INVESTIGATION OF ONE-STEP SUPERGLUE FUMING FOR VISUALISATION OF LATENT FINGERMARKS

Nur Fatin Nabihah Said, Nik Fakhuruddin Nik Hassan*

Forensic Science Programme, School of Health Sciences, Universiti Sains Malaysia, 16150, Kubang Kerian, Kelantan.

* *Forensic Science Programme, School of Health Sciences, Universiti Sains Malaysia, 16150, Kubang Kerian, Kelantan; Email: nikf@usm.my*

ABSTRACT: The superglue fuming (cyanoacrylate) fuming method is a well-established method for developing latent fingermarks for decades. One of the drawbacks of this method is the lacking of contrast due to the white cyanoacrylate polymer, particularly on light-coloured background. It would be ideal to develop latent fingermarks that can be readily viewed with alternate light source without the need for secondary treatment. The aim of this study was to develop a one-step cyanoacrylate fuming method for visualisation of latent fingermarks using fluorescent dyes incorporated into superglue prior to fuming. Following fuming, an alternate light source was utilised to observe the developed fingermarks. This study shows that Sudan Black-superglue and Rhodamine B-superglue mixtures have successfully developed latent fingermarks via the fuming process. The quality of developed fingermarks, however, varied when tested on various non-porous and semi porous surfaces.

Keywords: Latent fingermarks; one-step cyanoacrylate fuming; visualisation.

Introduction

The super glue fuming or also known as cyanoacrylate fuming method (CFM) is a powerful method for developing latent fingermarks, especially on non-porous substrates, including plastic, glass and metallic surfaces [1,2]. In the late 1970s, it was reported that latent fingermarks development was possible when exposed to cyanoacrylate (CA) vapour [3]. Adhesives consisting of alkyl 2-cyanoacrylates (methyl-2-cyanoacrylate, ethyl-2-cyanoacrylate or a combination of the two) are generally used the term CA or commonly known as ‘Super Glue’ [3]. A white polymer coating on the substrate allows the visualisation of latent fingermarks, derived from the interactions between fingermark residue and CA vapour which causes rapid polymerisation [2]. Generally, it was achieved by exposing latent fingermarks to the fumes from CA adhesive that heated in an enclosed chamber. Such fuming chamber could be a home-made, a commercial unit or an improvised system, such as a plastic tent or a modified glass fish tank [1].

One of the drawbacks of the CFM is over-fuming. If the latent fingermarks were fumed for an extended duration than necessary, the quality of ridge detail could be reduced because the polymers will adhere in between the latent fingermarks ridges [4]. Another shortcoming with CFM is the processing of aged latent fingermarks that have been exposed to extreme environments. Conventional process of latent fingermarks enhancement using CA fuming was also frequently found to be lacking in contrast, especially on light-coloured background [5,6]. Subsequently, a second step, namely the dye staining using Rhodamine 6G, Ardrox and Basic Yellow 40 were required for further enhancement [5]. However, these second steps are time consuming and the dyes could contain carcinogenic compounds, requiring adequate protection and appropriate waste elimination [7].

Since early 1980s, one-step fluorescent CA fuming products incorporating a fluorescent dye with CA had been researched [8]. However, only a few recent products were marketed as a one-step fluorescent CFM, including Polycyano (Foster + Freeman Ltd), Lumicyano (Global Forensics Ltd), PECA Multiband (BVDA), Fuming Orange and CN Yellow (Aneval Inc) [8]. These products involve the use of fluorescent dye (fluorophore) incorporated into CA which can reduce overall cost, more quickly, no need for a dye tank and drying space, and also could reduce the possible interference with subsequent DNA analysis from the dyeing procedure [9]. Most fluorescent dyes contain hazardous compounds and the fuming process by heating CA could release highly toxic hydrogen cyanide which pose a concern regarding health and safety issue towards laboratory workers [7,10].

Previous studies had attempted to develop a one-step CFM using protein and hemoglobin stains, commercial colourants, sublimation dyes, hair dye, printer ink and also pre-coloured commercial glues, but none of these methods proved successful [4]. Hence, this study effort for modification of one-step CA fuming process using commercial superglue and various fluorescent dyes in search for improvement in latent fingermarks development process.

Materials and Methods

General Approach

Two-step process was carried out as a preliminary experiment. In this study, both groomed eccrine and sebaceous latent fingermarks were investigated and optimisation step was conducted to determine the amount of superglue required and the fuming period for development of fingermarks on glass substrate. Subsequently, the one-step process was optimised to determine the dissolution of fluorescent dyes in superglue-solvent mixture. The effectiveness of one-step process utilising the best combination of fluorescent dye and superglue was further investigated through depletion and accelerated aging studies. All developed fingermarks were photographed using alternate light source (ALS) with a proper filter and digital camera. The assessment of the quality of the developed marks was conducted according to fingermarks visibility scoring system, as demonstrated in Table 1 [11].

Table 1: The fingermarks visibility scoring system

GRADE	CRITERIA
1	No fingermark developed
2	Poor fingermark development: very few ridges visible, poor contrast
3	Medium fingermark development: either contrast or ridge detail was not good
4	Good fingermark development: either contrast or ridge detail was visible
5	Excellent fingermark development: contrast as well as ridge details are very clear

Fuming Chamber Set-Up

An enclosed custom-made prespex chamber measuring approximately 36 cm × 36 cm × 46 cm was employed as a fuming chamber for fuming process (Figure 1). A smart electrical stove was used as the heating source for superglue. Disposable aluminum foils were used as tray to contain the superglue and superglue-fluorescent dye mixture to be heated on a hot plate. A metal container containing water was also heated on the stove to increase the humidity of the chamber.

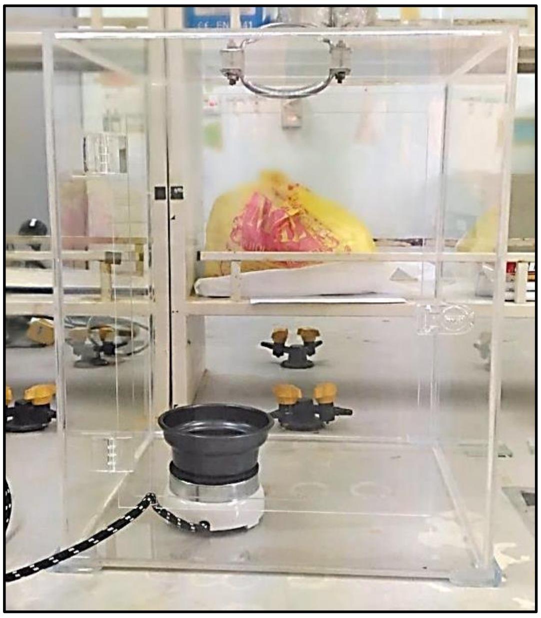


Figure 1: Fuming chamber set up

Samples preparation

Surfaces

The surfaces used in this study included non-porous and semi-porous surfaces, namely glass plate, tiles, plastic file, compact disc (CD) and glossy paper for fingermark deposition. All the substrates (except for CD and tiles) were cut to 5 cm × 5 cm in sizes. The surfaces were cleaned with acetone and ethanol in order to remove any pre-existing marks and other contaminants before fingermarks being deposited.

Fingermarks deposition

Two types of fingermarks were used in this study, namely groomed eccrine and sebaceous fingermarks.

a) Groomed eccrine fingermarks [3] — the donor was asked to wash her hands with soap and water, then rinsed her hands thoroughly with ethanol. Her hands were allowed to dry completely before putting on un-powdered latex gloves for 45 mins while doing her normal activities. This step was to ensure that only eccrine secretions were developed on the fingers. The gloves were removed and fingers were rubbed against each other just before deposition was made.
b) Groomed sebaceous fingermarks [3,12] — the donor was asked to wash her hands with soap and water, then rinsed her hands thoroughly with ethanol. Her hands were allowed to dry completely. She was then asked to wipe her right thumb finger along sebaceous areas of her face, from bridge of nose across forehead. All of these parts were repeated for ten times. Finally, fingers were rubbed against each other and deposited immediately.

Split Depletion Series Study

This study was performed to compare the effectiveness of two fluorescent dyes; Sudan Black and Rhodamine B-superglue mixture. Only groomed sebaceous fingermarks and the chosen substrate were utilised in this study. The substrate was cut into two halves and the surfaces were cleaned with acetone and ethanol to prevent contaminants before depositing the fingermarks. Both halves of substrate were arranged side by side and four fingermarks were deposited in a depletion series continuously at the junction of the two pieces using the same right thumb finger. Samples were then left at room temperature for about half an hour before developed via superglue fuming.

Accelerated Aging Study

Similarly to depletion study, this study also utilised groomed sebaceous fingermarks. The surfaces were cleaned with acetone and ethanol before fingermarks being deposited. After deposition of fingermarks on the substrates, they were then kept overnight in the oven and heated at 100°C.

Methods

Optimisation of Superglue Fuming and Superglue Mixture

The optimisation was carried out for both two-step and one-step CA fuming process. A few conditions were optimised prior to fuming process of both steps, namely the amount of superglue and the duration of time taken for fuming process. The dissolution of different fluorescent dyes in superglue-solvent mixture was also optimised in one-step CA fuming process. Only latent fingermarks deposited on glass plates were investigated for optimisation.

Development of Fresh Latent Fingermarks

After fingermarks deposition on the selected substrates, all samples were left at room temperature for 30 minutes before being developed via fuming process. These experiments were carried out in triplicates. The whole experiment only involved single donor to prevent differences in fingermark composition as well as the clarity of ridges details.

Fingermark Powder Dusting Method for Two-Step CA Fuming Process

Fresh latent fingermarks deposited on non-porous surfaces were developed using CA fuming method in an enclosed chamber. Commercial superglue was used in the fuming process. Prior to CA fuming, latent fingermarks samples were placed into the enclosed fuming chamber. Then, commercial superglue was heated on the stove. Chamber door was tightly closed to ensure that fuming vapour did not escape from the fuming chamber. This process was allowed for 10 minutes. A white colour polymer formed on the substrate needed further enhancement for visualisation using powder dusting method. In this experiment, commercial orange and green fingermark fluorescent powders (Sirchie®) were investigated.

Incorporation of Fluorescent Dyes to Cyanoacrylate Prior To Fuming For One-Step CA Fuming Process

Fluorescent dyes were incorporated into commercial superglue as solid and solution forms. Tested dyes included commercial orange fluorescent powder, commercial green fluorescent powder, Sudan Black, Rhodamine B, batik dye (Remazol Black B), Crystal Violet and glittery ink. Dye solutions were prepared in distilled water, methanol, ethanol, acetone and hydrochloric acid (HCl) prior to mixing with CA, except for glittery ink.

The mixture was heated in the fuming chamber and the door was closed to ensure that fuming vapour remained in the chamber. This process was allowed for 10 minutes. After the glass substrates bearing the fingermarks were removed from fuming chamber, the photographs of the developed fingermarks viewed under white light and ALS (Crime-lite®2) were taken for the assessment of the visibility and quality. Two fluorescent dyes-superglue mixtures that produced good clarity of developed fingermarks on glass plates were then selected for further investigation on other substrates.

Split Depletion Series Study

The substrate was cut into two halves; the left half-fingermark was developed with Sudan Black and the right half-fingermark was developed with Rhodamine B. Note that both fluorescent dyes used were the selected dyes based on the optimisation experiment. The both halves were re-combined for comparison purposes to determine the effectiveness of each fluorescent dye-superglue mixture. All developed fingermarks were photographed under white light and ALS (Crime-lite®2) for the assessment of the quality.

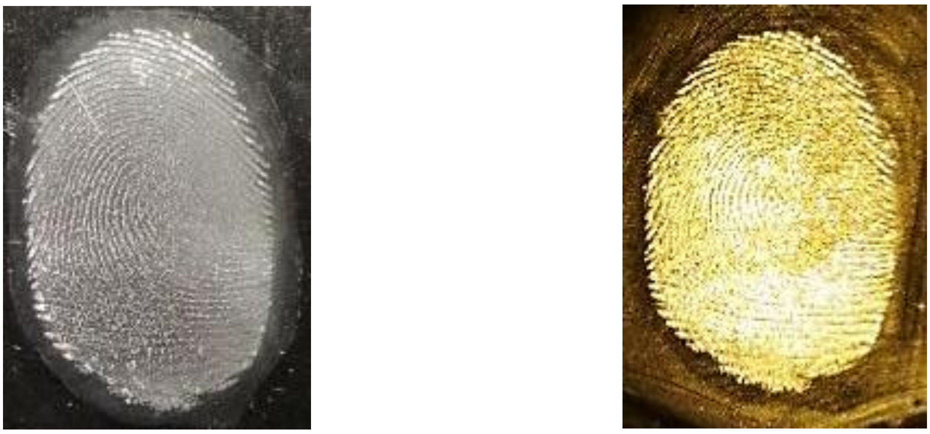
Accelerated Aging Study

The substrates were later removed from the oven and each half-fingermarks samples were developed with Sudan Black and Rhodamine B as previously described in depletion study. All developed fingermarks were photographed under white light and ALS (Crime-lite®2) for the assessment of the quality.

Results and Discussion

Optimisation for Two-Step CA Fuming Process

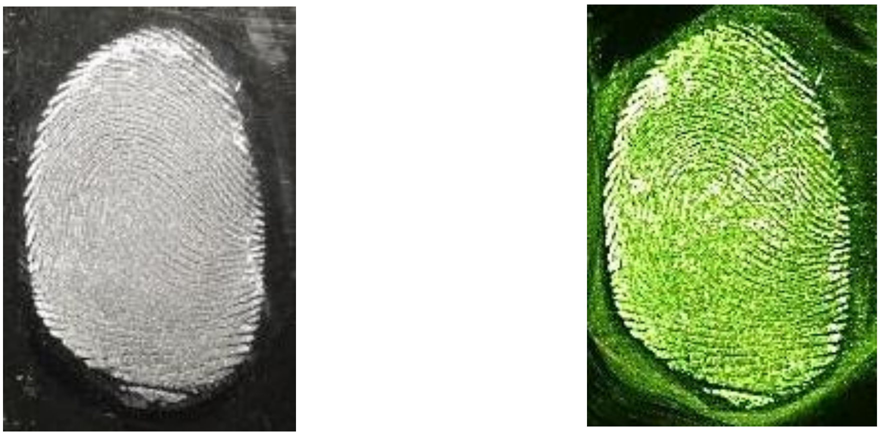
The orange and green fluorescent powders were employed to enhance and visualise the developed fingermarks (Figures 2 and 3). The developed sebaceous fingermarks have demonstrated better quality fingermarks as compared to its eccrine counterparts. This was because CA polymers are more likely to attach to secretions from the sebaceous glands than secretions from the eccrine glands [3]. All superglue fumed fingermarks developed using both fluorescent powders showed good quality fingermarks with identifiable ridge characteristics when viewed under blue/green light and orange filter.



(a) First step – superglue fuming (white light)

(b) Second step – powdering with fluorescent powder (blue/green light)

Figure 2: Sebaceous fingermarks fumed with superglue followed by powdering with fluorescent powder



(a) First step – superglue fuming (white light)

(b) Second step – powdering with fluorescent powder (blue/green light)

Figure 3: Sebaceous fingermarks fumed with superglue followed by powdering with fluorescent powder

Optimisation for One-Step CA Fuming Process

One-step CA fuming process involved the incorporation of fluorescent dye into the superglue prior to fuming (a single step process). Non-porous substrate (glass plate) was used for deposition of fresh groomed sebaceous and eccrine latent fingermarks. In this experiment, acetone was the only solvent that dissolved fluorescent dyes and commercial superglue. This mixture was then optimised using various types of fluorescent dyes.

Based on optimisation results, the development of fingermarks containing groomed sebaceous residue produced better clarity than those of eccrine residue. Thus, groomed sebaceous fingermarks were only employed for the remaining of the study. In addition, most of the fluorescent dyes in this study did not co-polymerise with superglue that resulted in no fluorescence of the latent fingermarks observed with an ALS. From of all tested dyes, only Sudan Black and Rhodamine B dyes demonstrated good fingermarks visibility during fuming with superglue (Figure 4). Hence, both were used as fluorescent dyes for one-step CA fuming process in subsequent experiments on various non-porous and semi-porous surfaces, split depletion series and accelerated ageing fingermarks studies.

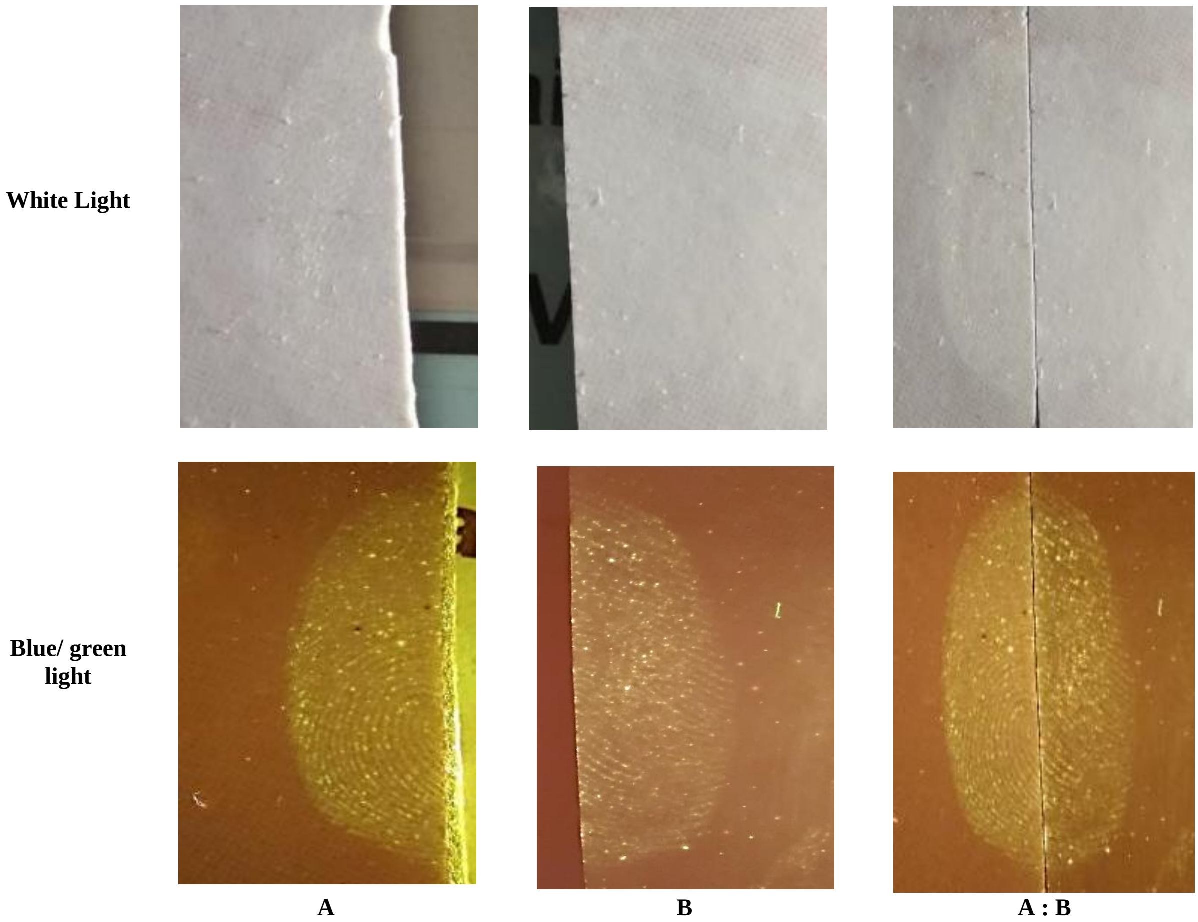


Figure 4: The development of fresh latent fingermarks on tile (A: Sudan Black; B: Rhodamine B)

Choice of Substrate for the Development of Latent Fingermarks Using Split Depletion Series and Accelerated Ageing Study

In this study, five substrates were selected for latent fingermarks deposition, including plastic file, CD, glass plate, tile and glossy paper. Results from the trials demonstrated that the development of latent fingermarks on tile produced better quality of fumed fingermarks with better contrast from the background and low reflection of light. Hence, tile was selected as the receiving substrate for fingermarks deposition in depletion series and accelerated ageing study.

The Development of Latent Fingermarks in Split Depletion Series Study

Depletion series study is generally carried out to determine the sensitivity of a technique [13]. The use of split depletion series of fingermarks have more advantages where half fingermarks with the same chemical composition, quantity of material and the pressure during deposition can be compared [13]. Figure 5 represents the images of developed depleted fingermarks following fuming process in split depletion series study on tile. Although the developed fingermarks have poor visibility under white light, it was noted that Sudan Black and Rhodamine B-superglue mixture developed good quality fingermarks in first depletion until fourth depletion. The fingermarks fluoresced when irradiated with blue/green light and ridge characteristics were visible *via* observation using orange filter. In addition, the decrease in fingermarks residue on the surface from first depletion to fourth depletion were not pronounced in terms of the recovery of identifiable ridge characteristics.

Depletions **Sudan Black** **Rhodamine B**

1

2

3

4

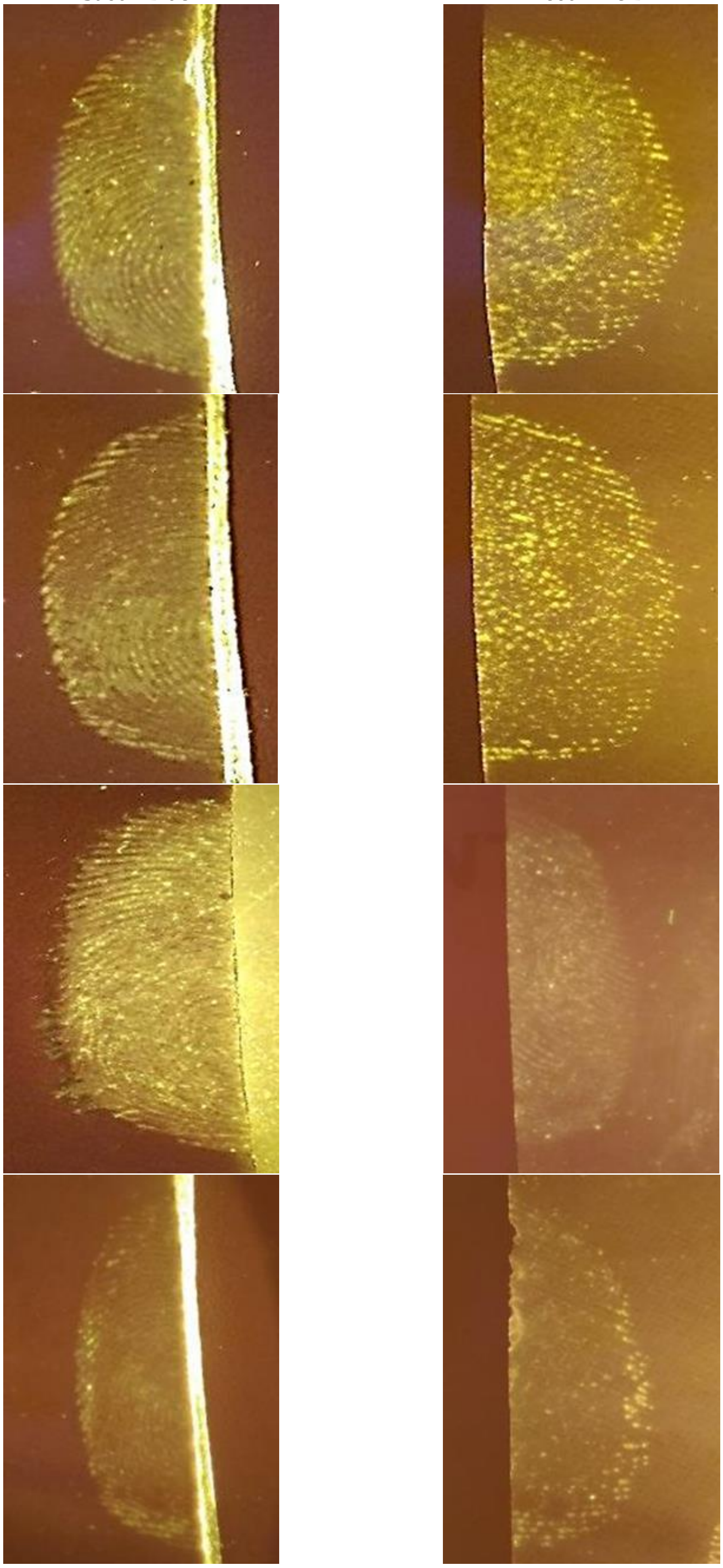
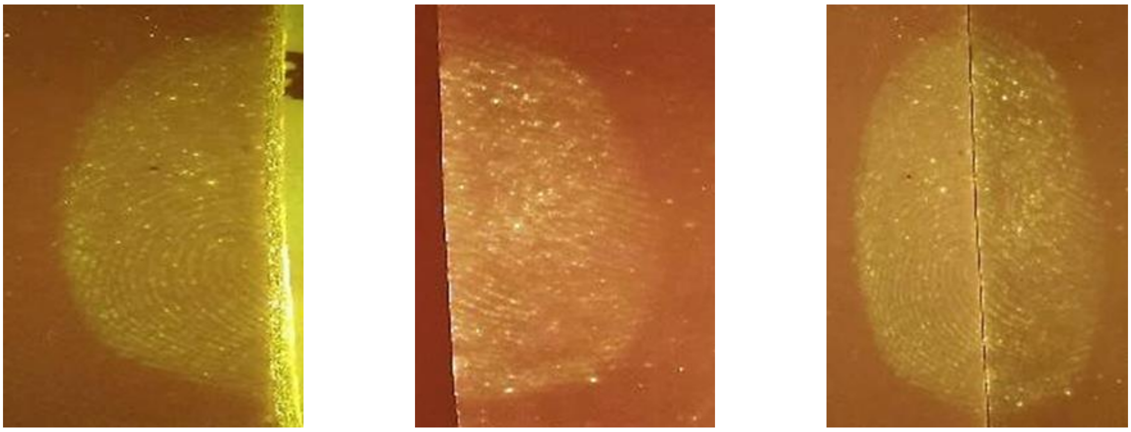


Figure 5: Developed fingermarks in split depletion series study on tile

The Development of Latent Fingermarks in Accelerated Ageing Study

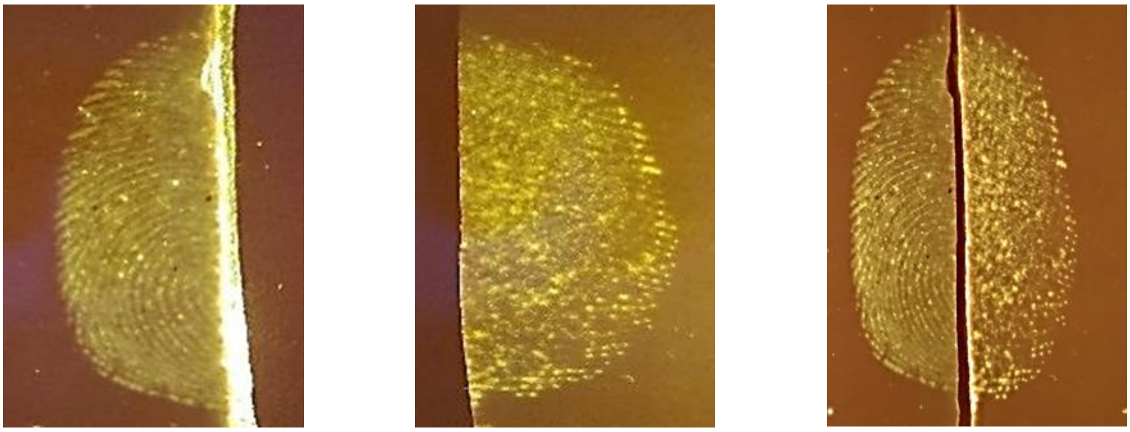
The change of the chemical composition of fingermarks against time could lead to less efficient CA polymerisation. The high amount of water could cause to a less efficient reaction, however a small amount of water is useful in initiating polymerisation [14]. The ageing process such as exposure to heat, light and moisture have been reported which may cause alteration, and subsequently lead to degradation of latent fingermarks [15].

This part of the study focused on the accelerated ageing of latent fingermarks by exposing them to high temperature at 100˚C in the oven overnight. Figure 6 shows the images of fumed fingermarks on tile substrate. The quality of the developed fingermarks using both Sudan Black and Rhodamine B-superglue mixture were poor as compared to fresh fingermarks in which only visible fluorescent marks without clear ridge detail were observed using blue/green light and orange filter. It was thought that at higher temperature, the fingermarks residue was degraded, and therefore affected the effectiveness of the fuming process.



Sudan Black (A) **Rhodamine B (B)** **A : B**

Figure 6: Fingermarks developed on tile substrate in accelerated ageing study



Sudan Black (A) **Rhodamine B (B)** **A : B**

Figure 7: Fingermarks developed on tile substrate (fresh fingermarks)

Conclusion

This study was carried out in an attempt to modify one-step CA fuming process by mixing commercial superglue with various fluorescent dyes. It was aimed to develop latent fingermarks that can be readily viewed with ALS without needed for post-treatment. The preliminary experiment, two-step CA fuming process was set-up to determine the amount of commercial superglue used to develop excellent latent fingermarks during fuming phase. This two-step cyanoacrylate fuming experiment concluded that the developed sebaceous fingermarks demonstrated better quality fingermarks as compared to its eccrine counterparts. All superglue fumed fingermarks developed using both fluorescent powders showed good quality fingermarks with identifiable ridge characteristics when viewed under blue/green light and orange filter.

One-step cyanoacrylate fuming process was carried out to create co-polymerisation process of vapourised cyanoacrylate monomers and fluorescent dyes molecules on latent fingermark residues. Fuming process was investigated using fluorescent powder, Sudan Black, Batik dye, Crystal Violet, Rhodamine B and glittery ink with addition of acetone for dissolution of fluorescent powder and commercial superglue. This study concluded that Sudan Black-superglue and Rhodamine B-superglue mixtures were successfully developed latent fingermarks via fuming process. The quality of developed fingermarks, however, varied when tested on various non-porous and semi-porous surfaces.

Split depletion series demonstrated that Sudan Black and Rhodamine B showed good quality fingermarks and fluoresced but the clarity of ridge details were not too discernible. Accelerated ageing studies concluded that the developed fingermarks using both Sudan Black and Rhodamine B fluoresced, however, no clear ridge details were observed. In conclusion, one-step CA fuming process using commercial superglue and various fluorescent dyes was feasible to be employed in forensic settings. Sudan Black and Rhodamine B have shown to be great potential as alternatives for development of latent fingermarks using one-step CA fuming process in forensic investigation.

Future research should attempt to develop one-step fuming process by using natural substances to mimic the properties of CA. It could be an alternative to replace carcinogenic CA vapour during fuming at lower cost and environmental friendly approach.

Acknowledgements

This project was supported by Research University Grant, Universiti Sains Malaysia (1001/PPSK/812125).

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