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FROM LITTER TO RESOURCE: CIRCULAR UTILIZATION OF CIGARETTE FILTER WASTE IN SUSTAINABLE TEXTILE DYEING

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Abstract
There has been a rapid increase in the use of synthetic textile colorants in textile industries all over the world, which discharge toxic waste into the environment. These wastes pose significant threats to humans. The toxic waste affects not only human life directly, but also the ecosystem. In addition to synthetic industrial waste, waste from cigarettes that people consume on a daily basis also affects the environment greatly. Throwing away cigarette butts after cigarette consumption hugely affects our environment, and so as living beings. Cellulose acetate material that makes these cigarette butts also contains toxic materials such as nicotine and other heavy metals. Thus, this study explores the possibility of incorporating textile coloration with dyeing source from consumed cigarette butts waste. The study focused on using 100% cotton textile substrate for dyeing with the extracted colorants to produce wearable products. The colorants were extracted at temperatures of 100-120° Celsius. The extracted dye was used to dye the chosen textile substrate at different temperatures. The produced colored fabrics were evaluated based on ISO testing standards for color fastness to washing, rubbing fastness, and color strength (K/S) and washing fastness. The results revealed a sustainable approach to dye extraction and textile coloration with adequate outcomes. Outcomes at a higher temperature range were reasonably acceptable in terms of color strength and fastness properties. The findings of this study can provide an alternative approach to managing the waste from consumed cigarette butts and also offer a sustainable approach to recycling waste in textile processes for wearable products.

1. INTRODUCTION

Synthetic dyes are widely used in textile dyeing, and the world production is estimated to be more than 700,000 tons per year [1, 2]. Most of the synthetic dyes are preferred over natural dyes for fastness to color, a large palette of shades, and cost-effectiveness. But, during dyeing, 10-15% of the dyes are wasted and discharged to wastewater streams as effluent [3]. Synthetic dyes, especially azo dyes, are non-biodegradable and release toxic aromatic amines on biodegradation, which are of high health risk to human beings and cause carcinogenic effects [4, 5]. The untreated dye effluent also increases water pollution, reduces light penetration, and causes a deficiency of oxygen in the aquatic ecosystem [6]. Moreover, the natural dye pollutants are complex and resistant to degradation, and hence cannot be completely removed by the conventional wastewater treatment plants [7]. Therefore, there is an increasing demand to find sustainable and environmentally friendly substitutes, such as natural dyes obtained from renewable resources.

Consumption of tobacco generates a huge amount of waste, such as cigarette butts, tobacco waste during consumption, and processing waste generated from the manufacturing of tobacco products. Every year, approximately 4.5 trillion cigarette filters are discarded and are commonly referred to as the most common waste item found globally [8, 9]. The major problem with these disposed items is that they are mainly composed of cellulose acetate, which is non-biodegradable and persists in the environment for many years, even decades [8, 10]. Some toxic compounds, including nicotine, heavy metals, and PAHs, also leach out from discarded tobacco products that could enter the environment through various routes and adversely affect the ecosystem and human health [11-13].

In addition to soil contamination and toxicity to water, incorrect disposal of waste from tobacco can also affect the health of animals, especially aquatic species, which can ingest microfibers or be attacked by toxins leached from garbage [13-15]. To transform this garbage into useful products for man and reduce his environmental responsibility, appropriate methods for its valorization are needed. As a garbage to be used as a source of natural colors, garbage has long been discussed in the light of the principles of the circular economy. Within recent studies [16-19], the use of industrial and agricultural waste as a colorant has also been investigated. One of the underutilized garbage to be used as a dye is tobacco waste, which has a high content of organic matter, such as nicotine, polyphenols, alkaloids, and pigments [20-22]. The residues of this garbage contain nitrogenous compounds and brownish-yellow pigments, which make them suitable as an alternative for dyeing fabrics. Preliminary studies have demonstrated that the extracts obtained from tobacco waste can provide cotton, wool, and silk fabrics with earthy tones, with moderate fastness, moderate to light, and good dye uptake [23, 24]. The extracts from tobacco also have antibacterial and UV-protective activities that provide fabrics with functional finishes [25]. In addition to the coloring function, the dual function of these dyes increases their value offer.

Many techniques have been researched and developed in recycling and reusing the ecological damage of cigarettes. Some of the already studied approaches are the biological degradation of cigarette butts and also the incorporation of these degraded objects in construction materials such as asphalt and bricks [26-29]. Additionally, studies have been conducted concerning the detoxification of cigarette waste using biological methods, in which the degrading action of fungi has demonstrated considerable results [30, 31]. However, when approaching the reuse of cigarette waste in textile productions, it is possible to notice that there is still a great gap to be filled, especially regarding uses in which cigarette waste is utilized as a coloration source. This approach to reusing waste from cigarettes is in line with the principles of the circular economy and of sustainable development, since it transforms a series of waste materials into products of greater value. Cigarettes are predominantly composed of cellulose acetate, and cellulose-based fibers are commonly used in the production of textile fabrics. The molecular structure of these fibers can interact with dye molecules, and the remaining chemicals from the residues of cigarette filters that are extracted when disposed of in a controlled manner can also participate in the coloration process.

This research aims to investigate the feasibility of using cigarette butt waste as a sustainable source of colour for textile applications. The study explores the process of extracting colour chemicals from spent butt material and applying them to mercerised cotton textile. The performance of the extracted dye was evaluated for suitability and durability for practical use through measurement of important textile parameters, including color strength (K/S values), rubbing fastness, washing fastness, and light fastness. The paper presents a 'waste-to-resource' approach with potential for sustainable use in textile industry processing for practical industrial application. Synthetic dyes are major pollutants of the environment, and large amounts of butts are produced globally every year. This study highlights a new approach to sustainable textile application and opens up new avenues of potential for the reuse of waste butts. To date, there is little research into the use of cigarette butts in textile colouring. More research is needed into the sustainable use of cigarette butt waste in the textile industry.

Approaches to dye extraction from plant waste have included processes such as aqueous extraction, solvent extraction (using ethanol and methanol), ultrasonic-assisted extraction, and microwave-assisted extraction [32, 33]. Of these, approaches based on the use of environmentally friendly extraction solvents, namely ethanol/water mixtures suitable for industrial scale, have received most attention, especially with regard to processes yielding high amounts of dye with good colour intensity. These processes have been shown to offer a 'green' approach to the extraction of valuable molecules from a wide range of non-conventional sources, including tobacco waste.

The growing environmental awareness and legislation banning hazardous chemicals have drawn attention to natural colorants, which are the best alternatives to synthetic colorants, as they are generally non-toxic and biodegradable in nature and sourced from renewable resources [34]. Although these natural colorants have a limited shade range and inferior colour fastness, these limitations can be overcome by using appropriate mordants and dyeing conditions [35]. Dyes derived from biowastes have been shown to have improved fixation and colour stability when appropriate pre-treatment methods are used.

Despite the numerous studies conducted on bio-waste material utilization, tobacco waste has not been fully explored. However, bio-waste tobacco applications are not unknown. It can be utilized as a dye for dyeing of cellulosic and protein-based fibers [20, 21, 23], with obtained results comparable to synthetic dyes, which promote its use in sustainable textile practices. The use of tobacco waste as a dye source is still an underresearched area, and the interest in it has increased in recent years due to the growing demand for natural dyes and waste management. Most studies regarding tobacco waste have focused on environmental hazards, as well as potential applications in the field of energy (bio-energy) and materials (adsorption materials, bio-materials for energy storage). This study attempts to bridge the knowledge gap by evaluating the extraction of colors from tobacco waste materials and testing their dyeing effectiveness on various textile materials with the aim of sustainable textile processing and waste management.

Currently, there are limited publications on the use of waste materials such as cigarette butts for the production of fabric dye, despite an increasing interest in the use of alternative and sustainable practices within textile production. The processes of textile dyeing and the disposal of used cigarettes have well-documented environmental issues, but little has been researched into potential interactions between the two. This work explores the possibility of using cigarette butts as a sustainable source of natural fabric dye.

2. Research Methodology

2.1 Materials selection

For wearable textile applications, cotton textiles, especially in their 100% cotton content form, are frequently chosen because of their physiological comfort, safety, and functional performance [36-39]. From the perspective of material science, cotton is a natural cellulosic fiber (cellulose ~90–95%), with a hydrophilic structure full of hydroxyl (–OH) groups [40]. Given their considerable moisture absorption (usually 7–8% moisture recovery under normal circumstances), cotton textiles can effectively absorb perspiration and facilitate the transfer of moisture vapor [41]. Since aforementioned textiles promote enhanced moisture transportation, clothing made entirely of cotton offers excellent thermo-physiological comfort, particularly in warm and humid situations [42].

Two further significant advantages of cotton fabrics are their breathability and air permeability [43]. The morphology and yarn structure of cotton fibers allow for adequate air circulation, preventing heat buildup and maintaining a healthy microclimate between the skin and the

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garment. As a result, cotton is regarded as a suitable material for daily wear [44].
100% causticized or mercerized cotton fabric samples prepared in identical dimensions of one square inch to maintain consistency throughout the dyeing process have been chosen as test specimens to be dyed with colorants extracted from trashed tobacco butts. The superior dye uptake qualities of mercerized cotton [45], which come from structural changes made during the mercerization process, are the reason it was chosen. Better interaction between the extracted dye and the fabric is made possible in this way.

2.2 Dye extraction, sample preparation, and characterization

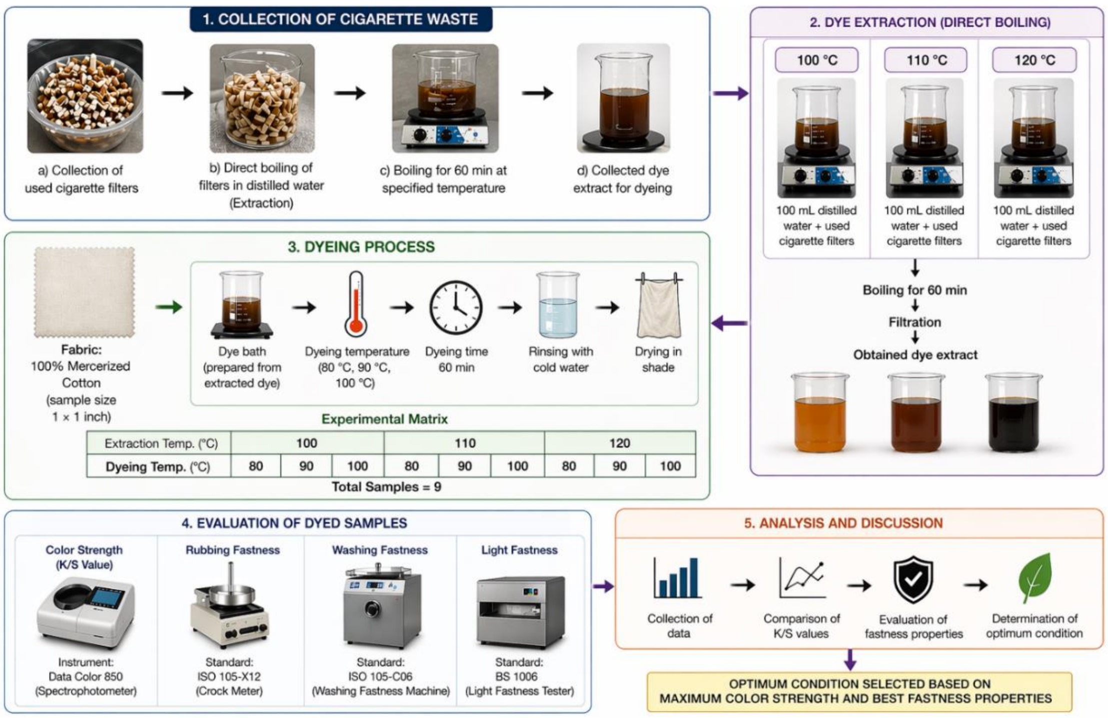

Figure 2-1. Dye Extraction process from trashed cigarette butts

Figure 2-1 demonstrates a full experimental process for extracting color from cigarette filter waste, deploying it to chosen textile test specimens, and then conducting a methodical performance assessment. It clearly illustrates a framework for sustainable textile processing since it successfully combines waste collection, dye extraction, fabric dyeing, testing, and optimization.
This illustration demonstrates the collection and processing of cigarette waste. Simple and economical extraction of natural colorants from empty cigarette filters involves placing the filters in a suitable solvent and boiling for 60 minutes, at which point the colorant compounds are dissolved into the solution and can be used to dye various materials, such as textiles, after an hour.
The effect of temperature on dye extraction was also tested at 100°C, 110°C, and 120°C. An apparent dye solution was made by boiling and filtering away a predetermined ratio (for example, 100 mL of distilled water plus used filters). The extracted dye was a darker colour than previous extracts and showed the effect of extraction conditions on dye yield and quality.
The procedures to dye 100% mercerized cotton fabric are detailed in Section 3. The extracted solution was utilized to formulate the dye bath, and dyeing was performed for 60 minutes at three different temperatures, 80°C, 90°C, and 100°C.

After dyeing, the treated samples were rinsed with cold water and allowed to air dry in the shade.

Table 2-1. Dye Extraction Parameters

Extraction Batch	Extraction Temperature (°C)	Dye Solutions Prepared	Sample Quantity (g)	Distilled Water (mL)	Time (minutes)
Batch 1	100	3	5	100	60
Batch 2	110	3	5	100	60
Batch 3	120	3	5	100	60

Table 2-2. Dyeing Parameters

Sample	Dye Extraction Temperature (°C)	Dyeing Temperature (°C)	Sample Quantity (g)	Time (minutes)
Sample 1	100	80	5	60
Sample 2	100	90	5	60
Sample 3	100	100	5	60
Sample 4	110	80	5	60
Sample 5	110	90	5	60
Sample 6	110	100	5	60
Sample 7	120	80	5	60
Sample 8	120	90	5	60
Sample 9	120	100	5	60

Results tabulated in

Table **2-1** highlights the dye extraction parameters considered during the extraction process. Some controlled variations in the temperature range during the extraction process were kept, while similar samples were kept of the same quantity, solvent volume, and processing time. Likewise,

Table **2-2** tabulates the dyeing process parameters for different samples that demonstrate the systematic process conditions for dye extraction and temperature ranges. These systematic changes in process parameters help to understand and evaluate their effect on dye uptake and performance. It represents not just the technical approach but also the more general objective of eco-friendly textile innovation and waste valorization.

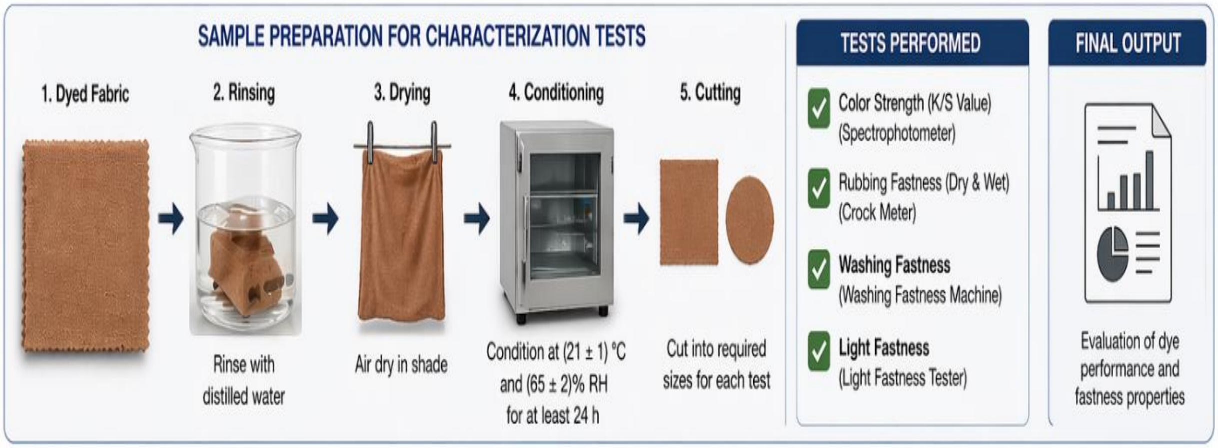

Figure 2-2. Sample preparation and characterization techniques

Figure 2-2. Sample preparation and characterization techniquesFigure 2-2 outlines the standardized testing and sample preparation procedures used before assessing colored textile products. It emphasizes how consistent testing protocols and carefully managed pre-treatment are necessary to produce accurate and repeatable textile characterization results.

The evaluation of colored samples using standardized textile testing techniques is highlighted in the fourth part, carried out after the dyeing process, which includes fabric testing like color strength and fabric fastness properties, that need to be assessed once the fabric is dyed successfully.

The starting point of this study is dyed fabric. For this study, samples that have gone through the dyeing process were used as a starting point. After dyeing, all samples were rinsed with distilled water. Rinsing with distilled water was performed to remove any unfixed or loosely attached dye molecules from freshly dyed samples. The purpose of this procedure was to ensure that the following measurements would only reflect the fixed chemically bound dye (within the fiber), and not any dye that was deposited on the fabric's surface. Test specimens were then air-dried in an open shade. It is worth noting that once the test specimens are dried directly under sunlight, this may cause a change in dye shade when kept for a prolonged duration. If so, this could mislead the actual dye shade, and the test specimen may mismatch the original sample. Shade drying was therefore done to maintain the real color) of the samples before they were tested.

The dyed test material should be conditioned to a temperature of 21 ± 1°C and relative humidity of 65 ± 2% for a minimum of 24 hours before testing. The properties of fibres and yarns, particularly those related to their moisture content, can be sensitive to ambient conditions. Conditioning criteria in textile test methods, therefore, play a crucial criterion to reduce as far as possible any variation introduced by the surroundings and to ensure that all test samples attain a uniform condition before testing.

2.3 Instruments needed to conduct experiments

To make sure we get reproducible results, we assessed the resulting fabric for certain characterization tests. We used machines that were found in our laboratory. The machine used includes the HT dyeing machine, which is also known as the Rapid Labortex H-12C. This machine is really good at dyeing the samples we were testing. It does this under controlled conditions, which means the temperature was monitored closely. A Data Colour 850 spectrophotometer was used to read and compare the colour strength and uniformity of the tested material and provide K/S values. A crock meter was used to compare the fastness of the tested material to rubbing, in accordance with ISO 105-X12 standards. The light fastness parameters of the material were also tested using a light fastness tester. This tester simulates exposure to light over a period of time, and results are published in accordance with British Standard BS 1006. Finally, a washing fastness test was carried out in the HT machine, and samples were compared with the control sample.

3. Results & Discussion

3.1 Evaluation of Dyeing Results

Evaluation of dyed fabric samples is presented in order to assess colour performance, shade uniformity, and overall efficacy of the dyeing process under controlled experimental conditions. Color strength of evaluated samples was quantified in terms of K/S values that express the extent of dyeing and fixation to cotton fibers. The interaction of the extracted dye compounds with the molecular structure of mercerized cotton is governed by physical adsorption, including possible hydrogen bonding between the cellulose hydroxyl groups and the groups of the extracted dye compounds. Fastness properties such as crocking fastness and washing fastness were also studied to test how the physical adsorption is maintained under mechanical stress and exposure to water. In addition, the evaluated fabrics were visually observed in terms of shade uniformity and fabric surface smoothness to test if they possess texture stability suitable for textile applications.

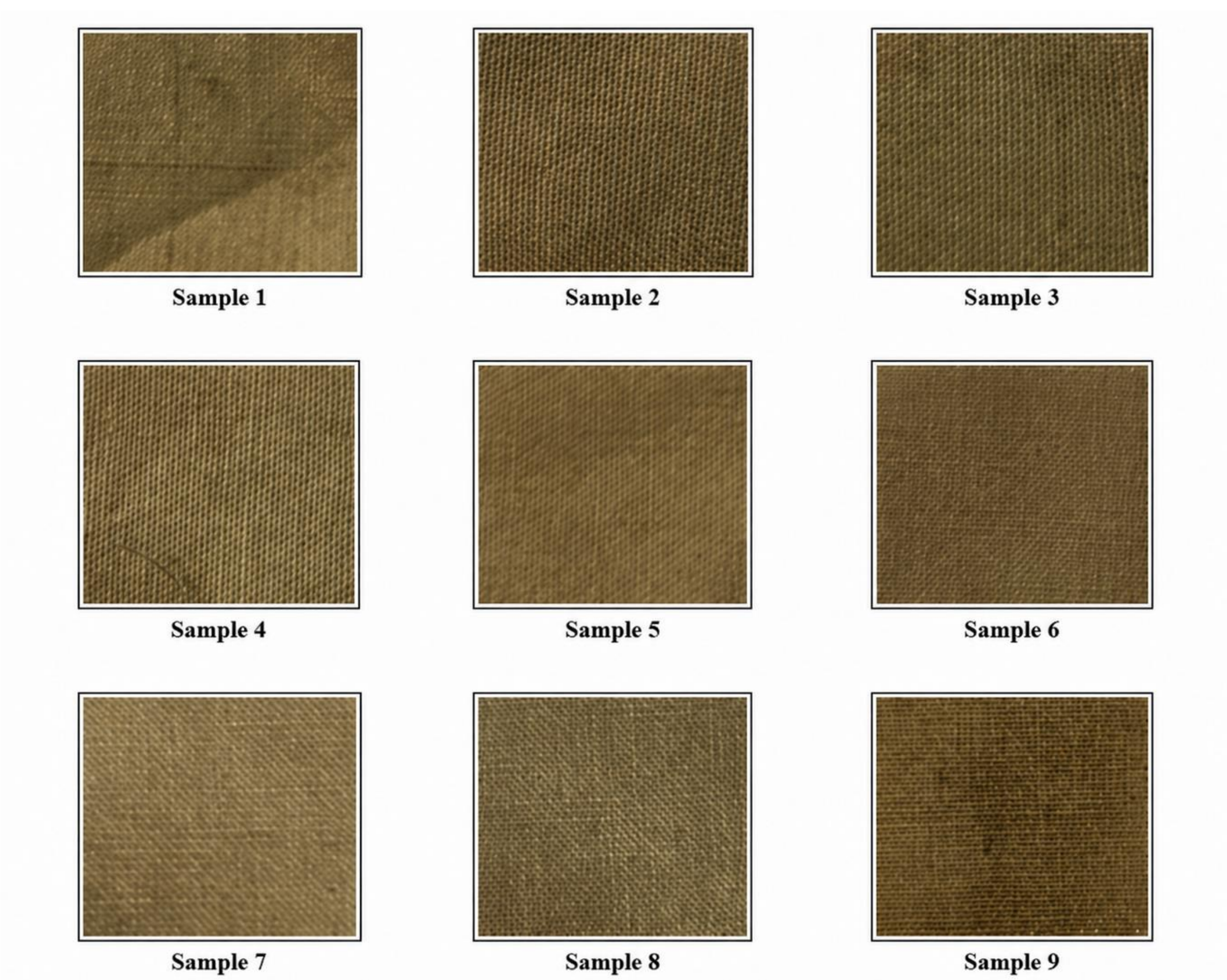

Figure 3-1. Cotton fabric samples (Samples 1–9) dyed under varying extraction and dyeing temperature conditions, demonstrating noticeable variations in shade depth, color intensity, and surface uniformity.

3.2 Color Strength (K/S Values)

The colour strength of the dyed samples was assessed in terms of K/S values. This was measured to see how well the dye uptake process worked. The findings were that the colour strength increases with the higher temperature of extraction and dyeing. This was especially true when the temperature was really high. The reason the colour strength was better is that the dye and the fibre were bonded more. This is because the molecules were moving around more, and the dye was attached better to the cotton fibres when it was hotter. The reason for the improved color strength is this. Improved thermodynamic affinity of dye molecules with cellulose molecules, along with enhanced hydrogen bonding and van der Waals interactions, also contribute to the phenomenon. The highest K/S values for the samples were attained when dyeing at 100 °C with dye solution extracted at the same temperature, indicating the best conditions for maximum dye diffusion, adsorption, and fixation into the fiber matrix. Although samples dyed at 80 °C showed obviously lower K/S values, due to lower kinetic energy, lower rate of dye diffusion, and weaker interaction forces between the dye and fiber molecules, results are summarized graphically in Figure 3-2 and reveal a good positive correlation between the temperature of dyeing and shade color obtained.

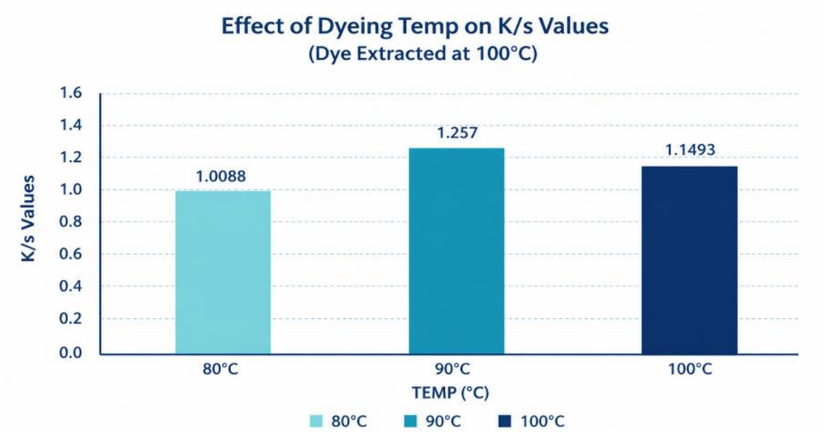

Figure 3-2. Effect of Dyeing Temp on K/S Values (Dye Extracted at 110°C)

The graphical representation of K/S values for the samples dyed using the 100 °C extract shows the effect of dyeing temperature on color strength. As seen from the figure, the K/S values increase with an increase in dyeing temperature. The K/S values were found to increase with a rise in dyeing temperature from 80 °C to 90 °C. This increased colour intensity at higher dyeing temperature could be due to increased molecular mobility and enhanced diffusion rate of the dye molecules at higher temperature, resulting in increased penetration of the dye molecules into the amorphous regions of the cotton fibre molecules and subsequent increased interactions between the dye molecules and cotton fibre molecules.

At 100°C, the K/S value decreases slightly from that measured at 90°C. As with the 90°C results, this would suggest that above an optimal temperature, excessive heat may cause some desorption or decrease the ability of the fibre matrix to promote dye aggregation. Alternatively, it may reflect changes in the fibre/dye/water distribution coefficient (i.e., the equilibrium distribution of dye between the fibre and the water containing a specific concentration of dye) such that, although the dye is more efficiently diffusing into the fibre at higher temperature, optimal color strength is achieved at a lower dyeing temperature, approximately 90 ° C in this study.

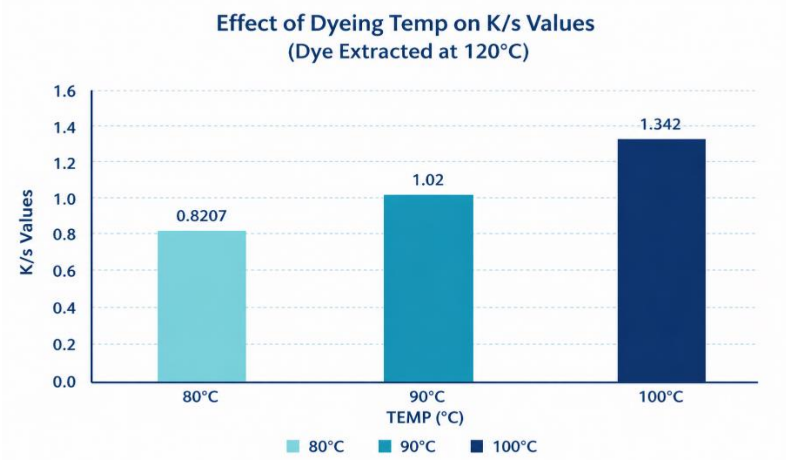

Figure 3-3. Effect of Dyeing Temp on K/S Values (Dye Extracted at 120ºC)

Figure 3-3 shows the variation of K/S values for samples that were dyed with the extracted solution from the cigarette butts obtained at 120°C. It is depicted that the K/S values go up consistently. The K/S values increase progressively from 80°C to 100 °C. This means that the color gets stronger as the temperature for dyeing increases. This is probably because the thermal energy increases, and this energy helps the dye penetrate into the cotton fibers and increases the interaction between the fibers and dye.

When the temperature for dyeing is low, for instance, 80 °C, the K/S values are low. This is because the fibers do not move much, and the dye molecules cannot enter the fibers easily. When the temperature goes up to 90°C, and then to 100°C, the dye molecules get more energy, and they can stick to the fibers better. On the other hand, when the temperature is high, the K/S values do not go down. This suggests that the dye extracted at 120 °C makes a dye system that works well with the fibers even when it is hot. The results show that the temperature for dyeing and the color strength are related to each other. So if you increase the temperature for dyeing, you can achieve color. This means dye penetrates into the fiber at higher temperatures, which is evident in the results above.

3.3 Crocking Fastness (Rubbing Fastness)

The rubbing fastness of dyeing products was evaluated by means of a crocking test, illustrated through Figure 3-4, after drying (dry crocking) and after wetting (wet crocking). The test results obtained show an excellent fastness of approximately 5/5 based on the change in the shade of the original dyeing and color transferred to the test fabric. This excellent fastness implies good fixing of study products into dye fibers. Study results show strong adsorption and good interaction between dye constituents and cellulose hydroxyl groups.

Wet crocking tests indicated a slight colour transfer to the dampened white cotton strip, rated 4/5, showing good rubbing fastness. The transfer was very slight and did not affect the shade and texture of the coloured fabrics markedly. The transfer ratings indicated that samples dyed at lower temperature had greater transfer, whereas samples dyed at higher temperature, especially at 100 °C, had better wet fastness. Improved wet fastness may be due to increased dye penetration into the amorphous regions of cotton and higher affinity between dye and fibre, which resulted in reduced mobility of loosely attached surface dye molecules.

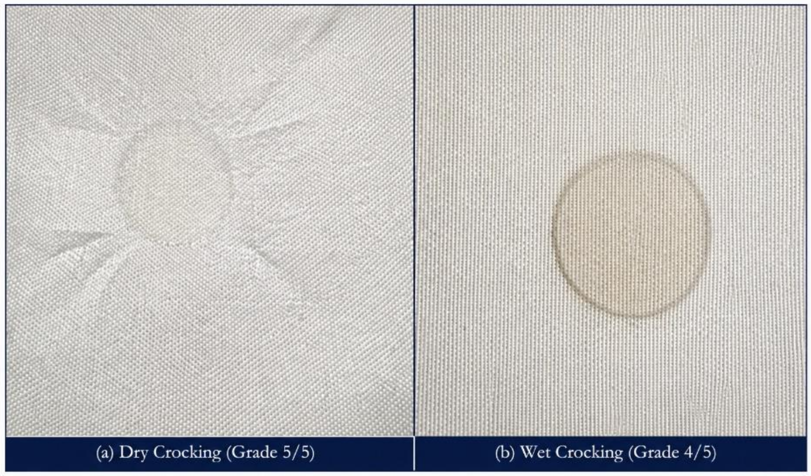

Figure 3-4. Dry & Wet Crocking results

Results of the crocking tests demonstrate the efficacy of the dyeing process and resistance to wash-off, especially at higher dyeing temperatures, where increased diffusion kinetics and strong interactions of macromolecules render fabrics highly resistant to both dry and wet abrasion.

3.3 Washing Fastness

Washing fastness of the tested products was evaluated for color change and shade difference after washing by using the standard test method. Three samples were evaluated for each treatment. The samples washed out lightest had a very slight change in shade, and the shade change decreased as the dyeing temperature increased. Results, illustrated in Figure 3-5, support the theory that increased temperature during dyeing allows for greater dye diffusion and better fixation of the dye onto the cellulose fibers by penetrating into the amorphous regions of the cellulose and fixing the color better than lower temperatures.

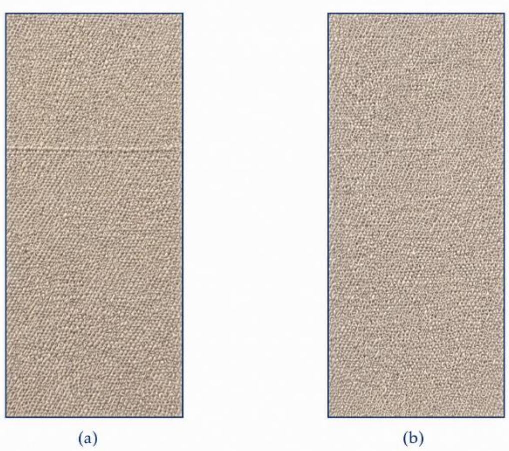

Figure 3-5. Before (a) & after washing (b)

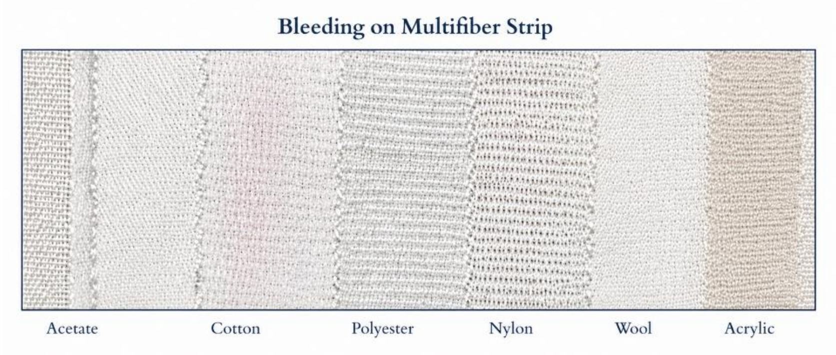

Figure 3-6. Bleeding on a multifiber strip

Figure 3-6 shows some colour bleeding onto adjacent multifiber strips, but this was slight. There was a small amount of loosely bound dye molecules that had not fully entered into binding with the fibers. However, as can be seen from the fastness results, there was very little loss of colour performance. The observed bleeding is attributed to dye that is adsorbed onto the fibre surface and not fully incorporated into the fibre matrix. During washing, the surface-adsorbed dye can be removed.

The washing fastness test revealed that although the degree of fixation was high, there was still room for improvement in the efficiency of the bonding, as well as in reducing the residual surface dye. Nevertheless, the degree of bleeding from the resulting dyeing materials is small, ensuring that they can be put to practical use.

3.4 Light Fastness

In accordance with the results of colour strength and fastness tests, the light fastness revealed another stable behaviour of the obtained pigment from the aqueous solution of cigarette butt extract. The dyed samples showed excellent resistance to photodegradation Figure 3-7. The light fastness (ISO 105-F02 method) obtained the highest rating of 8 on the ISO light fastness scale (1–8). Such excellent resistance to fading indicates that the dye molecules are highly photochemically stable and retain their structure along with their chromophoric characters even after prolonged exposure to light.

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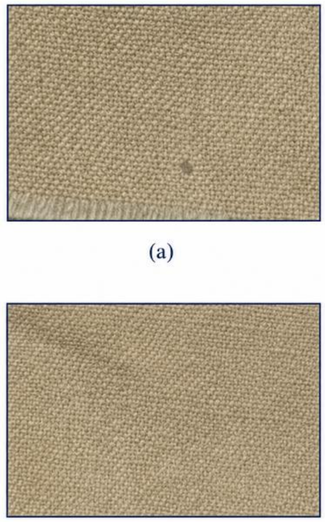

(a)

(b)

Figure 3-7. Before (a) & after (b) exposure to light

The coloration process was normal with no problems in how the dye binds to the fiber or color uniformity. There was no fading, color change, or difference in shade after a long time exposure to light. This happened because the dye molecule stayed stable and created a bond with the cellulose fiber, which stopped it from breaking down when exposed to light and kept the color intact.

In combination with good washing and crocking fastness results, excellent light fastness in this test further illustrates the excellent fixation of the extracted dye into the fiber. It substantiates superior dyeing performance comparable to that of synthetic dyes currently used in industry and confirms that the extracted dye will have excellent durability for wear and long-lasting high color strength even after many washes and exposure to light. It may be stated that the performance of this extracted dye is superior to that of natural dyes studied so far.

4. Conclusion

Comparative assessment of all nine samples revealed the optimum conditions to be the fabric dyed at 100 °C with a dye solution prepared at 110 °C. The sample showed the maximum K/S value and thus the best dyeing performance. The cotton fibre dyed under these conditions showed superior colour as well as excellent resistance to dry and wet crocking. The findings suggest excellent fixation of the dye molecules into the fibre matrix.

Very little change in shade was observable, and only very slight bleeding was noticed. This indicates that the majority of the dye molecules have been rigidly fixed into the cellulose structure as opposed to simply being adsorbed onto the fibre surface. The light fastness was also found to be excellent with no noticeable loss of colour on irradiation.

The results obtained in this study suggest that the optimal processing conditions for achieving high-performance and durable colouration of textile materials are the extraction of dye at 110 °C and dyeing at 100 °C. Under these conditions, there was observed optimal dye diffusion, satisfactory dye fixation, and enhanced dye stability with maximum colour strength and excellent fastness properties.

This study further reveals the environmental significance of utilising the world's most widespread form of litter, waste cigarette filters, as an alternative dyeing material. Utilising waste cigarette filters as a dyeing agent helps prevent waste buildup. It also offers an option for synthetic dyes. These synthetic dyes can cause environmental and health issues.

By combining waste reuse with textile processing, this study follows circular economy principles. It achieves material innovation.

The findings from this work help develop eco-dyeing technologies. They show how to reduce impacts. It will help improve the sustainability and efficiency of potential textile applications.

REFERENCES

R. Kant, "Textile dyeing industry an environmental hazard," *Natural science*, vol. 4, pp. 22-26, 2012.

M. C. B. Araújo and M. F. Costa, "A critical review of the issue of cigarette butt pollution in coastal environments," *Environmental research*, vol. 172, pp. 137-149, 2019.

C. R. Holkar, A. J. Jadhav, D. V. Pinjari, N. M. Mahamuni, and A. B. Pandit, "A critical review on textile wastewater treatments: possible approaches," *Journal of environmental management*, vol. 182, pp. 351-366, 2016.

H. Alzain, V. Kalimugogo, K. Hussein, and M. Karkadan, "A review of environmental impact of azo dyes," *Int J Res Rev*, vol. 10, pp. 673-689, 2023.

R. Saini and K. Choudhary, "Toxic potential of Azo dyes: A broader Understanding," in *Hazardous chemicals*, ed: Elsevier, 2025, pp. 469-481.

D. Yaseen and M. Scholz, "Textile dye wastewater characteristics and constituents of synthetic effluents: a critical review," *International journal of environmental science and technology*, vol. 16, pp. 1193-1226, 2019.

H. Hotel, "Environmental Science and Technology," 2012.

T. E. Novotny, "Environmental accountability for tobacco product waste," *Tobacco Control*, vol. 29, pp. 138-139, 2020.

T. E. Novotny and R. O'Connor, "Cigarette filters: implications for smoking behaviour, health effects and the environment," *WHO Technical Report Series*, 2025.

T. E. Novotny and L. Hamzai, "Cellulose acetate cigarette filter is hazardous to human health," ed: BMJ Publishing Group Ltd, 2024.

S. Dobaradaran, T. C. Schmidt, W. Kaziur-Cegla, and M. A. Jochmann, "BTEX compounds leachates from cigarette butts into water environment: a primary study," *Environmental Pollution*, vol. 269, p. 116185, 2021.

S. Dobaradaran, T. C. Schmidt, N. Lorenzo-Parodi, W. Kaziur-Cegla, M. A. Jochmann, I. Nabipour, *et al.*, "Polycyclic aromatic hydrocarbons (PAHs) leachates from cigarette butts into water," *Environmental pollution*, vol. 259, p. 113916, 2020.

S. Dobaradaran, F. Soleimani, R. Akhbarizadeh, T. C. Schmidt, M. Marzban, and R. BasirianJahromi, "Environmental fate of cigarette butts and their toxicity in aquatic organisms: A comprehensive systematic review," *Environmental Research*, vol. 195, p. 110881, 2021.

D. S. Green, A. D. Tongue, and B. Boots, "The ecological impacts of discarded cigarette butts," *Trends in ecology & evolution*, vol. 37, pp. 183-192, 2022.

N. F. da Silva, M. C. B. de Araújo, and J. S. Silva-Cavalcanti, "Cigarette butts in the environment: a growing global threat?," *Environmental Reviews*, vol. 31, pp. 229-242, 2023.

M. Sharma, K. Sridhar, V. K. Gupta, and P. K. Dikkala, "Greener technologies in agri-food wastes valorization for plant pigments: Step towards circular economy," *Current Research in Green and Sustainable Chemistry*, vol. 5, p. 100340, 2022.

R. P. Singh, K. Kaur, H. Kaur, A. Saroa, S. Gupta, and A. Singh, "Harnessing the potential of fruit processing industrial waste for circular economy: a comprehensive review," *Journal of Food Science and Technology*, pp. 1-21, 2026.

M. P. Dantas, C. R. S. de Oliveira, N. Ueda Yamaguchi, A. H. da Silva Júnior, R. M. Peralta, A. Bracht, *et al.*, "Pathways in Agro-Industrial Waste Upcycling: A Review of Sustainable Textile Innovations and Economic Perspectives," *Plants,* vol. 14, p. 3574, 2025.

C. Moreno-Díaz, S. González-Arranz, and C. Martínez-Cerezo, "Bacterial cellulose production within a circular economy framework: utilizing organic waste," *Polymers,* vol. 16, p. 2735, 2024.

L. Wang, W. Chen, Y. Wan, A. He, J. Liu, and X. Hu, "Extraction of tobacco extract from discarded tobacco leaves for cigarette yarns dyeing and neophytadiene separation," *Frontiers in Chemistry,* vol. 13, p. 1682505, 2025.

F. Yılmaz and M. İ. Bahtiyari, "Use of tea and tobacco industrial wastes in dyeing and antibacterial finishing of cotton fabrics," *AATCC Journal of Research,* vol. 7, pp. 25-31, 2020.

M. Banožić, J. Babić, and S. Jokić, "Recent advances in extraction of bioactive compounds from tobacco industrial waste-a review," *Industrial Crops and Products,* vol. 144, p. 112009, 2020.

W. Nongnuch, P. Suwanruji, and J. Setthayanond, "Colour properties of cigarette smoke-exposed cotton and silk fabrics and their nicotine release," *Ind. Textila,* vol. 69, pp. 328-333, 2018.

M. Kayar, Y. Boztoprak, and B. G. Nallbani, "Cigarette smoke uptake by different woven fabrics: Analysis of mechanical and colour properties," *Coloration Technology,* vol. 140, pp. 585-597, 2024.

A. M. Thakker and D. Sun, "Sustainable plant-based bioactive materials for functional printed textiles," *The Journal of the Textile Institute,* vol. 112, pp. 1324-1358, 2021.

M. T. Rahman, "Recycling cigarette butts in bitumen and asphalt concrete for pavement construction," RMIT University, 2024.

S. Cavagnoli, A. Pazzaglia, C. Fabiani, F. F. de Albuquerque Landi, B. Castellani, and A. L. Pisello, "Sustainable approach to cigarette butts management: From waste to new building material component," *Sustainable Energy Technologies and Assessments,* vol. 72, p. 104039, 2024.

M. T. Rahman, A. Mohajerani, and F. Giustozzi, "Recycling of waste materials for asphalt concrete and bitumen: A review," *Materials,* vol. 13, p. 1495, 2020.

A. Mohajerani, S. Qun Hui, C. Shen, J. Suntovski, G. Rodwell, H. Kurmus, *et al.*, "Implementation of recycling cigarette butts in lightweight bricks and a proposal for ending the littering of cigarette butts in our cities," *Materials,* vol. 13, p. 4023, 2020.

M. del Pilar Núñez, E. G. L. Loveira, S. E. Domínguez, L. M. Calfayan, R. F. Itria, and M. Butler, "Assessment of nicotine and degradation products in cigarette butts leachates after detoxification by white rot fungi," *Journal of Hazardous Materials,* vol. 492, p. 138059, 2025.

R. Morales-Vera, J. Cantillana, F. Arto-Paz, C. Hernández, A. Echeverría-Vega, and C. Valdés, "Treatment of cigarette butts: biodegradation of cellulose acetate by rot fungi and bacteria," *Microorganisms,* vol. 12, p. 2285, 2024.

M. Shahid and F. Mohammad, "Recent advancements in natural dye applications: a review," *Journal of cleaner production,* vol. 53, pp. 310-331, 2013.

P. Rana and S. Sethi, "Utilising agro-waste in textile industry: advancing sustainability with a year-round waste cycle," *Materials Circular Economy,* vol. 7, p. 30, 2025.

T. Bechtold and R. Mussak, *Handbook of natural colorants* vol. 8: John Wiley & Sons, 2009.

A. K. Samanta and P. Agarwal, "Application of natural dyes on textiles," *Indian journal of fibre & textile research,* vol. 34, pp. 384-399, 2009.

M. Tausif, A. Jabbar, M. S. Naeem, A. Basit, F. Ahmad, and T. Cassidy, "Cotton in the new millennium: advances, economics, perceptions and problems," *Textile Progress,* vol. 50, pp. 1-66, 2018.

P. Venkatraman, "Fabric properties and their characteristics," *Materials and technology for sportswear and performance apparel,* pp. 53-86, 2015.

H. Khanzada, M. Q. Khan, and S. Kayani, "Cotton based clothing," in *Cotton science and processing technology: Gene, ginning, garment and green recycling*, ed: Springer, 2020, pp. 377-391.

Z. Khatri, A. Khatri, U. Saleem, G. Mayakrishnan, B. S. Kim, K. Wei*, et al.*, "Pad dyeing of cellulose acetate nanofibres with disperse dyes," *Coloration Technology,* vol. 129, pp. 159-163, 2013.

M. Shahriari-Khalaji, A. Alassod, and Z. Nozhat, "Cotton-based health care textile: A mini review," *Polymer Bulletin,* vol. 79, pp. 10409-10432, 2022.

N. Ali, R. Almas, U. Saleem, M. Shahzad, S. A. Malik, A. Ali*, et al.*, "Study on tencel fabric dyeing with acacia nilotica bark natural dyes," *Mehran University Research Journal Of Engineering & Technology,* vol. 43, pp. 183-189, 2024.

K.-P. M. Tang, C.-W. Kan, and J.-t. Fan, "Evaluation of water absorption and transport property of fabrics," *Textile Progress,* vol. 46, pp. 1-132, 2014.

S. H. Ravandi and M. Valizadeh, "Properties of fibers and fabrics that contribute to human comfort," in *Improving comfort in clothing*, ed: Elsevier, 2011, pp. 61-78.

H. Özdemir, "Thermal comfort properties of clothing fabrics woven with polyester/cotton blend yarns," *Autex Research Journal,* vol. 17, pp. 135-141, 2017.

S. Fu, D. Hinks, P. Hauser, and M. Ankeny, "High efficiency ultra-deep dyeing of cotton via mercerization and cationization," *Cellulose,* vol. 20, pp. 3101-3110, 2013.