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Conference: 13th AICLST, Kolkata, 6–8 March 2026

Paper reference: TI-99/P

Printed pages: 475–478

Source: *Leather 2050: Challenges & Opportunities*, ILTA (2026)

Leather Dyeing towards Sustainability: The Role of Natural

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Ref. No. TI-99/P

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Abstract

Growing environmental concerns and strict regulation on the use of synthetic dyes have increased interest in eco-friendly and sustainable alternatives for leather processing. Natural dyes derived from plant sources offer a biodegradable, non-toxic, and renewable option for coloration of leather. In the present study, Marigold (Tagetes erecta) flowers were selected as a natural dye source to their high pigment content, mainly carotenoids and flavonoids, which impart yellow to orange shades. The dye was extracted from dried marigold flower petals using an aqueous extraction method under controlled temperatures and time conditions. The extracted dye-solution was applied to chrome tanned and vegetable-tanned leather samples using conventional dyeing techniques adopted in leather processing. To improve dye uptake and fixation, suitable mordants were employed during the dying process. The dyed leather samples were evaluated for dye penetration, brilliancy, depth and shade uniformity. Cross-sectional analysis was carried out to study the depth of dye penetration, while color strength and levelness were assessed by visual and instrumental methods. In addition, fastness properties such wash and rub fastness were examined to determine the suitability of marigold dye for leather applications. The results indicate that marigold dye

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exhibits good penetration and acceptable color uniformity in leather, particularly when appropriate mordanting techniques are used. This study demonstrates the marigold dye can be a promising natural colorant for leather, contributing to sustainable and environmentally friendly leather processing practices.

Keywords: Natural dyes, mordants, tanned leather, eco-friendly, fastness, Tagetes erecta

1. Introduction

Leather processing involves four major steps pretanning, tanning, post-tanning and finishing. Pre-Tanning is the process of cleaning and preparing the material for the next stage, Tanning is the process in which permanent preservation is done, building of functional and bulk properties is achieved through post-tanning while aesthetic feel and look is accomplished by finishing process. Leather is lifestyle material and closely associates with fashion, hence color and texture plays a vital role in leather manufacturing.

The leather industry is under increasing scrutiny due to its reliance on synthetic dyes, which often contain toxic chemicals and generate hazardous effluents. Regulatory frameworks worldwide are tightening, pushing manufacturers toward greener alternatives. Natural dyes,

derived from renewable sources such as plants, insects, and minerals, present a viable solution. They are biodegradable, non-toxic, and align with circular economy. Among plant-based sources, marigold (Tagetes erecta) flowers are particularly promising because of their high pigment content, primarily carotenoids (lutein, zeaxanthin) and flavonoids, which impart vibrant yellow to orange hues. Previous studies have demonstrated their use in textiles, but limited research exists on their application in leather dyeing. This study explores the

potential of marigold dye as an eco-friendly colorant for leather, focusing on its extraction, application, and performance evaluation such as of dye penetration, uniformity, and fastness properties.

2. Materials and Methods

Material

Dried marigold flower petals were chosen as the dye source and the same was procured from M/s Natural Dye house, Tamil Nadu. Alum, Ferrous sulfate, Manganese sulfate, chitosan, tannic acid, and myrobalan are procured from SRL private limited and local manufacturers.

Methods

Dye extraction process

Aqueous extraction was carried out to optimize the temperature and time by varying the temperature from 60–80°C and time from 30 min –2 hours to maximize yield under stirring. The extracts were further characterised using UV-Visible, fluorescence and FTIR spectroscopy and LC-MS/MS. Further, phenolic content, color value, and solubility of the dye was studied.

Dyeing in Leather Processing

Generally, the post tanning is single step process which incorporates filling the substance with synthetic tanning agents to bring uniformity, colouring of leather by dyeing and fibre lubrication by fatliquoring operation. Though post tanning is single step however the depth of the colour could be altered through the dyeing process by single or double bath process where post tanning is carried out

without dyeing and colouring would be carried out in the second bath. The mordant addition varied in different concentration of mordant, order of addition (before, along and after dye) has been studied and optimised the conditions for the mordant. Further, the dye percentage also optimised. To evaluate the experimental and control leathers on dyeing, wet & dry rub fastness, light fastness, wash fastness, colour values, microscopical and visual examination for the depth of dyeing and uniformity.

3. Results and Discussion

The dye extraction process parameters have been optimized as 70 °C and 1 hour under aqueous condition for the better yield. Followed by, the extracted dyes were used to dye the chrome tanned suede leather. Enhanced penetration has been observed on the mordant treated leathers than the non-mordant leathers. Mordant-treated crust leather exhibited improved brilliancy and shade uniformity compared to non-mordanted crust leather. Alum mordant produced brighter yellow hues, while ferrous sulfate shifted towards deeper orange-brown tones and manganese sulfate shifted the tone towards green. Similarly, bio-mordants also shifted the tone towards orange/green.

Inorganic mordants improved the wash fastness than the bio mordants. Whereas moderate resistance was observed without mordants. Wet and dry rub fastness of the mordanted crust samples shows resistance to transfer color (with minimal color transfer in mordanted crust samples) than the non-mordanted leather.

4. Conclusion

This study demonstrates that marigold (Tagetes erecta) dye can serve as a promising natural colorant for leather processing with the improved penetration, uniformity, and fastness properties in the presence of organic and inorganic modrants. Its application supports sustainable and environmentally friendly practices in the leather industry, aligning with global efforts to reduce chemical pollution and promote eco-conscious manufacturing.

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