Utilization of *Komagataeibacter xylinus* for Bacterial Cellulose Production from Food Waste: A Sustainable Approach for Reducing Agricultural Pesticide Use

MNATSAKHANYAN M.[1], HOVHANNISYAN S.[2]

[1] Biogen Nanotechnologies, Yerevan State Medical University

[2] Biogen Nanotechnologies, Research Institute of Biology, Yerevan State University.

svetlana.hovannisyan@ysu.am

*corresponding author:

e-mail: manvel.h.mnatsakanyan@gmail.com

Abstract: The widespread and intensive use of chemical fertilizers and pesticides has led to significant environmental and agricultural challenges, severely impacting soil health, reducing biodiversity, and contributing to long-term ecological imbalances. These adverse effects not only threaten agricultural productivity but also pose risks to human health and environmental sustainability. Therefore, developing eco-friendly and sustainable alternatives to conventional agricultural practices has become a global priority. One promising approach to mitigating these negative consequences is the valorization of food waste for the production of high-value biomaterials, particularly bacterial cellulose (BC). However, despite its potential, the high production costs and relatively low yield of BC remain major barriers to its large-scale adoption. This study focuses on addressing these challenges by exploring the production of BC from food waste using the bacterial strain *Komagataeibacter xylinus* under non-sterile conditions. By employing a resource-efficient and cost-effective approach, the research aims to enhance the economic feasibility of BC production while simultaneously contributing to waste valorization and circular economy principles. Furthermore, this work presents an environmentally friendly alternative to reduce the dependence on chemical fertilizers and pesticides, potentially improving soil health and promoting more sustainable agricultural practices.

Keywords: Bacterial cellulose, food waste, *Komagataeibacter xylinus*, agroecology, sustainability

Introduction

In recent decades, increasing the sustainability of agriculture and mitigating its negative environmental impact have become global priorities. The extensive use of chemical fertilizers and pesticides has severely degraded soil quality, contaminated water resources, and disrupted biodiversity(Canton, 2021). Agricultural intensification has exacerbated soil erosion, altered microbial composition, and led to the development of pesticide-resistant pests. Addressing these pressing issues requires innovative and environmentally friendly approaches that minimize chemical inputs, maintain soil health, and support sustainable agricultural practices. One promising solution is bacterial cellulose (BC), a biopolymer synthesized by certain bacteria in the presence of carbon sources. BC has exceptional water-holding capacity, mechanical strength, and biodegradability, making it a valuable material for improving soil structure, enhancing moisture retention, and offering a natural way to control pests(Brown et al., 2015)(Amorim et al., 2022). This study investigates the potential of BC derived from food waste as a sustainable agroecological solution to reduce chemical inputs in agriculture. By repurposing organic waste into a high-value biomaterial, this approach aligns with circular economy principles and offers a practical, scalable strategy for fostering resilient, environmentally sustainable agricultural systems. The findings of this research aim to contribute to the development of novel, nature-based solutions that support soil conservation and reduce the ecological impact of conventional farming practices.

Materials and Methods

2.1. Bacterial strain

The bacterial strain *Komagataeibacter xylinus*, known for its high capacity to synthesize cellulose, was used in the experiments.

2.3. Fermentation conditions

BC synthesis was carried out at 28°C for 14 days under non-sterile, open culture conditions (Mouro et al., 2025).

2.4. Measurements and analysis

- Cellulose thickness: The thickness of the BC layer was measured during the incubation period.
- Reduction in the use of chemical fertilizers.

Based on the results of the literature that BC application reduces the amount of pesticides by up to 60%, it was used as an additive to reduce the use of pesticides.

BC's effectiveness in reducing pesticide use and increasing the microbial activity necessary for soil health was evaluated.

3. Results and Discussion

Our experiments showed that Komagataeibacter xylinus can synthesize high-quality BC under non-sterile conditions using food waste as a carbon source. The average thickness of the BC layer produced was 3 cm (Figure 1) (Skiba et al., 2023). The literature suggests that BC can reduce pesticide use through the following: Plant protection – BC acts as a barrier against pests. Absorption – BC absorbs excess pesticides, preventing soil accumulation. Biodegradation – BC enhances microbial activity, accelerating the degradation of pesticides. These mechanisms can reduce pesticide use by up to 60%, contributing to agricultural sustainability. BC as a soil amendment, an experiment was conducted using barley (Hordeum vulgare) in saline and non-saline soils. The study evaluated the effect of BC on plant growth and soil structure under stress conditions.

Experiment Design

Soil samples were divided into four groups.

1. Saline soil + BC – treated with BC derived from food waste. 2. Saline soil (Control) – No BC added. 3. Non-saline soil + BC – BC applied under normal conditions. 4. Non-saline soil (Control) – No BC added. The results show that saline soil + BC in the variation improved root and shoot biomass, increased plant height, and reduced salt stress symptoms. Non-saline soil + BC also showed the same results, although less pronounced, suggesting that BC enhances soil aggregation and nutrient retention. The high water retention and biodegradability of BC likely mitigated the effects of salinity by improving soil moisture and aeration.

Conclusion: Bacterial cellulose (BC) is a promising, environmentally friendly soil additive that significantly improves soil quality and increases crop resilience, especially in soils that are saline and infertile. Since it is obtained from the processing of food waste, BC is fully compatible with the principles of the circular economy, while addressing both waste management and soil degradation issues. Further research should be aimed at optimizing the production process of bacterial cellulose and expanding its application in different agricultural systems.

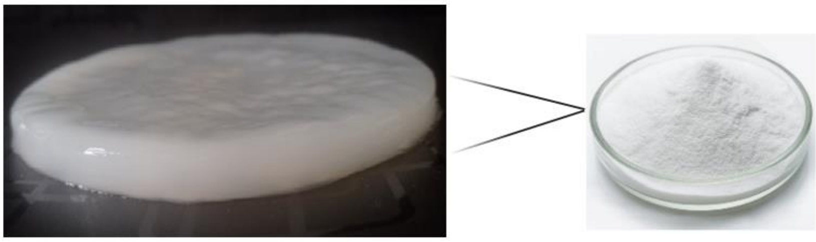

Figure 1. The final-stage BC layer was synthesized by *Komagataeibacter xylinus* after 14 days.

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