Green Technology-Derived Extracts from *Spirulina* for Natural Foot Deodorizing Spray

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Abstract

Foot odor is caused by bacterial growth on the skin, leading to the production of volatile compounds responsible for unpleasant smells. This study investigated the extraction and bioactivity of *Spirulina* using environmentally friendly extraction methods. Three ethanol-based techniques microwaveassisted extraction (MAE), ultrasound-assisted extraction (UAE) and maceration were compared in terms of extraction yield total phenolic content antioxidant activity and antibacterial activity against three bacterial isolates. Extraction methods significantly affected yield ($p < 0.05$) with MAE providing the highest yield. TPC values showed no significant difference among methods. UAE exhibited the strongest antioxidant activity, while MAE demonstrated the highest antibacterial efficiency at a minimum inhibitory concentration (MIC) of 500 µg/mL. These findings support the potential application of green extraction-derived *Spirulina* extracts in the development of a natural skin-friendly foot deodorizing spray.

Introduction

Foot odor is a common hygiene problem caused by sweat accumulation and bacterial growth on the skin. Although commercial deodorants can temporarily reduce odor many contain synthetic chemicals that may cause skin irritation. Currently, there is growing interest in natural and environmentally friendly products. Green extraction technology offers improved efficiency with reduced energy consumption. *Spirulina*, a cyanobacterium rich in phenolic compounds, phycocyanin and chlorophyll, has been reported to exhibit antioxidant and antibacterial activities, suggesting its potential for deodorizing applications. Additionally, cell-free supernatant (CFS) from *Lactobacillus plantarum* demonstrates antimicrobial activity and may enhance the effectiveness of natural extracts.

Objectives

1. To extract bioactive compounds using green extraction methods.
2. To evaluate the antioxidant and antibacterial activities of the extracts.
3. To develop a natural, skin-friendly foot deodorizing spray.

Materials and Method

1. Raw Materials Preparation



Spirulina



Lactobacillus plantarum

Extraction Solvents



- Natural Deep Eutectic Solvent (Choline chloride–Lactic acid)
- 95% (v/v) Ethanol

2. Extraction of *Spirulina* Biomass



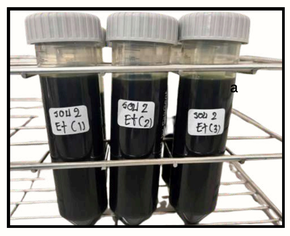
Microwave-Assisted Extraction (MAE)



Ultrasound-Assisted Extraction (UAE)



Maceration



Spirulina extract

3. Bioactivity Evaluation

Antioxidant Assays

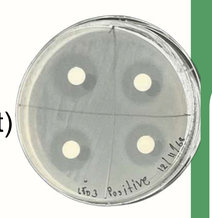
- DPPH radical scavenging assay
- Total Phenolic Content (TPC)



Antibacterial Assays

Againt foot-odor causing bacteria

- Disk diffusion method (DES extract)
- Minimum Inhibitory Concentration (MIC) (Ethanol extract)



4. Spray Formulation and Evaluation (in progress)



Components

- Spirulina extract
- CFS
- Base formulation

- Physical appearance
- pH measurement
- Antibacterial activity (agar well diffusion method)
- Consumer acceptance test



Results

Effect of Extraction Method on %Yield (Ethanol)

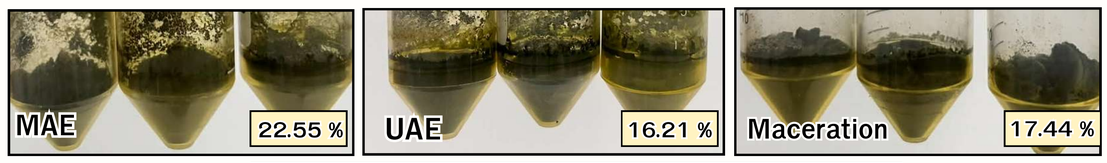


Figure 1. MAE showed the highest extraction yield. (22.55%)

Extraction Method	%Yield (Mean ± SD, n = 3)
Microwave-Assisted Extraction (MAE)	22.55 ± 1.67^{a}
Ultrasound-Assisted Extraction (UAE)	16.21 ± 3.67^{b}
Maceration	17.44 ± 1.14^{ab}

Note: Different superscript letters indicate significant differences ($p < 0.05$) according to one -way ANOVA followed by Tukey's test.

Antioxidant activity of Spirulina extracts

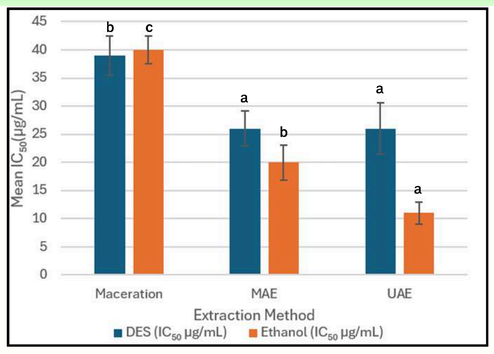


Figure 2. DPPH radical scavenging activity expressed as IC_{50} (µg/mL). UAE (ethanol) showed the strongest antioxidant activity (lowest IC_{50}), followed by MAE, while maceration exhibited the weakest activity ($p < 0.05$). Ethanol extracts were generally more effective than DES extracts. Values represent mean ± SD (n = 3).

Effect of Extraction Method on Antibacterial Activity

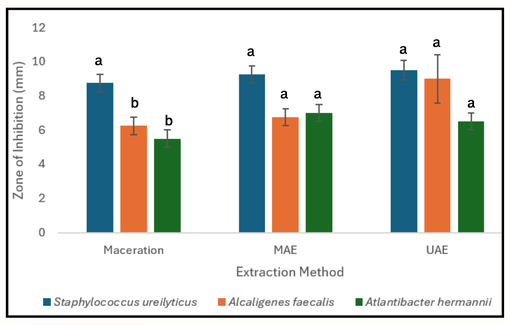
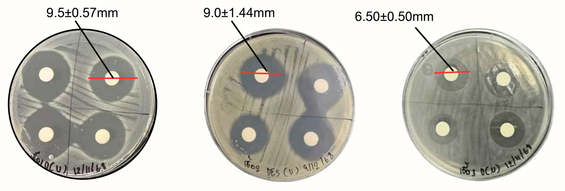


Figure 3. Disk diffusionof DES extracts



Staphylococcus ureilyticus *Alcaligenes faecalis* *Atlantibacter hermannii*

Figure 4. inhibition zones of UAE DES extracts against three bacteria (mean ± SD, n = 3).

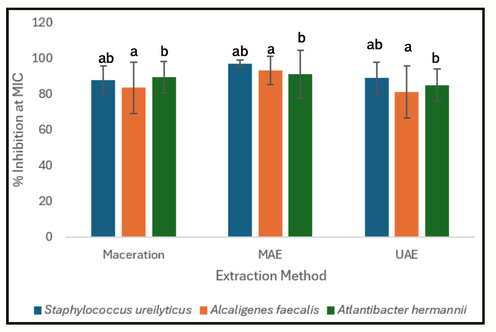


Figure 5 MIC of ethanol extracts

All extraction methods showed identical MIC values (500 µg/mL). However, MAE exhibited slightly higher % inhibition, indicating stronger antibacterial performance despite equal MIC.

Discussion and Conclusion

MAE produced the highest extraction yield, while UAE showed the strongest antioxidant activity (lowest IC_{50}). Compared with Aftari et al. (2017) the present study demonstrated stronger antioxidant activity possibly due to different extraction conditions. MAE and UAE also exhibited stronger antibacterial activity than maceration.

References

- Aftari, A. V., Morales, D., & Hossain, M. B. (2017). Microwave-assisted versus ultrasound-assisted extraction of bioactive compounds from Spirulina platensis: Effects on phenolic content and antioxidant activity. Food Chemistry, 237, 123–130.
- Usharani, G., Srinivasan, G., Sivasakthi, S., & Saranraj, P. (2015). Antimicrobial activity of Spirulina platensis extracts against pathogenic bacteria. International Journal of Current Microbiology and Applied Sciences, 4(1), 374–382.