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SUMMARY

„Design of technology for the formulation of anticaking agents used in the production of nitrate fertilizers"

Worldwide, fertilizers and sustainable fertilization are extremely important for the proper functioning of countries, and they have a significant influence on the development of various industries. The market for the production of mineral fertilizers, which form the basis for feeding the growing population, is limited due to the increasingly lower quality and depletion of raw materials and uncertain economic and political situations. In the European Union, two major programs have been proposed in this area: the Circular Economy and the Resource Efficient Economy. Both programs are in line with the thesis of sustainable development. Formal requirements related to these programs have been developed in Regulation (EU) 2019/1009 of the European Parliament and the Council of June 5, 2019, laying down rules on the making EU fertilizing products available on the market, applicable from July 16, 2022, with the principle that all fertilizers and fertilizer components must meet the relevant quality requirements. From July 2026, the component materials, i.e., organic coatings, need to be highly biodegradable.

This doctoral dissertation aimed to develop effective, economically justifiable technologies that do not pose threats to process safety and biodegradable formulations of anticaking agents used in the production of ammonium nitrate fertilizers. Effective protection of fertilizers against caking prevents material loss and improves the quality of fertilizers during production, storage, and use.

The literature part includes a review of publications and patent reports on obtaining and using anticaking formulations used in mineral fertilizers. The properties of ammonium nitrate were analyzed, including its tendency to caking, and the caking mechanisms and anticaking agents proposed in the literature were discussed. Using economic data, a review of the European and national markets of anticaking agents for mineral fertilizers and the market of a new biodegradable raw material used in the obtained formulations was carried out. Based on the literature data, patent data, monographs, and standards, the methodology and research analytics used were selected.

The experimental part of this dissertation was carried out in a full research-and-development cycle, from basic research to obtaining effective biodegradable anticaking agents in the laboratory, under semitechnical and industrial conditions. Using various methods such as the Box–Behnken design (BBD) and statistical data analysis, the influence of the content of individual raw materials in anticaking agents on the effectiveness of preventing caking of ammonium nitrate fertilizers was established, and the optimal composition of the biodegradable anticaking agent was determined for both ammonium nitrate and calcium ammonium nitrate.

The chemical composition and physicochemical parameters (density, viscosity, base number, and water content) of commercial preparations and developed formulations were investigated using gas chromatography-mass spectrometry (GC-MS). The degree of biodegradation was designated in the prepared anticaking agents with optimized composition. The degree of coverage of the fertilizer with the anticaking agent (Soxhlet method), its anticaking effectiveness, and its crushing strength of the granules were determined, and the morphology of the surface of the granules covered with anticaking agents by scanning electron microscopy (SEM) was assessed. Ammonium nitrate is an unstable substance prone to uncontrolled decomposition. Due to the process safety of the production, storage, and transport of ammonium nitrate-based fertilizers, it is necessary to evaluate the impact of the applied formulations on the decomposition of ammonium nitrate. Hence, thermal analysis using thermogravimetry (TG) and differential thermal analysis (DTA) was adopted and applied.

The practical aspect of the research was developing a technological concept of new biodegradable formulations of anticaking agents using a biodegradable raw material: tall oil—specifically, tall oil fatty acids. The developed anticaking formulation for fertilizers effectively protected ammonium nitrate (AN) and calcium ammonium nitrate (CAN) against caking, in both laboratory tests (100% efficiency for both fertilizers) and industrial conditions (100% efficiency for the AN fertilizer and 99.1% for the CAN fertilizer). The composition of the developed anticaking formulation was submitted to the Patent Office of the Republic of Poland for reservation (application name "Anti-caking agent for mineral fertilizers"). The utilitarian nature of this doctoral dissertation was reflected in the preimplementation work and implementation projects of a company manufacturing ammonium nitrate fertilizers (GA ZAK S.A.).

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