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Wrocław, 21.01.2026 r.

THE REVIEW OF DOCTORAL DISSERTATION

written by **Zahra Askarniya MSc. Eng.**

entitled **„Studies on the application of the acoustic cavitation as a pre-treatment technique for the fermentation of food waste-based feedstocks to produce lactic acid"**

prepared under the scientific supervision of

Prof. Grzegorz Boczkaj

1. The basis for the preparation of the review

The formal basis for the preparation of the review is a letter from the Dean of The Faculty of Civil and Environmental Engineering, Gdańsk University of Technology Prof. Ewa Wojciechowska.

Following Article 187 of the Law of July 20, 2018. - Law on Higher Education and Science (Journal of Laws 2018, item 1668, as amended), the doctoral dissertation presents the candidate's general theoretical knowledge in a discipline or disciplines and the ability to conduct scientific or artistic work independently. In addition, the subject of the doctoral dissertation is to be an original solution to a scientific problem, an original solution to the application of the results of one's scientific research in the economic or social sphere, or an original artistic achievement. Doctoral dissertation may be written work, including a scientific monograph, a collection of published and thematically related scientific articles, a design construction, technological, implementation, or artistic work, and an independent and isolated part of a collective work. According to the guidelines of the Council for Scientific Excellence1, "the opinion on a given dissertation should include the following elements[1]:

1) an assessment with a justification of whether the doctoral dissertation demonstrates the general theoretical knowledge of the applicant for the doctoral degree in a specific discipline or disciplines.

2) an evaluation with justification of whether the doctoral dissertation demonstrates the ability of the applicant to conduct scientific or artistic work independently.

3) an assessment with the justification of whether the doctoral dissertation represents an original solution to a scientific problem, an original solution to the application of the results of one's scientific research in the economic or social sphere, or an original artistic achievement."

The review was prepared following the above recommendations to the extent specified in the contract for the preparation of the review in the doctoral proceeding.

2. Thesis characteristics

The dissertation submitted for review is a monography consisted of 123 pages including summary of the dissertation both in English and Polish, Acknowledgements, introduction to the topic, aim and objectives, description of used methods, presentation of the results and their discussion, conclusions, and the list of the 230 references. The thesis contains 23 figures showing the concept of the experiments, used methods, and obtained results. Part of the data were presented in the form of the 3 tables. The Author included also the list of used symbols and abbreviations. The dissertation is generally well structured. First, Author did excellent work studying the massive number of scientific papers. In the section Introduction, the Author presented the knowledge regarding the food waste issues and their valorization due to different technologies including incineration, gasification, composting, biodiesel, adsorbents, and biopolymers production, enzymes recovery, and anaerobic digestion. Next, organic waste pretreatment methods were discussed covering mechanical, thermal, chemical, physical, and biological methods. Next subsection describes the advanced oxidation processes. At the end of the Introduction aspects of acoustic cavitation were presented. All mentioned subjects are strictly related with the topic of the thesis and fall within the scope of the scientific discipline of environmental engineering, mining, and energy. Here, I conclude that doctoral dissertation demonstrates the general theoretical knowledge of the applicant for the doctoral degree in a discipline environmental engineering, mining, and energy. On that base the Author formulated

[1] Rada Doskonałości Naukowej. 2022. Recenzje w postępowaniach o awans naukowy. Poradnik

the aim of the study and scientific hypotheses. Next, general section Methodology, contains description of most of the used materials, chemicals, apparatus for food waste pretreatment, feedstock fermentation units, experimental matrix, analytical procedures for the determination of chemical properties of the food waste, inoculum, and digestate. I did not find the description of the statistical methods used for the research data evaluation. Author determined average values and standard deviations for each variant, however the ANOVA analysis for the validation of the significance of the differences between variants was not used. Additionally, some mathematical models based on the liner or nonlinear regression analysis could be determined, to show the mathematical description of the influence of the independent variables depending on variables. I consider it the biggest issue in this thesis, and I recommend using statistical validation of the research data in future papers. However, the experiment is well designed and proper methods are used. Therefore, I conclude that the doctoral dissertation demonstrates the ability of the applicant to conduct scientific work independently. In section 4 the Author presented and discussed the results obtained. The sequence and presentation of the data is organized properly and clearly. The results are well discussed; however, more deep discussion could be included for the microbiological data. Finally, the Author proposed the well-organized conclusions, which refer to the obtained data and put hypotheses.

3. The significance of the research topic undertaken for the development of the discipline of environmental engineering, mining, and energy

In my opinion, the research problem undertaken, in the reviewed work, is an important and topical issue, falling within the discipline of environmental engineering, mining, and energy. One of the identified problems is proper management of food waste. Obviously, food waste can be treated due to composting or/and anaerobic digestion for fertilizer and biomethane production. That solution doesn't lead to the generation of value-added products except electricity, heat, and fertilizer. Moreover, due to the low economic value of compost and biomethane, and relatively high investment and operational costs investors look for new solutions with higher economic and environmental benefits. One of the leading directions is the conversion of food waste into lactic acid, being an important precursor to biomaterials, bioplastics production. However, due to the complex nature of food waste, and due to the differences in the biodegradation rate of the different compounds, additional pre-treatment is required. It leads to the homogenization of the feedstock for the biological production of lactic acid or volatile fatty acids (VFA). Among the different physical, chemical, and biological methods, acoustic cavitation seems to be novel and economically feasible. Numerous research groups work on the optimization of food waste conversion to lactic acid and VFA. One of the branches of this activity is the application of acoustic cavitation combined with some chemical reagents. Biological treatment of food waste into lactic acid and VFA are widely recognized. However, initial pre-treatment methods are under intensive experimental and inventive development for the optimization of the lactic acid and VFA production efficiency. This is a solution that meets the goals of sustainable development and circular bioeconomy, by returning carbon from food waste to the form of biopolymers precursors. It may bring solutions for the utilization of food waste both for the mitigation of greenhouse gasses emission and production of value-added biopolymers. The proposed solutions are synergistic and represent a new approach to the problem and can be developed in the future at higher TRL levels. Considering the above remarks, I conclude that the problems undertaken by the author of the dissertation are topical and justified. It is a new and necessary direction of research, and further development of these issues can make a significant contribution to the development of food waste conversion and the production of lactic acid and VFA. Here, I conclude that the doctoral dissertation represents an original solution to a scientific problem.

Considering the above, I believe that the goal of the dissertation has been achieved. I also believe that the dissertation presents the Ph.D.'s general theoretical knowledge at a high level in the field of study and in the discipline of environmental engineering, mining, and energy. In my opinion, the dissertation demonstrates the Ph.D.'s ability to conduct scientific work independently. The experiments were designed correctly, however without statistical evaluation of the results and more advanced regression analysis could be done. I believe that the dissertation represents an original solution to a scientific problem in application of the acoustic cavitation for the food waste pretreatment before the lactic acid and VFA production, having the potential for further development and final implementation in the industrial practice, which is important in engineering sciences.

4. Specific comments

Despite the relevance of the topic undertaken and the innovative approach, there are issues in the work, and formulations that raise questions and doubts. These comments are arranged in the chronological order of reading the work.

Page 19. The Author described the thermal treatment of waste including waste incineration, showing some environmental concerns. However, in my opinion, the aspects of furans and dioxins emission, being the most significant concern, were hardly mentioned. It could be expanded and discussed, especially if the waste incineration, at this moment, has been excluded from European Union taxonomy, important factor in environmental investment financial support.

Page 20. The description of waste composting lacks odors emission issues. It should be added as an important environmental and social aspect.

Page 33. The Author mentioned that the inoculum to substrate ratio (ISR) was used at the level of 1:4 or 1:6. Usually, it is counted on the base of the volatile matter of inoculum and substrate. These values are strange, as ISR ranging from 1.0-2.0 was found optimal resulting in higher organic matter removal and VFA degradation. Furthermore, a high ISR (2.0-4.0) is favorable to methanogenesis, while a lower ISR (<1.0) is prone to irreversible acidification. I would like to ask the Author for an explanation of the reasons for using ISR in the range of the 1:4-1:6.

Page 57. What does it mean "pyrolysis of water" Is it a thermolysis of water, or pyrolysis of organics in the presence of water? Could the Author clarify?

Page 72. Figure 12. Why *Firmicates* bacteria dominates in all pH variants? The pH values were completely different; however, it didn't influence the composition of microbiota consortium. Could the Author explain it?

Page 88. Table 1. There are results of the total nitrogen content. The method of TN determination has not been described in the Methods section.

Section 4.6. Economic evaluation. How was the energy consumption measured? It has not been described in the methods section.

5. Conclusions

The topic of the dissertation is topical and important both from a scientific and practical point of view. The results obtained contribute to the development of the discipline of environmental engineering, mining, and energy in the development of lactic acid (ant other fatty acids) production after the pre-treatment due to acoustic cavitation of food waste. The content of the dissertation is consistent with the title, the stated goal of the work has been fulfilled, and the hypotheses have been verified. The dissertation was edited correctly from the formal side. The

dissertation confirms the author's very good knowledge of general theoretical knowledge in the analyzed area of the discipline of environmental engineering, mining, and energy. The dissertation also confirmed the author's ability to conduct scientific work independently, apply her experimental solutions, and formulate conclusions, although the results obtained could have been subjected to statistical analysis.

The author's extensive previous experience and acquired knowledge allow me to believe that the research will be continued and developed to improve the technological readiness of the proposed solutions. This will allow, at a further stage of scientific development the Doctoral Student, to supplement the presented results with specific studies on a semi-technical and technical scale.

I conclude that the issues taken up by the author of the dissertation are justified. It is a new and current direction of research, and further development of these issues can make a significant contribution to the development of food waste pretreatment for the lactic acid and FVA production.

When evaluating the doctoral dissertation of " Zahra Askarniya MSc. Eng., the following were considered: the significance and originality of the subject matter undertaken, the correctness of the formulation of the objectives and research hypotheses, the design of the research methodology, the description and interpretation of the results obtained, the structure of the dissertation and its technical side. Considering the above criteria and the comments made in the review, I conclude that, despite the listed shortcomings and doubts, the doctoral dissertation I have evaluated entitled „Studies on the application of the acoustic cavitation as a pre-treatment technique for the fermentation of food waste-based feedstocks to produce lactic acid" meets the requirements of the Law of July 20, 2018. - Law on Higher Education and Science (Journal of Laws 2018 item 1668, as amended) and I request that it be admitted to public defense.

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