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Development of Latent Finger- and Palm Marks on Non-Porous Synthetic Papers Using Alizarin Red Lake and Ninhydrin

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Abstract

The development of latent fingermarks on non-porous synthetic papers using chemical reagents remains a significant challenge in forensic chemistry due to the unique physical and chemical properties of these substrates. In this study, Alizarin Red Lake, in powder form (solid), is used for the first time to develop and visualize latent fingermarks on synthetic papers. The effectiveness of Alizarin in developing and visualizing latent fingermarks and palm marks was compared to that of ninhydrin. Various synthetic papers were employed: polyester (Premium and Select grades), polyolefin (Soft grade), and polypropylene. Ninhydrin, commonly used in fingermark development, was used in this study for comparison. The results show that Alizarin produced finger and palm marks with a distinctive reddish/burgundy color and without the use of visual enhancement, whereas ninhydrin's results showed the characteristic Ruhlmann purple and deep blue colors after the marks were enhanced at low heat (30˚C - 40˚C) for visualization. Both reagents produced continuous ridge details, visible across the marks and under daylight, highlighting Alizarin's potential in forensic applications involving synthetic substrates as evidence. These findings suggested that Alizarin Red Lake was a promising alternative method to ninhydrin for latent mark development on challenging non-porous synthetic papers. Future work will focus on the validation of the reagent using synthetic substrates from the real world crime scenes, a comparative study of the sensitivity of Alizarin and other chemical reagents used in the development of fingermarks, such as DFO, Black powder, etc., understand the specific reaction of fingermarks' chemical components (sebum) with Alizarin, and the formulation of Alizarin Red Lake for a broader forensic application.

Keywords

Alizarin Red Lake, Synthetic Paper, Polyester, Polyolefin, Polypropylene, Non-Porous Substrates, Latent Fingermarks, Palm Marks, Ninhydrin

1. Introduction

The development and visualization of latent fingermarks remain a cornerstone of forensic identification, offering a reliable means of associating individuals with objects left at crime scenes [1] [2]. Latent fingermarks at crime scenes are used to convict or exonerate suspects [3]. Due to their invisible nature, these fingermarks must be developed and enhanced to achieve sufficient clarity for courtroom use. Depending on the nature of the surface (*i.e.*, porous or non-porous) on which the prints are deposited, different reagents or methods [4]-[6] are best suited for development.

The two most widely used chemical methods for developing latent marks on porous surfaces are ninhydrin and 1,8-diazafluoren-9-one (DFO) [5] [7]. Fingermarks treated with ninhydrin form a Ruhlmann's purple product [5] [7] visible in daylight, while DFO-treated marks appear red, pale pink, or pale purple in daylight [5] [7] [8] and fluoresce under UV light. This fluorescence enhances the clarity of the fingermark, making it easier to analyze and photograph [9]. While numerous development techniques have been optimized for porous substrates such as wood-pulp or cellulose-based materials like paper and cardboard, their effectiveness is often diminished on modern synthetic substrates. Non-porous synthetic papers, such as Teslin® and Yupo®, pose a unique challenge due to their polymeric composition and surface characteristics [10].

Synthetic papers, engineered from materials like polyethylene and polypropylene, are commonly used in high-security documents such as passports, ID cards, and driver's licenses. Their resistance to water, tearing, and environmental degradation makes them ideal for long-term use. However, these properties also limit the absorption and retention of latent fingermark residues, which typically consist of water-soluble eccrine components, lipids, and amino acids. Consequently, conventional development reagents like ninhydrin, which rely on absorption into the substrate and subsequent reaction with amino acids, often prove ineffective.

Alizarin Red Lake (1,2-dihydroxyanthraquinone), an anthraquinone-based dye, has been investigated in recent years for its applications in forensic sciences and criminal investigations [11] [12]. Recent studies have explored structurally similar compounds, such as substituted 1,2-dihydroxyanthraquinones, as latent fingermark reagents for porous substrates, resulting in encouraging fluorescence and contrast outcomes [11] [12]. These findings suggest that Alizarin Red Lake's chemical affinities might extend to non-porous synthetic papers.

In this report, fingermarks and palm marks were developed on synthetic papers (non-porous substrates) using the Alizarin Red Lake for the first time and ninhydrin for comparison. The synthetic substrates were made of polyester, polyolefin, and polypropylene, all non-cellulose materials. The REVLAR® synthetic papers [13] were made of polyester or polyolefin and were available in three grades: Premium (polyester), Select (polyester), and Soft (polyolefin). The Premium and Soft models have an aqueous coating, while the Select model's coating is termed "industrial." The polypropylene is made by NARA® [14]. These papers are waterproof and tear-resistant, with applications in everyday life. They play a significant role in criminal investigations and forensic sciences due to their widespread availability in forms such as maps, restaurant menus, ID cards, manuals, labels, loyalty cards, fishing licenses, charts, and tags, making them potential physical evidence at crime scenes.

The developed fingermarks and palm marks were photographed with an iPhone 11.

2. Materials

Ninhydrin (Lynn Peavey, Lenexa, KS, USA), Alizarin Red Lake (Art Supply Warehouse, Westminster, CA, USA), REVLAR Premium synthetic paper (Relyco, Dover, NH, USA), REVLAR Soft synthetic paper (Relyco, Dover, NH, USA), REVLAR Select synthetic paper (Relyco, Dover, NH, USA), Long handle brush (Sirchie, Youngsville, NC, USA), Nara synthetic paper polypropylene (B7, Hema Industrial Estate, Maharashtra, India), Dell laptop computer, and iPhone 11 (iOS 18.4.1, Cupertino, CA, USA).

3. Methods

3.1. Stock Solution

Ninhydrin stock solution, concentration 0.5% (w/v), was used as purchased (Lynn Peavey, KS, USA) without further formulation. The stock was aliquoted into a beaker (100 mL) and used as a working solution.

3.2. Alizarin Red Lake Stock

Alizarin Red Lake dry powder was used as purchased (Art Supply Warehouse, Westminster, CA, USA) without further formulation. A small amount (50 mg) of Alizarin powder was poured into a container for use on fingermarks and palm marks in a dusting mode using a long-handled brush.

3.3. Latent Fingermark and Palm Mark

Synthetic papers were used as purchased, without any prior pretreatment, which was usually intended to facilitate the adhesion of the chemical reagent to the substrate. They were cut into finger- and palm-sized pieces for finger and palm impressions. In general, latent marks were made by applying sebum-rubbed fingers and palms onto the synthetic substrates and were developed and visualized immediately. The hand (fingers and palms) was rubbed on the face and in the hair long enough to produce natural [15] [16] sebum-imbibed fingers and palms for impression. The impressions were made voluntarily by an adult male. Immediately after the impressions were made, they were used to develop and visualize finger and palm marks.

3.4. Latent Fingermark and Palm Mark Development Method

1) *Ninhydrin*: Fingermarks on substrates were dipped (5 seconds) in a working solution of ninhydrin (25 mL) in a 150 mL beaker. After air drying (10 - 15 seconds), the substrates were gently heated on a hot plate (knob set to 1, 30˚C - 40˚C) for visual enhancement until the marks became visible to the naked eye [3].

2) *Alizarin Red Lake*: Alizarin powder (50 mg) was poured into a container and used to dust latent fingermarks and palm marks using a long-handled brush. The non-porous synthetic substrates—Premium, Soft, Select, and polypropylene—were cut into appropriate sizes for finger and palm impressions. Latent marks were made with sebum-coated palms and fingers and the impressions were photographed with an iPhone 11. The finger or palm was rubbed on the forehead.

3.5. Photography

Developed marks were visualized in daylight and photographed using an iPhone 11 with iOS 18.4.1.

4. Results

Latent fingermarks and palm marks were developed on synthetic papers using Alizarin Red Lake and were compared to those developed using ninhydrin. **Figure 1** displays fingermarks on Premium synthetic paper developed with ninhydrin and visualized in daylight. **Figure 2** and **Figure 3** show fingermarks on Select and Soft synthetic papers, respectively, also developed with ninhydrin. The marks were visible in daylight with distinctive friction ridges. **Figures 4-6** display fingermarks on Premium, Select, and Soft synthetic papers developed with Alizarin Red Lake. The marks show distinctive reddish/burgundy friction ridges in daylight. **Figure 7** shows palm marks on polypropylene synthetic paper developed with Alizarin, with visible friction ridges in daylight. **Figure 8** displays distinctive fingermarks on polypropylene synthetic paper developed with Alizarin. In **Figure 9**,

Figure 1. Fingermark on premium synthetic paper after treatment with ninhydrin and visualized in daylight.

Figure 2. Fingermark on select synthetic paper after its treatment with ninhydrin and visualized in daylight.

Figure 3. Fingermark on soft synthetic paper after its treatment with ninhydrin and visualized in daylight.

Figure 4. Fingermark on premium synthetic paper after application of Alizarin and visualized in daylight.

Figure 5. Fingermark on select synthetic paper after application of Alizarin and visualized in daylight.

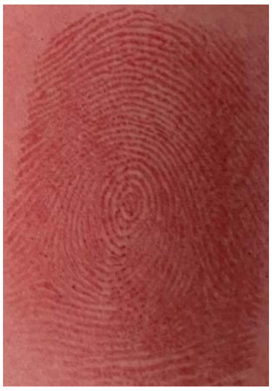

Figure 6. Fingermark on soft synthetic paper after application of Alizarin and visualized in daylight.

Figure 7. Palm mark on synthetic paper (polypropylene) after application of Alizarin and visualized in daylight.

Figure 8. Fingermark on synthetic paper (polypropylene) after application of alizarin and visualized in daylight.

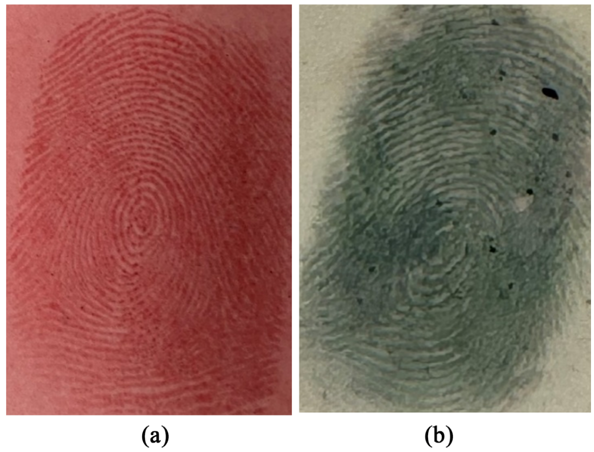

Figure 9. Side-by-side comparison of the friction ridges developed using Alizarin (a) and ninhydrin (b).

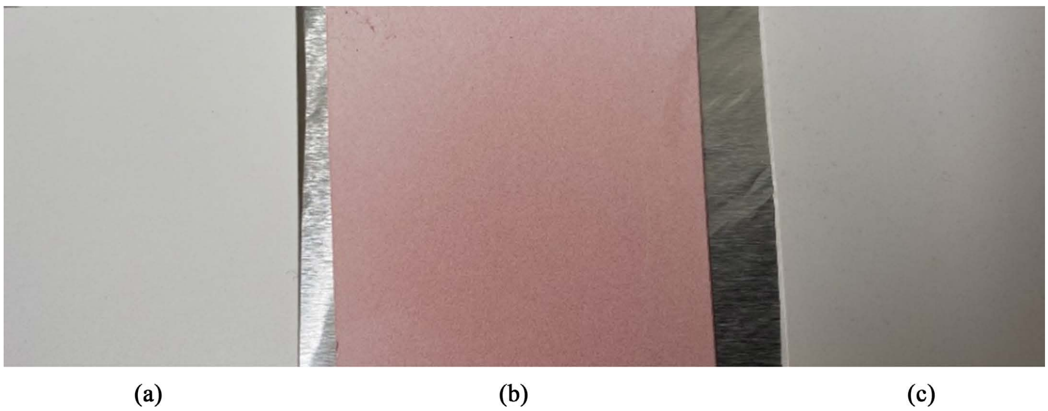

Figure 10. Synthetic papers without fingermarks or pal marks: (a) blank, (b) treated with Alizarin, (c) treated with ninhydrin.

a side-by-side comparison of marks developed by a) Alizarin and b) ninhydrin can be observed, while in Figure 10, the final figure in this report, are displayed, synthetic papers without fingers or palm impression: a) blank synthetic paper, b) synthetic paper treated with Alizarin, and c) synthetic paper treated with ninhydrin.

5. Discussion

This study employs Alizarin Red Lake to develop fingermarks and palm marks on various synthetic substrates and ninhydrin was used for comparison. To our knowledge, this is the first time that Alizarin powder was used with synthetic papers in the development of fingermarks and palm marks, making this study unique. In addition, the polymer substrates used have applications in everyday items (*i.e.*, ID cards, restaurant menu cards, etc.) that are valuable in forensic science and criminal and civil investigations.

Three types of synthetic substrates were used: polyester (Premium and Select), polyolefin (Soft), and polypropylene. The variety of substrates enabled the assessment of Alizarin's versatility in its applications. The substrates were not pretreated to alter reagent adhesion [17]. All latent marks were developed immediately after the impressions were made. Ninhydrin, used on non and porous surfaces [3] and Alizarin powder, used for the first time on synthetic paper, were evaluated. Latent marks were obtained from an adult male volunteer and were deposited on the substrates using the sebum-coated fingers and palms [3]. Both hands (right and left) were used to collect the marks.

A visual comparison of the developed marks on all the synthetic papers with Alizarin and ninhydrin revealed distinctive fingermarks and palm marks, along with detailed friction ridges. The fingermarks developed with ninhydrin (**Figure 1** and **Figure 2**) showed the characteristic Ruhlmann's purple on polyester synthetic paper [3]. However, on Soft synthetic paper (**Figure 3**), a deep blue color was observed, possibly due to the interference of the paper's background, though no supportive evidence was available. The images revealed defined, visible friction ridges similar to those developed on porous surfaces [3].

Low heat (30˚C - 40˚C) was employed for visual enhancement and to avoid the destruction of the synthetic substrates. In addition, ninhydrin concentration was maintained at 0.5% (w/v), the standard concentration customarily used for ninhydrin in fingermark development [17]-[19].

Latent marks developed with Alizarin Red Lake (**Figures 4-8**) consistently showed a reddish/burgundy color [20] with no observed background interference, and resulted in distinctive friction ridges. The ridges were continuous, visible across the entire mark with excellent contrast, no background staining interference, and clear minutiae. Unlike with ninhydrin, Alizarin did not require heat enhancement to visualize the marks. Instead, Alizarin powder was dusted off from the substrates to reveal the marks.

Both reagents produced continuous ridge details, visible across the marks and good background contrast [21] as revealed by the side-by-side comparison (**Figure 9**). The interaction of Alizarin with the synthetic papers was evaluated. Although Alizarin stained synthetic papers, **Figure 10**, and ninhydrin did not, the interference of the stained synthetic papers with the finger and pal marks was not observed, **Figure 9**.

6. Conclusions

In this study, Alizarin Red Lake and ninhydrin were used to develop latent fingermarks and palm marks on synthetic substrates made of polyester (Premium and Select), polyolefin (Soft), and polypropylene. The visual comparison of fingermarks and palm marks developed with ninhydrin, and those developed with Alizarin Red Lake, employed for the first time in this study on synthetic papers, is as follows. Both methods displayed characteristic colors when reacted with the fingermarks and palm marks: reddish/burgundy for Alizarin and Ruhlmann's purple and deep blue (Soft synthetic) for Ninhydrin. We speculated that the deep blue color was the result of the interaction or reaction of ninhydrin with the background of the Soft synthetic paper. The visual enhancement of fingermarks and palm marks at low temperatures (30˚C - 40˚C) was observed using Ninhydrin. However, this step was not necessary with Alizarin powder. The quality of the friction ridges in both methods was distinctive and visible under daylight.

The future direction of this project may include several paths. The assessment of the relative sensitivity of ninhydrin and Alizarin on synthetic papers and other non-porous substrates. From the preliminary study, it appeared that Alizarin Red Lake, in powder form, is more sensitive than ninhydrin formulated in liquid solution. Another path of this project will be the comparison of Alizarin red lake with black powder. Black powder is routinely used in police work; Both reagents (alizarin and black powder) are used in powder form. The various surfaces on which they are both applicable, and their relative sensitivities, may be studied. Their relative sensitivity to hydrophilic versus hydrophobic substrates will also be studied. Lastly, the reaction of Alizarin with chemical components of the fingermarks, such as lipids and amino acids, will be studied.

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Author Contributions

Conceptualization, project administrator, formal analysis, resources, supervision, original draft writing, and validation: Jules Guei.

Methodology and Investigation: Jules Guei and Ti'Yanna Watson.

Data curation and reviewing & editing: Jules Guei, Mebougna Drabo, and Ti'Yanna Watson.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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