Abstract of a doctoral thesis

„Innovative chelates for agricultural use”

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Current UN demographic population estimates indicate that the total global population will increase to 8.5 billion in 2030 and 9.7 billion in 2050. Humanity has a limited resource of land intended for food production, which is systematically decreasing due to the urbanization of agricultural areas. Therefore, the key to further development is the intensification of agricultural production in available areas. This trend is called sustainable agriculture fertilization. According to the principles of sustainable fertilization, its methods should be optimized to the provide to plant the nutrients it needs at the right time, in accordance with Liebig's law of Minimum. The key in this matter is the addition of essential microelements and biostimulants to fertilizers, which will result in better plant vegetation conditions and protection against pests and pathogens.

The aim of the dissertation is to expand the Company's portfolio with additional ligands and chelates with biodegradation potential, which will be consistent with previously conducted R&D projects. In previous years, a project with EU funding was carried out in which several innovative microelement chelates (chelates and complex compounds of the following elements: Fe, Zn, Cu, Mn, Mo) for use in solid and/or liquid fertilizers. The developed chelates are more biodegradable than classic EDTA chelators. Two patents have been granted for the developed inventions to protect the intellectual property rights.

The work was divided into two parts: a public part and a secret part due to the fact that most of the data contained in this part was classified as "Business Secret".
The public part contains a review of the literature on the application of microelement compounds to nitrogen fertilizers, the topic of microelement fertilization and topics related to chelates. The secret part contains market analyzes and forecasts, analysis of the availability of raw materials, analysis of patent purity, laboratory tests with conclusions at the end of each stage.

The stages of work carried out in the secret part were:
Selection of potential molecules for chelation and synthesis tests, along with a review of the literature and patent purity analysis.
Syntheses of basic molecule chelates - 35 products were obtained, which are part of 7 product series consisting of 5 reaction products of an ligand and a inorganic microelement salt. The obtained products were analyzed. Spectral studies confirmed or rejected the thesis that expected complexes.
Syntheses of ligands and chelates of complex molecules - 20 products were obtained, which are part of 4 product series consisting of 5 reaction products of the synthesized innovative ligand and

inorganic microelement salt. The obtained products were analyzed. Spectral studies confirmed or rejected the thesis that expected complexes.

Optimization and scaling up the syntheses of selected molecules. The most advantageous processes were scaled up to 500 ml, 1 l and 20 l volume vessels.

Due to the nature of the implementation doctoral dissertation carried out for a product manufactured on the largest volume (in a 20 l. reactor vessel), design assumptions for a pilot plant for potential implementation along with the material balance were presented.

The Ph.D. thesis envisages the use of future available infrastructure, which will be created based on the assumptions developed as part of the EU granted project (chelates production plant).

As part of the task: application of the developed additives to the liquid and solid fertilizer matrix, the following formulations were created:

- solid fertilizers formulations with developed complex compounds (based on Salmag® fertilizer(CAN)) The obtained solid fertilizer formulations are safe under the process conditions, which was confirmed by DSC analyses. An additional marketing advantage may be the color of the obtained granulates.
- 15 formulations of liquid fertilizers with developed complexes compounds developed (based on RSM® fertilizer (UAN)). Liquid fertilizer formulations are stable, which was confirmed by aging tests and chromatographic analyses. The color of the obtained compounds may be an additional marketing advantage.
- 11 liquid fertilizer formulations with developed basic complexes (based on RSM® fertilizer (UAN)) The obtained products were analyzed. For the last group of formulations, phytotron tests were carried out and a comparison of their effectiveness with the basic carriers of microelements, inorganic salts - was prepared. RSM® mixtures with the ligands are a valuable addition to liquid fertilizers due to the results achieved in phytotron tests.

Among the synthesized molecules of complex ligands, several key substances with good functional properties were selected that allowed for potential implementation. However, it should be remembered that the market dictates the sales conditions. An appropriate marketing campaign may allow the introduction of innovative products, but this requires an individual farmer's approach to fertilizers that have additional benefits in exchange for a higher price.