Towards Sustainable Cleaning Products: Development of a Composite Sustainability Index for Biosurfactants

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Composite Sustainability Assessment highlights the sustainability trade-off between biosurfactants and conventional surfactants

The developed Composite Sustainability Index, integrating environmental, technological, and economic indicators, revealed that biosurfactants have greater sustainability potential than conventional surfactants in cleaning products, particularly regarding environmental performance and renewable resource utilization. However, conventional surfactants remained more competitive in economic indicators, demonstrating that surfactant sustainability strongly depends on the balance between environmental, technological, and economic priorities.

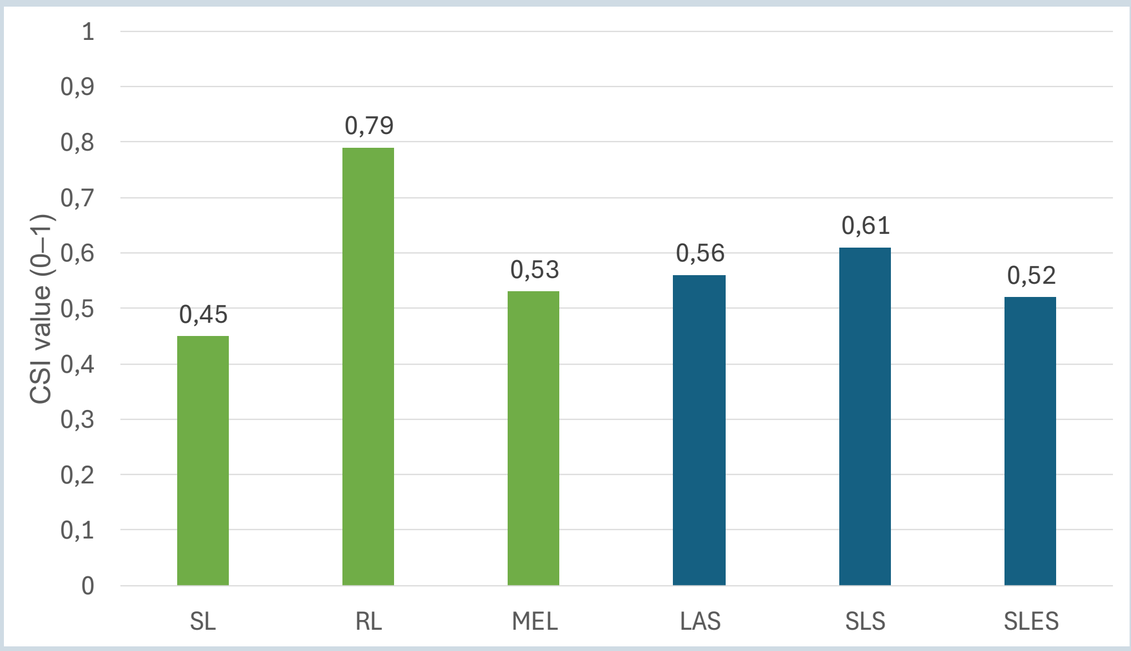

Fig. 2. CSI values in the base scenario using AHP expert weights. SL – sophorolipid; RL – rhamnolipid; MEL – mannosylerythritol lipid; LAS – linear alkylbenzene sulfonate; SLS – sodium lauryl sulfate; SLES – sodium laureth sulfate

Introduction

Surfactants are widely used in cleaning products due to their ability to remove dirt and disperse oils in water. Conventional synthetic surfactants dominate the market because of their low cost and high efficiency; however, they are associated with environmental pollution and petrochemical resource use.

Biodegradable surfactants (biosurfactants) represent a more sustainable alternative due to their biodegradability, lower toxicity, and renewable substrate potential, although their wider application is limited by higher production costs and complex production processes.

This study developed a Composite Sustainability Index (CSI) to compare biodegradable and conventional surfactants in cleaning products based on environmental, technological, and economic indicators identified through bibliometric analysis.

Methodology

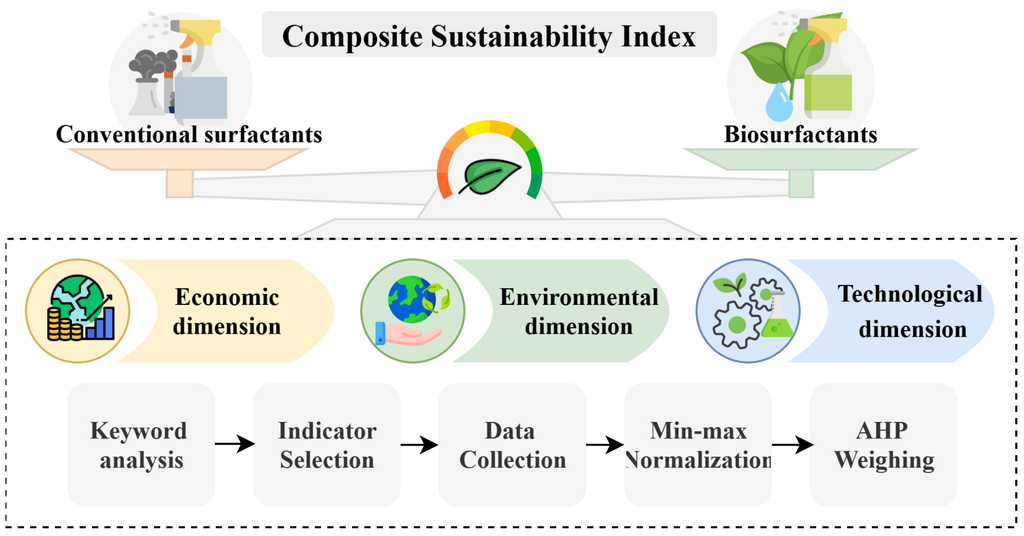

Fig. 1. Workflow of the research

- Bibliometric analysis was used to identify sustainability indicators for environmental, technological, and economic dimensions.
- Indicator values for biosurfactants and conventional surfactants were collected from the literature and normalized using the min–max method.
- Indicator and dimension weights were determined using AHP expert assessment, and a CSI was calculated for each surfactant.
- Sensitivity analysis was then performed to evaluate how changes in dimension weights affected the final ranking.

Results and Discussion

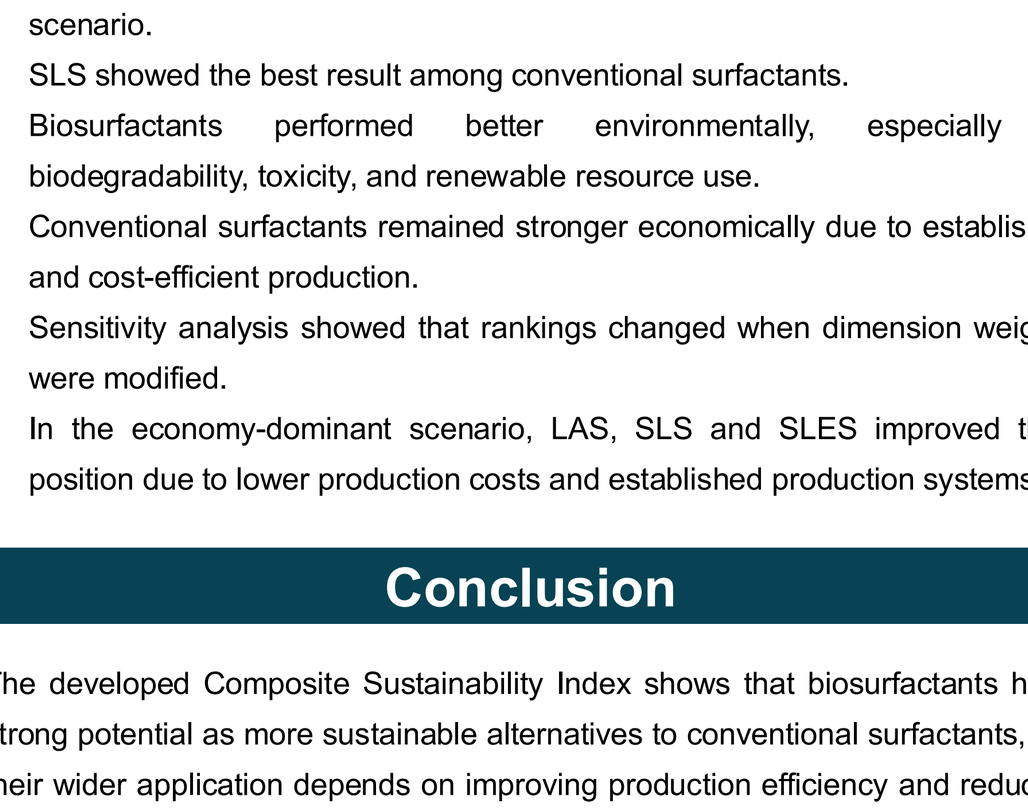

Fig. 3. CSI sensitivity analysis under different weighting scenarios

- RL achieved the highest CSI value among biosurfactants in the base scenario.
- SLS showed the best result among conventional surfactants.
- Biosurfactants performed better environmentally, especially in biodegradability, toxicity, and renewable resource use.
- Conventional surfactants remained stronger economically due to established and cost-efficient production.
- Sensitivity analysis showed that rankings changed when dimension weights were modified.
- In the economy-dominant scenario, LAS, SLS and SLES improved their position due to lower production costs and established production systems.

Conclusion

The developed Composite Sustainability Index shows that biosurfactants have strong potential as more sustainable alternatives to conventional surfactants, but their wider application depends on improving production efficiency and reducing costs.

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