



SUSTAINABLE DYEING OF TEXTILES USING TOMATO WASTE EXTRACTS: INFLUENCE OF FeSO_4 MORDANT ON COLOR QUALITY

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Received: 4 September 2025
Revised: 7 Oktober 2025
Accepted: 8 Oktober 2025
Published: 30 Oktober 2025

PFTJ: Practice of Fashion and
Textile Education Journal
E-ISSN: 2798-5407



Abstract. *The use of tomato waste as an effort to reduce the accumulation of organic waste and environmental pollution due to textile dyeing requires mordant material as a color fixer. This study aims to analyze the effectiveness of iron $\text{Fe}(\text{SO}_4)$ mordant in dyeing cotton fabrics using natural dyes from tomato waste extract. The research was carried out by an experimental method, namely by dyeing textiles in the form of cotton cloth with dyeing techniques using the results of tomato waste extracts with variations in mordant iron concentrations, namely 0%, 2%, 5%, and 7%. The staining results were analyzed using a spectrodensitometer to measure the CIEL*a*b* value and test the color fastness to light. The results showed that 7% iron mordant produced the most intense red-yellow color with an L* value of 64.38, an a* value of 28.7, and a b* value of 51.22. The staining results with a 7% iron mordant had a very good color fade resistance value (scale 4-5), while the sample without a mordant had a very poor fade resistance ($\Delta E=25.19$). Iron mordant $\text{Fe}(\text{SO}_4)$ has been proven to have good effectiveness in producing more intense colors in fabric dyeing results and increasing color fastness in textile dyeing results with tomato waste extract.*

Keywords : *tomato waste, natural dye, iron mordant.*

PRELIMINARY

Indonesia is a major tomato-producing country with high production figures. Tomato production in Indonesia reached 1,143,788 tonnes in 2023 (BPS, 2024). The high production figures have led to problems such as the accumulation of organic waste, which comes from tomatoes that are no longer fit for consumption, rotten tomatoes, and tomato waste from food industry processes such as peels and seeds. On the other hand, the textile industry still uses synthetic dyes in its dyeing processes. The synthetic dyes used in the textile industry have negative impacts such as environmental pollution and health issues (Alegbe & Uthman, 2024). Therefore, developing environmentally friendly textile dyeing alternatives is crucial to mitigate the impact of synthetic dye waste (Khattab 2020). The use of synthetic dyes poses serious environmental problems such as water pollution due to harmful chemical compounds, heavy metals, and volatile organic compounds (VOCs) in synthetic dyes. The development of textile dyeing using environmentally friendly materials is one of the most important things to do to reduce environmental pollution caused by textile waste. The use of tomato waste as a natural dye for textile dyeing can be

explored as an effort to manage organic waste and reduce textile waste that can damage the environment.

Tomatoes contain carotenoid pigments such as lycopene, β -carotene, phytoene, phytofluene, lutein, and zeaxanthin. Lycopene is the most abundant type of carotenoid found in tomatoes, so tomatoes are called the top producer of lycopene (Hasfikasari & Amin, 2024). These carotenoid pigments are responsible for the red-orange colour of tomatoes and will be extracted for use as natural dyes for textile dyeing. Carotenoid pigment extracts from tomatoes have been widely used as colouring agents in cosmetics such as sheet masks and lip products like lip cream (Billi et al., 2024). However, tomato waste extracts as natural textile colouring agents have the drawback of low colourfastness or colour fade resistance compared to synthetic dyes, necessitating the addition of mordant agents for colour fixation (Laksono & Subiyati, 2021). Their application in textiles remains limited. Compared to other natural sources such as leaves, barks, and flowers that have been extensively studied (Wahyuni & Novrita, 2024; Wiji Lestari et al., 2020), the use of tomato waste offers a distinctive advantage by addressing two sustainability issues simultaneously: (1) reducing food waste and (2) providing an eco-friendly dyeing alternative. Mordants function as binding agents between natural dye molecules and fabric fibers, thereby enhancing colourfastness against external factors such as washing, friction, light, water, and sweat. The use of iron mordant in this study was chosen because dyeing with iron mordant tends to result in high colour intensity and good colourfastness (D. S. & Alvin, 2019). Previous studies have shown that iron mordant influences the lightness and darkness of the colour obtained from dyeing fabric using jackfruit leaf extract (Wahyuni & Novrita, 2024). Research conducted by Wiji Lestari et al., (2020) and Sholikhah Anggun Prawati Maratu Sholikhah & Widowati, (2024) shows that the addition of mordant material produces different characteristics of colouring results. However, to date, there has been no research discussing the effectiveness of iron mordant as a colour fixative in textile dyeing using tomato waste extract. This study aims to determine the effectiveness of iron mordant in textile dyeing using natural dyes from tomato waste, such as the intensity of the colour produced, the colourfastness value against light, in textile dyeing using tomato waste extract with the dyeing technique.

RESEARCH METHODS

This study uses an experimental method with a quantitative approach. The types of data used in this study were primary data, namely CIEL*a*b* values measured using a Spectro densitometer, as well as colour fastness values will be obtained after lightfastness testing. The experiment was conducted with the following sample design:

Table 1. Sample Design

Factor Iron Mordantt Concentra	Sample			
	1	2	3	4
	0%	2%	5%	7%

Five repetitions were performed on each sample to obtain a total of 20 samples to analyze the characteristics of textile dyeing results using tomato waste extract with the addition of iron mordant as a fixative agent with different concentrations.

Preparation of Equipment and Materials

The process began with collecting the main raw material, tomato waste, obtained from the local market. Other materials used include ethyl acetate as a solvent for the extraction process, water, cotton fabric, iron sulphate (FeSO₄), and detergent. The equipment used in this study includes an oven, blender, ultrasonic bath, chemical glassware, hotplate, thermometer, drying apparatus, spectrodensitometer, cardboard, and lightfastness chamber.

Extraction Process

The tomato waste was dried using an oven for 48 hours at a heating temperature of 45°C. After the drying process, the tomato waste was ground using a blender. The extraction process was carried out using the Ultrasound-Assisted Extraction (UAE) method with ethyl acetate as the solvent, with a material-to-solvent concentration ratio of 1:5. The extraction process was carried out for 20 minutes at a temperature of 60°C.

Dyeing Process

This process begins with a scoring process, which involved soaking the cotton fabric in a detergent solution for 24 hours to remove dirt from the fabric. The cotton fabric was then boiled for one hour and left to stand for 24 hours to optimise colour absorption. After 24 hours, the fabric is dried using a dryer. The dyeing stage is carried out using the immersion technique, where the dried cotton fabric is immersed in tomato waste extract and heated at 50°C for 60 minutes, then dried. The dried cotton fabric is soaked in a mordant solution for 60 minutes, then rinsed and dried again using a dryer.

Colour Value Measurement Process

The CIEL*a*b* value of the dyeing is measured before testing the colourfastness to light (lightfastness). Measurements are taken using a spectrodensitometer. The CIEL*a*b* colour space has three axes: L* for brightness, a* for the red-green axis, and b* for the blue-yellow axis.

Lightfastness Testing

The test was conducted in accordance with ISO 105-B02:2014 standards regarding methods for testing the lightfastness of textile colours under artificial light (simulation of daylight D65). The dyed cotton fabric test samples were attached to cardboard. The test samples were then exposed to xenon light in a lightfastness chamber for 24 hours. After the testing was completed, the CIEL*a*b* colour values of the test samples were measured to calculate the colour change value (ΔE).

Table 2. Color Change Value Reference (SNI ISO 105-A02:2010)

Scale	Value	Color Change Value (ΔE)	Tolerance	Category
1	Scale 5	0	0.2	Excellent
2	Scale 4-5	0.8	0.2	Excellent
3	Scale 4	1.7	0.3	Good
4	Scale 3-4	2.5	0.35	Fairly Good
5	Scale 3	3.4	0.4	Fair
6	Scale 2-3	4.8	0.5	Poor
7	Scale 2	6.8	0.6	Poor
8	Scale 1-2	9.6	0.7	Bad
9	Scale 1	13.6	1.0	Bad

The colour fastness value is obtained by comparing the colour change value of each sample to the reference or standard value used.

RESULTS AND DISCUSSION

CIEL*a*b* Colour Values

Table 3. shows the results of CIEL*a*b* colour value measurements of cotton fabric dyed with natural dyes extracted from tomato waste with the addition of iron mordant. All test samples had positive CIEL*a*b* values with relatively high CIEL*a*b* values. This indicates that all test samples exhibited a deep red-yellow colour. Based on the data presented in the table, differences in colour characteristics were observed in the dyed cotton fabric as the concentration of iron mordant increased. The highest average L* value, indicating the highest brightness level, was 75.79 in the sample without mordant, while the sample with 7% iron mordant had the lowest average L* value of 64.38. The a* values of all test samples were positive, indicating that tomato waste extract produces red-colour components. The highest average a* value was obtained in the sample with 7% mordant, which was 28.7, while the sample without mordant had the lowest average a* value, which was 20.27. The b* values in all test samples were positive, indicating that tomato waste extract produces yellow colour components in the dyeing results.

Table 3. CIEL*a*b* Color Value Data in Dyeing Results

Concentration	Sample	L*	a*	b*
0%	1	76.63	19.67	45.87
	2	75.45	17.67	46.4
	3	75.45	20.55	45.6
	4	74.93	20.4	45.37
	5	76.49	23.05	43.55
2%	6	74.65	20.91	46.12
	7	72.83	22.17	48.66
	8	73.78	21.22	48.05
	9	73.57	20.78	47.52
	10	73.9	20.69	41.47
5%	11	69.6	24.48	48.88
	12	70.34	23.37	52.57
	13	71.79	23.35	51.02
	14	72.54	20.81	49.61
	15	70.99	21.17	49.47
7%	16	62.51	29.63	54.22
	17	64.4	27.89	53.01
	18	63.88	27.72	48.56
	19	65.65	29.76	48.65
	20	65.49	28.88	51.68

The highest average b* value in the sample with 7% mordant was 51.22, and the lowest average b* value in the sample without mordant was 45.36. The high CIEL*a*b* value in the sample with 7% mordant indicates the effectiveness of the mordant in enhancing the intermolecular bonding between the dye and the fabric fibres, resulting in a more intense dyeing effect on the cotton fabric. This aligns with previous research findings that indicate the use of mordant can produce more intense colours (Gustiani & Novrita, 2024). The iron content in the mordant is highly reactive and easily oxidised, so dyeing with the mordant tends to produce darker colours.

Colour Fastness Test (Lightfastness)

The colour change value is measured after the colour fastness test against light is conducted. The CIEL*a*b* value is measured after the test using a spectrodensitometer.

Table 4. Colour Change Value (ΔE)

No	Iron Mordant Concentration			
	0%	2%	5%	7%
1	27.05	5.58	3.09	1.00
2	26.58	4.28	3.17	1.00
3	25.43	4.67	2.19	0.74
4	22.92	4.71	2.24	0.83
5	23.99	4.64	2.74	0.67
Average	25.19	4.78	2.69	0.85

Based on the colour change values (ΔE) in Table 4, there is a significant difference in the colour stability of the fabric before and after testing the colour fastness to light between samples without mordant and samples with 2%, 5%, and 7% mordant. The average ΔE value for the sample without mordant was 25.19, which falls into the very poor category according to ISO standards. Meanwhile, for the sample with 2% mordant, the average ΔE value decreased significantly to 4.78 on a scale of 2-3, indicating that the test sample has lightfastness in the poor category. The test sample with 5% mordant showed lightfastness on a scale of 3-4 with an average ΔE value of 2.69, indicating fairly good lightfastness. Very good lightfastness was obtained in the test sample with 7% mordant, which had a lightfastness value on a scale of 4-5 with an average ΔE value of 0.85.

An increase in the concentration of iron mordant is inversely proportional to the colour change value, meaning that the higher the concentration of iron mordant, the better the colour fastness value to light in the dyeing of cotton fabric with tomato waste extract. The higher the concentration of tannin mordant, the more bonds between the dye molecules and the fabric fibres are formed, resulting in better colourfastness (Astuti & Subiyati, 2020). The high ΔE value in the sample without mordant indicates that natural dyes have weak bonds with the fabric fibres, making them prone to degradation due to light exposure. This aligns with previous research by Laksono & Subiyati, (2021) and Djamaludin, (2024) showing that dyeing without a mordant results in poorer colourfastness compared to dyeing using a mordant.

CONCLUSION

The dyeing of cotton fabric with natural dyes extracted from tomato waste produces colours with a deep reddish-yellow hue, with colour intensity increasing as the concentration of iron mordant increases. At a mordant concentration of 7%, the lowest L* value, highest a* value, and highest b* value were obtained, indicating a darker and more intense dyeing result. The lightfastness test results showed a significant difference between samples without mordant and those using mordant. Samples without mordant had very poor lightfastness, while samples with 7% mordant had very good lightfastness on a scale of 4–5. Mordant proved effective in improving lightfastness in the dyeing of cotton fabric with natural dye in the form of tomato waste extract.

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