
Conference or Workshop Item:
Houghton, J.A., Tidder, A., Stenton, M. et al. (Accepted: 2024) Coloration in Flow: The Potential of In Situ Anthocyanin Based Coloration of Casein Fibres to Mitigate Environmental Impact of Traditional Dyeing Methods. In: 11th International Workshop on Anthocyanins & Betalains (IWA&B 2024), 17-19 Sep 2024, Leeds, UK. (Unpublished)

Coloration in Flow: The Potential of *In Situ* Anthocyanin Based Coloration of Casein Fibres to Mitigate Environmental Impact of Traditional Dyeing Methods

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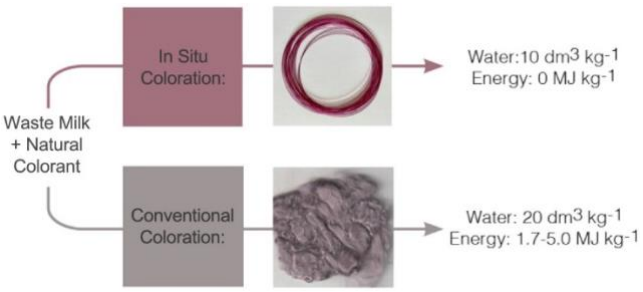
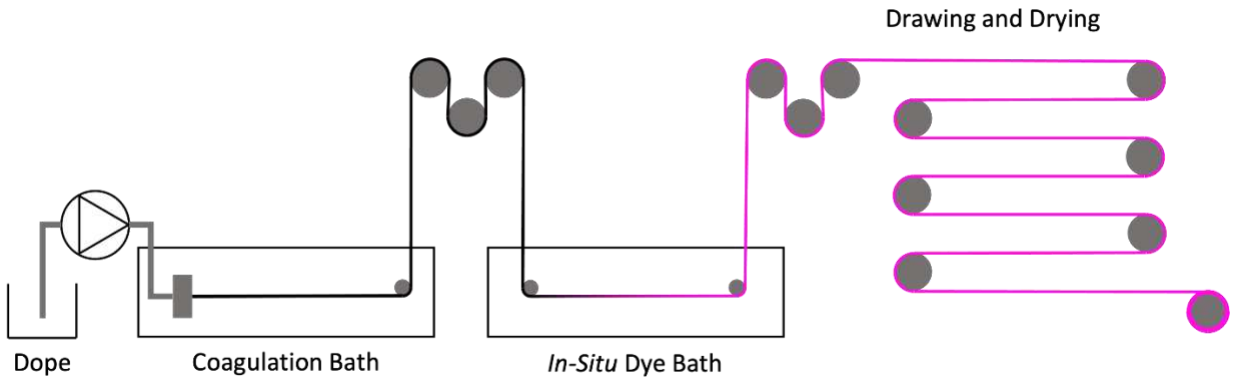
The environmental impact of the textiles and food industries can no longer be ignored, and while combining natural protein-based fibres with natural colorants, each derived from food waste, has the potential to offer increased sustainability based on a circular economy, it fails to address other environmentally detrimental textile production steps, such as colouration. This work explores the potential of a new, novel method for in situ colouration of regenerated protein fibres using an anthocyanin-based natural dye, used within the wet-spinning process, to reduce the environmental impact of the dyeing process. It is observed that similar or improved dye sorption and much improved 3D sustainability metrics (energy and material intensity) can be achieved through dyeing of casein fibres in flow, with higher colour strength ($K/S\lambda_{max}$ = 2.5) observed under milder conditions (room temperature, 10 s) compared to conventional dyeing ($K/S\lambda_{max}$ = 1.0 at 40 °C, 30 min; $K/S\lambda_{max}$ = 2.7 at 80 °C, 30 min). Interestingly, the increased dye penetration observed during the in situ dyeing process also leads to a retention of the pink colouration (and therefore a higher mol fraction of the anthocyanin flavylium cation form) observed when dyeing under acidic conditions, whereas with conventional dyeing a much higher proportion of the quinonoidal base and anionic quinonoidal base forms are present after rinsing with neutral water (seen by a shift towards blue via CIELab colour analysis. It is hypothesised that this is due to the dyeing occurring during the fibre forming, and therefore a certain amount of the dye is 'locked' within the fibre and protected from external pH changes.

Energy intensity calculations show conventional dyeing requires 1.7–5.0 MJ kg^{-1} fibre, depending on the dyeing temperature for experiments performed in this paper and up to 13.4 MJ kg^{-1} fibre for examples in the literature. Using coloration in flow, energy intensity is negligible showcasing a vast improvement in energy-based metrics. The in situ experimental method showed a material intensity of 10.2 compared to 21.2 of the conventional method explored and up to 40.2 for examples in the literature, making the process in flow far less material intensive than conventional coloration methods, with additional potential for further material savings due to the recycling potential of the dyebath, which does not require auxiliary dyeing chemicals. Space time yield calculations showed that the productivity of the proposed method in flow is much higher (182.4 g L^{-1} h^{-1}) compared to the conventional batch process (33.3–60.0 g L^{-1} h^{-1}).




Drawing and Drying
Dope
Coagulation Bath
In-Situ Dye Bath