Analyzing the lightfastness of woad-dyed cotton in batch dyeing, using sustainable reducing agents and chemical finishing with lemon's nutrient

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Literature review: Water pollution is an issue for textile coloration, especially for denim industries, where dyeing industries use toxic synthetic indigo dyes and reducing agents (Prof. R. B. Chavan, n.d.). Hence, using green reducing agents (e.g., glucose, fructose) in cotton dyeing with synthetic vat dyes is a sustainable approach (Saikhao et al., 2018). Glucose and fructose act as good reducing components, and their reducing potential is significant to reduce the vat dyes (Blackburn & Harvey, 2004). Also, applying woad and Indigo (i.e., natural vat dyes) in this coloring process advances this sustainable approach to another stage (Hartl et al., 2015). However, natural colorants are light-sensitive and quickly fade under sunlight (Affat, 2021). Some anti-oxidants can absorb UV radiation and prolong these natural colorants' fading due to light exposure. Cristea and Vilarem received improved lightfastness results by applying several anti-oxidants on dyed fabrics (Cristea & Vilarem, 2006). Using anti-oxidants from natural sources to improve resistance to light, will add advantages, as it will be a sustainable approach. Lemon's nutrient contains several anti-oxidants, such as Vitamin C (ascorbic acid), and Flavonoid (Mamede et al., 2020). So, our study aims to analyze the lightfastness of lemon-treated woad-dyed and Indigo-dyed fabrics in sustainable dyeing (i.e., natural vat dye, and green reducing agents), and to compare the lightfastness ratings among those natural vat-dyed fabrics in a qualitative way with or without lemon-treatment.

Experimental method: We scoured the 100% cotton woven fabric by the following recipe: detergent 1g/l, amount of NaOH for pH 11.5, liquor ratio 1:15, time 45min, temperature 90 degrees C (Khan, 2020). We chose Indigo and Woad dyes to color the fabric and vat the dye solution using the following recipe: indigo or woad 3g/l, NaOH 4.4g/l, liquor ratio 1:20, temperature 50-degree centigrade, time 1 hour, and reducing agent—either thiourea dioxide 4.7g/l or fructose/glucose 42.3g/l separately for each variation. After vatting, we dyed the pretreated cotton fabrics in batch dyeing and the mentioned recipe: liquor ratio 1:20, temperature 30-degree centigrade for 20min; which we rinsed for 2min in cold water, and then washed by using detergent 2g/l in a bath for 10min. After drying, the fabrics were dried at 100-degree centigrade for 2min (Chavan & Chakraborty, 2001) followed by being treated with lemon's (*Citrus limon*) nutrient 10ml juice/100ml, M:L 1:20, 50 temperature for 30min (Wolela, 2020), and dried at 45-degree centigrade for 2min.

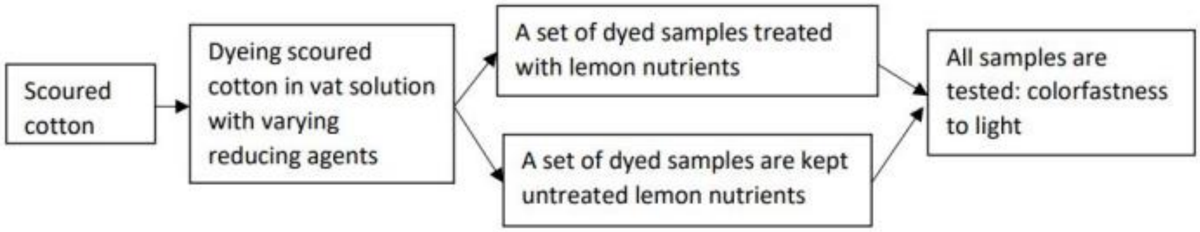
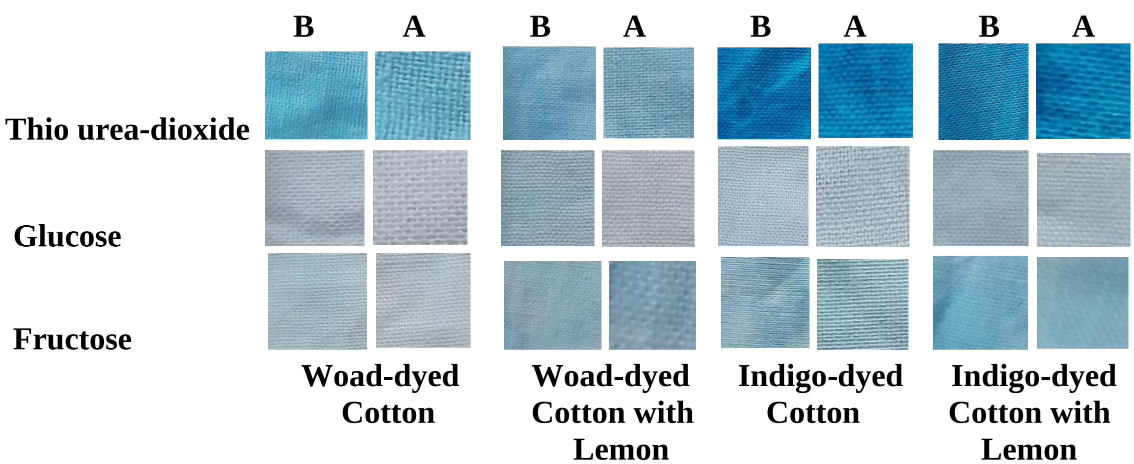


Figure 1: Flow chart for conducting the experiment



*B and *A means dyed fabrics before light fastness testing and after respectively

Figure 2: Woad and Indigo-dyed cotton fabrics with varying reducing agents and treated or untreated lemon's nutrient.

Evaluation of colorfastness to light: AATCC 16.2 was used as an evaluation guide with a custom built light exposure device modeled after Australian test method 2001.4.21:, and samples were mounted in the circular lamp and exposed to continuous light for 72 hours. After completion of the test, AATCC EP-1 Grey Scale for Color Change, using .5 rating gradations, was used for light fastness rating. Cotton colored with woad, using thio-urea dioxide shows good light fastness rating 4, and excellent lightfastness rating 5 can be observed, when treating with lemon. In terms of indigo dyeing with this same reducing agent, indigo-dyed cotton has a rating of 4, and lemon treated has slightly improved rating 4.5. As for glucose, woad-dyed cotton also has a better lightfastness rating than non-treated woad-dyed cotton: rating 3.5 found on only woad-dyed cotton, and rating 3.5 on woad-dyed cotton with lemon treatment. Moving to the standard dye indigo with glucose, untreated and treated with lemon have same rating 4. In case of fructose as a reducing agent, woad-dyed cotton shows moderate light fastness (rating 4); however, when this cotton fabric treated with lemon shows improved rating 4.5. As for indigo-dyed cotton using fructose, light fastness rating shows improvement from 3.5 to 4, when lemon treatment is applied on dyed fabrics.

Conclusion: Using lemon on woad-dyed fabrics, for all cases, better light fastness rating is observed; and this similar improved lightfastness is also found for indigo-dyed cotton fabrics. So, lemon nutrient can be applied on both indigo and woad dyed fabrics for achieving better lightfastness results. As for varying the reducing agents on both the woad-dyed cotton and indigo dyed fabrics, better light fastness can be achieved, using thio urea dioxide and fructose; adding to that, using lemon will also upgrade this result. Overall, considering the colorant issue, both woad and indigo would be the excellent choice with green reducing agents in terms of light fastness issue. In addition, when lemon nutrient is applied on both woad and indigo-dyed fabrics, better light fastness results are found on woad-dyed and indigo-dyed fabrics; except woad-dyed cotton with glucose. From the previous light fastness analysis on woad and indigo-dyed fabrics with varying reducing agents, woad-dyed cotton using fructose and treating with lemon would be an option for sustainable dyeing approach in denim production. However, the woad-dyed cotton with fructose has light depth of color, which might be an issue. On the other hand, indigo-dyed cotton fabrics with both green reducing agents and lemon treatment would be an effective choice, as indigo-dyed cotton has better depth shade color than woad-dyed cotton. So, more research on woad-dyed cotton with fructose, and indigo-dyed cotton with green reducing agents with other dyeing parameters require further advancement in sustainable dyeing.

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