1</sup> d. m., chlorophyll a – 1185.4 i 326.9 mg kg<sup>-1</sup> d. m., chlorophyll b – 477.2 i 155.5 mg kg<sup>-1</sup> d. m., total chlorophyll – 1656.6 i 4482.0 mg kg<sup>-1</sup> s. m.. After the freezing process, there was a decrease in the content of pigments at the level of: 2.4 and 6.4%; 1.5 and 1.8%; 2.7 and 16.3%; 1.1 and 7.3%.

The antioxidant capacity (FRAP) of both fresh and frozen leaves was significantly higher (31.8 and 29.7 mmol kg<sup>-1</sup> d. m.) compared to the antioxidant capacity of the stems

(20.7 and 17.3 mmol kg<sup>-1</sup> d. m.). In addition, frozen basil leaves and stems had a significantly lower antioxidant capacity than the raw material in its fresh state of 6.6 i 16.6 %. The antioxidant capacity of herbs and other plant products depends, among other things, on the content of plant pigments. [2, 3] This is confirmed by the calculated positive correlation coefficients between antioxidant capacity (FRAP) and the content of chlorophyll a, chlorophyll b, total chlorophyll and total carotenoid pigments, which amounted to:  $r=0.869$ ,  $r=0.772$ ,  $r=0.770$  and  $r=0.871$  ( $p<0.05$ ). Studies have shown a high health-promoting value of basil waste. The freezing process reduces the health-promoting value of both basil leaves and stems to a negligible extent.

The waste material generated in the production process of frozen basil is a valuable raw material for obtaining an extract with high nutritional values. The obtained extract can be widely used in the food industry, m.in. as a natural food colorant, as well as in gastronomy, especially in mass catering.

The management of plant waste contributes to increasing the economic efficiency of the processing process by reducing production costs. In addition, the savings obtained can be used for further development of the company.

#### References:

- [1] I.F. Benzie, J.J. Strain, The ferric reducing ability of plasma (FRAP) as a measure of “antioxidant power”: the FRAP assay. *Analytical Biochemistry*, **1996** 239(1): 70-76. <https://doi.org/10.1006/abio.1996.0292>.
- [2] A.J. Keutgen, E. Wszelaczyńska, J. Pobereźny, Influence of cultivar and UGmax on antioxidative properties of carrot roots (*Daucus carota* L.) and their stability during freezing process. *Ochrona Środowiska i Zasobów Naturalnych*, **2014**, 25, 4(62): 19-22.
- [3] P. Piszcz, B.K. Głód, Właściwości antyoksydacyjne ziół zbadane różnymi metodami. *Camera Separatoria*, **2016**, 8(1): 23-31.
- [4] A.R. Wellburn, The Spectral Determination of Chlorophylls a and b, as well as Total Carotenoids, Using Various Solvents with Spectrophotometers of Different Resolution. *Journal of Plant Physiology*, **1994**, 144: 307-313. [https://doi.org/10.1016/S0176-1617\(11\)81192-2](https://doi.org/10.1016/S0176-1617(11)81192-2).

# BASIL WASTE AS A SOURCE OF POTENTIAL CONTAMINANTS AND HEALTH SAFETY

**Elżbieta WSZELACZYŃSKA<sup>a</sup>, Jarosław POBEREŻNY<sup>a</sup>,  
Katarzyna BRĄŻKIEWICZ<sup>a</sup>**

<sup>a</sup> *Department of Agronomy and Food Processing, Faculty of Agriculture and Biotechnology,  
Bydgoszcz University of Science and Technology, 7 Kaliskiego St.,  
85-796 Bydgoszcz, Poland  
e-mail address: [wszela@pbs.edu.pl](mailto:wszela@pbs.edu.pl)*

Common basil (*Ocimum basilicum* L.) is a species of annual plant from the Lamiaceae family. It is a honey plant. It is used in the food, spirits and pharmaceutical industries and as an ornamental plant. Its essential oils reduce the growth of microorganisms, including harmful bacteria, extending the shelf life of food products. In order to obtain high yields of herbs with an intense green color, intensive cultivation is often used, which can lead to the synthesis of harmful compounds such as nitrates or nitrites. Excessive consumption of these compounds can lead to a number of complications, including methemoglobinemia. and cancer. Therefore, standards have been introduced specifying the permissible content of harmful nitrogen compounds for various groups of vegetables, including leafy vegetables, and the permissible standards of daily intake of these compounds (EC Regulation No. 1258/2011).

The aim of the research was to determine the usefulness of waste (stems) generated during the production of frozen basil in terms of their safety for the health of consumers. The material for the research was Basil common - Genovers variety from a processing company RUN Chłodnia sp. z o. o. in Włocławek (Kuyavian-Pomeranian Voivodeship), a Polish producer of frozen vegetables.

In terms of the safety of the raw material (leaves and stems), the content of chlorates and perchlorates was determined (PB-07 wyd. I from day 10.02.2017 r.); cadmium and lead (PB-68/ICP wyd. III from day 18.09.2012 r.); pesticides – screening – PQ4LC (PN-EN 15662:2008)-(GC-MS/MS);  $\beta$ -glucuronidase-positive *Escherichia coli* counts (PN-ISO 16649-2:2004); mesophilic aerobic microbes (PN-EN ISO 4833-2:2013-12); Enterobacteriaceae count (PN-ISO 21528-2:2005); staphylococci count (PN-EN ISO 6888-1:2001/A1:2004); mold and yeast numbers (PN-ISO 21527-1:2009); presence of *Salmonella* spp. (PN-EN ISO 6579:2003); presence of *Listeria monocytogenes* (PN-EN ISO 11290-1:1999/A1:2005). In fresh and frozen raw material, the content of  $\text{NO}_3^-$  and  $\text{NO}_2^-$  was determined by ion-selective method using the CX-721 multifunction apparatus from Elmetron. [1] The level of  $\text{NO}_2^-$  ions was determined after their oxidation.

The conducted tests showed that the raw material intended for freezing did not show contamination with bacteria and molds and pesticide residues, which can lead to food poisoning. Importantly, no pesticide residues were found, and the content of the active substance Chlorpyrifos from the use of organophosphorus pesticides was well below normal. In addition, it was shown that the numbers of bacteria such as *E. coli*, *Salmonella* spp., *Listeria monocytogenes*, *Staphylococcus*, *Enterobacteriaceae* and aerobic mesophilic microorganisms determined in the studies did not exceed the limits set in the standards. It was also shown that fresh basil did not contain chlorine compounds (chlorates, perchlorates), the main source of which is groundwater, and drinking water used in the technological process. The tested basil contained both Cd and Pb, but these amounts were trace and the set content standards for these carcinogenic heavy metals, which are  $<0.2$  and  $<0.3$  mg kg<sup>-1</sup> dry matter, respectively, were not exceeded.

Studies have shown that the NO<sub>2</sub><sup>-</sup> content in fresh and frozen basil leaves and stems met the set standard (EC Regulation No. 1258/2011) nitrites, as their concentration in both leaves and stems was  $<100$  mg kg<sup>-1</sup> fresh matter. On the other hand, the NO<sub>3</sub><sup>-</sup> content in fresh leaves was 1564, and in frozen and 1411 mg kg<sup>-1</sup> of fresh weight. This indicates that the permissible content of NO<sub>3</sub><sup>-</sup> in fresh basil was slightly exceeded at the level of 1500 mg kg<sup>-1</sup> f. m. On the other hand, the norm of nitrate content in both fresh and frozen stems was not exceeded, as the content was 1364 and 1231 mg kg<sup>-1</sup> f. m, respectively. Taking into account the amount of basil consumption and the set daily intake standards (ADI) for NO<sub>3</sub><sup>-</sup> (5 mg kg<sup>-1</sup> body weight) and NO<sub>2</sub><sup>-</sup> (0.1 mg kg<sup>-1</sup> body weight), the obtained NO<sub>3</sub><sup>-</sup> content did not pose a threat to consumers.

Basil met all safety requirements in terms of the presence of mold and yeast, bacteria, pesticide residues, heavy metals and chlorine compounds. Both in basil stems and leaves, the permissible NO<sub>2</sub><sup>-</sup> content limits were not exceeded. Basil stems were safer in terms of NO<sub>3</sub><sup>-</sup> content compared to leaves. The waste obtained in the process of freezing common basil can be used to produce a new product in the form of, for example, an extract. The resulting new product – the extract – can be used for food purposes, as well as in processing for coloring food products.

#### References:

[1] W. H. Baker, T. L. Thompson, Determination of nitrate nitrogen in plant samples by selective ion electrode. *Plant Anal. Ref. Proc. for S. US*, **1992**, 368: 23-26.

# THE IMPACT OF EXERCISE TRAINING ON MAGNESIUM CONTENT IN THE HEART, KIDNEYS, AND SKELETAL MUSCLES OF SPONTANEOUSLY HYPERTENSIVE RATS.

**Damla SELVAN<sup>a</sup>, Katarzyna SKRYPNIK<sup>a</sup>, Damian SKRYPNIK<sup>b</sup>,  
Joanna SULIBURSKA<sup>a</sup>**

<sup>a</sup> *Department of Human Nutrition and Dietetics, Institute of Food Science and Nutrition,  
Poznań, Wojska Polskiego 28, 60-637, Poland*

<sup>b</sup> *Department and Division of Obesity Treatment, Metabolic Disorders, and Clinical Dietetics;  
Poznan University of Medical Sciences; ul. Szamarzewskiego 84; 60-569 Poznań, Polska  
e-mail address: [damla.selvan@up.poznan.pl](mailto:damla.selvan@up.poznan.pl)*

**Introduction:** Magnesium is essential for maintaining normal cardiovascular and skeletal muscle function [1], and inadequate levels have been linked to the development and progression of hypertension [2]. While exercise training is recognized for its impact on mineral homeostasis [3], its precise influence on magnesium distribution within specific organs in hypertensive models has not been thoroughly investigated. **Aim:** This study aims to investigate how regular exercise training influences magnesium distribution in the heart, kidneys, and skeletal muscles of spontaneously hypertensive rats (SHR), providing new insights into the role of physical activity in modulating mineral homeostasis under hypertensive conditions.

**Methodology:** This project builds upon the **Sonata17/project no: 2021/43/D/NZ7/00660** study. It approved by the bioethics committee (approval number 62/2023, Local Ethics Committee for Animal Studies in Poznań), involves 16 **SHR** strain. These animals are divided into **2 groups**: SHR-T (n=8), SHR-NT (n=8), T=undergo physical training, NT= without physical training. SHR-T group undergo a 12-week treadmill exercise regimen while being fed a standard diet (AIN-93M), with blood pressure measurements using CODA systems (Kent Scientific Corporation). The physical training protocol consists of a walking speed of 10 m/min, a treadmill inclination of 5°, a training frequency of five days per week, and a session duration of 10 minutes per day. Before euthanasia body mass was measured. Following euthanasia, tissues are collected, along with the heart, kidney and musculus rectus femoris and stored at -80°C. Tissue samples (0.5–0.6 g) were digested with 7 mL of concentrated HNO<sub>3</sub> (65%) using a MARS 2 microwave digestion system (CEM Corp.). After cooling, digests were transferred to acid-washed 50 volumetric flasks and diluted with deionized water and and lanthanum chloride (LaCl<sub>3</sub>). Mg levels were quantified via atomic absorption spectrometry (AAS). All statistical analyses were conducted using GraphPad Prism version 10. Comparisons between groups were performed using an

unpaired t-test with Welch's correction to account for unequal variances. Results were considered statistically significant at  $p < 0.05$ .

**Results:** Body mass was significantly reduced in the SHR-T group compared to the SHR-NT group. Both systolic (SYS) and diastolic (DIA) blood pressure were significantly reduced in the SHR-T group compared to the SHR-NT group. The concentration of Mg ug/g dry mass in heart, kidney, and muscle were comparable between groups.

**Discussion:** In SHR rats, exercise training resulted in decreased body weight and lowered blood pressure, indicating enhanced cardiovascular and metabolic function. Although changes in magnesium levels were observed across tissues, these changes were not statistically significant, implying that exercise did not affect magnesium status in the rats.

**Conclusions:** Regular exercise training does not impact magnesium status in SHR rats. Further investigation is warranted to better understand the role of magnesium in mediating these exercise-induced physiological adaptations.

**Funding:** The study was funded by National Science Centre, Poland; grant SONATA 17: 2021/43/D/NZ7/00660, grant holder: Damian Skrypnik. The funding source had no role in the study design, data collection or analysis, data interpretation, writing of the manuscript, or decision to publish the results.

#### References:

- [1] S. Liguori, A. Moretti, M. Paoletta, F. Gimigliano, and G. Iolascon, "Role of Magnesium in Skeletal Muscle Health and Neuromuscular Diseases: A Scoping Review," *Int J Mol Sci*, **Oct. 2024**, vol. 25, no. 20, p. 11220, doi: 10.3390/ijms252011220.
- [2] M. Houston, "The Role of Magnesium in Hypertension and Cardiovascular Disease," *The Journal of Clinical Hypertension*, **Nov. 2011**, vol. 13, no. 11, pp. 843–847, doi: 10.1111/j.1751-7176.2011.00538.x.
- [3] D. Wang, Z.-X. Li, D.-M. Jiang, Y.-Z. Liu, X. Wang, and Y.-P. Liu, "Magnesium ions improve vasomotor function in exhausted rats," *PLoS One*, **Feb. 2023**, vol. 18, no. 2, p. e0279318, doi: 10.1371/journal.pone.0279318.

# ELEMENTAL COMPOSITION OF INFANT FORMULA PRODUCTS AND THEIR IMPACT ON NUTRITIONAL STATUS

**Małgorzata DOBRZYŃSKA<sup>a</sup>, Zofia WOJCIECHOWSKA<sup>b</sup>,  
Karol JAKUBOWSKI<sup>a</sup>, Hanna MARKOWSKA<sup>a</sup>, Juliusz PRZYSŁAWSKI<sup>a</sup>,  
Przemysław NIEDZIELSKI<sup>b</sup>, Sławomira DRZYMAŁA-CZYŻ<sup>a</sup>**

*<sup>a</sup> Poznań University of Medical Sciences, Department of Bromatology,  
Rokietnicka 3 Street, 60-806 Poznań, Poland*

*<sup>b</sup> Department of Analytical Chemistry, Faculty of Chemistry, Adam Mickiewicz University,  
Uniwersytetu Poznańskiego 8 Street, 61-614 Poznań, Poland*

**Introduction:** During infancy, breast milk serves as the primary source of essential nutrients necessary for proper growth, development, and maintenance of a child's health. According to the World Health Organization (WHO), exclusive breastfeeding is recommended for the first six months of life. In cases where breastfeeding is not possible, infant formula provides an appropriate alternative. The composition of infant formula is designed to closely resemble that of human milk, and the content of key nutrients, including micro- and macroelements, is strictly regulated by the Scientific Committee on Food (SCF), the European Food Safety Authority (EFSA), and relevant guidelines outlined in European Union (EU) Directives [1,2]. Literature analyses indicate that only 40–48% of infants aged 0–5 months are exclusively breastfed [3–6]. In Poland, despite noticeable improvements since 1988, the percentage of exclusively breastfed infants remains relatively low. Approximately 40% of children receive only breast milk up to the third month of life, while only 8% are exclusively breastfed until the end of the sixth month [7]. These data clearly highlight the significant role of infant formula in infant nutrition, emphasizing the need to ensure its highest quality and compliance with current safety and nutritional standards.

**Objective:** The aim of the study was to determine the concentrations of selected mineral components (Na, K, Ca, P, Mg, Fe, Zn, Cu, Mn) as well as potentially toxic and toxic elements (As, Cd, Co, Cr, Hg, Sn, Ni) in infant formula products. Additionally, their impact on health was assessed by calculating the estimated daily intake (EDI).

**Materials and Methods:** All powdered infant formula products available on the Polish market between 2019 and 2023 (n=149), intended for consumption during the first year of life, were analyzed. Element concentrations were assessed using inductively coupled plasma mass spectrometry (ICP-MS). The obtained data were converted to mg or µg per 100 kcal. Estimated daily intake (EDI) was calculated for the analyzed elements. The results were compared with nutritional recommendations applicable in Poland, as defined by EFSA.

**Results:** The concentrations of most analyzed elements in the tested formulas complied with EU recommended standards, with exceptions noted for copper (median 72 µg/100 kcal, range 0–338 µg/100 kcal) and potassium (155 µg/100 kcal, range 103–316 µg/100 kcal), which in some formulas did not meet the guidelines for minimum and maximum values. Additionally, significant differences in manganese concentrations were observed between formulas

(range 1–91 µg/100 kcal). In some formulas, nickel content exceeded 4.3 µg, which, according to EFSA guidelines, may increase the risk of eczema-like skin changes in sensitive individuals.

**Conclusions:** Regular monitoring of the composition of infant formula is recommended. It is also advisable to consider revising EU guidelines regarding manganese content limits and to introduce specific guidelines for nickel content in infant formula.

# THE IMPACT OF PARENTAL NUTRITIONAL EDUCATION ON IRON STATUS IN INFANTS

**Kinga ILNICKA-BOROWCZYK<sup>a,b</sup>, Dagmara WOŹNIAK<sup>a</sup>,  
Małgorzata DOBRZYŃSKA<sup>a</sup>, Tomasz PODGÓRSKI<sup>c</sup>, Karol SZYMANOWSKI<sup>d</sup>,  
Anna BLASK-OSIPA<sup>b</sup>, Klaudia MIELOSZYK<sup>e</sup>, Sławomira DRZYMAŁA-CZYŻ<sup>a</sup>**

*<sup>a</sup> Poznan University of Medical Sciences, Department of Bromatology,  
Rokietnicka 3 Street, 60-806 Poznan, Poland*

*<sup>b</sup> Complex of Healthcare Institutions, Kosciuszki 96 Street, 64-700 Czarnkow, Poland*

*<sup>c</sup> Department of Biochemistry, Poznan University of Physical Education, 61-871 Poznan, Poland*

*<sup>d</sup> Specialized Medical Care Unit for Mothers and Children, Wrzowska 1 Street, 60-663 Poznan, Poland*

*<sup>e</sup> Central Laboratory, Karol Jonscher Clinical Hospital of the Poznan University of Medical Science,  
Szpitalna 27/33, Poznan*

**Introduction:** Iron is an essential nutrient that supports proper development throughout childhood. It plays a key role not only in the synthesis of red blood cells and muscles but also in DNA replication, brain development, and the functioning of the nervous and immune systems. In infancy, iron deficiency may be associated with memory and attention disorders, an increased risk of attention-deficit/hyperactivity disorder (ADHD), dysfunctions in visual and auditory processing, and disturbances in social and emotional behavior. Iron deficiency anemia (IDA) affects approximately 51% of children under the age of four in developing countries and about 12% in developed countries. Both iron deficiency and its consequence—iron deficiency anemia—can negatively impact growth, energy levels, and motor and cognitive development. Although iron supplementation is an effective treatment for anemia, its use in prevention is generally not recommended due to potential side effects such as nausea, vomiting, constipation, indigestion, diarrhea, dark stools, and tooth discoloration. Therefore, ensuring an adequate diet and providing young children with sufficient iron from food sources appears to be extremely important.

**Objective:** The aim of the study was to assess the impact of an intensive nutritional education program on iron status in infants.

**Materials and Methods:** Parents of 200 infants were randomly assigned to two groups: the intervention group, which received intensive nutritional education, and the control group (no intervention). At the beginning and end of the study (i.e., around 2 and 12 months of age), the intake of nutrients affecting iron status (i.e., iron, vitamin C, protein, and dietary fiber) was assessed, as well as biochemical parameters related to iron profile, including concentrations of iron, ferritin, hepcidin, ferroportin, UIBC, TIBC, and hsCRP.

**Results:** Statistically significant differences were observed in the intake of iron and vitamin C between the intervention and control groups as a result of nutritional education

( $p < 0.05$ ). Ferritin and ferroportin concentrations, as well as TIBC values, differed significantly between the groups ( $p < 0.05$ ).

**Conclusions:** Targeted nutritional education for parents contributes to improved iron metabolism in children. After one year of intervention, the study group showed not only higher iron intake but also elevated ferritin levels and reduced concentrations of parameters typically associated with increased iron absorption—namely total iron-binding capacity (TIBC) and ferroportin. Considering that adequate iron levels are essential for proper child development, implementing nutritional education for parents of infants is fully justified.

## DETERMINATION OF BIO- AND UNDESIRABLE ELEMENTS IN FOOD ADDITIVES - METHODOLOGICAL PROBLEMS

**Beata KRASNODEBSKA-OSTREGA, Monika SADOWSKA, Natalia PAPUGA**

*University of Warsaw, Faculty of Chemistry, Warsaw, Poland  
e-mail address: [bekras@chem.uw.edu.pl](mailto:bekras@chem.uw.edu.pl)*

Currently produced food, especially on an industrial scale, is modified, for example, with silicate additives or "fortified" with nutrients to improve its nutritional properties. Natural food additives are particularly valued. Therefore, this work focuses on the analysis of selected bio-elements (i.e. Cu, Mg, Se, and Zn), and elements considered undesirable in food additives (i.e. As, Be, Cd, and Pb). The food additives studied included bread ferment, bentonite, pollen, and an antioxidant. A significant problem in these studies is the heterogeneity of the tested samples, which requires a significant number of analyses and homogenization. In the case of bread ferment, the content of natural carbon dioxide was a significant problem. Particles of bentonite (layered silicates) have different grain sizes, which results in physical fractionation. Regarding the purpose of use and the properties of bentonite, determining the total content is not entirely informative. More important was assessing the potential for contamination by adsorbed substances, and thus in case of bentonites, sample decomposition was replaced with selective extraction. The digestion step was also not trivial for all the matrices. The applied procedure required incorporation of unusual steps, such as homogenization through sonication, grinding, sieving, and extraction. The determinations were performed using the ICP-MS technique. To sum up, it can be stated that: Bread fermentation does not introduce hazardous trace elements (As, Pb, Cd < norm); Bee pollen addition can supplement the diet with Cu, Zn, and Se; Antioxidants contain trace amounts of As and Be, which can be safely neglected in the case of quantities used; Bentonite with grains <0.1 mm is the best supplement, as it is compatible with the pH of gastric juice.

# THE EFFECT OF FERTILIZATION WITH PYROLYSIS WASTE PRODUCTS ON CARBON SEQUESTRATION AND CHEMICAL COMPOSITION OF GRASSES

**Ślawomir J. KRZEBIETKE<sup>a</sup>, Piotr J. ŻARCZYŃSKI<sup>a</sup>, Katarzyna SZWARC<sup>b</sup>,  
Katarzyna KŁODAWSKA-PEĆIŃSKA<sup>b</sup>, Dariusz RYDZYŃSKI<sup>b</sup>,  
Łukasz WAŃKOWICZ<sup>b</sup>**

<sup>a</sup>University of Warmia and Mazury in Olsztyn, Faculty of Agriculture and Forestry, Olsztyn, Poland

<sup>b</sup>Hodowla Roślin Grunwald Sp. z o.o. Grupa IHAR, Mielno, Poland

e-mail address: [slawomir.krzebietke@uwm.edu.pl](mailto:slawomir.krzebietke@uwm.edu.pl)

P-Krzebietke Ślawomir J.

Over the past two decades, significant emphasis has been placed on issues related to carbon management, both in terms of energy and environmental pollution caused by greenhouse gases (water vapor, CO<sub>2</sub>, methane, CFCs, nitrous oxide, ozone, etc.), which are also the result of human activity. Since the dawn of time, gases such as water vapor, carbon dioxide, and methane have been present in the Earth's environment and atmosphere, generated by natural processes (volcanic eruptions, fires, ocean evaporation, mineralization, respiration, etc.). However, the natural environment is currently unable to withstand human pressure in this regard, responding with serious, unstable climate change.

The aim of the study was to assess the chemical composition of the above-ground parts and roots of grasses (*Lolium multiflorum* Lam., *Lolium perenne* L.) and their carbon sequestration potential as a result of fertilization with waste products derived from the pyrolysis of grass seed cleaning waste.

In 2023, a field experiment was established at the premises of Hodowla Roślin Grunwald Sp. z o. o. in Mielno (Warmian-Masurian Voivodeship) using soil columns in two replications. Two popular grasses were selected for the study: *Lolium multiflorum* Lam. 'Bakus' and (*Lolium perenne* L.) 'Bajka'. PVC pipes with a diameter of 160 mm and a length of 500 mm, after being buried to a depth of 500 mm, were half-filled (25-50 cm) with soil collected from the same field (parent rock). The 0-25 cm soil layer was collected from the experimental field and constituted a specially prepared soil layer. The experiment included 6 experimental treatments: control (no fertilization); treatment with mineral fertilization (nutrients: N, P, K, Ca, Mg were supplemented to the optimal level for grasses); biochar (10% of the volume of the 0-25 cm soil layer); Biochar + fertilization; biochar + liquid waste from pyrolysis (5% of the 0-25 cm soil layer volume); fertilization + biochar + liquid waste. During the growing season, grasses were fertilized with NH<sub>4</sub>NO<sub>3</sub> at a dose of 153 mg N for each treatment. The grass was harvested during flowering into paper envelopes and dried to an air-dry mass. After the growing season, the columns were dug out, all roots were collected in paper envelopes, and after being brought to an air-dry state, they were weighed. The organic carbon content was determined in the soil from two levels: 0-25 cm and 25-50 cm, as well as in the above-ground parts and roots obtained from each site separately. The yield

of air-dry mass of above-ground parts and grass roots was also determined for each object. Plant parts were ground and, after mineralization in concentrated  $\text{H}_2\text{SO}_4$  in the presence of  $\text{H}_2\text{O}_2$ , quantitatively transferred to 100  $\text{cm}^3$  flasks. In the samples thus prepared,  $\text{N}_{\text{og}}$  was determined - using the Kiejldahl method, P - using the vanadium-molybdenum method; Ca, K – using the ESA method and Mg – using the ASA method.

In the first year of the experiment, grass roots contained between 37.4% and 44.0% organic carbon. Perennial ryegrass accumulated 5.1% more carbon in its roots than *Lolium multiflorum* Lam. *Lolium multiflorum* Lam. accumulated more carbon when fertilized and supplemented with biochar. *Lolium perenne* L., however, did not exhibit this tendency. A lower carbon concentration was found in the aboveground parts than in the roots. *Lolium multiflorum* Lam. contained 1% less carbon in its aboveground parts than in the roots, while perennial ryegrass contained 3.2% less carbon. In the soil (0-25 cm) from treatments fertilized with biochar in combination with fertilization, 43.5% more carbon was found for *Lolium multiflorum* Lam. and 65.1% more carbon for *Lolium perenne* L. than in the control treatment, respectively.

The chemical composition of the above-ground parts and roots varied depending on the experimental objects tested and the grass species. Nitrogen content ranged from 20.09 to 38.07  $\text{g kg}^{-1}$  for the above-ground parts and from 7.80 to 18.7  $\text{g kg}^{-1}$  for the roots. *Lolium multiflorum* Lam. contained a higher concentration of nitrogen in the above-ground parts than *Lolium perenne*. The highest concentration of this macroelement in both roots and above-ground biomass was observed after full fertilization in combination with the addition of biochar and liquid pyrolysis waste. The contents of phosphorus, potassium, and calcium ranged, respectively: 2.78–4.47 P; 20.74–37.54 K, and 3.71–7.42 Ca  $\text{g kg}^{-1}$  for the above-ground parts and 0.86–2.85 P for the underground parts; 1.33–7.19 K and 2.76–4.17  $\text{g kg}^{-1}$  of the analyzed forage grasses. *Lolium perenne* L. had a higher magnesium concentration in both the above-ground parts (1.49  $\text{g kg}^{-1}$ ) and roots (0.73  $\text{g kg}^{-1}$ ). The highest Mg concentration was found in the above-ground parts of grasses from the control treatments and those fertilized solely with biochar, in the case of *Lolium multiflorum* Lam. Both tested grasses accumulated the most magnesium in their roots after using the combination of biochar + fertilization + liquid waste from pyrolysis as a fertilizing agent.

The chemical composition of grasses is significantly modified as a result of fertilization with waste products. Biochar has a positive effect on growing grass plants, especially when combined with optimal fertilization and the application of liquid waste. Roots contain a higher concentration of carbon than the above-ground parts of grasses. When the soil is very low in carbon, the use of biochar significantly increases its concentration in the soil.

# THE IMPACT OF BIOMASS-DERIVED FERTILIZER APPLICATION IN HORTICULTURAL PRODUCTION ON YIELD, MAGNESIUM CONTENT, AND SELECTED NUTRIENTS: A CASE STUDY OF BROCCOLI

**Katarzyna PRZYGOCKA-CYNA<sup>a</sup>, Maria BIBER<sup>a</sup>, Witold SZCZEPANIAK<sup>a</sup>**

*<sup>a</sup> Department of Agricultural Chemistry and Environmental Biogeochemistry,  
Poznan University of Life Science, Wojska Polskiego 28, 60-637 Poznan, Poland*

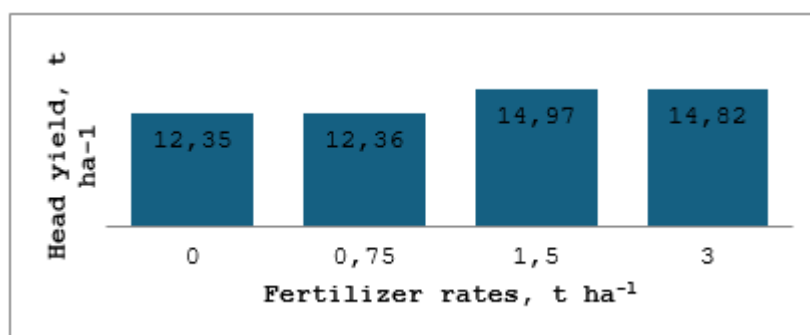
Poland is one of the leading vegetable producers in Europe, and broccoli cultivation is an important aspect of this. The nutritional value of broccoli, its culinary versatility, and the growing demand for healthy food ingredients make it a significant product, driving the development of the broccoli market in Poland, resulting in increased production and expansion of cultivation areas [1]. In 2020, the area of broccoli cultivation was 3,665.81 hectares. In 2021, producers decided to increase the production area by as much as 1180.01 hectares, while in 2023 it amounted to 4882.36 hectares [2].

About 15% of Europe's broccoli is produced in Poland. To achieve optimal growth and healthy broccoli yields, cultivation requirements must be adhered to [3]. The challenges faced by broccoli producers include not only ensuring high quality and quantity of yields but also the issue of cost-effectiveness. In order to obtain high and good quality yields, broccoli requires an optimal supply of elements such as nitrogen, magnesium, and boron.

Classic mineral fertilization forms the basis for supplementing nutrients in the soil in broccoli cultivation. However, fertilizers produced from agricultural waste are increasingly becoming an alternative and a valuable source of nutrients in crop production. Vegetables are often treated as test crops for evaluating biofertilizers derived from recycled materials. It should be remembered, however, that assessing the fertilizing value of products from agricultural waste is not simple or straightforward. For these reasons, validation of this group of fertilizers requires consideration of three groups of criteria: 1) production, 2) ecological, and 3) human health [4, 5]. The conducted study aimed to evaluate the yield-forming response and the content of Mg and selected elements in broccoli to the application of a prototype fertilizer produced from biomass.

The experiment was established in the town of Krobia on light soil, on a site previously cultivated with winter barley. Broccoli was grown on plots: 3 rows x 10 plants in a row = 3 x 0,7 m x 6 m = 12, 6 m<sup>2</sup>. Three main experimental variants were established: A. The tested fertilizer at rates of: 0, 500, 1000, 2000, 3000, 4500 kg/ha + N (only nitrogen applied at the standard rate for broccoli); B. The tested fertilizer at rates of: 0, 500, 1000, 2000, 3000, 4500

kg/ha, -N (no nitrogen fertilization applied, with standard P and K fertilization maintained); C. The tested fertilizer at rates of: 0, 500, 1000, 2000, 3000 kg/ha + NPK (applied at standard rates for broccoli).



Ryc.1. Broccoli yield (t·ha<sup>-1</sup>)

Tab.1. Content of macronutrients in the plant at the 4-6 leaf stage

| Tested<br>fertilizer<br>+NPK | Fertilizer<br>rate | N     | P     | K     | Na    | Mg    | Ca    |
|------------------------------|--------------------|-------|-------|-------|-------|-------|-------|
|                              |                    | %     |       |       |       |       |       |
|                              | 0                  | 5,955 | 0,564 | 0,801 | 0,103 | 0,089 | 0,903 |
|                              | 0,75               | 6,038 | 0,562 | 0,907 | 0,102 | 0,100 | 0,895 |
|                              | 1,5                | 6,293 | 0,523 | 0,955 | 0,099 | 0,113 | 0,909 |
|                              | 3,0                | 6,299 | 0,574 | 1,386 | 0,137 | 0,182 | 1,345 |

Based on the conducted research, the effectiveness of the fertilizer prototype was evaluated, and it was found that its application increases yields and improves the quality of soil and plants by raising the levels of macro- and micronutrients. The effects depend on the fertilizer dose and the presence of NPK. Average fertilizer rates (750-1500 kg/ha) combined with NPK produce optimal results, increasing both yields and nutrient content in the soil and plants. Higher doses (3000, 4500 kg/ha) can increase yields, but not always proportionally to the amount of fertilizer applied, which is associated with the lack of profitability of using the prototype.

#### References

- [1] M. Niewęgłoski, M. Olizaruk, Opłacalność produkcji brokołu włoskiego na przykładzie indywidualnego gospodarstwa rolnego, *Agronomy Science*, **2025**, VOL. LXXX (1)
- [2] F. Kapusta, Zmiany produkcji warzyw i owoców oraz ich przetwórstwa w Polsce. *Nauki Inż. Technol.* **2011**, 3, 97–113.
- [3] M. Orłowski, Połowa uprawa warzyw. *Wyd. Brasika, Szczecin*, **2000**, 5–75.
- [4] K. Przygocka-Cyna, W. Grzebisz, R. Łukowiak, M. Biber, Biomass ash and biogas digestate bio-fertilizers as a source of nutrients for light acid soil—An exhaustion lettuce test. *J. Elem.*, **2018**, 23, 413–428.
- [5] K. Przygocka-Cyna, W. Grzebisz, M. Biber, Evaluation of the potential of bio-fertilizers as a source of nutrients and heavy metals by means of the exhaustion lettuce test. *J. Elem.*, **2018**, 23, 429–445.

# ASH FROM WOOD BIOMASS USED TOGETHER WITH DIGESTATE AS AN ALTERNATIVE SOURCE OF MACROELEMENTS (K, Mg and Ca) IN MAIZE CULTIVATION\*

**Elżbieta ROLKA<sup>a</sup>, Mirosław WYSZKOWSKI<sup>a</sup>, Anna SKORWIDER-NAMIOTKO<sup>a</sup>,  
Radosław SZOSTEK<sup>a</sup>**

<sup>a</sup> *Department of Agricultural and Environmental Chemistry, Faculty of Agriculture and Forestry, University of Warmia and Mazury in Olsztyn, Olsztyn, Poland;  
e-mail address: [elzbieta.rolka@uwm.edu.pl](mailto:elzbieta.rolka@uwm.edu.pl)*

\* Funded by the Minister of Science under „the Regional Initiative of Excellence Program”.

The starting point for this research was the need to find a method for rationally managing woody biomass ash (WBA), which is produced in biomass combined heat and power plants and is currently treated as waste [1]. Soil application of WBA increases plants yield and its macronutrient content, including K, Mg, and Ca [2]. However, low N concentrations in WBA can reduce this positive effect [3]. In the current study, a combined application of WBA and digestate from an agricultural biogas plant (DG) in maize cultivation was attempted. WBA (from the Municipal Heat Energy Company in Olsztyn, Poland) was applied at three increasing rates: 0.5, 1.0, and 1.5 HAC, which were determined based on the overall alkalinity of this material. DG (from Agricultural Biogas Plant in Łęguty, Poland) was treated as a supplemental N source and applied as three fractions: unseparated liquid (ULD), separated solid (SSD), and separated liquid (SLD). The aim of the study was to determine the effect of combined WBA and selected DG fractions on maize green matter yield and its K, Mg, and Ca content. The study was based on a pot experiment comprising four series of treatments: 1) WBA; 2) WBA + ULD; 3) WBA + SSD, and 4) WBA + SLD. Each series included a control treatment (without WBA). The soil used was characterized by a very acidic and a poor sorption complex. WBA and selected DG fractions were alkaline, WBA was also distinguished by its high Ca and K content.

WBA doses did not significantly affect maize biomass yield, but the combined use of WBA and DG produced positive results (Figure 1). Maize yield in the WBA and DG treatments was 28-52% higher. The most favorable results were achieved using liquid formulations (ULD and SLD). The chemical composition of maize biomass was dominated by K content (21.02 g), with much lower levels recorded for Mg (0.798 g) and Ca (0.763 g kg<sup>-1</sup> DM) (Figure 2). The content of these macronutrients was significantly dependent on the WBA doses used ( $0.537^{**} \leq r \leq 0.700^{**}$ ). Increasing WBA doses resulted in a 30% increase in K content, a 20% increase in Mg content, and a 33% increase in Ca content. DG applications typically improved the chemical composition of maize (increasing

macronutrient content), with the most beneficial effects being achieved with liquid DG formulations (ULD and SLD). Combined use of WBA and ULD increased K and Mg content, while combined use of WBA and SLD increased K content. However, combined use of WBA and SSD negatively affected K and Ca content in maize biomass.

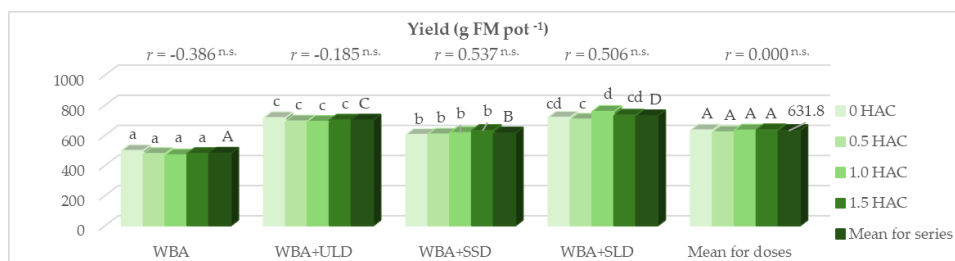


Figure 1. Yield of maize above ground mass (g FM pot<sup>-1</sup>)  $r$  - correlation coefficient; \*\* - significant at  $p \leq 0.01$ ; \* - significant at  $p \leq 0.05$ ; n.s. - not significant.

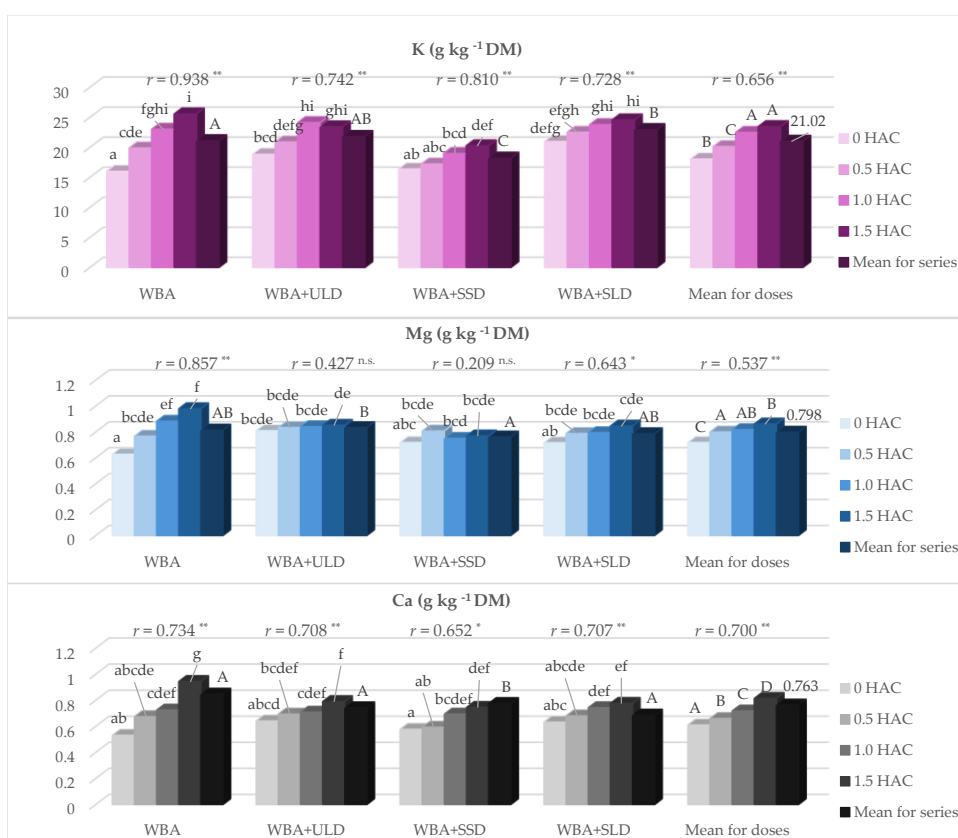


Figure 2. Content of K, Mg and Ca of maize (g kg<sup>-1</sup> DM)  $r$  - correlation coefficient; \*\* - significant at  $p \leq 0.01$ ; \* - significant at  $p \leq 0.05$ ; n.s. - not significant.

In order to improve the obtained results, a small addition of selected nutrients (P, S and/or B) may be considered in the future, as suggested by other authors [4].

The presented results are part of published research [5].

#### References:

- [1] J.I. Odziejewicz, E. Wolejko, U. Wydro, M. Wasil, A. Jabłońska-Trypuć, *Energies*, **2022**, *15*, 9653.
- [2] E. Rolka, A.C. Żołnowski, M. Wyszowski, A. Skorwider-Namietko, *Energies*, **2024**, *17*, 2783.
- [3] J.I. Johansen, M.L. Nielsen, M. Vestergård, L.H. Mortensen, C. Cruz-Paredes, R. Rønn, R. Kjølner, M. Hovmand, S. Christensen, F. Ekelund, *Environ. Experim. Bot.*, **2021**, *185*, 104424.
- [4] K. Weimers, K.J. Bergstrand, M. Hultberg. *Front. Plant Sci.*, **2022**, *13*, 770179.
- [5] E. Rolka, M. Wyszowski, A. Skorwider-Namietko, R. Szostek. *Agronomy*, **2025**, *15*, 1968

# THE EFFECT OF MELWORM FRASS ON THE NITROGEN CONTENT OF CRISPHEAD LETTUCE

**Anna NOGALSKA**

*University of Warmia and Mazury in Olsztyn, Faculty of Agriculture and Forestry, Department of  
Agricultural and Environmental Chemistry, Olsztyn, Poland  
e-mail address: [anna.nogalska@uwm.edu.pl](mailto:anna.nogalska@uwm.edu.pl)*

With the rapid development of insect farms and the associated production of waste products (exuviae and frass), research into the fertilizing potential of frass is essential for their management. Knowing the chemical composition of food used in insect breeding, we know that the excrements obtained are environmentally safe. Due to their high content of organic carbon, nitrogen, and other macro- and micronutrients, this waste should be used as an organic fertilizer. Therefore, vegetation studies on the fertilizing use of mealworm frass were undertaken in the a greenhouse at the University of Warmia and Mazury in Olsztyn. The aim of this study was to evaluate the effect of *Tenebrio molitor* L. frass on the nitrogen content of crisphead lettuce (*Lactuca sativa* L. var. *capitata*), variety Beata. Three nitrogen rates were applied: 0; 1.0 and 1.5 g pot<sup>-1</sup>, which was delivered to the soil in mealworm frass or urea (46% N). Six fertilization treatments were established: 1) "0" (no fertilization), 2) "0" N (no nitrogen)+PK, 3) 1.0 g N (urea 46% N)+PK, 4) 1.5 g N (urea 46% N)+PK, 5) 1.0 g N (frass)+PK, 6) 1.5 g N (frass)+PK·pot<sup>-1</sup> (10 kg of soil). The results were processed by two-factor analysis of variance in STATISTICA 13.3. The first factor was the type of fertilizer (frass or urea), the second – the N rate. The significance of differences between means was tested using the Tukey test at  $P<0.01$ .

The study showed that the application of mealworm frass resulted in a significant reduction in the nitrogen content in the dry matter of crisphead lettuce (by 11.5%), compared to urea fertilization. Lettuce was richest in nitrogen after the application of 1.5 g N·pot<sup>-1</sup>, regardless of the fertilizer used. As the N dose increased, the nitrogen content in lettuce increased. The fertilizing potential of insect frass should be investigated in comprehensive vegetation experiments with various plant species, as they may provide an alternative to mineral fertilizers.

The research was financed from the research and service project (No. 30.690.085-500) entitled: "Assessment of the impact of mealworm (*Tenebrio molitor* L.) frass on soil and plants" commissioned by the Tenebria Sp. z o.o., Dworcowa Street 36, 14-260 Lubawa, Warmian-Masurian Voivodeship.

# RESPONSE OF WINTER WHEAT TO POTASSIUM AND MAGNESIUM FERTILIZATION

**Przemysław BARŁÓG, Jarosław POTARZYCKI**

*Department of Agricultural Chemistry and Environmental Biogeochemistry  
Poznan University of Life Sciences, Poland  
e-mail address: [przemyslaw.barlog@up.poznan.pl](mailto:przemyslaw.barlog@up.poznan.pl); [jaroslaw.potarzycki@up.poznan.pl](mailto:jaroslaw.potarzycki@up.poznan.pl)*

Winter wheat is a crucial crop for global food security, providing a valuable source of plant-based protein, especially in populations with limited access to animal proteins [1]. Wheat grain yield (GY) and quality are influenced by a variety of factors, primarily soil and climate conditions, as well as fertilization [2]. As with other crops, the most important nutrient in wheat is nitrogen (N). However, the effect of N on wheat depends on two key elements that control its utilization from fertilizers: potassium (K) and magnesium (Mg) [3,4]. The research assumed the following hypothesis: the effect of Mg fertilization on wheat yield depends on the content of plant-available K in the soil. To verify the hypothesis, the effect of kieserite application on the GY, straw yield (SY), yield components, and nutrient content of wheat was examined in soils with different K content.

Field trials with winter wheat (Florenzia cultivar) were carried out during 2016–2020 at the Brody Experimental Farm (Poznan University of Life Sciences). The experiment tested the effect of two factors: the level of K in the soil, as well as the current fertilization with potassium ( $K_1$ ,  $K_2$ ,  $K_3$ ,  $K_4$ ); and fertilization with magnesium (0 and 15 kg ha<sup>-1</sup> of Mg). The experiment was part of a long-term project initiated in 1990, in which K-doses were applied at 0, 25, 50, and 100% of the plants' requirements. For winter wheat, these doses were 0, 25, 50, and 100 kg ha<sup>-1</sup>, respectively. Potassium (KCl), was applied in the autumn before sowing wheat. Magnesium in the form of magnesium sulfate (MgSO<sub>4</sub>·H<sub>2</sub>O) was applied in early spring before vegetation began. The doses of N and phosphorus (P) were 160 and 35 kg ha<sup>-1</sup>, respectively. The experiment was conducted using a split-plot design with 4 replications. Each plot was 25.2 m<sup>2</sup>. Plants were harvested using a plot combine. Samples of the plants for laboratory analysis were collected from an area of 0.5 m<sup>2</sup>. The chemical composition of the plant was analyzed using standard methods. The effects of individual research factors (year, K, Mg) and their interactions were assessed by means of 3-way ANOVA (STATISTICA 13 software).

The GY, SY and yield components depended mainly on the weather conditions during the growing season. The tested features depended also on the soil's K content and the application of Mg (Table 1). Under the experimental conditions, no significant interaction

was observed between K and Mg. Each factor acted independently, increasing GY and other parameters. However, it can be observed that in Mg-deficient conditions the wheat yield at the K<sub>4</sub> level was lower than at the K<sub>3</sub> level.

Table 1. Effect of K treatments, Mg application, and K×Mg interaction on grain yield (GY), straw yield (SY), and yield components of winter wheat.

| Factor                     | GY<br>t ha <sup>-1</sup> | SY<br>t ha <sup>-1</sup> | Harvest<br>index, % | Spikes<br>number, No.<br>m <sup>2</sup> | 1000 grain<br>weight, g | Grain<br>number per<br>spike |
|----------------------------|--------------------------|--------------------------|---------------------|-----------------------------------------|-------------------------|------------------------------|
| Effect of K treatments     |                          |                          |                     |                                         |                         |                              |
| K <sub>1</sub>             | 6.45 <sup>c</sup>        | 8.10 <sup>a</sup>        | 44.2 <sup>a</sup>   | 490 <sup>b</sup>                        | 39.5                    | 33.9 <sup>ab</sup>           |
| K <sub>2</sub>             | 6.73 <sup>b</sup>        | 8.14 <sup>ab</sup>       | 45.2 <sup>ab</sup>  | 500 <sup>b</sup>                        | 40.8                    | 32.8 <sup>b</sup>            |
| K <sub>3</sub>             | 7.19 <sup>a</sup>        | 8.51 <sup>a</sup>        | 45.7 <sup>a</sup>   | 526 <sup>a</sup>                        | 39.8                    | 34.7 <sup>a</sup>            |
| K <sub>4</sub>             | 7.06 <sup>a</sup>        | 8.41 <sup>ab</sup>       | 45.6 <sup>ab</sup>  | 526 <sup>a</sup>                        | 40.4                    | 32.5 <sup>b</sup>            |
| <i>F</i> ratio             | 19.9***                  | 3.60*                    | 3.08*               | 9.74***                                 | n.s.                    | 4.77**                       |
| Effect of Mg fertilization |                          |                          |                     |                                         |                         |                              |
| -Mg                        | 6.58 <sup>b</sup>        | 8.06 <sup>b</sup>        | 44.8 <sup>b</sup>   | 504 <sup>b</sup>                        | 40.0                    | 33.1                         |
| +Mg                        | 7.14 <sup>a</sup>        | 8.52 <sup>a</sup>        | 45.5 <sup>a</sup>   | 517 <sup>a</sup>                        | 40.3                    | 33.8                         |
| <i>F</i> ratio             | 57.1***                  | 3.60*                    | 3.08*               | 4.29*                                   | n.s.                    | n.s.                         |
| Effect of K×Mg interaction |                          |                          |                     |                                         |                         |                              |
| K <sub>1</sub>             | 6.15                     | 7.72                     | 44.2                | 478                                     | 39.8                    | 33.1                         |
| K <sub>1</sub> +Mg         | 6.75                     | 8.48                     | 44.2                | 501                                     | 39.3                    | 34.7                         |
| K <sub>2</sub>             | 6.35                     | 8.04                     | 44.1                | 496                                     | 41.1                    | 32.1                         |
| K <sub>2</sub> +Mg         | 7.12                     | 8.23                     | 46.3                | 504                                     | 40.5                    | 33.6                         |
| K <sub>3</sub>             | 7.04                     | 8.35                     | 45.6                | 519                                     | 39.5                    | 34.5                         |
| K <sub>3</sub> +Mg         | 7.35                     | 8.67                     | 45.8                | 533                                     | 40.2                    | 34.8                         |
| K <sub>4</sub>             | 6.77                     | 8.10                     | 45.3                | 524                                     | 39.5                    | 32.8                         |
| K <sub>4</sub> +Mg         | 7.34                     | 8.71                     | 45.8                | 528                                     | 41.3                    | 32.2                         |
| <i>F</i> ratio             | n.s.                     | n.s.                     | n.s.                | n.s.                                    | n.s.                    | n.s.                         |

\*, \*\*, \*\*\* *F*-ratio significant at  $p \leq 0.05$ ; 0.01; 0.001; respectively, n.s. no significant. Different letters indicate significant differences between treatments at  $p \leq 0.05$  (Tukey's test).

In conclusion, the research hypothesis should be rejected. Wheat's demand for magnesium was independent of the plant-available potassium content in the soil. In addition, magnesium application did not increase N and Mg concentration in grain, which can be explained by the dilution effect.

#### References:

- [1] K. Sharma, P.K. Sharma. **2025**, Wheat as a Nutritional Powerhouse: Shaping Global Food Security. IntechOpen publisher.
- [2] L. Hlisnikovský, P. Ivičic, P. Barlóg, W. Grzebisz, L. Menšík, E. Kunzová. *Plants*, **2022**, *11*, 1825.
- [3] W. Grzebisz, J. Diatta, P. Barlóg, M. Biber, J. Potarzycki, R. Łukowiak, K. Przygocka-Cyna, W. Szczepaniak. *Plants*, **2022**, *11*, 2841.
- [4] K. Xie, I. Cakmak, S. Wang, F. Zhang, S. Guo. *Crop J.*, **2021**, *9*, 249-256.

# COMBUSTION REACTION KINETICS OF SELECTED GASEOUS FUELS USING SOLID OXYGEN CARRIERS OF SPINEL-TYPE

**Ewelina KSEPKO<sup>a</sup>, Rafal LYSOWSKI<sup>a</sup>, Tibor DUBAJ<sup>b</sup>, Peter SIMON<sup>b</sup>**

<sup>a</sup> *Wroclaw University of Science and Technology, Department of Engineering and Technology of Chemical Processes, Wroclaw University of Science and Technology, Wroclaw, Poland*

<sup>b</sup> *Slovak University of Technology in Bratislava, Institute of Physical Chemistry and Chemical Physics, Bratislava, Slovakia*

*e-mail address: [ewelina.ksepko@pwr.edu.pl](mailto:ewelina.ksepko@pwr.edu.pl)*

The process of fuel combustion in a chemical oxide cycle is a promising recent technology for reducing carbon and nitrogen oxide emissions. It uses a solid oxygen carrier that transfers oxygen from air to fuel through a redox reaction. To scale this newly developed material from the laboratory to an industrial setting, studying the process kinetics is crucial. This helps to understand the reaction mechanism and identify the kinetic parameters.

This collaborative study examined the kinetics of the redox reaction involving solid oxygen carriers with a spinel structure containing iron and manganese oxides. The experiments were carried out using a thermogravimetric analyzer, TGA NETSCH STA 449 F5 Jupiter (Poland). The effects of process temperature and hydrogen concentration in the atmosphere on the reaction rate were analyzed. Calculations were performed with MathCad Prime 7 software, and more than ten different gas-solid reaction models were tested. The most appropriate reaction model was selected based on a thorough analysis.

Additionally, another experiment with synthesis gas was conducted, using SEIKO SII TG/DTA 6300 (Slovakia) to assess its ability to combust a more complex gas similar in composition to gas produced from coal gasification.

*Acknowledgment:*

*The work was financed by the National Science Centre, Poland, Project No. 2020/37/B/ST5/01259.*

# APPLICATION OF THE ICP-MS METHOD FOR DETERMINING BIOELEMENTS IN EDIBLE MUSHROOMS

**Kacper GÓRSKI<sup>a</sup>, Marta DOBROWOLSKA<sup>a</sup>, Danuta ZIELIŃSKA<sup>a</sup>**

<sup>a</sup> *University of Warmia and Mazury in Olsztyn, Faculty of Agriculture and Forestry,  
Department of Chemistry, Olsztyn, Poland  
e-mail address: [kacper.gorski@edu.uwm.edu.pl](mailto:kacper.gorski@edu.uwm.edu.pl)*

The growing interest of consumers in edible mushroom species and their use as a dietary ingredient causes the necessity for monitoring the qualitative and quantitative composition of bioelements contained in their mycelium. Bioelements accumulated from the environment by mushrooms play an important role in them as components of enzymes or their activators, and are also present in the structure of the pigments of these organisms. The anti-cancer and antioxidant properties of medicinal mushrooms are associated, among other things, with their ability to accumulate significant amounts of selenium in their mycelium [1].

Among the various analytical methods most commonly used in the analysis of bioelements in mushrooms are spectroscopic methods: Atomic Absorption Spectrometry AAS [2], Inductively Coupled Plasma – Atomic Emission Spectrometry ICP-AES [3] and Inductively Coupled Plasma – Mass Spectrometry ICP-MS.

The aim of the study was to optimize and apply the ICP-MS method for the analysis of bioelements in edible mushrooms. The following mushroom species were selected for the study: Oyster mushroom (*Pleurotus ostreatus*), Lion's mane mushroom (*Hericium erinaceus*), and dark Reishi mushroom (*Ganoderma sinense*).

The freeze-dried mushroom samples were mineralized using a Perkin Elmer Titan MS System Mineralizer with concentrated nitric acid and microwave energy, where the temperature and pressure of the process were fully controlled. Next, using the inductively coupled plasma mass spectrometry technique ICP-MS (Nexion 1000 Perkin Elmer) the following elements were determined: Mg, Fe, Mn, Co, Ni, Cu, Cr, Ag, Zn, Ba, V, and Se. In order to obtain maximum intensity for the elements being determined, parameters such as plasma power, carrier gas flow, and sample flow rate were selected accordingly.

As a result of the analyses, the content of individual bioelements in the tested mushroom species was found to be within the following concentration ranges: magnesium 706-1264 mg/kg; iron 24-45 mg/kg; manganese 7-33 mg/kg; nickel 0.1-0.7 mg/kg; copper 3-9 mg/kg; chromium 0.005-0.07 mg/kg; silver 0.01-0.08 mg/kg; zinc 21-40 mg/kg and barium 0.01-0.16 mg/kg. Among the mushroom species selected for the study, relatively

high levels of magnesium, iron, and zinc were found in Oyster mushrooms and Lion's mane mushroom. Dark Reishi mushrooms, on the other hand, were characterized by a relatively high content of manganese, copper, and barium. No cobalt, vanadium, or selenium was found in the tested mushroom species.

The research conducted has shown that relatively less popular mushroom varieties, such as Lion's mane and Reishi, are a rich source of bioelements, especially magnesium, manganese, iron, copper, and zinc. Optimization of mineralization parameters and spectrometer settings enabled the simultaneous determination of 11 elements in mushroom samples.

References:

- [1] P. Świsłowski, M. Rajfur, *Proceedings of EC Opole*, **2017**, 11(2), 591-599.
- [2] A. Krakowska, W. Reczyński, T. Krakowski, K. Szewczyk, W. Opoka, B. Muszyńska, *Molecules*, **2021**, 26, 5165.
- [3] W. Widzicka, L. Bielawski, A. Mazur, J. Falandysz, *Bromat. Chem. Toksykol.*, **2008**, XLI, 2, 121-128.

# THE EFFECT OF CARDIAC REHABILITATION ON SERUM MAGNESIUM CONCENTRATION IN PATIENTS AFTER ACUTE CORONARY SYNDROME - THE CARDIO-REH RANDOMISED STUDY.

**Katarzyna SKRYPNIK<sup>a</sup>, Damian SKRYPNIK<sup>b</sup>, Agnieszka MARIOWSKA<sup>c</sup>,  
Rui AZEVEDO<sup>d</sup>, Agostinho Almiro de ALMEIDA<sup>e</sup>, Joanna SULIBURSKA<sup>a</sup>**

<sup>a</sup> *Department of Human Nutrition and Dietetics, Faculty of Food Science and Nutrition, Poznan University of Life Sciences, Poznan, Poland*

<sup>b</sup> *Department of Treatment of Obesity, Metabolic Disorders and Clinical Dietetics, Faculty of Medical Sciences, Poznan University of Medical Sciences, Poznan, Poland*

<sup>c</sup> *Student Scientific Association of Lifestyle Medicine, The Student Scientific Society of Poznan University of Medical Sciences, Poznan University of Medical Sciences, Poznan, Poland*

<sup>d</sup> *LAQV/REQUIMTE, Department of Chemical Sciences, Faculty of Pharmacy, University of Porto, Porto, Portugal*

<sup>e</sup> *LAQV/REQUIMTE, Department of Applied Chemistry, Faculty of Pharmacy, University of Porto, Porto, Portugal*

*e-mail address: [katarzyna.skrypnik@gmail.com](mailto:katarzyna.skrypnik@gmail.com)*

## Introduction and aim

Cardiac rehabilitation (CR) is a key component in the comprehensive management of patients after acute coronary syndrome (ACS), contributing to improved cardiovascular outcomes and quality of life. [1] Previous studies have highlighted the potential impact of cardiac rehabilitation on metabolic parameters, although mineral disturbances remain an underexplored area. [2] This study aimed to investigate the influence of cardiac rehabilitation on serum magnesium concentration in patients after acute coronary syndrome.

## Materials and methods

The study protocol was approved by the Bioethics Committee, Poznan University of Medical Sciences (no. 476/19). Sixty eight post-ACS patients underwent a 2-weeks long CR program. Before the CR program, patients underwent cardiac stress test or 6-minute walk test to adjust the training load to the patients' health state. The CR programme consisted of, inter alia, continuous and interval training on a cycle ergometer with electrocardiogram monitoring, free active exercises, individual and group general fitness exercises, marching training, and station training. At baseline and at completion of the study anthropometric, body composition, blood pressure and heart rate measurements were taken and blood sampling was performed. Magnesium serum concentration was quantified using inductively coupled plasma mass spectrometry (ICP-MS).

## Results and discussion

In our study, a significant decrease in serum magnesium level after CR was observed. The values of systolic and diastolic blood pressure, and body weight also showed significant

reductions after CR. The change in percentage body fat content reached borderline statistical significance. There was no significant difference in heart rate.

Our findings confirm the beneficial effects of CR on blood pressure and anthropometric parameters, consistent with prior reports. [2,3] However, the observed reduction in serum magnesium level, though within reference ranges, raises clinical concerns due to the role of magnesium in cardiac electrophysiology. [4] Our results highlight the importance of individualized monitoring during cardiac rehabilitation and may suggest the need for magnesium supplementation in selected patients.

## Conclusion

Two-weeks long cardiac rehabilitation decreased serum magnesium concentration in patients after acute coronary syndrome.

**Funding:** *The study was funded by National Science Centre, Poland; grant SONATA17: 2021/43/D/NZ7/00660, grant holder: Damian Skrypnik. The funding source had no role in the study design, data collection or analysis, data interpretation, preparation of the presentation/poster, or decision to publish the results. ClinicalTrials.gov ID: NCT03935438. The CARDIO-REH randomised study.*

## References:

- [1] R. S. Taylor, H. M. Dalal, S. T. J. McDonagh. The role of cardiac rehabilitation in improving cardiovascular outcomes. *Nat. Rev. Cardiol.*, **2022**, 19(3), 180–94.
- [2] M. Sadeghi, A. Salehi-Abargouei, Z. Kasaei, et.al., Effect of cardiac rehabilitation on metabolic syndrome and its components: A systematic review and meta-analysis. *J. Res. Med. Sci.*, **2016**, 21(1), 18.
- [3] B. Bellmann, T. Lin, K. Greissinger, L. Rottner, et.al. The Beneficial Effects of Cardiac Rehabilitation. *Cardiol. Ther.*, **2020**, 9(1), 35–44.
- [4] R. Noordam, W. J. Young, R. Salman, et al. Effects of Calcium, Magnesium, and Potassium Concentrations on Ventricular Repolarization in Unselected Individuals. *J. Am. Coll. Cardiol.*, **2019**, 73(24), 3118–31.

# INFLUENCE OF SUPPLEMENTATION OF PROBIOTIC BACTERIA LACTOBACILLUS PLANTARUM AND LACTOBACILLUS CURVATUS ON MAGNESIUM CONTENT IN DUODENUM AND LIVER IN RATS ON HIGH-FAT IRON-DEFICIENT DIET

**Katarzyna SKRYPNIK<sup>a</sup>, Agnieszka OLEJNIK-SCHMIDT<sup>b</sup>, Marcin SCHMIDT<sup>b</sup>,  
Joanna SULIBURSKA<sup>a</sup>**

<sup>a</sup> *Department of Human Nutrition and Dietetics, Faculty of Food Science and Nutrition,  
Poznań University of Life Sciences, Poznań, Poland.*

<sup>b</sup> *Department of Food Biotechnology and Microbiology, Faculty of Food Science and Nutrition,  
Poznań University of Life Sciences, Poznań, Poland.*

*e-mail: [katarzyna.skrypnik@gmail.com](mailto:katarzyna.skrypnik@gmail.com)*

## **Introduction**

Dietary magnesium (Mg) is absorbed mainly in the small intestine [1] and stored in soft tissues, including the liver [2]. It has been shown that a high-fat (HF) diet [3,4], and dietary iron (Fe) deficiency [5] may be associated with disorders of Mg metabolism. Disturbances in intestinal absorption or hepatic storage may reflect systemic Mg imbalance [6,7]. Probiotic supplementation may have a beneficial effect on magnesium metabolism [8]. However, the effect of probiotics, especially *Lactobacillus plantarum* (*Lactiplantibacillus plantarum*) and *Lactobacillus curvatus* (*Latilactobacillus curvatus*), on Mg hepatic and duodenal content in conditions of high-fat diet (HFD) deficient in iron remains not well investigated.

## **Aim**

The aim of our study was to assess the effect of 8-week oral supplementation with *Lactobacillus plantarum* and *Lactobacillus curvatus* on the Mg content in the liver and duodenum in rats fed a high-fat, iron-deficient diet.

## **Materials and methods**

The study was approved by the Local Ethics Committee in Poznań, Poland (no. 57/2019). Forty female Wistar rats were divided into groups and subjected to two sequential 8-week dietary interventions. During the first stage, the animals were fed one of the following diets: standard (AIN-93M, group C, n = 8), high-fat (HF, n = 8), or high-fat iron-deficient (HFDEF, n = 24). In the second stage, rats from the C and HF groups continued their original diets, while the HFDEF group was divided into three: HFDEF (n=8), HFDEF<sub>Lp</sub> (n = 8) and HFDEF<sub>Lc</sub> (n = 8). The HFDEF<sub>Lp</sub> and HFDEF<sub>Lc</sub> groups received the same iron-deficient high-fat diet, but additionally were supplemented with *L. plantarum* (HFDEF<sub>Lp</sub>) or *Lactobacillus curvatus* (HFDEF<sub>Lc</sub>) in a dose of  $5 \times 10^9$  CFU/day. At the end of the experiment, liver and duodenum samples were collected. Liver

and duodenum tissues were mineralized using 65% nitric acid in a microwave digestion system. The Mg content in liver and duodenum samples was determined using flame atomic absorption spectrometry (Carl Zeiss AAS-3, Jena, Germany).

## Results and discussion

The results showed no statistically significant differences in Mg content in the liver and duodenum between the groups. Thus, in our study we have shown that neither *Lactobacillus plantarum* nor *Lactobacillus curvatus* supplemented orally influenced magnesium level in these two investigated tissues in conditions of high-fat diet deficient in iron.

## Conclusions

Eight-weeks long oral supplementation with *Lactobacillus plantarum* or *Lactobacillus curvatus* did not influence duodenal and hepatic magnesium content in rats on high-fat iron-deficient diet.

### Funding information

*This study was funded by the National Science Centre, Poland, (K.S., Grant No 2019/33/N/NZ9/00699). The funding source had no role in the study design, data collection, data analysis, data interpretation, preparation of the presentation/poster or decision to publish the results.*

### References:

- [1] S. Chamniansawat, N. Suksridechacin, N. Thongon, Current Opinion on the Regulation of Small Intestinal Magnesium Absorption. *http://www.wjgnet.com/*, **2023**, 29 (2), 332–342. <https://doi.org/10.3748/WJG.V29.I2.332>.
- [2] R. Swaminathan, Magnesium Metabolism and Its Disorders. *Clin Biochem Rev.*, **2003**, 24 (2), 47.
- [3] S. Kurstjens, B. Smeets, C. Overmars-Bos, H. B. Dijkman, D. J. W. den Braanker, T. de Bel, R. J. M. Bindels, C. J. J. Tack, J. G. J. Hoenderop, J. H. F. de Baaij, Renal Phospholipidosis and Impaired Magnesium Handling in High-Fat-Diet-Fed Mice. *FASEB Journal*, **2019**, 33 (6), 7192–7201. <https://doi.org/10.1096/FJ.201801778RR>.
- [4] C. H. Sales, E. H. S. Gaievski, A. Lobo, L. A. S. dos Santos, C. Colli, Effects of High-Fat Diet on Magnesium Status and Insulin Sensitivity in Rats. *Annals of Nutrition & Metabolism*, **2011**, 58, 82-83 res. 27/497.
- [5] T. Rolić, M. Yazdani, S. Mandić, S. Distant, Iron Metabolism, Calcium, Magnesium and Trace Elements: A Review. *Biol Trace Elem Res.*, **2025**, 203 (4), 2216–2225. <https://doi.org/10.1007/S12011-024-04289-Z>.
- [6] J. P. Schuchardt, A. Hahn, Intestinal Absorption and Factors Influencing Bioavailability of Magnesium- An Update. *Curr Nutr Food Sci.*, **2017**, 13 (4). <https://doi.org/10.2174/1573401313666170427162740>.
- [7] M. Liu, H. Yang, Y. Mao, Magnesium and Liver Disease. *Ann Transl Med.*, **2019**, 7 (20), 578. <https://doi.org/10.21037/ATM.2019.09.70>.
- [8] R. A. Varvara, D. C. Vodnar, Probiotic-Driven Advancement: Exploring the Intricacies of Mineral Absorption in the Human Body. *Food Chem.*, **X 2024**, 21, 101067. <https://doi.org/10.1016/J.FOCHX.2023.101067>.

# AERATED GELS INDUCED BY CALCIUM IONS

**Marta TOMCZYŃSKA-MLEKO<sup>a</sup>**

*<sup>a</sup> University of Life Sciences in Lublin, Institute of Plant Genetics, Breeding and Biotechnology,  
Lublin, Poland*

*e-mail address: [marta.mleko@up.lublin.pl](mailto:marta.mleko@up.lublin.pl)*

The aim of the research was to use low-mineral egg white albumin isolate to obtain aerated calcium ion-induced gels and to investigate their aptitude as matrices for active ingredients release.

The material was egg white albumin “low mineral, high gel type” (88.1 % protein) (Kewpie Corporation, Tokyo, Japan). Protein and fat concentrations were determined by the Kjeldahl and the Soxhlet method, accordingly. Mineral analysis of the isolate was performed by a flame atomization atomic absorption spectrometry using a Varian SpectrAA 280 atomic absorption spectrometer equipped with a GTA graphite furnace, Zeeman background correction, and a 4.0 mA Mg hollow cathode lamp (Varian, Inc., Palo Alto, USA). The samples were dissolved in a 1 % aqueous solution of nitric acid. Throughout the analysis for all analysis, the analytical line at 202.6 nm was used. As the inert transport gas argon was applied for all analyses. Measurements were taken on 10 µl samples using pyrolytical-coated graphite tubes. Aerated gels were prepared by adding calcium ions to pre-heated protein dispersions with simultaneous aeration.

20 mM calcium concentration was an optimal concentration at which the maximum viscosity and hardness of the gels were found. For higher concentrations of calcium ions (25–30 mM), aerated gels were characterized by lower values of the moduli and tangent of the phase angle was larger for aerated gels which indicated more viscous character than that of non-aerated gels. Increased ions concentration causes higher aggregation of protein matrix and less smooth microstructure of the interface between the gel and air. An increase in calcium concentration from 5 to 30 mM caused an increase in an average bubble size. The release of calcium ions from aerated gels was measured in an artificial stomach. It occurred by Fickian diffusion through the swelling matrix and it was faster for the gels with higher concentration of calcium. An increase in calcium concentration caused an increase in surface roughness of the aerated gels. There were linear correlations between the quadratic mean of the surface roughness and “n” coefficient from the Ritger and Peppas equation and between the maximum roughness size and “n”. The increased calcium concentration made the gel microstructure more particulate and the surface rougher, which enabled faster proteolysis of the gel in an artificial stomach and faster diffusion of calcium ions.

# EFFECT OF HUMIC ACIDS ON MAIZE BIOMASS ON SOIL WITH IRON APPLICATION

**Mirosław WYSZKOWSKI, Natalia KORDALA**

*University of Warmia and Mazury in Olsztyn, Department of Agricultural and Environmental Chemistry,  
Olsztyn, Poland*

*e-mail address: [miroslaw.wyszkowski@uwm.edu.pl](mailto:miroslaw.wyszkowski@uwm.edu.pl)*

Plant biomass is an attractive raw material for food, feed and energy purposes due to its renewability, widespread availability and relatively low cost [1]. One such plant is maize, which has been identified as having high and versatile potential for use. It is indeed feasible to cultivate plants for energy production in contaminated areas, such as those with high iron content [2].

The objective of the present study was to ascertain the impact of humic acids on the yield as well as the chemical composition of maize biomass applied as a phytostabiliser on soil with iron application. The soil exhibited iron levels ranging from 0 to 750 mg per kilogram. The amount of humic acid added to the soil ranged from 0 to 0.9 g per kg of soil.

The presence of iron in the soil significantly affected various physiological characteristics of the plants, including reduced plant height and dry matter yield, as well as a lower SPAD index at the fifth unfolded leaf stage compared to the stem elongation stage. Additionally, changes were observed in the sodium, magnesium and phosphorus content, with an increase in the calcium, potassium and nitrogen content of the maize. Applying humic acids to the soil had a positive and significant effect on the studied height and biomass parameters, resulting in increased plant height and dry matter yield. It has been demonstrated that humic acids contribute to a decrease in the SPAD index value during the maize stem elongation phase. Furthermore, humic acids have been shown to reduce the effect of iron on the content of all macronutrients in maize biomass. Furthermore, the application of humic acids has been shown to significantly increase maize dry matter yield.

Using humic acids to phytostabilise soils with excess iron has been shown to be an effective approach for cultivating crops.

## References:

- [1] F. Martins, C. Felgueiras, M. Smitkova, N. Caetano, Analysis of fossil fuel energy consumption and environmental impacts in European countries. *Energies* **2019**, *12*, 964.
- [2] V. Strezov, C. Chaudhary, Impacts of iron and steelmaking facilities on soil quality. *J. Environ. Manag.*, **2017**, *203*, 1158–1162.

# EVALUATION OF THE YIELD FORMATION AND NUTRITION REACTION OF TWO VARIETIES OF WINTER WHEAT TO INCREASING LEVELS OF NITROGEN FERTILIZATION

**Witold SZCZEPANIAK<sup>a</sup>, Michał KULWICKI<sup>b</sup>, Katarzyna PRZYGOCKA-CYNA<sup>a</sup>,  
Maria BIBER<sup>a</sup>, Agnieszka ANDRZEJEWSKA<sup>a</sup>**

<sup>a</sup> *Department of Agricultural Chemistry and Environmental Biogeochemistry, Poznan University of Life Science, Wojska Polskiego 28, 60-637 Poznan, Poland*

<sup>b</sup> *Syngenta Polska, Szamocka 8, 01-748 Warszawa, Poland*  
*e-mail address: [witold.szczepaniak@up.poznan.pl](mailto:witold.szczepaniak@up.poznan.pl)*

In Poland, wheat varieties can be classified into one of five grain quality groups: E, A, B, C and K. It is assumed that quality varieties (A) have a lower yield potential than bread-making varieties (B) [4]. Fertilization of cereals with nitrogen, i.e. the main yield-forming component, should be carried out according to the realistic yield that is possible to obtain under farming conditions, taking into account the quality characteristics of the cultivated varieties [1, 2, 3].

The aim of the study was to assess the yield-forming and nutritional response of two winter wheat cultivars to the increasing level of nitrogen fertilization. A strict two-factor field experiment was established on fertile soil, which belongs to the II quality class, in a split-block system in 2018-2021 in the town of Borówno in the "Złoty Kłosa" seed farm, located in the Kujawsko-Pomorskie Voivodeship. The factors of the experiment were: 1) Varieties (O): Arktis and KWS Emil; 2) Nitrogen (N) doses: 0, 40, 80, 120, 160, 200 and 240 kg N ha<sup>-1</sup>. Arktis wheat is a quality variety - A, while KWS Emil is a bread-making variety - B. Nitrogen in the form of ammonium nitrate was sown at three different times: 1) before the start of spring vegetation, but not earlier than March 1st - up to a dose of 80 kg N ha<sup>-1</sup>, 2) at the stage of the end of tillering/beginning of stem elongation (BBCH 29-31) - up to a dose of 160 kg N ha<sup>-1</sup>; 3) at the flag leaf stage (BBCH 39) - up to a dose of 240 kg N ha<sup>-1</sup>. The grain yield was assessed by harvesting with a combine harvester from an area of 160 m<sup>2</sup>, while plants for the assessment of nutrient content (N, P, K, Mg, Ca) at the BBCH 65 stage were taken from 0.5 m<sup>2</sup>. The results were subjected to the analysis of variance for factorial experiments in the Statistica 13® software. The differences between the levels of experimental factors were determined on the basis of Tuckey's post-hoc test.

The statistical analysis showed that both the yield and the quality parameters of winter wheat grain were shaped by the weather conditions in individual years of the study, as well as by the factors tested in the experiment. At the same time, the analyzed cultivars did not differ in the content of phosphorus in leaves and phosphorus and magnesium in the stalks.

On the other hand, nitrogen doses did not determine the phosphorus content in leaves and ears.

The highest grain yield was obtained in 2020 ( $9.099 \text{ t ha}^{-1}$ ), when a favorable amount and distribution of rainfall during the flowering and grain pouring period was recorded. On the other hand, yields in the first and third year of the study were similar, however significantly lower than in the second year (on average by  $1.5 \text{ t ha}^{-1}$ ). The conducted research confirmed the higher potential of bread-making varieties (B) compared to the quality varieties (A). In the experiment, the KWS Emil cultivar obtained a yield higher by  $1.933 \text{ t ha}^{-1}$  compared to the Arktis cultivar. The analysis of nitrogen fertilization showed that the highest yield in the experiment ( $8.729 \text{ t ha}^{-1}$ ), which was obtained on the plot fertilized with  $200 \text{ kg N ha}^{-1}$ , differed only from those obtained on the plots fertilized within the range of  $0\text{-}80 \text{ kg N ha}^{-1}$ . However, compared to the plot fertilized with  $120 \text{ kg N ha}^{-1}$  it was higher by only  $0.118 \text{ t ha}^{-1}$ , i.e., by 1.4%. This indicates the high fertility of the site where the experiment was conducted. The relationship between grain yield and nitrogen doses for both varieties is best described by second-order polynomial equations, which show that the Arktis variety would reach its maximum yield at 190, while the KWS Emil variety at  $181 \text{ kg N ha}^{-1}$ . Therefore, despite the significant difference in yields, both varieties are characterized by a similar yield-forming response to nitrogen doses.

The analysis of the nutritional status of plants in the flowering phase showed a higher concentration of the studied components in the organs of the Arktis cultivar, apart from the content of nitrogen and potassium in the leaves and magnesium and calcium in the ears. At the same time, the correlation matrix showed positive relationships between grain yield and the content of nitrogen, magnesium and calcium in leaves, phosphorus in stalks and phosphorus, magnesium and calcium in ears in the case of a quality cultivar. In the case of the bread-making variety, however, grain yield was correlated with the nitrogen content in the leaves and the phosphorus and potassium content in the ears. At the same time, it was shown that the increase in the level of nitrogen fertilization generally contributed to the improvement of plant nutrition, both with nitrogen and other tested macronutrients.

#### References:

- [1] S. E. D. Faizy, S. A. Mashali, S. M. Youssef, S. M. Elmahdy. Study of Wheat Response to Nitrogen Fertilization, Micronutrients and their Effects on Some Soil Available Macronutrients. *J. Sus. Agric. Sci.*, **2017**, Vol. 43, No.1, pp. 55-64.
- [2] W. Grzebisz. Technologie nawożenia roślin uprawnych - fizjologia plonowania. *Zboża i kukurydza. Tom 2. PWRiL*, **2012**, Poznań, s. 280.
- [3] W. Grzebisz. Nawożenie Roślin Uprawnych. Podstawy Nawożenia. *Tom 1. PWRiL*, **2015**, Warszawa, s. 428.
- [4] [www.coboru.gov.pl](http://www.coboru.gov.pl) - 10.07.2025.

# **BLOOD PLASMA MAGNESIUM, CALCIUM AND HS-CRP LEVELS IN AN ABDOMINAL AORTIC ANEURYSM: THE EFFECT OF PRE- AND POSTOPERATIVE TREATMENT**

**Bogna GRYSZCZYŃSKA<sup>a</sup>, Joanna GRUPIŃSKA<sup>a</sup>, Magdalena BUDZYŃ<sup>a</sup>,  
Magdalena P. KASPRZAK<sup>a</sup>, Zbigniew KRASIŃSKI<sup>b</sup>, Maria ISKRA<sup>a</sup>**

*<sup>a</sup> Chair and Department of Medical Chemistry and Laboratory Medicine,  
Poznan University of Medical Sciences, Poznań, Poland*

*<sup>b</sup> Department of Vascular, Endovascular Surgery, Angiology and Phlebology,  
Poznan University of Medical Sciences, 60-701 Poznań, Poland*

*e-mail address: [bognagry@ump.edu.pl](mailto:bognagry@ump.edu.pl)*

Abdominal aortic aneurysm (AAA) is undoubtedly a life-threatening condition, and its early diagnosis, treatment and perioperative care significantly affect the patient's prognosis [1]. Clinical and epidemiological evidence demonstrates that the pathogenesis of AAA is highly complex. Several key mechanisms involved in aneurysm formation have been identified, including proteolytic degradation of the aortic wall's connective tissue, inflammatory processes, and genetic predisposition [2]. In recent years, increasing attention has been drawn to oxidative stress as an essential destructive factor contributing to AAA development [3,4]. It is well established that ischemia–reperfusion injury occurring during conventional open repair (OR) promotes the generation of reactive oxygen species (ROS), thereby aggravating oxidative stress [4,5]. Given the considerable risk of perioperative complications associated with OR, particularly in patients with comorbidities, less invasive strategies have been introduced. Endovascular aneurysm repair (EVAR), a minimally invasive technique, has been shown to substantially reduce both intraoperative and postoperative complications [6]. Maintaining macroelements and microelements homeostasis may restrict chronic inflammation and oxidative stress. Reduced Mg levels result in the activation of inflammation via leukocyte and macrophage activation, the release of inflammatory cytokines and C-reactive protein, and an increased generation of ROS.

The present study aimed to evaluate the impact of postoperative management on plasma magnesium, calcium, and hs-CRP levels in AAA patients undergoing OR or EVAR. We also evaluated how the patient's preoperative condition, surgical approach, and subsequent postoperative care influenced the concentrations of these selected biomarkers.

Based on the interview and the clinical examination, patients were classified as high- and low-surgical-risk and further scheduled for the target surgery. Twenty individuals were qualified for endovascular aneurysm repair (EVAR), while twenty were assigned to open repair (OR). Venous blood samples were collected from all participants at three defined time

points: prior to the procedure, on the first postoperative day, and between the second and fourth postoperative day.

In the present study, the mean Mg and Ca levels were found within the reference range and did not differ significantly between the two studied groups of patients before the surgery (OR: Mg=2.18±0.26 [mg/dl]; Ca=8.32±0.98 [mg/dl]; EVAR: Mg=2.11±0.33 [mg/dl]; Ca=8.50±0.88 [mg/dl]). A significantly lower Mg concentration in the OR group was found 2-4 days after surgery in comparison to the EVAR group. No significant differences in the Ca/Mg ratio were found between the OR and EVAR groups either before surgery (OR: 4.05 ± 0.51; EVAR: 4.04 ± 0.78), on the first postoperative day (OR: 3.80 ± 0.55; EVAR: 4.05 ± 0.83), or between the second and fourth postoperative day (OR: 4.38 ± 0.86; EVAR: 3.97 ± 0.63). A statistically significant increase in hs-CRP level was demonstrated in the OR group in the postoperative period (1 day after surgery: 22.93±3.70 mg/L; 2-4 days after: 23.02±3.30 mg/L) as compared to the values prior to surgery (OR: 8.90±6.98 mg/L). Moreover, a significantly lower hs-CRP in the EVAR group was found 1 day after surgery in comparison to the OR group. The division of OR and EVAR patients into groups with lower and higher hs-CRP levels than the median showed that Mg, Ca, and Ca/Mg ratios remain changeless.

The AAA development did not affect the concentration of Ca and Mg in the blood. Plasma Mg levels remained within the reference range following both surgical approaches; however, a postoperative decline was observed exclusively after OR. Open repair, together with the associated blood loss, may predispose patients to an extended period of postoperative management. Despite a significant increase in inflammation in the postoperative period compared to before OR and EVAR procedures, no relationship between the decrease in Mg level and inflammation was demonstrated. Increasing the size of both groups could demonstrate such a relationship, especially in the OR group.

- [1] M. Kośmicki. *Przewodnik Lekarza*, **2004**, 7(11), 35-43.
- [2] H. Kuivaniemi, E.J.Ryer, J.R. Elmore, G.Tromp, *Expert Rev Cardiovasc Ther.*, **2015**, 13(9), 975-987.
- [3] B. Gryszczyńska, D. Formanowicz, M. Budzyń et al, *Biomed Res Int.*, **2017**, 2017(1), 4975264.
- [4] F.J. Miller Jr, W.J. Sharp, X. Fang, L.W. Oberley, T.D. Oberley, N.L. Weintraub, *Arterioscler Thromb Vasc Biol.*, **2002**, 22(4), 560-565.
- [5] W. Majewski, R. Krzymiński, M. Stanisić, M. Iskra et al. *Med Sci Monit*, **2014**, 20:2453–2460.
- [6] A. Siwko, W. Hendiger, A. Eberhardt, Z. Kwietniak, G. Madycki, W. Staszkiwicz, *Post N Med*, **2016**, 29(11B), 21-24.

# **PARTICIPATION OF IRON IONS AND THEIR CORRELATION WITH PARAMETERS OF OXIDATIVE STRESS AND INFLAMMATION IN PATIENTS STRATIFIED BY ABDOMINAL AORTIC ANEURYSM SIZE**

**Magdalena P KASPRZAK<sup>a</sup>, Bogna GRYSZCZYŃSKA<sup>a</sup>, Andrzej JAWIEŃ<sup>b</sup>,  
Joanna GRUPIŃSKA<sup>a</sup>, Magdalena BUDZYŃ<sup>a</sup>, Krzysztof STRZYŻEWSKI<sup>a</sup>,  
Zbigniew KRASIŃSKI<sup>b</sup>, Dorota FORMANOWICZ<sup>a</sup>**

<sup>a</sup> *Chair and Department of Medical Chemistry and Laboratory Medicine,  
Poznan University of Medical Sciences, Poznan, Poland*

<sup>b</sup> *Department of Vascular, Endovascular Surgery, Angiology and Phlebology,  
Poznan University of Medical Sciences, 60-701 Poznań, Poland  
e-mail address: [magdarut@ump.edu.pl](mailto:magdarut@ump.edu.pl)*

Abdominal aortic aneurysm (AAA) is usually detected incidentally in adults over 65 due to its symptom-free nature, yet rupture can be fatal. AAA is defined as a permanent aortic enlargement exceeding 3 cm in diameter or 50% over the vessel's original size. The only curative treatment is surgery, either via open repair or endovascular methods. The interplay between oxidative stress, inflammation, and iron metabolism may contribute to the pathophysiology and progression of abdominal aortic aneurysm (AAA). This study investigated the role and correlation of iron ions ( $\text{Fe}^{2+}$ ) with key biomarkers of redox status and clinical parameters including bilirubin (Bilb), paraoxonase (PON1) heme oxygenase (HO-1), nuclear factor erythroid 2-related factor 2 (Nrf2), and C-reactive protein (CRP) in AAA patients stratified by aneurysm size.

Forty-four AAA patients admitted for surgical intervention were divided into three groups based on aneurysm diameter: Group I (<55 mm), Group II (55–70 mm), and Group III (>70 mm). Serum  $\text{Fe}^{2+}$  levels and related biochemical markers — including NRF2, HO-1, PON1, bilirubin, and CRP — were quantified. Correlations between  $\text{Fe}^{2+}$  and these parameters were analyzed for each aneurysm size group. Multivariate regression assessed the predictive value of  $\text{Fe}^{2+}$  on antioxidant enzyme PON1.

Iron ion concentrations across groups were relatively stable and showed no significant differences by ANOVA. However, correlation matrix analysis revealed statistically significant positive correlations between  $\text{Fe}^{2+}$  and PON1 in the entire cohort ( $p=0.015$ ), suggesting coordinated participation in antioxidant defense. In Group I (small aneurysm), PON1 correlated positively with  $\text{Fe}^{2+}$  and HO-1, and a nonsignificant negative correlation between  $\text{Fe}^{2+}$  and NRF2 was observed. In transitional Group II, the PON1– $\text{Fe}^{2+}$  correlation weakened, while multivariate analysis demonstrated  $\text{Fe}^{2+}$  as a significant predictor of PON1 levels ( $p=0.0051$ ) alongside HO-1, bilirubin, and CRP, highlighting complex regulatory

interactions during moderate aneurysm progression. In the largest aneurysm group (Group III),  $\text{Fe}^{2+}$  direct correlations with other parameters diminished, and the system was dominated by persistent oxidative stress and worsening inflammation, as shown by rising CRP and shifting biomarker associations.

Although serum  $\text{Fe}^{2+}$  levels do not vary significantly between AAA size groups, their positive correlation with antioxidant enzyme PON1 in the overall cohort, and their independent predictive value for PON1 concentration in transitional aneurysm states, suggest an active role for iron ions in modulating antioxidant defense mechanisms during aneurysm progression. Disruption of these correlations and increasing inflammation may mark the critical transition to advanced disease. Iron homeostasis in conjunction with redox and inflammatory networks could serve as a diagnostic or therapeutic target for patients with AAA of different sizes.

# MAGNESIUM NUTRITION STATUS OF WINTER WHEAT IN ROTATION DEPENDING ON THE POTASSIUM FERTILIZATION SYSTEM

**Remigiusz ŁUKOWIAK<sup>a</sup>, Dominik MŁODECKI<sup>b</sup>, Tomasz RAFAŁOWICZ, Przemysław BARŁÓG**

<sup>a</sup> Department of Agricultural Chemistry and Environmental Biogeochemistry,  
Poznan University of Life Sciences, Wojska Polskiego 28, 60-637 Poznan, Poland

<sup>b</sup> K+S Polska sp. z o.o. Poznan, Street 28 Czerwca 1956 r No. 404, 61-441 Poznan, Poland  
e-mail address: [remigiusz.lukowiak@up.poznan.pl](mailto:remigiusz.lukowiak@up.poznan.pl):

The basic component determining nitrogen uptake, transport of nitrates from the soil to the assimilation parts of the plant – leaves, and then transport of assimilates from leaves to fruits and seeds, is potassium [1]. In intensive, sustainable crop production, the amount of potassium absorbed by plants significantly exceeds the amount of nitrogen absorbed [2]. The prerequisite for obtaining sufficient potassium from the soil is rich soil, not only in the surface layer (0-20 cm), but also throughout the entire soil profile. However, it is potassium in the surface layer that determines the growth rate of the plant in the first vegetation period, and together with magnesium, the rate and speed of photosynthesis[3].

Field experiment with winter wheat as the main crop in crop rotation: winter wheat, winter rapeseed, winter wheat, established in Złotniki at the Experimental Farm of the University of Life Sciences in Poznań (N 52.486973, E 016.827442) on soil formed from heavy clayey sands, classified as proper podzolic soil, bonitation class IVa.

The field experiment was conducted between 2021 and 2024, and a detailed analysis covered two growing seasons of winter wheat in a two-factor system. The first factor was the potassium fertilisation system, which comprised four sub-levels: 1) potassium control - KA, 2) fertilisation under each plant - KB, 3) split system, K dose for rapeseed and wheat - KC, and 4) cumulative K dose for wheat, the first plant in the crop rotation - KD. The second factor was nitrogen fertilisation at doses of 0, 120, 180 and 240 kg N ha<sup>-1</sup>.

Plant material samples were collected from an area of 1 m<sup>2</sup> during three stages of wheat development (BBCH-30/31, BBCH-89). The magnesium content was determined using the AAS method. The obtained research results were subjected to stepwise regression analysis and analysis of variance for factorial experiments in Statistica 13®. The differences between the levels of experimental factors were determined based on Tuckey's post-hoc test. Microsoft Excel was used to perform calculations, simple correlations and create correlation matrices.

In the 2021/2022 growing season, the magnesium content in winter wheat at BBCH stage 30-31, despite the high soil content of available magnesium, was 732.3 to 848.4 mg Mg kg<sup>-1</sup> dry matter, respectively. No interaction between experimental factors was observed in this phase. The magnesium content in the grain was low, ranging from 854.3 to 880.9 mg Mg kg<sup>-1</sup> d.m., showing no correlation with grain yield. The effect of the interaction between the two experimental factors was mainly evident in the combination of 240 kg N ha<sup>-1</sup> and only in the KC and KD variants. The Mg content in straw showed a significant response to the interaction of both experimental factors. In variants KA and KB, a decrease in the content of the component was observed with increasing nitrogen doses. The absence of this correlation was most evident in the KD variant.

During the 2023/2024 growing season, the magnesium nutrition status of wheat at BBCH stage 30-31, based on optimal ranges, averaged 952.4 mg Mg kg<sup>-1</sup> dry matter, which was below the optimal range. The influence of the fertilisation system and nitrogen fertilisation was observed, but no interaction between these factors was demonstrated. Grain yield significantly depended on the magnesium content in straw  $PLZ=14+5,45N-0,019Mg$  for  $n=16, R^2=0,67$  i  $p \leq 0,001$ . An analysis of the above equation shows that a decrease in magnesium content in straw led to an increase in grain yield. The magnesium content in the grain was generally low (average 729.7 mg Mg kg<sup>-1</sup> dry matter) and showed very high variability in response to experimental factors. In the KA system, the average highest value was 742.6 mg Mg kg<sup>-1</sup> d.m., showing a downward trend with nitrogen dose. High stability was observed in the KD system with the highest value of 751.7 mg Mg kg<sup>-1</sup> d.m. on the fertilised combination of 240 kg N·ha<sup>-1</sup>. The highest magnesium content was found in system B on a fertilised combination of 240 kg N ha<sup>-1</sup>, amounting to 777.1 mg Mg kg<sup>-1</sup> dry matter.

#### References:

- [1] H. Marschner. Mineral Nutrition of Higher Plants, 2nd ed.; *Elsevier Ltd., Academic Press*: London, UK, **1995**; 899 p.
- [2] P. B. Barraclough. The growth and activity of winter wheat roots in the field: nutrient uptakes of high-yielding crops. *The Journal of Agricultural Science*. **1986**;106(1):45-52. doi:10.1017/S0021859600061712
- [3] W. Grzebisz, J. Diatta, P. Barłóg, M. Biber, J. Potarzycki, R. Łukowiak, K. Przygocka-Cyna, W. Szczepaniak. Soil Fertility Clock—Crop rotation as a paradigm in nitrogen fertilizer productivity control. *Plants*, **2022**, 11, 2841.

# **GOLD AND SILVER NANOPARTICLE-ASSISTED IMPROVEMENT OF ANTICANCER EFFICACY OF MOXIFLOXACIN AGAINST COLON CANCER**

**Anna BOGUSZEWSKA-CZUBARA<sup>a</sup>, Magdalena DUBIŃSKA-REJENT<sup>a</sup>,  
Elżbieta MEGIEL<sup>b</sup>, Olga ŚWIECH<sup>b</sup>**

*<sup>a</sup> Medical University of Lublin, Department of Medical Chemistry, Lublin, Poland*

*<sup>b</sup> University of Warsaw, Faculty of Chemistry, Warsaw, Poland*

*e-mail address: [anna.boguszevska-czubara@umlub.edu.pl](mailto:anna.boguszevska-czubara@umlub.edu.pl)*

Cancer remains one of the leading causes of death globally, with colorectal cancer ranking among the most prevalent malignancies. Increasing evidence suggests that chronic infections and long-term inflammation significantly contribute to the initiation and progression of certain cancers, particularly those occurring in infection-prone organs such as the colon, bladder or stomach. This connection between infection and carcinogenesis has encouraged exploration of therapeutic compounds that combine antimicrobial and anticancer properties.

Fluoroquinolones, a class of broad-spectrum antibacterial agents, have recently attracted interest for their potential anticancer effects [1]. These drugs inhibit bacterial DNA gyrase and topoisomerase IV, but can also interact with eukaryotic topoisomerase II, leading to DNA damage and apoptosis in tumour cells. Beyond their direct anticancer activity, fluoroquinolones have also been shown to enhance the safety and efficacy of conventional chemotherapeutics by mitigating adverse effects such as cardiotoxicity [2]. Moxifloxacin (MOXI), a fourth-generation fluoroquinolone, is known for its high bioavailability, broad antibacterial spectrum, and low toxicity, making it a promising candidate for drug repurposing in oncology.

The aim of this study was to evaluate the impact of gold (AuNPs) and silver nanoparticles (AgNPs) on the anticancer efficacy of moxifloxacin against colon cancer cells, and to compare the relative effectiveness of AuNP–MOXI and AgNP–MOXI complexes.

Gold and silver nanoparticles were synthesised and characterised for size, shape, and stability using spectroscopic and microscopic methods [3, 4]. Moxifloxacin was conjugated with AuNPs and AgNPs to form nanocomplexes. Human colon cancer cell lines were treated with MOXI alone, AuNP–MOXI and AgNP–MOXI. Cell viability and cytotoxicity were assessed using MTT assays, while morphological changes were observed under phase-contrast microscopy. Statistical analysis was performed to determine significant differences between treatment groups.

Both AuNP–MOXI and AgNP–MOXI complexes demonstrated significantly higher cytotoxic activity against colon cancer cells compared with moxifloxacin alone. The gold

nanoparticle conjugates exhibited stronger effects, suggesting a superior synergistic interaction between AuNPs and MOXI. The enhanced efficacy may result from improved cellular uptake, increased drug stability, and nanoparticle-induced oxidative stress within cancer cells.

The results are consistent with previous findings on the role of noble metal nanoparticles in drug delivery systems. Gold and silver nanoparticles, due to their biocompatibility and minimal metabolic interference, provide a safe and efficient platform for enhancing the therapeutic potential of conventional drugs. Their inherent antimicrobial activity may also be beneficial in treating cancers associated with chronic infection or inflammation.

To conclude, the conjugation of moxifloxacin with gold and silver nanoparticles significantly enhances its anticancer efficacy in colon cancer cells. Gold-based nanocomplexes showed particularly promising activity, indicating that AuNP–MOXI formulations could serve as potential candidates for future anticancer therapies. This study supports the concept of integrating antimicrobial nanotechnology with oncology and suggests a novel strategy for the treatment of inflammation- and infection-related cancers. Further in vivo and mechanistic studies are necessary to confirm these findings.

#### References:

- [1] A.E. Kassab, *Future Med. Chem.*, **2025**, *17(16)*, 2067–2078.
- [2] O. Święch, A. Boguszevska-Czubara, *Chem. Biol. Interact.*, **2025**, *414*, 111496.
- [3] K.P. Steckiewicz, P. Cieciorński, E. Barcińska, M. Jaśkiewicz, M. Narajczyk, M. Bauer, W. Kamysz, E. Megiel, I. Inkielewicz-Stępnia, *Int. J. Nanomed.*, **2022**, *17*, 495–517.
- [4] P. Krystosiak, W. Tomaszewski, E. Megiel, *J. Colloid Interface Sci.*, **2017**, *498*, 9–21.

# THE INFLUENCE OF PROBIOTICS AND IRON SUPPLEMENTATION ON TRACE ELEMENTS DISTRIBUTION IN KIDNEY

**Julia FRACKOWIAK<sup>a</sup>, Izabela KOMOROWICZ<sup>a</sup>, Adam Sajnóg<sup>a</sup>, Katarzyna Skrypnik<sup>b</sup>, Joanna Suliburska<sup>b</sup>, Anetta Hanć<sup>a</sup>**

<sup>a</sup>Adam Mickiewicz University, Faculty of Chemistry Department of Trace Analysis  
Uniwersytetu Poznańskiego 8, 61-614 Poznań,

<sup>b</sup>Poznan University of Life Sciences, Department of Human Nutrition and Hygiene  
Wojska Polskiego 31, 60-624 Poznań  
e-mail address: [julfra6@amu.edu.pl](mailto:julfra6@amu.edu.pl)

Probiotics can be defined as living microorganisms, which have a positive influence on the host's health when administered in sufficient amounts. Main purpose of probiotics is to diversify intestinal flora. Gut microbiota is considered to be 'hidden organ', which can affect other systems, such as renal [1]. Kidney's functioning depends also on elemental composition, which has been widely described in literature [2]. Consuming various dietary supplements with micro- and macroelements might lead to disturbance in elemental homeostasis, which could negatively influence the human organism.

This study investigates the influence of multistrain probiotics and iron supplementation on the distribution and interaction of trace elements in the kidneys of Wistar rats using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) bioimaging. The obtained two-dimensional maps of the distribution of elements reveal distinct locations of Cu, Fe, Mn, and Zn in specific tissues of rat kidneys. Due to 2D maps it is possible to observe how elements affects each other distribution. Specifically, Cu and Fe were co-localized in the renal cortex, while Zn was mostly absent from regions where Cu and Fe accumulated. Our research provides insights into the interactions between dietary supplements, probiotics, and trace element distribution in kidneys, paving the way for targeted nutritional interventions [3].

## References:

- [1] Mao, Z.-H.; Gao, Z.-X.; Pan, S.-K.; Liu, D.-W.; Liu, Z.-S.; Wu, P. Ferroptosis: A Potential Bridge Linking Gut Microbiota and Chronic Kidney Disease. *Cell Death Discov.* **2024**, *10* (1), 234.
- [2] Jiayi, H.; Ziyuan, T.; Tianhua, X.; Mingyu, Z.; Yutong, M.; Jingyu, W.; Hongli, Z.; Li, S. Copper Homeostasis in Chronic Kidney Disease and Its Crosstalk with Ferroptosis. *Pharmacological Research* **2024**, *202*, 107139.
- [3] Frackowiak, J.; Komorowicz, I.; Sajnóg, A.; Skrypnik, K.; Suliburska, J.; Hanć, A. Do Probiotics and Iron Supplementation Have Any Impact on Element Distribution in Rat Kidneys? – Bioimaging by Laser Ablation Inductively Coupled Plasma Mass Spectrometry. *Talanta* **2025**, *283*, 127112.

# PELLETS OF THE COMMON KESTREL *FALCO TINNUNCULUS* AS AN INDICATOR OF ENVIRONMENTAL POLLUTION WITH ELEMENTS

**Izabela KOMOROWICZ<sup>a</sup>, Piotr ZDUNIAK<sup>b</sup>, Joanna WOJCIECHOWSKA<sup>a</sup>,  
Zbigniew KASPRZYKOWSKI<sup>c</sup>**

<sup>a</sup> Department of Trace Analysis, Faculty of Chemistry, Adam Mickiewicz University in Poznań, Poland

<sup>b</sup> Department of Avian Biology and Ecology, Faculty of Biology, Adam Mickiewicz University in Poznań, Poland

<sup>c</sup> Faculty of Science, University of Siedlce, Poland

Agriculture is one of the most fundamental human activities, currently constituting a major economic sector in many countries. Maintaining a profitable economy in this area requires intensifying agricultural production, which inevitably involves the excessive use of synthetic fertilizers and plant protection products. Hence, agriculture is considered a major source of soil pollution, affecting plants, animals, and ultimately, humans [1].

Birds are considered good bioindicators of environmental quality and changes (Morelli et al., 2021). In the case of birds, the most frequently analyzed materials are their feathers and feces. Less frequently studied are undigested parts of food in the form of pellets. This situation persists despite the obvious advantage of analyzing bird pellets, which allows for the determination of the degree of environmental pollution at a given trophic level of food chains, which is particularly important in the context of the bioaccumulation of harmful chemicals that most severely impact apex predators.

This study aimed to determine the contamination level of agricultural land with elements (As, Cd, Cr, Cu, Mn, Ni, Pb, Se, and Zn) by analyzing pellets from the apex predator of agricultural ecosystems - the common kestrel (*Falco tinnunculus*) - nesting in agricultural areas of eastern Poland.



Fig. 1. Particular steps of the developed analytical procedure.

For this purpose, a strategy for sample homogenization and digestion was developed. This constituted a key step in the proposed analytical procedure. The procedure (Fig. 1) was validated, and the method's trueness was demonstrated by analysis of the certified reference material Human Hair NCS ZC81002B. The calculated recoveries ranged from 84% for Ni to 117% for Mn. The obtained concentrations of the studied elements in kestrel pellets indicate low contamination of arable land in eastern Poland with Cd, Cr, Ni, Pb, Se, and Zn, as well as slightly elevated concentrations of Cu and Mn resulting from the use of artificial fertilizers and plant protection products. The analysis revealed 15 significant correlations out of 35 possible

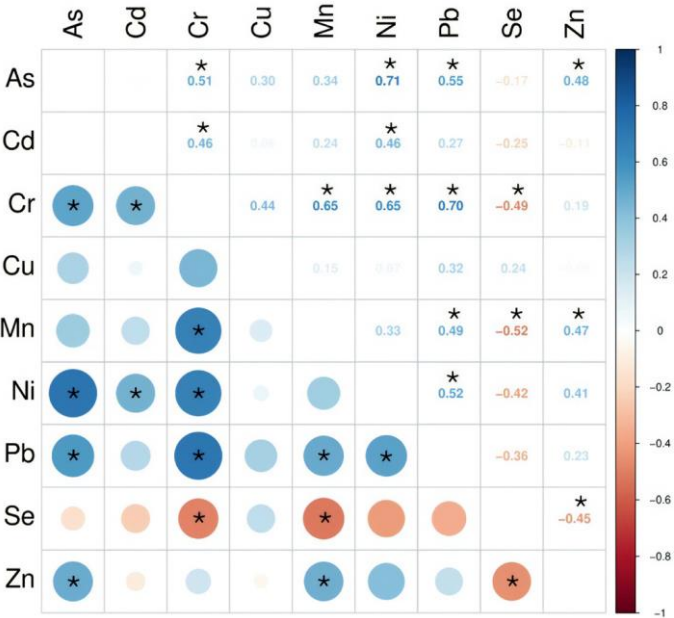


Fig. 2. Particular steps of the developed analytical procedure.

between the concentrations of the studied elements obtained from the analyzed kestrel territories (Fig. 2). This indicates variation in the degree of contamination between the studied locations, including multiple elements simultaneously. The presented research contributes to the knowledge necessary to understand the occurrence and accumulation of chemical elements at specific trophic levels in agricultural ecosystems.

References:

- [1] M. Taghavi, K. Bakhshi, A. Zarei et al., *Sci. Rep.*, **2024**, *14*, 8971.
- [2] F. Morelli, J. Reif, M. Díaz et al., *Ecol. Indic.*, **2021**, *133*, 108397.
- [3] P. Zduniak, J. Wojciechowska, Z. Kasprzykowski, I. Komorowicz, *Chemosphere* **2025**, *374*, 144231.

Financial support: project ID-UB 118/34/UAM/0083.

# RESPONSE OF WINTER RAPESEED TO THE APPLICATION OF MICROBIAL FERTILIZER PRODUCTS IN TERMS OF YIELD AND BIOMETRIC TRAITS

**Sylwia FIGIEL<sup>a</sup>, Marzena S. BRODOWSKA<sup>b</sup>**

<sup>a</sup> *University of Life Sciences in Lublin, Faculty of Agrobioengineering, Lublin, Poland*

<sup>b</sup> *University of Life Sciences in Lublin, Faculty of Agrobioengineering, Lublin, Poland*

*e-mail address: [Sylwia.figiel@up.lublin.pl](mailto:Sylwia.figiel@up.lublin.pl)*

## Introduction:

Sustainable crop production necessitates the adoption of environmentally friendly practices that preserve soil fertility and guarantee stable yields. Microbial fertilizers, containing beneficial microorganisms, are gaining attention as an alternative or complement to mineral fertilization. They can improve nutrient availability, enhance plant growth, and contribute to yield stability. Winter rapeseed (*Brassica napus* L.), as one of the most important oilseed crops in Europe, may benefit from such practices. This study aimed to evaluate the response of winter rapeseed to the application of selected microbial fertilizer products in terms of yield and biometric traits.

## Materials and Methods:

The field experiment was conducted at the Lublin Agricultural Advisory Center in Końskowola using a hybrid winter oilseed rape variety from Pioneer. The experimental objects consisted of 39 plots, on which microbiologically enriched nitrogen fertilizers containing various formulations of beneficial microorganisms (e.g., *Azotobacter*, *Bacillus*, *Pseudomonas*) were applied, compared to a control treatment without nitrogen fertilization [1-5]. The experiment was established in a randomized block design with three replications. During the growing season, biometric traits (plant height, number of branches, number of siliques per plant, thousand seed weight) were evaluated, and the final seed yield was determined at harvest. The data were subjected to statistical analysis using the Statistica software.

## Results:

The application of microbiological fertilizers had a positive effect on most biometric traits of winter oilseed rape. Plants treated with microbiological preparations showed increased height, a higher number of siliques per plant, and a greater thousand-seed weight compared to the control. On plots fertilized with microbiologically enriched fertilizers, a significant increase in yield was observed relative to plots without microbial additives, depending on the specific microbial formulation used [4-7]. Some differences between the preparations

were also noted, suggesting that the composition of microbial consortia affects their effectiveness.

#### Conclusions:

The study confirmed that microbiological fertilizers can improve both the biometric parameters and yield of winter oilseed rape [1,8]. Their application may contribute to reducing dependence on mineral fertilizers and enhancing the sustainability of oilseed rape cultivation [9,10]. Further research is needed to optimize the composition and application strategies under various environmental conditions.

#### Keywords:

winter oilseed rape, microbiological fertilizers, yield, biometric traits, sustainable agriculture

#### References:

- [1] Czuba, R. (Ed.) Nawożenie Mineralne Roślin Uprawnych; Police: Zakłady Chemiczne, Poland, **1996**.N.
- [2] Franche, C.; Lindström, K.; Elmerich, C. Nitrogen-fixing bacteria associated with leguminous and non-leguminous plants. *Plant, Soil* **2009**, *321*, 35–59
- [3] Martínez-Viveros, O.; Jorquera, M.A.; Crowley, D.E.; Gajardo, G.; Mora, M.L. Mechanisms and practical considerations involved in plant growth promotion by rhizobacteria. *J. Soil Sci. Plant Nutr.* **2010**, *10*, 293–319
- [4] Okon, Y.; Hadar, H. Microbial inoculants as crop-yield enhancers. *Crit. Rev. Biotechnol.* **1987**, *6*, 61–85
- [5] Schulz, T.J.; Thelen, K.D. Soybean seed inoculant and fungicidal seed treatment effects on soybean. *Crop Sci.* **2008**, *48*, 1975–1983.
- [6] Malusá, E.; Vassilev, N. A contribution to set a legal framework for biofertilisers. *Appl. Microbiol. Biotechnol.* **2014**, *98*, 6599–6607.
- [7] Xavier, I.J.; Holloway, G.; Leggett, M.; Bios, P. Development of Rhizobial Inoculant Formulations. *Crop Manag.* **2004**, *3*, 1.
- [8] Grzebisz, W. Podstawy Nawożenia, Nawożenie Roślin Uprawnych; Państwowe Wydawnictwo Rolnicze i Leśne: Poznań, Poland, **2008**.
- [9] Smith, R.S. Legume inoculant formulation and application. *J. Microbiol.*, **1992**, *38*, 85–492
- [10] Muresu, R.; Sulas, L.; Caredda, S. Legume—Rhizobium symbiosis: Characteristics and prospects of inoculation. *Rivol. Agron.*, **2003**, *37*, 33–45.

## INDEX OF AUTHORS

- Almeida Agostinho Almiro De 61  
Andrzejewska Agnieszka 30, 67  
Andrzejewska-Juskowiak Agnieszka 33  
Azevedo Rui 61
- Barlóg Przemysław 9, 56, 73  
Biber Maria 30, 32, 51, 67  
Biber Stanisław W. 32  
Biniek Łukasz 17  
Blask-Osipa Anna 46  
Blecharczyk Andrzej 33  
Boguszewska-Czubara Anna 75  
Brądkiewicz Katarzyna 38, 40  
Brodowska Marzena S. 12, 80  
Budzyń Magdalena 37, 69, 71  
Bulska Ewa 15
- Cholik Rafsan 27
- Diatta Jean 22  
Dobrowolska Marta 59  
Dobrzyńska Małgorzata 44, 46  
Dołowy Krzysztof 7  
Drzymała-Czyż Sławomira 44, 46  
Dubaj Tibor 58  
Dubieńska-Rejent Magdalena 75  
Dzieniszewski Dominik 37
- Figiel Sylwia 80  
Formanowicz Dorota 37, 71  
Francke Anna 25  
Frąckowiak Julia 77
- Gerendás Jóska 19  
Górski Kacper 59  
Grupińska Joanna 37, 69, 71  
Gryszczyńska Bogna 37, 69, 71  
Grzebisz Witold 9
- Halicz Ludwik 15  
Hané Anetta 25, 77
- Illicka-Borowczyk Kinga 46  
Iskra Maria 37, 69
- Jaghdani Setareh Jamali 19  
Jagielska Agata 15  
Jakubowski Karol 44  
Jawień Andrzej 11, 71
- Kaja Elżbieta 37  
Karasinski Jakub 15  
Kasprzak Magdalena P. 69, 71  
Kasprzykowski Zbigniew 78  
Kłodawska-Pęcińska Katarzyna 49  
Komorowicz Izabela 77, 78  
Kordala Natalia 66  
Kraśński Zbigniew 37, 69, 71  
Krasnodębska-Ostręga Beata 48  
Krzebietke Sławomir J. 49  
Ksepko Ewelina 14, 58  
Kulwicki Michał 30, 7
- Lewenstam Andrzej 7, 15  
Lysowski Rafał 14, 58
- Łukowiak Remigiusz 73  
Łukowiak Remigiusz 9
- Majewski Michał 25  
Majkowska-Gadomska Joanna 25  
Maj-Żurawska Magdalena 7, 15  
Mariowska Agnieszka 61  
Markowska Hanna 44  
Megiel Elżbieta 75  
Mieloszyk Klaudia 46  
Młodecki Dominik 73  
Mrówczyński Radosław 21
- Niedzielski Przemysław 44  
Nogalska Anna 55
- Olechnik-Schmidt Agnieszka 63
- Palinska-Saadi Adriana 15  
Papuga Natalia 48  
Pobereźny Jarosław 38, 40  
Podgórski Tomasz 46  
Potarzycki Jarosław 17, 32, 56  
Potrawiak Marcin 17  
Przygocka-Cyna Katarzyna 30, 32, 51, 67  
Przysławski Juliusz 44  
Pużyńska Katarzyna 28  
Pużyński Stanisław 28
- Rafałowicz Tomasz 73  
Ridiger Bartosz 17  
Rolka Elżbieta 53  
Rydzyski Dariusz 49

Sadowska Monika 48  
Sajnóg Adam 36, 77  
Sawinska Zuzanna 33  
Schmidt Marcin 63  
Selvan Damla 42  
Simon Peter 58  
Skorwider-Namiotko Anna 53  
Skrypnik Damian 42, 61  
Skrypnik Katarzyna 42, 61, 63, 77  
Strzyżewski Krzysztof 71  
Suliburska Joanna 27, 42, 61, 63, 77  
Szczepaniak Witold 30, 51, 67  
Szostek Radosław 53  
Szwarc Katarzyna 49  
Szymanowski Karol 46  
Święch Olga 75

Tomczyńska-Mleko Marta 65  
Tupys Andrii 15  
Urbanowicz Tomasz 13  
Wagner Barbara 15  
Wańkiewicz Łukasz 49  
Wichłacz-Bellucci Agnieszka 24  
Wojciechowska Joanna 78  
Wojciechowska Zofia 44  
Woźniak Dagmara 46  
Wszelaczyńska Elżbieta 38, 40  
Wyszkowski Mirosław 53, 66  
Zduniak Piotr 78  
Zielińska Danuta 59  
Żarczyński Piotr J. 49

## TABLE OF CONTENTS

|                                                                                                                                                                                                                                                                                                                                                                                                                |    |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| <b>Lewenstam Andrzej, Maj-Żurawska Magdalena, Dołowy Krzysztof</b><br>MEASURING LITHIUM AND MAGNESIUM IN BIOLIQUIDS USING ION SENSORS:<br>FROM CONCEPT TO THE FIRST COMMERCIAL BLOOD ANALYZER.....                                                                                                                                                                                                             | 7  |
| <b>Grzebisz Witold, Barłóg Przemysław, Łukowiak Remigiusz</b><br>CALCIUM AND MAGNESIUM - CRITICAL NUTRIENTS FOR NITROGEN USE EFFICIENCY.....                                                                                                                                                                                                                                                                   | 9  |
| <b>Jawień Andrzej</b><br>FROM AMPUTATION TO INNOVATION: MAGNESIUM IN VASCULAR MEDICINE.....                                                                                                                                                                                                                                                                                                                    | 11 |
| <b>Brodowska Marzena S.</b><br>BIOSTYMULATION FOR ADAPTING TO CLIMATE CHANGE.....                                                                                                                                                                                                                                                                                                                              | 12 |
| <b>Urbanowicz Tomasz</b><br>MAGNESIUM AND THE HEART: ARE THE ANTIARRHYTHMIC PROPERTIES<br>THE ONLY ONES?.....                                                                                                                                                                                                                                                                                                  | 13 |
| <b>Ksepko Ewelina, Lysowski Rafal</b><br>MODIFYING MG-DOPED MATERIALS FOR POTENTIAL USES IN HARD COAL<br>COMBUSTION THROUGH CHEMICAL LOOPING.....                                                                                                                                                                                                                                                              | 14 |
| <b>Tupys Andrii, Maj-Żurawska Magdalena, Palinska-Saadi Adriana, Karasinski Jakub,<br/>Halicz Ludwik, Jagielska Agata, Wagner Barbara, Lewenstam Andrzej, Bulska Ewa</b><br>MAGNESIUM IN DIABETES MELLITUS AND APPLICATION OF MULTICollector MASS<br>SPECTROMETRY AND LASER ABLATION IN THE STUDY OF MAGNESIUM ISOTOPES<br>FRACTIONATION PHENOMENON DURING TRANSPORT THROUGH AN ION-SELECTIVE<br>MEMBRANE..... | 15 |
| <b>Potarzycki Jarosław, Potrawiak Marcin, Biniek Łukasz, Ridiger Bartosz</b><br>MAGNESIUM - A NUTRIENT RESPONSIBLE FOR THE EFFECTIVENESS OF NITROGEN<br>IN PLANT FERTILIZATION.....                                                                                                                                                                                                                            | 17 |
| <b>Jaghdani Setareh Jamali, Gerendás Jóska</b><br>IMPACTS OF MAGNESIUM (Mg) ON CROP PHYSIOLOGY AND QUALITY.....                                                                                                                                                                                                                                                                                                | 19 |
| <b>Mrówczyński Radosław</b><br>APPLICATIONS OF METAL IONS IN BIOMATERIALS.....                                                                                                                                                                                                                                                                                                                                 | 21 |
| <b>Diatta Jean</b><br>USE OF PBET (PHYSIOLOGICALLY BASED EXTRACTION TEST) FOR ASSESSING<br>THE RELEASE AND POTENTIAL ABSORPTION OF MINERAL ELEMENTS OF CLAYS<br>AVAILABLE IN THE POLISH MARKET.....                                                                                                                                                                                                            | 22 |
| <b>Wichlacz-Bellucci Agnieszka</b><br>TO SOFTEN WATER OR NOT TO SOFTEN? ...THAT IS THE QUESTION! PRESENTATION<br>OF TEST RESULTS FOR DRINKING WATER AND WATER AFTER ADDITIONAL<br>TREATMENT PROCESSES, PERFORMED AT THE SALUBRIS LABORATORY.....                                                                                                                                                               | 24 |

|                                                                                                                                                                                                                                                                                                         |    |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| <b>Majewski Michał, Hanć Anetta, Majkowska-Gadomska Joanna, Francke Anna</b><br>THE CONTENT OF SELECTED MACRO- AND MICROELEMENTS IN DIFFERENT<br>BEETROOT CULTIVARS (BETA VULGARIS L.) DEPENDING ON THE LEVEL<br>OF SOIL FERTILIZATION WITH SELENIUM.....                                               | 25 |
| <b>Cholik Rafsan, Suliburska Joanna</b><br>THE IMPACT OF SALICYLATE TREATMENT ON MAGNESIUM CONCENTRATION IN<br>MATERNAL-FETAL TISSUES IN PREECLAMPTIC RATS.....                                                                                                                                         | 27 |
| <b>Pużyńska Katarzyna, Pużyński Stanisław</b><br>THE CONTENT OF MAGNESIUM AND OTHER BIOELEMENTS IN ORGANICALLY AND<br>CONVENTIONALLY GROWN SOYBEANS.....                                                                                                                                                | 28 |
| <b>Szczepaniak Witold, Kulwicki Michał, Przygocka-Cyna Katarzyna, Biber Maria,<br/>Andrzejewska Agnieszka</b><br>EVALUATION OF THE YIELD FORMATION AND NUTRITION REACTION OF TWO VARIETIES<br>OF WINTER WHEAT TO INCREASING LEVELS OF NITROGEN FERTILIZATION.....                                       | 30 |
| <b>Biber Stanisław W., Potarzycki Jarosław, Biber Maria, Przygocka-Cyna Katarzyna</b><br>DYNAMICS OF ELEMENTS IN SOIL – A MATHEMATICAL APPROACH AT CAPTURING THE<br>CHANGES IN PHOSPHORUS FORMS.....                                                                                                    | 32 |
| <b>Andrzejewska-Juskowiak Agnieszka, Sawinska Zuzanna, Bleharczyk Andrzej</b><br>THE IMPACT OF LONG-TERM DIVERSIFIED SOIL USE ON THE CONTENT OF TRACE<br>ELEMENTS AND THEIR DISTRIBUTION WITH SOIL DEPTH.....                                                                                           | 33 |
| <b>Sajnog Adam</b><br>CHEMICAL METROLOGY – AN IMPORTANT TOOL TO OBTAIN VALID ANALYTICAL<br>RESULTS.....                                                                                                                                                                                                 | 36 |
| <b>Grupińska Joanna, Dzieniszewski Dominik, Kaja Elżbieta, Gryszczyńska Bogna,<br/>Iskra Maria, Krasinski Zbigniew, Formanowicz Dorota, Budzyń Magdalena</b><br>DOES THE CONCENTRATION OF MAGNESIUM AND CALCIUM IN THE BLOOD SERUM OF<br>WOMEN WITH BREAST CANCER CHANGE DURING DISEASE TREATMENT?..... | 37 |
| <b>Pobereźny Jarosław, Wszelaczyńska Elżbieta, Brądkiewicz Katarzyna</b><br>HEALTH-PROMOTING PROPERTIES OF BASIL WASTE: EVALUATION<br>OF CHLOROPHYLL, CAROTENOID AND ANTIOXIDANT POTENTIAL.....                                                                                                         | 38 |
| <b>Wszelaczyńska Elżbieta, Pobereźny Jarosław, Brądkiewicz Katarzyna</b><br>BASIL WASTE AS A SOURCE OF POTENTIAL CONTAMINANTS AND HEALTH SAFETY.....                                                                                                                                                    | 40 |
| <b>Selvan Damla, Skrypnik Katarzyna, Skrypnik Damian, Suliburska Joanna</b><br>THE IMPACT OF EXERCISE TRAINING ON MAGNESIUM CONTENT IN THE HEART,<br>KIDNEYS, AND SKELETAL MUSCLES OF SPONTANEOUSLY HYPERTENSIVE RATS.....                                                                              | 42 |
| <b>Dobrzyńska Małgorzata, Wojciechowska Zofia, Jakubowski Karol, Markowska Hanna,<br/>Przysławski Juliusz, Niedzielski Przemysław, Drzymala-Czyż Sławomira</b><br>ELEMENTAL COMPOSITION OF INFANT FORMULA PRODUCTS AND THEIR<br>IMPACT ON NUTRITIONAL STATUS.....                                       | 44 |

|                                                                                                                                                                                                                                                                                                |    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| <b>Ilnicka-Borowczyk Kinga, Woźniak Dagmara, Dobrzyńska Małgorzata, Podgórski Tomasz, Szymanowski Karol, Blask-Osipa Anna, Mieloszyk Klaudia, Drzymala-Czyż Sławomira</b><br>THE IMPACT OF PARENTAL NUTRITIONAL EDUCATION ON IRON STATUS IN INFANTS.....                                       | 46 |
| <b>Krasnodębska-Ostręga Beata, Sadowska Monika, Papuga Natalia</b><br>DETERMINATION OF BIO- AND UNDESIRABLE ELEMENTS IN FOOD ADDITIVES -<br>METHODOLOGICAL PROBLEMS.....                                                                                                                       | 48 |
| <b>Krzebietke Sławomir J., Żarczyński Piotr J., Szware Katarzyna, Kłodawska-Pęcińska Katarzyna, Rydziński Dariusz, Wańkowicz Łukasz</b><br>THE EFFECT OF FERTILIZATION WITH PYROLYSIS WASTE PRODUCTS ON CARBON<br>SEQUESTRATION AND CHEMICAL COMPOSITION OF GRASSES.....                       | 49 |
| <b>Przygócka-Cyna Katarzyna, Biber Maria, Szczepaniak Witold</b><br>THE IMPACT OF BIOMASS-DERIVED FERTILIZER APPLICATION IN HORTICULTURAL<br>PRODUCTION ON YIELD, MAGNESIUM CONTENT, AND SELECTED NUTRIENTS:<br>A CASE STUDY OF BROCCOLI.....                                                  | 51 |
| <b>Rolka Elżbieta, Wyszowski Mirosław, Skorwider-Namietko Anna, Szostek Radosław</b><br>ASH FROM WOOD BIOMASS USED TOGETHER WITH DIGESTATE AS AN ALTERNATIVE<br>SOURCE OF MACROELEMENTS (K, Mg AND Ca) IN MAIZE CULTIVATION*.....                                                              | 53 |
| <b>Nogalska Anna</b><br>THE EFFECT OF MEL WORM FRASS ON THE NITROGEN CONTENT<br>OF CRISPHEAD LETTUCE.....                                                                                                                                                                                      | 55 |
| <b>Barlóg Przemysław, Potarzycki Jarosław</b><br>RESPONSE OF WINTER WHEAT TO POTASSIUM AND MAGNESIUM FERTILIZATION.....                                                                                                                                                                        | 56 |
| <b>Ksepko Ewelina, Lysowski Rafał, Dubaj Tibor, Simon Peter</b><br>COMBUSTION REACTION KINETICS OF SELECTED GASEOUS FUELS USING<br>SOLID OXYGEN CARRIERS OF SPINEL-TYPE.....                                                                                                                   | 58 |
| <b>Górski Kacper, Dobrowolska Marta, Zielińska Danuta</b><br>APPLICATION OF THE ICP-MS METHOD FOR DETERMINING BIOELEMENTS<br>IN EDIBLE MUSHROOMS.....                                                                                                                                          | 59 |
| <b>Skrypnik Katarzyna, Skrypnik Damian, Mariowska Agnieszka, Azevedo Rui, Almeida Agostinho Almiro De, Suliburska Joanna</b><br>THE EFFECT OF CARDIAC REHABILITATION ON SERUM MAGNESIUM<br>CONCENTRATION IN PATIENTS AFTER ACUTE CORONARY SYNDROME -<br>THE CARDIO-REH RANDOMISED STUDY.....   | 61 |
| <b>Skrypnik Katarzyna, Olejnik-Schmidt Agnieszka, Schmidt Marcin, Suliburska Joanna</b><br>INFLUENCE OF SUPPLEMENTATION OF PROBIOTIC BACTERIA LACTOBACILLUS<br>PLANTARUM AND LACTOBACILLUS CURVATUS ON MAGNESIUM CONTENT IN<br>DUODENUM AND LIVER IN RATS ON HIGH-FAT IRON-DEFICIENT DIET..... | 63 |
| <b>Tomczyńska-Mleko Marta</b><br>AERATED GELS INDUCED BY CALCIUM IONS.....                                                                                                                                                                                                                     | 65 |
| <b>Wyszowski Mirosław, Kordala Natalia</b><br>EFFECT OF HUMIC ACIDS ON MAIZE BIOMASS ON SOIL WITH IRON APPLICATION.....                                                                                                                                                                        | 66 |

|                                                                                                                                                                                                                                                                                                                                                  |    |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| <b>Szczepaniak Witold, Kulwicki Michał, Przygocka-Cyna Katarzyna, Biber Maria, Andrzejewska Agnieszka</b><br>EVALUATION OF THE YIELD FORMATION AND NUTRITION REACTION<br>OF TWO VARIETIES OF WINTER WHEAT TO INCREASING LEVELS<br>OF NITROGEN FERTILIZATION.....                                                                                 | 67 |
| <b>Gryszczyńska Bogna, Grupińska Joanna, Budzyń Magdalena, Kasprzak Magdalena P., Krasiński Zbigniew, Iskra Maria</b><br>BLOOD PLASMA MAGNESIUM, CALCIUM AND HS-CRP LEVELS IN AN ABDOMINAL<br>AORTIC ANEURYSM: THE EFFECT OF PRE- AND POSTOPERATIVE TREATMENT.....                                                                               | 69 |
| <b>Kasprzak Magdalena P., Gryszczyńska Bogna, Jawień Andrzej, Grupińska Joanna, Budzyń Magdalena, Strzyżewski Krzysztof, Krasiński Zbigniew, Formanowicz Dorota</b><br>PARTICIPATION OF IRON IONS AND THEIR CORRELATION WITH PARAMETERS<br>OF OXIDATIVE STRESS AND INFLAMMATION IN PATIENTS STRATIFIED<br>BY ABDOMINAL AORTIC ANEURYSM SIZE..... | 71 |
| <b>Łukowiak Remigiusz, Młodecki Dominik, Rafałowicz Tomasz, Barłóg Przemysław</b><br>MAGNESIUM NUTRITION STATUS OF WINTER WHEAT IN ROTATION DEPENDING<br>ON THE POTASSIUM FERTILIZATION SYSTEM.....                                                                                                                                              | 73 |
| <b>Boguszewska-Czubarą Anna, Dubińska-Rejent Magdalena, Megiel Elżbieta, Święch Olga</b><br>GOLD AND SILVER NANOPARTICLE-ASSISTED IMPROVEMENT OF ANTICANCER<br>EFFICACY OF MOXIFLOXACIN AGAINST COLON CANCER.....                                                                                                                                | 75 |
| <b>Frąckowiak Julia, Komorowicz Izabela, Sajnóg Adam, Skrypnik Katarzyna, Suliburska Joanna, Hanć Anetta</b><br>THE INFLUENCE OF PROBIOTICS AND IRON SUPPLEMENTATION ON TRACE<br>ELEMENTS DISTRIBUTION IN KIDNEY.....                                                                                                                            | 77 |
| <b>Komorowicz Izabela, Zduniak Piotr, Wojciechowska Joanna, Kasprzykowski Zbigniew</b><br>PELLETS OF THE COMMON KESTREL FALCO TINNUNCULUS AS AN INDICATOR OF<br>ENVIRONMENTAL POLLUTION WITH ELEMENTS.....                                                                                                                                       | 78 |
| <b>Figiel Sylwia, Brodowska Marzena S.</b><br>RESPONSE OF WINTER RAPESEED TO THE APPLICATION OF MICROBIAL FERTILIZER<br>PRODUCTS IN TERMS OF YIELD AND BIOMETRIC TRAITS.....                                                                                                                                                                     | 80 |
| <b>INDEX OF AUTHORS.....</b>                                                                                                                                                                                                                                                                                                                     | 82 |
| <b>TABLE OF CONTENTS.....</b>                                                                                                                                                                                                                                                                                                                    | 84 |