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Original Research Article

A green approach to fingerprint enhancement: The potential of alternanthera dentata leaf powder

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ABSTRACT

Background: The field of forensic science necessitates the utilization of efficient techniques for the enhancement of latent fingerprints. Environmental issues are frequently raised when traditional approaches are employed in this context. This study introduces an innovative and ecologically responsible solution to this challenge in the form of Alternanthera Dentata (AD) leaf powder. AD is renowned for its striking and vivid deep purple leaves, and it unveils remarkable properties as a natural pH indicator. Its distinctive characteristic lies in the ability to undergo a vivid transformation from a rich crimson hue to a greenish-yellow tint, responding to alterations in pH levels, a phenomenon attributed to its anthocyanin content.
Results: The research demonstrates the versatility of AD leaf powder across diverse surfaces and its distinctive ability to indicate pH levels. The use of methanol for AD leaf powder extraction enhances the sensitivity of anthocyanins to pH fluctuations. The innovative approach not only proves the efficacy of AD leaf powder in enhancing fingerprint clarity but also emphasizes its eco-friendliness and cost-effectiveness.
Conclusions: This study establishes Alternanthera Dentata (AD) leaf powder as a promising and sustainable solution for latent fingerprint enhancement in forensic science. The compatibility of AD with various surfaces, coupled with its natural pH indicator properties, positions it as a valuable resource. The incorporation of methanol further boosts sensitivity, highlighting the eco-friendly and cost-effective nature of this innovation. By embracing environmental sustainability principles, this research contributes to a greener and more responsible future for forensic science applications.

1. Introduction

Fingerprints are comprised of intricate patterns formed by the residual traces of perspiration and fatty acids secreted through the pores situated on the friction ridge skin of the fingertips. These concealed or latent fingerprints typically remain imperceptible to the naked eye when encountered at a crime scene. The inherent secretions emanating from the fingers originate from eccrine, apocrine, and sebaceous glands. The palms of the hands notably harbour an abundance of eccrine glands, which exude clear, colorless perspiration. This perspiration is primarily comprised of approximately 99% water, along with 0.5% organic and 0.5% inorganic constituents. Eccrine sweat constitutes a multifaceted blend encompassing diverse substances like amino acids, choline, creatinine, lactic acid, proteins, sugars, urea, and uric acid. Conversely, sebaceous sweat comprises fatty acids, glycerides, squalene, sterol

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esters, and wax esters within its composition.[1–7] To reveal latent fingerprints on non-porous, dry surfaces, a frequently utilized method is the application of powder dusting.[8,9] This process is straightforward and efficient, involving the application of a finely divided powder mixture onto latent fingermark residues. Afterward, excess powder is brushed and blown away. The effectiveness of powder dusting relies on the powder's ability to adhere to the moisture and oily components present in the latent fingermark.[10] The size and shape of the particles in the powder formulation impact their adhesion qualities, with smaller particles adhering more effectively than larger, coarser ones. However, it's crucial to recognize that there isn't a universally applicable powder formulation that suits all surface types for revealing latent fingerprints. Historically, fingerprint powders have been the go-to choose for enhancing latent fingerprints across diverse substrates. Notably, metallic powders are recognized for their prolonged shelf life compared to their organic counterparts.[11,12] Nevertheless, due to their toxicity and complex application methods, metallic powders are rarely used. One of the principal rationales for exploring alternative fingerprint powders stems from the myriad of health hazards linked to conventional fingerprint powders during occupational exposure. Occupational exposure to inorganic fingerprint powders, including those containing lead or mercury, gives rise to substantial health apprehensions, particularly among forensic and law enforcement professionals. As a result, powder formulations containing lead and mercury have become outdated and no longer in use. Numerous research endeavours have delved into the occupational health risks associated with the use of fingerprint powders. Researchers have explored non-conventional materials readily available in everyday life as potential alternatives for visualizing latent fingerprints.[10,13] Using conventional powders for developing latent fingerprints comes with several disadvantages. These include issues like limited contrast, reduced sensitivity, and selectivity, as well as substantial toxicity. Numerous powders, such as those based on black (carbon or charcoal) or white (titanium), have been traditionally employed for latent fingerprint development. However, these powders contain chemicals that can pose health risks and even carcinogenic hazards to individuals using them.[14] A plethora of innovative fingermark powder formulations sourced from herbaceous plants have emerged in recent years. Garg et al. introduced a groundbreaking powdering technique for fingermark enhancement utilizing turmeric powder derived from a rhizomatous herb. Another pioneering approach involves the utilization of synthetic food and festival colors for fingermark development. Additionally, a novel fluorescent reagent incorporating natural yellow 3, a dye commonly employed as a food coloring agent, has been devised for revealing grease-contaminated fingerprints on non-porous dark surfaces.[15]

Alternanthera Dentata, a diminutive to moderately-sized perennial ornamental shrub, distinguished by its deep purple foliage, frequently sought for horticultural embellishment, is classified within the Amaranthaceae botanical family. The leaves of *Alternanthera Dentata* are endowed with the unique capacity to serve as a natural discernment tool in the context of neutralization titrations. The aqueous leaf extracts of this botanical specimen exhibit a vivid crimson hue, which undergoes a discernible transition to a greenish-yellow tint as the pH level shifts from an acidic to an alkaline milieu. This distinct alteration in coloration can be ascribed to the presence of anthocyanins, water-soluble compounds known for their remarkable pH sensitivity. Anthocyanins, in this context, operate with consummate efficacy as pH indicators, delivering outcomes that are commensurate with those attained by traditional acid-base indicators. This natural substitute not only manifests operational efficiency but also espouses environmentally responsible practices, proves to be fiscally prudent, and adds an aesthetically pleasing facet, setting it apart from commercially available counterparts.[16,17]

The leaf extract of this plant harbors a diverse array of phytochemicals, signalling its considerable medicinal potential. Hexadecanoic acid, the predominant compound found in the extract, exhibits notable antioxidant properties.[18] The primary objective of this research is to introduce Alternanthera Dentata (AD) leaf powder as a cutting-edge and ecologically sound solution for elevating the clarity of fingerprints. This undertaking involves a meticulous examination of the properties and distinctive attributes of AD leaf powder, as well as its compatibility with latent fingerprints. Our objective is to present an innovative, sustainable, and environmentally conscious alternative within the field of forensic science. This research objective seeks to provide a comprehensive understanding of the practicality and viability of AD leaf powder as a green fingerprint enhancement solution.

Study of natural fingerprint development powdersTable 1.

2. Materials and Methods

2.1. Sample collection and environmental exposure

Fingerprint samples from five diverse substrates (glass, borosilicate glass, metal, slab, and paper) were systematically gathered and subjected to ambient room conditions, exposed to dust and air, while maintaining room temperature.

Table 1: Illustration of a range of environmentally friendly and household products recommended for use as latent fingerprint powders.[10,14,15,19–24]

S. no.	Study and sample used	Methodology or conditions during development	Key Findings	Author's profile
2.1.	Comparative Study on Orange Peel and Lemon Peel Powders for Latent Fingerprints	Conducted in Jaipur, India, amidst a 45% humidity level in February, the study involved ten individuals tasked with placing their fingertips on different surfaces to collect latent fingerprints. The fingerprints were subsequently developed using orange peels and lemon peels.	Both powders prove to be economical, environmentally friendly, and efficient in revealing latent fingerprints on a multitude of surfaces. The prints are distinctly visible on both porous and non-porous surfaces, and suitable contrast was achieved for photography purposes.	Lohar, et al., (2022)[14]
2.2.	Unconventional powders to determine the latent fingerprint impressions Sample used: Turmeric, vermillion, talcum, fuller's earth	All samples were gathered from diverse surfaces within a temperature range of 26-32^{o}C. The relative humidity remained moderate, and the level of perspiration was minimal.	*Turmeric:* In paper, print lacked clarity due to the smooth surface, which hindered particle adhesion. In plastic sheet, a clearer print. *Talcum*: On polished wood, the prints are not clear. The smooth texture of powder helped in better particle adhesion. On metal, the print visibility excellent. *Vermillion:* no prints on wood, white paper displayed clear ridge patterns. Steel surfaces developed prints faster and visibly than paper, while glass surfaces produced superior results. **Fuller's Earth:** In glass surfaces identifiable prints, not ideal for smooth surfaces.	Niranjan et. al., (2022)[19]

Continued on next page

Table 1 continued

2.3.	Development of Natural Latent Fingerprint Powder from Durian Seeds.	500 g of Durian seeds finely ground into a talcum powder-like consistency. Eleven latent fingerprints on various surfaces, were collected. primarily composed of sebum, originating mainly from the face and forehead.	The use of Durian seed powder resulted in clear latent fingerprint ridge patterns on all these surfaces, except on white surfaces. Durian seed powder is an environmentally friendly alternative to conventional fingerprint powders.	Sekar et al., (2017)[20]
2.4.	Turmeric Powder for Developing Latent Fingerprints	Eleven sample latent fingerprints on various surfaces, consisting of sebum from the face and forehead were collected. Experiments took place during temperatures fluctuating between 35 and 42°C and relative humidity ranging from 60% to 80%.	Turmeric powder is effective in developing latent fingerprints on various surfaces, especially contrast surfaces.	Garg et al., (2011)[15]
2.5.	Banana Peel Activated Carbon Powder	Dried banana peels being carbonized at 400°C, activated using phosphoric acid, Pyrolysis was carried out at 800°C. After cooling, washes with 5 N HCl and hot water until reaching a neutral pH. Then rinsed and dried at 110°C. To examine the impact on powder quality, different amounts of sodium acetate (aq) were incorporated at varying weights. Mineral oil (commercial grade) was added at different volumes by weight (dissolved in lab-grade hexane). Fingerprint collected from same individual.	Activated carbon powder derived from banana peel adheres well to friction ridges and can be enhanced with methylene blue for better visibility.	Mopoung et al., (2009)[21]

Continued on next page

Table 1 continued

2.6.	Commonly Available Materials for Latent Fingerprints (Ramanan Vadivel et al.)	Previously done research studies were reviewed and discussed in this review.	Turmeric powder, white cement, silica gel G, and gram flour are effective for latent fingerprint visualization, while chilli-based powders are less effective.	Vadivel et al., (2021)[10]
2.7.	Using Salt & Sugar Powder for Latent Fingerprints.	Latent fingerprint developed on different types of porous and non-porous surfaces. One sugar powder and three types salt powder of 100 gm i.e., granulated sugar, table salt, smoked grey salt, rock salt are used.	Salt and refined sugar can improve the visibility of latent fingerprints, providing a practical and cost-effective method for crime scene analysis.	Mia et al., (2021)[22]
2.8.	Using Imperata Cylindrica (IC) Powder (Unspecified source).	Fingerprints composed of various constituents (eccrine, sebaceous, and natural fingerprints) on diverse surface types were employed. An acid-modified IC powder was utilized for fingermark development, and its quality was assessed through statistical analysis, comparing it with the effectiveness of Sirchie® Hi-Fi black powder. Additionally, the acid-modified IC powder was applied to develop fingerprints of varying ages, including aged fingerprints submerged in water.	Acid-modified IC powder is effective for developing distinct ridge details on various surfaces, including aged and water-submerged finger-marks.	Low et al., (2015)[23]
2.9.	Fuller's Earth (Multani Mitti) Powder for Latent Fingerprints.	Test fingerprints collected from 6 individuals aged 20–25 years.	Fuller's earth (Multani Mitti) powder is organic, cheap, non-toxic, and possesses good properties for latent fingerprint development on different substrates.	Thakur et al., (2016)[24]

2.2. Harvest and preparation of alternanthera dentata leaves

Five grams of fresh Alternanthera Dentata leaves were carefully procured from a garden and cleansed with distilled water.

The rinsed leaves underwent a controlled drying process in an oven until complete moisture elimination was achieved.

The desiccated leaves were meticulously ground into fine particles using an agate mortar and pestle.

The resulting powder was securely sealed within a glass vial and stored within a confined environment. A monitoring period of two days ensured the absence of lump formation or residual moisture content.

2.3. Application of leaf powder for fingerprint enhancement

The leaf powder was gently applied to surfaces bearing latent fingerprints using a specialized fingerprint brush, carefully tracing the ridges.

2.4. Development and environmental exposure of enhanced prints

The developed fingerprints were documented through photography and subsequently left exposed to the ambient room conditions at room temperature for a duration of two days.

2.5. Characterization of leaf powder

The fingerprint powder was subjected to a comprehensive examination using an Attenuated Total Reflectance- Fourier Transform Infra-Red Spectrometer (Instrument: ATR-FT-IR Bruker Alpha II, Wavelength range: 600 cm^{-1} to 6000 cm^{-1}, Background, and sample scan: 25 scans per sample) to elucidate its chemical composition.

To uncover the chemical attributes and phytochemical constituents, the powder was subjected to extraction within a beaker containing methanol.

2.6. Microscopic analysis of the leaf powder

The microscopic characteristics of the powder were scrutinized under a compound microscope, magnifying at both 10x and 40x, to gain an intricate understanding of its microstructure and features.

3. Results

3.1. Visualization of latent fingerprints on different surfaces using Alternanthera leaf powder

The visualization and development of latent fingerprints on a steel surface (Figure 1) were successfully achieved through the application of Alternanthera leaf powder. The result shows that the ridges were clear and prominent on steel surface when powder was applied and brushed gently along the ridges.

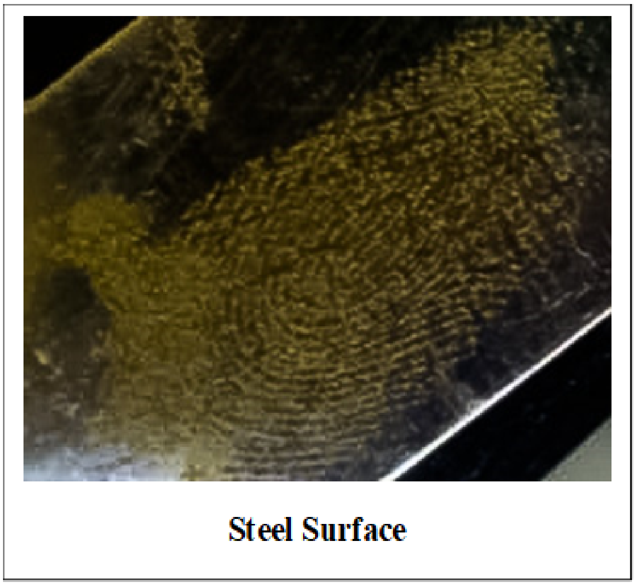

Figure 1: Visualization and development of latent fingerprints on steel surface using Alternanthera leaf powder.

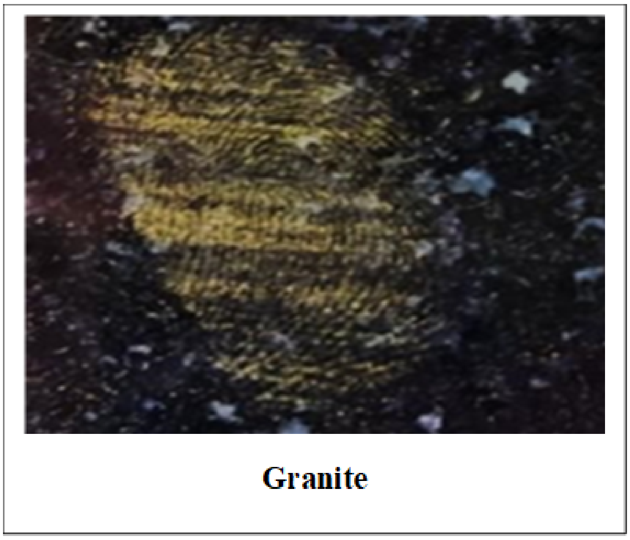

Figure 2: Visualization and development of latent fingerprints on slab surface (granite) using Alternanthera leaf powder.

The latent fingerprints on a slab surface (granite) (Figure 2) were visualized and developed using Alternanthera leaf powder. The result shows that the ridges were clear and prominent on slab when powder was applied and brushed gently along the ridges.

Figure 3: Visualization and development of latent fingerprints on borosilicate glass using Alternanthera leaf powder.

The latent fingerprints on borosilicate glass (Figure 3) were visualized and developed utilizing Alternanthera leaf powder. The result shows that the ridges were clear along the edges but smudged in the centre on the borosilicate glass surface when powder was applied and brushed gently along the ridges.

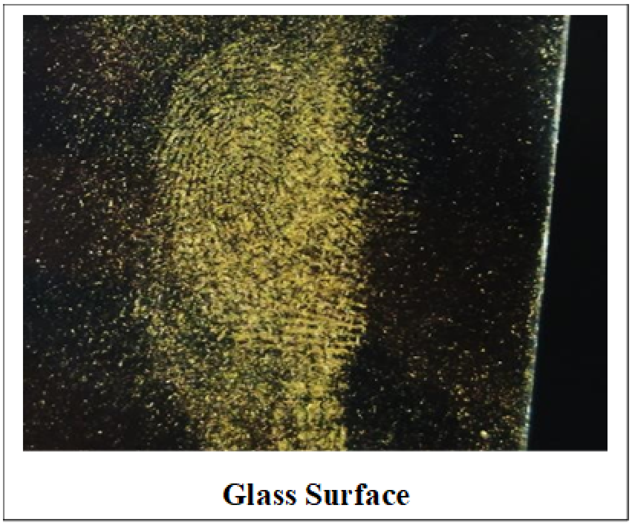

Figure 4: Visualization and development of latent fingerprints on glass surface using Alternanthera leaf powder.

The visualization and enhancement of latent fingerprints on a glass surface (Figure 4) were achieved through the utilization of Alternanthera leaf powder. The result shows that the ridges were clear and prominent on glass surface when powder was applied and brushed gently along the ridges.

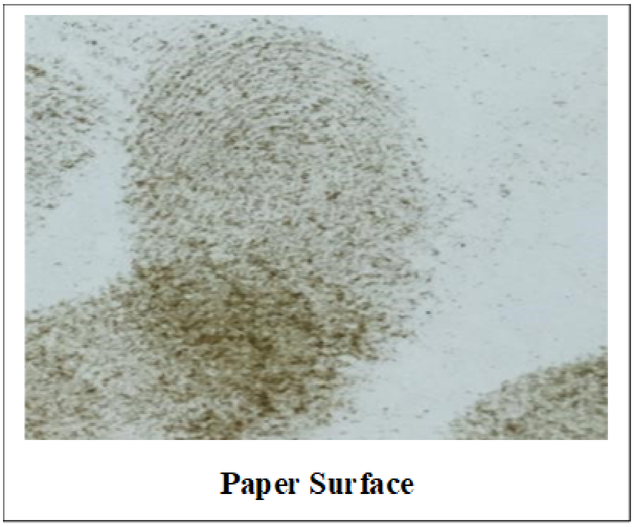

Figure 5: Visualization and development of latent fingerprints on paper using Alternanthera leaf powder.

The findings indicate that on a paper surface (Figure 5), the ridges were evident and well-defined along the edges, yet exhibited smudging in the center when powder was gently applied and brushed along the ridges, attributable to the smooth texture of the paper.

Figure 6: Visualization of fingerprint developed on borosilicate glass after 2 days.

(Figure 6) Result shows that when developed prints were exposed to air for 2 days, the yellow colour of the powder changed to pink colour due to the reaction of flavonoid (possibly anthocyanins) with sweat residue of fingerprints.

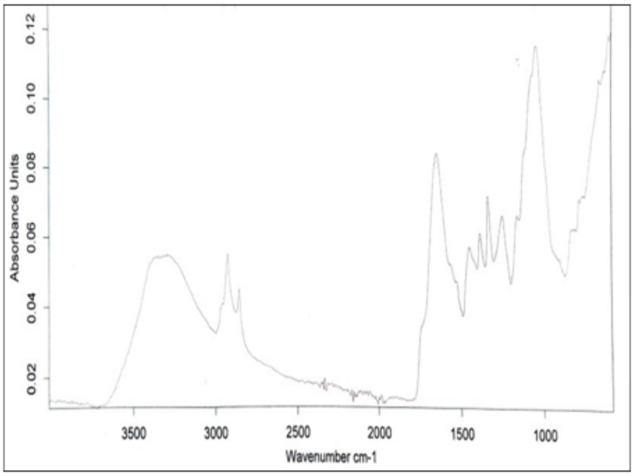

Figure 7: FTIR spectra of Alternanthera leaf powder

3.2. Characterization of Alternanthera leaf fingerprint powder using ATR-FTIR

Figure 7 represents the FTIR spectra of Alternanthera leaf powder. The Fourier transform infrared spectroscopy (FTIR) technique can be used to detect the chemical composition of a variety of organic compounds, polymers, paints, etc. FTIR can be used to analyse a variety of materials in bulk or thin films, liquids, solids, pastes, and other forms. FTIR analysis, when combined with the appropriate standards, can give quantitative analysis in addition to qualitative analysis.

Table 2: FTIR peaks of alternanthera leaf powder

Peak (cm^{-1})	Stretching
3290.40	O-H stretch
2917.98	C-H stretch
2849.98	C-H stretch
2333.89	——
2312.46	——
2112.46	CΞC stretch
1982.77	C-H stretch
1622.37	C=C stretch
1436.74	C-H stretch
1371.26	S=O stretch
1319.90	C-N/S=O stretch
1235.58	C-N stretch
1021.03	C-N stretch

The FTIR spectrum analysis of Alternanthera Dentata leaf powder results (Table 2) reveal distinct functional groups characterized by specific peaks. A prominent peak at 3290.40 cm^{-1} signifies O-H stretching, attributed to moisture content within the powdered sample. Notably, sharp, and moderate peaks at 2917.98 cm^{-1} and 2849.98 cm^{-1} correspond to C-H stretching vibrations. Meanwhile, weaker peaks at 2333.89 cm^{-1} and 2312.46 cm^{-1} are likely due to contamination and instrumental artifacts. Additional subtle peaks at 2112.46 cm^{-1} and 1982.77 cm^{-1} are indicative of CΞC and C-H stretching, respectively. An intense peak at 1622.37 cm^{-1} is attributed to C=C stretching, further elucidating the sample's composition. A moderate peak at 1436.74 cm^{-1} corresponds to C-H stretching vibrations. Sharp peaks at 1371.26 cm^{-1} and 1319.90 cm^{-1} are discernible, indicating S=O stretching, which can be attributed to the presence of sulfonate and sulphonamide functional groups in the powder. The peak at 1319.90 cm^{-1} may also be linked to C-N stretching, signifying the presence of aromatic amines. In the spectral data, a medium peak at 1235.58 cm^{-1} arises from C-N stretching. However, the most robust and well-defined peak at 1021.03 cm^{-1} is indicative of C-N stretching vibrations, providing further evidence of the amine content within the sample.

3.3. Characterization of alternanthera leaf fingerprint powder using compound microscope

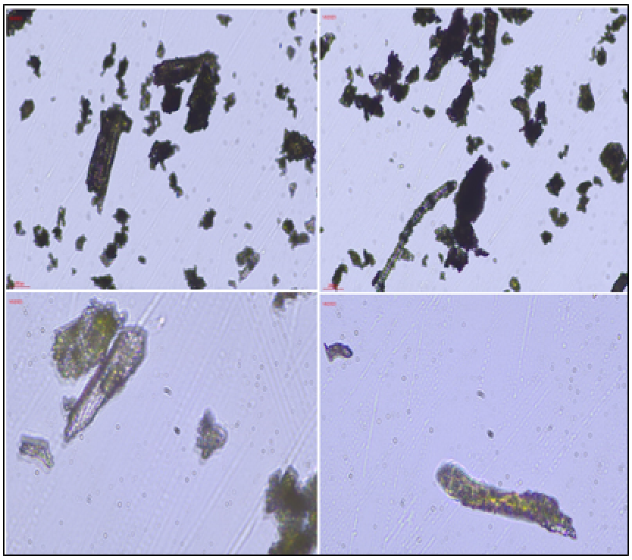

Figure 8: Alternanthera leaf powder under compound microscope at 10x (up) and at 40x (bottom)

Figure 8 showcases Alternanthera leaf powder under a compound microscope, with images captured at 10x (top) and 40x (bottom) magnifications. Microscopic examination revealed the existence of a purplish pigment that remained imperceptible to the unaided human eye. This purple pigment, potentially attributable to anthocyanin compounds, is encapsulated within a green matrix. Remarkably, it serves as the key factor in orchestrating a discernible alteration in coloration when subjected to atmospheric exposure over a duration of two days.

3.4. Characterization of Alternanthera leaf fingerprint powder using Methanol

Figure 9: Extraction ofAlternanthera leaf powder using methanol

Figure 9 illustrates the extraction process of Alternanthera leaf powder using methanol. The powdered substance was meticulously blended with methanol and subsequently subjected to filtration. The outcome revealed an intriguing transformation in the coloration of the Alternanthera powder, transitioning from yellow to a vivid green shade virtually instantaneously. Microscopic scrutiny strongly suggests that this chromatic metamorphosis is a direct consequence of the presence of anthocyanin compounds within the powder. Upon introducing methanol into the powder, it is plausible that this action induced a shift in the solution's pH. Methanol, with its inherent acidity exceeding that of water, likely catalysed the alteration in pH. This change in pH could, in turn, be responsible for the remarkable shift in the hue of the anthocyanins. Anthocyanins are renowned for their inherent pH-sensitive coloration, exhibiting a propensity to manifest green or blue hues under more alkaline conditions, thereby elucidating the observed color transformation.

4. Discussion

Positive outcomes are visible when using Alternanthera Dentata leaf fingerprint development powder, as it produces well-defined prints on nearly all surfaces. An effective plant-based material for latent fingerprint enhancement is demonstrated by the study of Lohar et al. on powdered orange and lemon peels, which also has shown the effectiveness of natural, affordable, and environmentally friendly powders.[14] Compared to other powders studied by Niranjan et al., like talcum, turmeric, vermillion, and fuller's earth, the special qualities of Alternanthera Dentata leaf powder—such as the color shift caused by anthocyanin compounds offer a unique viewpoint.[15,19] The Alternanthera Dentata leaf powder study highlights the powder's color transformation, whereas the Durian seed powder study of Sekar et al. concentrates on clarity on diverse surfaces; moreover, the potential of natural sources for environmentally friendly fingerprint enhancement is highlighted by both studies.[20] The studies on banana peel activated carbon powder by Mopoung et al. also investigates natural sources of latent fingerprint development.[21] The usefulness of widely accessible materials like gram flour, silica gel, and turmeric is highlighted by Vadivel et al., and the Alternanthera Dentata leaf powder study supports this notion by highlighting the availability and potential of natural materials for fingerprint enhancement.[10] Research on powdered Alternanthera Dentata leaves brings a fresh viewpoint to the study of latent fingerprint enhancement. The capacity of anthocyanins to change color and the use of plant-based materials expand the body of existing knowledge and provide new avenues for forensic science research. The study backs up the broader trend of searching for more environmentally friendly latent fingerprint development methods.

5. Conclusions

This research has revealed the exceptional potential of Alternanthera Dentata (AD) leaf powder, which can be used to improve fingerprints in environmentally friendly and sustainable ways. This small but exquisite perennial plant, distinguished by its vivid deep purple leaf, has shown to be more useful in forensic science than just a horticultural elegance. As the pH changes from acidic to alkaline, the aqueous leaf extracts of AD leaf powder change color from a brilliant crimson to a greenish-yellow, which is what makes it special as a natural indicator for neutralization titrations. This alteration, which is related to the presence of anthocyanins, shows how well AD leaf powder functions as a pH indication and can compete with conventional acid-base indicators. Due to the pH-altering properties of methanol, which in turn affected the anthocyanins, the extraction of AD leaf powder with methanol resulted in an unexpected color change. These findings highlight how sensitive anthocyanins are to pH changes, which makes them an excellent choice for use as natural pH sensors. It opens new possibilities for sustainable procedures in forensic science and has a special pH-indicating property, hinting at a greener and more environmentally conscious future for this crucial field. This study demonstrates how AD leaf powder can be used to improve fingerprint clarity while adhering to environmental sustainability guidelines. A potential, sustainable, and economically advantageous resource for fingerprint enhancement is Alternanthera Dentata leaf powder.

5.1. Ethics approval and consent to participate

Fingerprints are provided by researchers only and they have no objection in submission of the data.

6. Source of Funding

None.

7. Conflict of Interest

None.

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