From waste to wear: Transforming Coffee Grounds into Sustainable Textile Dye for cotton/hemp fabric

Farisa.M[1], A.Ashlin Prathisha[2], V.Abisha Shalini[3], Dr.K.S Saravanya[4]
[1 2 3] *III B.Sc Fashion Technology, Arunachala Arts and Science (Women) College ,*
[4] *Head of the Department Fashion Technology, Arunachala Arts and Science (Women) College*

***Abstract*—This study explores the potential of natural dyeing using coffee grounds on cotton/hemp blend fabric, promoting sustainable and eco-friendly coloration in the textile industry. Spent coffee grounds, a waste material, offer a unique opportunity for upcycling, reducing environmental impact, and creating a circular economy. By utilizing coffee grounds as a natural dye, this research aims to develop an innovative, environmentally friendly, and socially responsible textile dyeing process. This approach also enables a shift away from synthetic dyes, which can harm the environment, and instead, fosters a more sustainable and eco-friendly textile production. The use of cotton/hemp blend fabric, dyed with coffee grounds, yields a sustainable material for aesthetic end-products, providing a unique combination of style, comfort, and environmental responsibility. The findings of this study will contribute to the development of sustainable textile practices, offering a novel and appealing eco-friendly material solution for the textile industry.**

***Index Terms*—Coffee Grounds Dye, Cotton/Hemp, Natural Dye, Sustainable Textile Dyeing.**

I.INTRODUCTION

The word "textile" was originally used to define a woven fabric and the processes involved in weaving. Textile refers to any material made of interlacing fibers or Yarns. Textiles are formed by weaving, knitting, crocheting, knotting, or pressing fibers together (felt). [Jerry. L, (2022)].

The textile Industry primarily comprises the production of yarn, fabric and finished goods. Textile manufacturers procure or produce raw fibers and transform them into yarn, thread or webbing; they convert the yarn into fabric; they colour the yarn or fabric and finish them to have special attributes; finally, they use the fabric to construct a variety of end-use products. [Koushik CV and Prakash C, (2018)].

Industrial production and utilization of synthetic dyestuffs for textile dyeing have consequently become a gigantic industry today. Synthetic dyestuffs have introduced a broad range of colorfastness and bright hues. Nonetheless, their toxic character has become a reason of serious concern to the environment [Tawfik A Khattab,et.al.(2020)].

Spent coffee is the by-product of coffee brewing and amounted to 96,000 tons worldwide in 2015.The disposal of spent coffee in landfills or by incineration has negative effects on the environment. Spent coffee contains high levels of organic com-

Pounds that exert multiple biological effects, including antioxidant, antimicrobial, and other activities [Eunmi Koh,et.al.(2017)].This research examines the dyeing of cotton/hemp blend fabric using coffee grounds as a sustainable textile dyeing method. Specifically, this study investigates the dyeing process and sustainability of coffee grounds – dyed cotton/hemp blend fabric, highlighting it's potential as an eco-friendly alternative to traditional textile dyeing method.

II. REVIEW OF LITERATURE

2.1 NATURAL DYES:

Natural dyes have been used since ancient times of dyeing of body, food, walls of caves, textile, leather and objects of Daily use. A large number of plant, animal, insect or mineral sources have been identified for Extraction of dyes and pigments. The art of dyeing is as old as human civilisation. Dyed Textiles found during archaeological excavations at different places all over the world provide evidence to the practice of dyeing in ancient civilisations [Hana Křížová (2015)]. However, recently there has been revival of the growing interest on the application of natural dyes1,2

on natural fibres due to worldwide environmental consciousness.

Natural dyes, when used by themselves have many limitations of fastness and brilliancy of shade. However, when used along with metallic mordants they produce bright and fast colours. Therefore, instead of using unsustainable technology for producing colours one can use mild chemistry to achieve almost similar results. Natural dyes can produce special aesthetic qualities, which, combined with the ethical significance of a product that is environmentally friendly, gives added value to textile production as craftwork and as an industry [R.Kanchana,et.al.(2013)].

2.2 COFFEE GROUNDS AS SUSTAINABLE NATURAL DYE AGENTS:

Coffee grounds are left over after a person brews coffee. They are usually considered a waste product but can be useful. A person can get coffee grounds from brewing coffee at home or from coffee shops that are giving them away [Lois Zoppi,et.al.(2021)].

Approximately 7.4 million tons of coffee is produced each year and it is the most consumed luxury table beverage in the world. Coffee is also the second most traded commodity by volume after petroleum, indicating that the economic impact of coffee is substantial. Since coffee consumption has increased so dramatically, the amount of spent coffee grounds produced after brewing coffee cannot be ignored. Spent coffee grounds are not just food garbage; they are also a major cause of environmental pollution since they produce a large amount of methane gas, which has an adverse effect on global warming. However, spent coffee grounds still contain many functional components,such as phenolic compounds, terpenes, caffeine, and Maillard reaction products [Jihyun Bae,et.al.(2019)].Therefore, used coffee grounds for natural dyes can be a feasible commercial alternative to synthetic dyes in textile and dyeing industries [Changhyun Nam,et.al.(2019)].

2.3 COTTON/HEMP FABRIC:

Cotton is the most popular natural fiber used in apparel industry world over. Although cotton is cultivated in approximately 2.4% of the world's arable land, it accounts for 24% of the world's insecticide market.

FABRIC	WEIGHT	WARP COUNT	WEFT COUNT
Cotton/Hemp	400g	60's Cotton	24's Hemp

Industrial hemp is considered as the most sustainable raw material as substitute of cotton in textile industry. [Meenakshi Ahirwar,et.al.(2021)].

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Industrial hemp is a bast fibre with great potential of diverse end uses. It naturally grows on the roadside and waste lands in Uttarakhand and it is easily available in abundance. The hemp fiber has been known to have unique characteristics compared to other fibers[Anupriya Singh,et.al.(2016)].

Cotton blends with hemp fibre in three different proportion to check the yarn spinnability [K. Ramsanthosh1, et.al. (2021)]. Cotton is the most widely used natural fibre due to its comfort properties representing about 90% of all natural fibres and being extensively utilized in apparel, home furnishings, and industrial applications. However, other fibres like Hemp are also used to meet the increasing demand [Indu Gupta,et.al.(2024)].

III. METHODOLOGY

- FABRIC:

A plain-woven fabric made from a Cotton/Hemp blend was sourced from the Ayurvastra Textile Research and Training Centre. The fabric's properties were measured, and the results are summarized in the table below:

TABLE 1. The properties of the cotton/hemp fabric used in the dyeing process. Properties were measured before dyeing process.

- UCG PREPARATION:

Used Coffee Grounds (UCG) were collected from Chai Café, Nagercoil, Tamilnadu. The UCG was dried under sunlight for 24 hours, then 3 kg was boiled in 30 litres of water for 1 hour to extract the natural dye, which was set aside for further processing.

- DYEING PROCESS:

A lab dip process was conducted to determine the optimal mordant for Cotton/Hemp fabric. The results showed that iron water yielded the most satisfactory color outcome, confirming it as the optimal mordant.

- RFD PROCESS (READY FOR DYEING) : The RFD process prepares fabrics for optimal dye absorption by treating them in a soap nut and wood ash solution. In this study, 150g soap nut and 300g wood ash were boiled in 22L water for 1 hour. The fabric was then immersed for 30 minutes, rinsed 2-3 times, and dried, making it suitable for dyeing.
- PRE MORDANTING-PROCESS:

After RFD treatment, the fabric undergoes pre-mordanting to enhance dye-binding properties. The fabric is immersed in a solution of 125ml iron water diluted in 20L water for 1 hour, then removed and dried. This prepares the fabric for the subsequent colouration process.

- COLOURATION OF FABRIC:

The colouration process involves boiling the pre-extracted dye for 1 hour to release additional colourant. The fabric is then immersed in the dye solution for 1.5 hours, allowing the dye to penetrate and bind. After dyeing, the fabric is set aside for subsequent mordanting to enhance colourfastness and depth.

- COLOUR EVALUATION:

The final stage of the dyeing process involves colour evaluation, assessing the fabric's colour fastness to laundering and crocking. This critical step determines the fabric's resistance to colour loss or bleeding when exposed to water and friction, providing valuable insights into its colour fastness properties.

a) COLOUR FASTNESS TO WASHING:

The UCG-dyed fabric showed excellent colour fastness to washing, with no discernible colour bleeding. This indicates effective dye fixation, ensuring colour stability and durability, making the fabric suitable for applications requiring minimal colour transfer. (fig 1).

FIG:1 There was no colour bleed in the washing process.

b) COLOUR FASTNESS TO CROCKING: (Dry and Wet):

The colour fastness to crocking of the UCG-dyed fabric was evaluated using a Crock Meter. The results showed no discernible colour transfer, demonstrating excellent colour fastness to crocking. This indicates that the fabric's colour will remain stable even with repeated rubbing or abrasion. (fig 2,3).

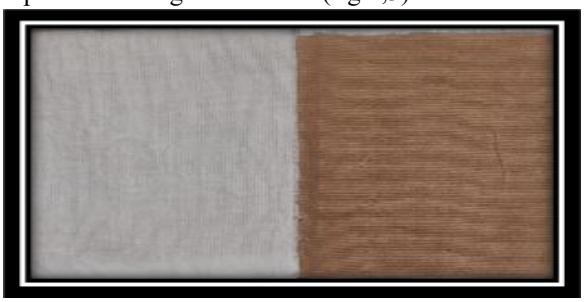


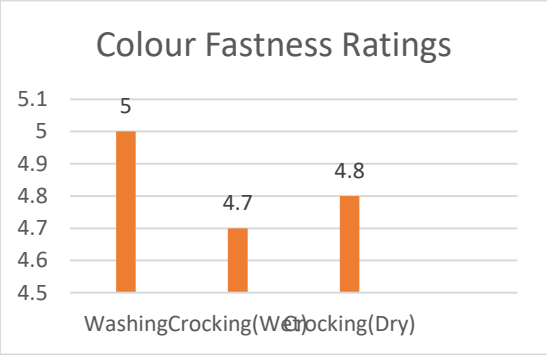
FIG: 2 There was no colour bleed in the wet crocking test

FIG: 3 There was no colour bleed in the wet crocking test

IV. RESULT AND DISCUSSION

The findings of this study demonstrate that utilizing UCG dye yields a fabric with satisfactory colourfastness, while also providing an eco-friendly alternative to traditional dyeing methods. In contrast to synthetic dyes commonly employed in the textile

industry, natural dyes derived from waste raw materials offer a sustainable solution. This approach not only reduces the environmental impact of landfill waste but also enables the creation of unique, aesthetically pleasing garments. The compositional profile of UCG dye proves advantageous in the dyeing process, with no detrimental effects on the fabric. This sustainable textile dyeing method serves as a exemplary model, particularly when applied to natural fibers such as Cotton/hemp blend fabric. The adoption of this eco-friendly approach by the textile industry can significantly mitigate environmental damage and promote a more sustainable future.



V. CONCLUSION

This study demonstrates the feasibility and effectiveness of utilizing Used Coffee Grounds (UCG) dye for natural dyeing of cotton/hemp fabric. The eco-friendly process employed in this study showcases a sustainable approach to textile dyeing, mitigating environmental harm and promoting waste reduction. The colour evaluation tests conducted revealed excellent colour fastness properties, with no discernible colour transfer from the dyed to undyed fabric. This study highlights the potential of repurposing waste materials, such as coffee grounds, as natural dyes, thereby reducing the environmental impact of chemical-based dyeing processes. The findings of this research contribute to the development of sustainable textile practices, offering a viable alternative to conventional dyeing methods and promoting environmentally responsible textile production.

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