UNIVERSITY OF LJUBLJANA | FS Faculty of Mechanical Engineering

Ljubljana, March 13th 2026

Subject: Report on the PhD Thesis "Studies on the application of acoustic cavitation as a pre-treatment technique for the fermentation of food waste-based feedstocks to produce lactic acid" submitted by Zahra Askarniya

I was nominated as an examiner of the thesis "Studies on the application of acoustic cavitation as a pre-treatment technique for the fermentation of food waste-based feedstocks to produce lactic acid" submitted by Zahra Askarniya. As a member of the jury, I'm submitting my evaluation report.

Introduction

The doctoral dissertation investigates the use of ultrasound-induced acoustic cavitation as a pre-treatment method to improve the fermentation of food waste for lactic acid production. The research addresses the challenge of efficiently converting food waste into valuable biochemical products within the framework of sustainable waste management and the circular economy.

The study focuses on enhancing the hydrolysis step, a key limitation in biological conversion processes, by using ultrasonic cavitation to increase the soluble chemical oxygen demand and thus improve substrate availability for microorganisms.

The results show that low-frequency ultrasound provides stronger cavitation effects, leading to increased feedstock solubilization and improved lactic acid production. A preliminary economic analysis suggests that ultrasonic pre-treatment may be a viable approach for food waste valorization.

Evaluation of the thesis

The thesis consists of 5 chapters. In total it has 126 pages. In the literature review chapter, the candidate compiled 230 references. I assess that the candidate prepared a comprehensive literature review and selected appropriate sources, which were meaningfully incorporated into the different chapters, predominantly introduction, of the dissertation. In doing so, the candidate demonstrated a good understanding of the research topic addressed in the doctoral work. The literature review

includes eight references in which the candidate appears as the first author, indicating her involvement in the respective research field.

In the *first chapter*, the candidate gives an overview of the scientific background and motivation behind the current thesis. The candidate first discusses the environmental and economic challenges associated with the increasing amount of global food waste and emphasizes the importance of developing sustainable waste-to-value strategies.
The chapter describes fermentation pathways leading to valuable products such as lactic acid, volatile fatty acids, biohydrogen, and biomethane. It highlights the limitations of these processes, particularly the slow hydrolysis stage that often limits conversion efficiency. A detailed overview of various pre-treatment techniques is presented. It includes mechanical, biological, thermal, chemical, and oxidative methods. These approaches aim to break down complex organic structures such as lignocellulose and increase substrate availability for microorganisms.
Particular emphasis is placed on cavitation, especially acoustic cavitation generated by ultrasound. Physical and chemical mechanisms associated with cavitation bubble formation and collapse, including the generation of microjets, shock waves, and reactive radical species such as hydroxyl radicals are explained.
The chapter concludes by identifying research gaps in the literature - a systematic application of (acoustic) cavitation as a pre-treatment step for enhancing lactic acid fermentation of food waste remains insufficiently explored, thus motivating the research presented in the dissertation.

The second chapter shortly gives the aim and objectives of the work. Namely to investigate the effectiveness of ultrasonic cavitation as a pre-treatment method for food waste fermentation by studying the effects of ultrasonic frequency, power density, treatment duration, feedstock concentration, and combined treatments with HCl, NaOH, and H_2O_2 on sCOD as well as on the production of lactic acid and volatile fatty acids.

Methodology is presented in the *third chapter*. It describes the experimental and analytical procedures used in the study. The experiments were conducted using both model and actual food waste collected from a university canteen, consisting mainly of pork, potatoes, and vegetables. These materials were processed into homogenized slurries and subjected to ultrasonic pre-treatment before fermentation.
Two ultrasonic reactors were employed, with the majority of experiments conducted in a low-frequency ultrasonic probe reactor (24 kHz) due to its stronger cavitation effects. The chapter provides detailed descriptions of reactor configurations, experimental parameters, and operating conditions.
Fermentation experiments were performed using anaerobic and aerobic sludge as inoculum, and several parameters were systematically varied, including ultrasonic frequency, power density, treatment duration, and feedstock concentration.
A variety of analytical techniques were used to characterize the processes and products. These included measurements of soluble chemical oxygen demand, lactic acid isomers, volatile fatty

acids, and radical formation. Instrumental analyses were conducted using ultra-high-performance liquid chromatography and spectrophotometric methods.
Overall, the methodology is well structured and designed to enable systematic investigation of the influence of cavitation parameters on fermentation performance.

Chapter 4 presents the experimental results and their interpretation. The initial experiments compared two ultrasonic reactors operating at different frequencies. The results showed that the low-frequency reactor produced stronger cavitation effects and higher hydroxyl radical formation, which resulted in more effective feedstock solubilization.
Subsequent experiments investigated the influence of power density, demonstrating that increasing power density significantly improved the breakdown of complex organic compounds and increased sCOD. Enhanced solubilization was directly correlated with increased production of lactic acid during fermentation. The results demonstrate that power density is a key parameter for making an enhancement in fermentation processes for lactic acid production. Also, feedstock concentration, and ultrasonic pre-treatment duration were investigated.
Further experiments explored combined processes where ultrasound was used together with HCl, NaOH, or hydrogen peroxide. These hybrid approaches significantly increased sCOD and, in some cases, enhanced lactic acid production.
The final part of the chapter focuses on the economic effectiveness of the method. Using current marketprices the analysis compares conventional fermentation with processes that include ultrasonic pre-treatment at different conditions. The results indicate that ultrasonic pre-treatment can significantly increase lactic acid yields compared to the control process, suggesting potential economic benefits despite higher energy input.
Overall, the chapter provides a useful initial assessment of the economic feasibility and scalability of the proposed approach, highlighting that process intensification through cavitation could improve the economic viability of food-waste valorisation technologies.

General conclusions of the thesis and recommendations for future research are given in the *sixth chapter*. The major findings of the dissertation are placed in the context of sustainable waste management and bioresource utilization.
The chapter concludes by highlighting the potential of cavitation-assisted technologies for sustainable conversion of food waste into valuable biochemical products, supporting circular economy principles.

In accordance to the above written report I find the thesis well written with a clear contribution to the science. A significant number of experiments and analyses were performed, many new insights were discovered and explained, also new questions, which are to be dealt with in the future, emerged. It needs to be emphasized that the work goes well beyond the “walls of the laboratory”, hence its contribution to solving real life challenges is even more valuable. Overall, this study provides a strong foundation for adopting advanced pre-treatment techniques in

bioengineering, with the potential to impact future research on renewable energy production and bioproduct synthesis. I am

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for the candidate to defend it.

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