OPINION

regarding the defense of the doctoral dissertation: "Innovative Methods for the Separation and Purification of Bioactive Substances"

for the award of the educational and scientific degree PhD in professional field 4.2 Chemical Sciences, scientific specialty "Processes and Apparatuses in Chemical and Biochemical Technology"

Candidate: Apostol Georgiev Apostolov, Assistant Researcher, Laboratory "Biochemical Engineering", Institute of Chemical Engineering – BAS

Prepared by: Daniela Ilieva Batovska, PhD, Professor, Institute of Chemical Engineering – BAS

1. Relevance of the Research Topic

The development of selective and environmentally friendly methods for the extraction and purification of bioactive substances is a leading trend in contemporary chemical and biochemical technologies. The dissertation investigates the synthesis of hydrophobic deep eutectic solvents (DES) for the selective extraction of L-lactic acid and geometric isomers of butenedioic acid, the application of pertraction as a membrane process for the transfer of organic acids, and the nanofiltration of wine matrices for the controlled separation of ethanol, sugars, and other components. These research directions fully correspond to current developments in green chemistry and modern separation technologies.

2. Review of the Dissertation and Analysis of the Results

The dissertation is clearly and logically structured, with a well-founded literature review, precisely formulated aims and objectives, and an accurately described experimental part. It presents the synthesis and characterization of two new hydrophobic DES, the investigation of their selectivity toward L-lactic acid and the geometric isomers of butenedioic acid, the application of pertraction under different pH and hydrodynamic conditions, as well as the nanofiltration and reverse osmosis of the red wine "Mavrud." The results are consistently presented and correctly interpreted, and the conclusions are convincingly supported by the experimental data.

3. Main Scientific and Applied Contributions

The dissertation contains significant scientific and applied contributions, including:

- the synthesis and characterization of new hydrophobic DES and the demonstration of their selectivity toward L-lactic acid and the geometric isomers of butenedioic acid;
- elucidation of kinetic dependencies and factors determining mass transfer during liquid-membrane pertraction;
- investigation of nanofiltration and reverse osmosis parameters and their influence on the separation of ethanol, sugars, and organic components in wine matrices;
- development of technological solutions integrating DES extraction, pertraction, and membrane processes as sustainable approaches for the separation of organic substances.

The research was conducted within several scientific projects and collaborations that ensured an appropriate experimental environment. Nevertheless, the personal contribution of the candidate is clearly distinguishable and

indisputable, as he independently performed the main experiments, processed the results, and formulated the scientific conclusions.

4. Description and Evaluation of the Submitted Materials

The materials submitted by the candidate fully comply with the requirements of the Law on the Development of the Academic Staff, the Regulations of BAS, and the internal criteria of the Institute of Chemical Engineering for the award of the PhD degree. The three publications related to the dissertation are in peer-reviewed scientific journals with impact factor (Q2/Q4 categories), and the total number of points (52) meets and exceeds the minimum criteria. One of the publications has been cited in an international peer-reviewed journal, which is a positive indicator of the scientific visibility of the work. The results of the dissertation have been presented at nine scientific forums, demonstrating active scholarly dissemination. The candidate has also submitted certificates and distinctions, including specialization in HPLC and a BAS award for a young scientist, further highlighting his scientific potential.

The submitted declarations and supporting documents are accurate and confirm full compliance with the regulatory requirements.

5. Critical Remarks and Recommendations

The dissertation is comprehensive and well-organized; nevertheless, several recommendations may enhance the clarity and completeness of the presentation:

- the literature review could be made more concise without compromising its analytical depth;
- some of the results would benefit from clearer identification of statistical treatment;
- the membrane-process sections could include more structured comparisons with existing literature;
- the mechanisms of interaction between organic acids and DES could be discussed in greater detail;
- the directions for future research could be formulated more specifically.

These remarks are developmental in nature and do not affect the overall positive assessment of the quality and significance of the dissertation.

6. Personal Impressions

The candidate demonstrates a high scientific level, strong experimental competence, and analytical thinking. He works consistently and independently and has clear potential for further development as a researcher.

CONCLUSION

The dissertation contains original contributions and fully meets the requirements for awarding the educational and scientific degree PhD in professional field 4.2 Chemical Sciences, specialty "Processes and Apparatuses in Chemical and Biochemical Technology." I recommend that the esteemed jury award the degree of PhD to Apostol Georgiev Apostolov.

03 December 2025

Signature: [redacted]

Sofia

/Prof. Daniela Batovska, PhD/