The development of a fossil-free textile chain: the revival of plant-based dyes

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This Wildcard project belongs to the flagship 'textiles' of the investment programme Transformative Bioeconomies

Objective(s)

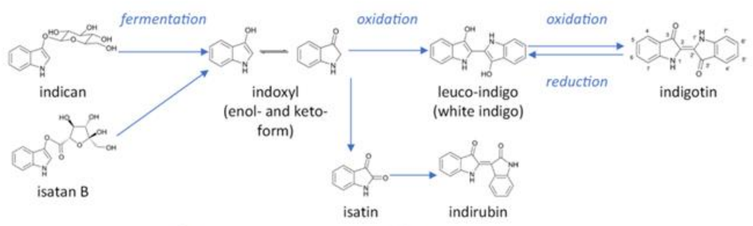
Create awareness of the problems associated with fossil-based dye production and stimulate the implementation of bio-based dyes in the textile industry by comparing fossil-based and bio-based pathways for the production of indigo.

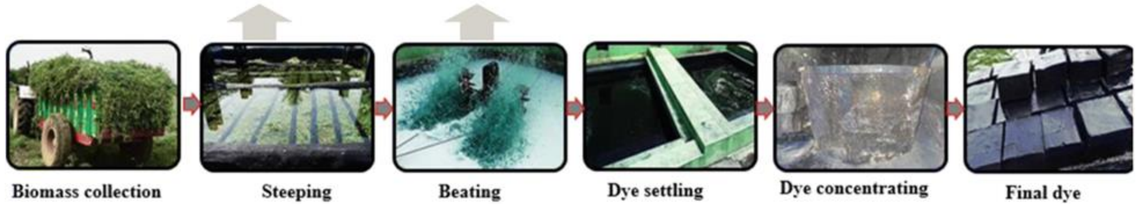
Main (Key) Result

Different pathways for indigo dye production

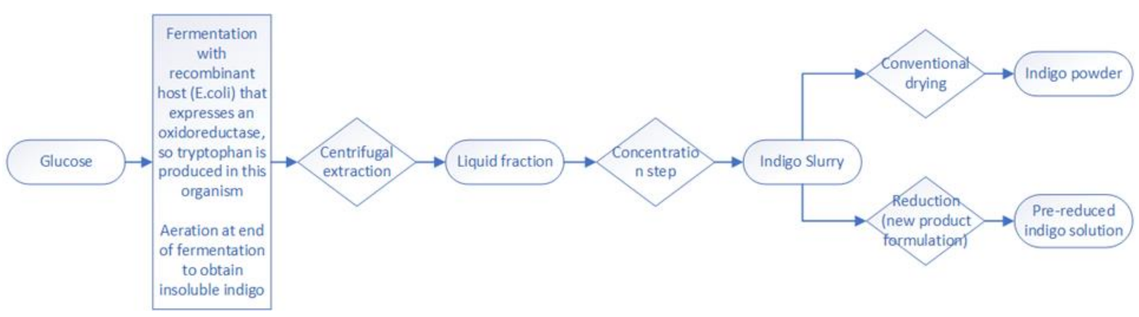
1. Fossil-based synthetic pathway
Pfleger & Heumann route based on Aniline from fossil resources.
Toxic products (e.g. cyanide, N-methylaniline, anthranilic acid)

2. Plant-based production pathway
Cultivation of plants yielding indigo precursors indican and isatan B
Extraction, fermentation, and oxidation.





3. Microbial production pathway
Still in conceptual phase (research is being conducted)
Tryptophan as intermediate



*Comparing fossil- and plant-based indigo dye production**

- Due to limited data availability, it was not possible to make an accurate comparison of the two pathways for indigo production.
- Based on collected information we can make some general statements on the impact of the two pathways:
  - In terms of economic performance, today's synthetic production pathway outcompetes the plant-based production pathway.
  - Both pathways involve using a large quantities of water.
  - Synthetic indigo generally results in higher emission of hazardous chemicals.
  - Plant-based indigo production has CO_2 capturing potential. But in traditional (open-field) production this is very limited.

Opportunities for improving plant-based production of indigo?

Based on the results in this project we see potential for plant-based indigo dye replacing fossil-based synthetic indigo in the textile industry. However, to realize this the plant-based production system should be improved, for example by:

- Selecting crops or varieties adapted to specific cultivation conditions and yielding higher amounts of indigo under these conditions.
- Optimizing cultivation conditions for optimal crop growth and indigo yield. → (partly) indoor cultivation?
- Optimizing of harvest and extraction procedures.
- Valorizing side streams

Lessons learned

- In this wildcard project the collaboration established during the 2022 wildcard project on plant-based dyes was continued.
- A workshop was organized in which WUR experts from other fields participated. This helped to get a better understanding of the different pathways and identify bottlenecks and possible opportunities for improvement.
- The wildcard project triggered the interest of a MSc student plant sciences, who is now writing a thesis on the topic of plant-based production systems for indigo dye.

Readiness

This project initially focused on comparing existing production systems for indigo production and not on developing a new technology.

We did conclude that plant-based production systems for indigo dye should be improved to make a transition from fossil-based synthetic indigo towards plant-based indigo possible. This would require designing a new production system. In first instance, this could be done by combining existing technologies.

Next steps

- Inform stakeholders about the findings of this project and create awareness of the necessity for a transition from fossil-based dyes to bio-based dyes and the potential of plant-based production systems to make this transition possible.
- Developing and testing novel plant-based systems for indigo dye production.

*Microbial production pathway was not included in comparison since there is no record of an established or practically tested large-scale system

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