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Evaluation of Hair Dye Powder as a Non-Conventional Alternative to Commercial Latent Fingerprint Powder on Porous and Non-Porous Surfaces

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ABSTRACT

The objective of this study was to evaluate the effectiveness of hair dye powder as a cost-effective alternative to commercial fingerprint powder. A traditional powder-dusting technique, relying on the mechanical adhesion of powder to the moisture and lipid components of latent fingerprint residues, was employed. Thirty-three latent prints were deposited on eleven different non-porous substrates. Visualization of ridge detail was generally satisfactory across most surfaces, allowing for both Level 1 and Level 2 comparisons. The clearest impressions were obtained on glass tumblers, CDs, wall and paper. These findings indicate that hair dye powder represents a viable substitute for commercial fingerprint powder on non-porous surfaces.

Keywords: *latent fingerprints, non-conventional fingerprint powder; hair-dye powder; non-porous surfaces, porous surfaces.*

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1. Introduction

Fingerprints are of utmost importance in the field of forensic science as they are corroborative evidence. Fingerprints are globally accepted for individual identification because their friction-ridge patterns remain unchanged throughout life. These ridges form during gestation and persist thereafter. Fingerprint analysis is a valuable tool in criminal investigation and solving different criminal cases. According to Lockard's exchange principle, any two entities that come into contact exchange particles. Latent fingerprints deposit sweat, oil, and other secretions onto the surface they come in contact with that are invisible to the naked eye and can be developed by various methods. Latent prints are developed by many physical and chemical methods. Physical methods include powder dusting, alternative light sources. Chemical method includes ninhydrin, iodine fuming, silver nitrate, cyanoacrylate fuming, small particle reagents. The most commonly employed traditional approach is powder dusting. It is a physical method of fingerprint development. In the powder dusting method a fine powder is dusted over the surface on which fingerprints are present. The excess powder is dusted of using a camel hair brush. The development of prints also depends on the surface on which prints are present, temperature, surface texture, age of prints and environmental conditions. The powder then adheres on the prints, and the prints are visible. Commercial fingerprint powders, however, are often expensive, not readily available in all regions, and may pose environmental and health risks due to their fine particulate nature and chemical constituents. Keeping this in view this study aimed to evaluate the potential of hair dye powder to develop a non-conventional method for latent fingerprint analysis. In this study, Level-1 and Level-2 fingerprint characteristics of samples were analyzed on porous as well as non-pours surfaces to compare the hair dye powder with commercially used fingerprint powder for developing latent fingerprints.

2. Material and Method

2.1 Selection of Powder: Commercial and hair-dye powders were evaluated as latent-fingerprint developers. The commercial control consisted of a standard black fingerprint powder, while the test reagents were Colourmate hair dye powders in Burgundy and Natural Brown. All the powders were purchased from well-reputed vendors and manufactured from well well-reputed factory. All dusting was performed with a fine camel-hair brush; additional supplies included nitrile gloves, transparent adhesive tape for lifting prints, and a DSLR camera for documentation under natural light.

2.2 Study surfaces:

1. Porous: Paper, wall.

2. Non porous: glass tumblers, mirrors, smartphone screens, plastic containers, floor tiles, steel plates, sun mica sheets, CD surfaces, and black glass panels.

2.3 Sample collection: All latent prints were deposited by volunteers aged 15–60 years. Before deposition, volunteers were well informed about how their samples would be used for study.

Volunteers washed and dried their fingers to remove extraneous oils and contaminants. For each combination of volunteer and powder type, three prints were collected on each of nine non-porous surfaces: glass tumblers, mirrors, smartphone screens, plastic containers, floor tiles, steel plates, sun mica sheets, CD surfaces, and black glass panels (from electronic weighing scales) and two porous: paper, wall.

2.4 Development method used: Fingerprint development followed a standardized dusting protocol: the powder was applied with light circular strokes, allowed to adhere briefly, and then gently swept away to reveal the ridge detail without smudging.

2.5 Recording of developed fingerprints: Developed prints were photographed in situ with a DSLR camera positioned perpendicularly to the surface; selected prints were subsequently lifted with transparent tape and mounted on white backing cards for further analysis.

2.6 Analysis of developed prints: Level 1 (overall ridge flow and pattern type) and Level 2 (minutiae detail) characteristics were examined under a stereomicroscope at up to 50× magnification. The clarity, contrast, and completeness of ridge impressions produced by each hair-dye powder were directly compared to those obtained with the commercial black powder, enabling both qualitative and quantitative assessment of their forensic suitability.

3. Results

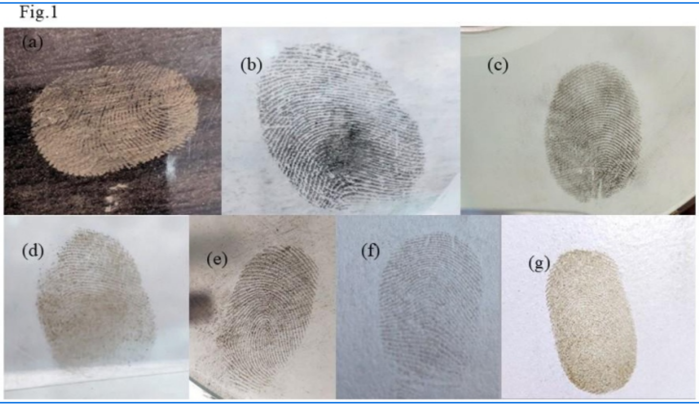
A total of 33 latent prints (three impressions per substrate) were collected across eleven porous and non-porous surfaces. All the prints on all the porous and non-porous surfaces were tested 3 times. The overall pattern distribution comprised four arches, two loops, and three whorls. Table 1 summarizes the success of Level 1 (ridge-flow) and Level 2 (minutiae) matching for each powder–substrate combination.

Table 1. Level 1 and Level 2 matching success across substrates and powders

Surface	Pattern	L1 Std	L1 Burgundy	L1 Natural Brown	L2 Std	L2 Burgundy	L2 Natural Brown
CD Surface	Arch	✓	✓	✓	✓	✓	✓
Tiled Floor	Loop	✓	✓	✓	✓	✓	✗
Sun Mica	Arch	✓	✓	✓	✓	✗	✓
Plastic container	Arch	✓	✓	✓	✓	⍰	⍰
Steel Plate	Loop	✓	✓	✓	✓	✗	✓
Smartphone Screen	Whorl	✓	✓	✓	✓	✓	✓
Black Glass (Weighing scale)	Whorl	✓	✓	✓	✓	✓	⍰
Mirror	Tented Arch	✗	✗	✗	✗	✗	✗
Wall	Arch	✓	✓	✓	✓	✓	✓
Paper	Arch	✓	✓	✓	✓	✓	✓
Glass Tumblr	Whorl	✓	✓	✓	✓	⍰	⍰

The standard fingerprint powder consistently demonstrated superior clarity at both Level 1 and Level 2 across most substrates, while Burgundy and Natural Brown hair-dye powders produced variable results depending on the surface type. Reflective surfaces such as mirrors failed to yield usable prints, whereas porous and smooth substrates, including paper, smartphones, CDs, and glass, showed successful recovery.

Fig.1



4. Discussion

The present study demonstrates that Colourmate hair-dye powders (Burgundy and Natural Brown) exhibit particle-size distributions and colorimetry comparable to those of a conventional black fingerprint powder, yet differ in surface affinity. Whereas the commercial powder adhered uniformly across substrates, the hair-dye powders showed slightly reduced adhesion (17), likely owing to their formulation for hair-fiber binding rather than lipid-eccrine residue interactions (3).

Despite this, both hair-dye variants produced ridge-flow (Level 1) impressions of equivalent clarity to the control on most test surfaces. Among the nine non-porous substrates, glass tumblers, CD surfaces, and steel plates yielded the highest success rates for hair-dye powders, with clear minutiae (Level 2) visualization nearly matching that of the commercial standard. These materials share relatively smooth, low-energy surfaces that facilitate pigment transfer and contrast, conditions under which pigment-based dyes excel. Conversely, highly reflective or hydrophobic surfaces (mirrors, black-glass weighing scales) posed challenges: the hair-dye powders' pigments produced insufficient optical contrast against specular highlights, whereas the commercial powder's fine carbonaceous particles maintained better visibility. Hair-dye powders offer several practical benefits. First, their unit cost is markedly lower than that of branded forensic powders, often by an order of magnitude, making them attractive for budget-constrained laboratories (8). Second, they are widely available in retail outlets where specialized forensic consumables may be scarce. Finally, their formulations lack heavy-metal oxides and synthetic polymers commonly found in fingerprint powders, reducing both inhalation hazard and environmental persistence (9). Two primary drawbacks emerged. Burgundy dye produced suboptimal contrast on light-colored surfaces, underscoring the need for pigment-surface compatibility assessment field use. Additionally, hair-dye formulations may provoke allergic contact dermatitis or respiratory irritation due to para-phenylenediamine (PPD) and related amine compounds—a risk well documented in dermatological literature (22). Appropriate personal protective equipment and ventilation are therefore essential when deploying such powders.

To enhance performance, hair-dye powders could be chemically modified—e.g., by grafting surfactant moieties or fluorescent tags—to improve adhesion and contrast under alternate-light sources. Parallel screening of other household pigments (e.g., textile dyes, food-colour powders) may further expand the palette of inexpensive, eco-friendly developers. Finally, exploring liquid or aerosolized formulations of hair dyes could combine wet-chemical deposition with particulate adherence, potentially yielding rapid, high-resolution latent-print visualization.

5. Conclusion

The findings indicate that Colourmate hair-dye powders can serve as cost-effective, readily accessible alternatives to conventional fingerprint powders on a range of non-porous substrates, particularly glass tumblers, CDs, and steel plates. From a practical standpoint, forensic units in resource-limited settings may adopt these powders to achieve satisfactory ridge and minutiae detail without incurring the high costs or logistical hurdles associated with specialized consumables. Although hair-dye formulations underperform on highly reflective surfaces and carry allergenicity risks, these shortcomings can be addressed through targeted formulation enhancements and safety protocols. Overall, hair-dye powders represent a promising avenue for "green" fingermark development, warranting further optimization and validation under standardized forensic guidelines.

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