DEVELOPMENT OF ENVIRONMENTALLY-FRIENDLY DYES

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INTRODUCTION

Textile industry is a large sector of economy, having a global impact. Dying of textiles creates enormous environmental pollution as it involves toxic chemicals such as azodyes or heavy metals[1]. Development of alternatives is of utmost importance for reducing pollution and lowering environmental impact of this globally acting industry branch.

At the Institute of Applied Synthetic Chemistry environmentally-friendly tools for synthesis are explored, such as multi-step biocatalysis or whole-cell systems. Microorganisms applied as biosynthesis factories may provide solutions for difficult synthetic tasks such as the production of complex dye molecules. Bacteria like *Janthinobacterium lividum*[2] or *Serratia marcescens*[3] were reported to produce coloured metabolites that can be used for textile dying. Producing colorants by fermentation instead of petroleum-based chemistry offers substantial improvements in environmental impact by consuming renewable resources and saving energy in the process.

EXPERIMENTS

The aim of the project was to find bacterial dyes (coloured secondary metabolites) and apply them in dying of most commonly used textile materials, e.g. cotton, linen, silk, wool, polyester. Microorganisms came from a project partner's library. Two well-known organisms were selected (*Janthinobacterium lividum* and *Serratia marcescens*) for conducting proof of concept experiments. Dyes produced by these two model organisms are the diindoles violacein/deoxyviolacein (*J. lividum*) and the tripyrrole prodigiosin (*S. marcescens*). Other organisms with unidentified dyes will follow in the same workflow.

Dye-producing microorganisms were cultivated in shaking flasks at TU Vienna and at 1.5-L-reactor scale at BOKU Vienna. Bacterial dyes were separated from biomass and purified according to standard preparative chemistry. Biomass was extracted with ethanol, crude extract dried and solvent removed. Dry crude extract was purified using silica gel flash chromatography. 1H-NMR measurements were made and compared to reference spectra from literature.

Dying of textile materials was performed by dipping textile samples into ethanol solution of crude or purified extracts. The solvent was removed and textiles subjected to a heat fixation step. Quality of dying with violacein/deoxyviolacein was assessed by ISO standard textile tests. ISO standard methods for wash fastness (ISO 105-C06), perspiration fastness (ISO 105-E01 and ISO 105-E04) and light fastness (ISO 105-B02) were applied. Results of these tests may range from 1 (very poor) to 5 (excellent). Light fastness has a different range, from 1 (worst) to 8 (best).

RESULTS AND DISCUSSION

Violacein/deoxyviolacein and prodigiosin could be successfully produced by aerobic fermentation in shaking flask and reactor. Their identity was confirmed by 1H-NMR measurements of purified substances. Classical dip dying method was suited to apply colour to textile materials (Figure 1).

Successfully dyed materials include plant fibres (cotton, linen), animal fibres (silk, wool) and man-made fibres (viscose, polyester, polylactic acid). Results of standardised textile tests for dyed cotton, silk and polylactic acid are displayed in Table 1. Washing fastness and perspiration fastness showed satisfying values. Colour change of dyed sample and staining of white reference textiles (by bleeding) were low, as scores around 4 (good) show. Light fastness still has to be improved; score is around 2 (poor).

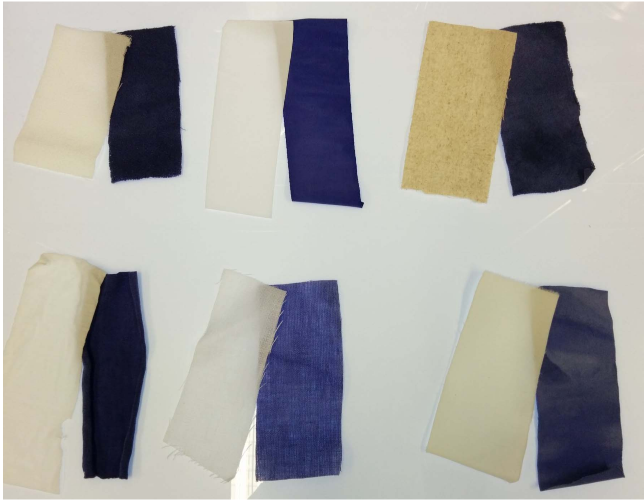

Figure 1: Textiles dyed with violacein.
Top: wool fabric, polyester, cotton-banana-mixed fibre.
Bottom: modal, linen, cotton.

Table 1: Results of ISO textile testing methods

	Wash fastness		**Perspiration fastness**		**Light fastness**
	Colour change	*staining*	*Colour change*	*staining*	
Cotton	3-4	3-4	3-4	3-4	2-3
Silk	3-4	4	3-4	3-4	1-2
PLA	4-5	3	4	4	1-2

CONCLUSION AND OUTLOOK

This proof of concept project showed that secondary metabolites of certain microorganisms are suited to dye different textile materials with good dying characteristics. Isolation and purification of the dyes are work-intensive tasks but may be facilitated by advanced extraction methods. Solid-phase extraction with suitable material may be successful, similar to Domröse et al.[4]. Low light fastness was identified as the most important challenge for the application of dyes from microorganisms. Methods for improving light fastness are already envisioned[5]. Biotechnologically produced dyes may present an environmentally-friendly alternative to synthetic dyes for textile industry. Their production and application may save resources, energy and water to decrease environmental impact of textile industry greatly.

REFERENCES

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