Article

Pseudo-Operational Trials of Lumicyano Solution and Lumicyano Powder for the Detection of Latent Fingermarks on Various Substrates

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Abstract: This study presents pseudo-operational trials comparing a one-step fluorescent cyanoacrylate process with a number of other enhancement techniques on a variety of substrates. This one-step process involves a product, 4% Lumicyano, which is a solution consisting of 4% by weight of a powdered dye (Lumicyano powder) dissolved in a cyanoacrylate-based solution (Lumicyano solution). The cyanoacrylate in the Lumicyano solution may be of a higher quality than that used in the two-step products.

One hundred items were collected from the place of work for each trial. Trial 1 involved a comparison of 4% Lumicyano with the conventional two-step cyanoacrylate fuming-dye staining for the detection of latent fingermarks on plastic carrier bags. Trial 2 assessed the quality of the Lumicyano solution (with no powdered dye) but used in a two-step process with basic yellow 40 (BY40). Trial 1, using 4% Lumicyano powder and traditional cyanoacrylate → BY40 detected a similar amount of fingermarks (~295); however, sequential BY40 treatment (i.e., after 4% Lumicyano) detected an additional 30% marks. Trial 2 resulted in the detection of 565 marks after Lumicyano solution → BY40 in comparison to 489 marks after traditional cyanoacrylate fuming and BY40 staining. Trials 3 through 5 com-

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pared 4% Lumicyano, 1,2-indanedione-zinc, and ninhydrin on junk mail, magazines, and cardboard used for food or cosmetic packaging; the detection rate was low for all techniques and substrates. Trial 6 on cardboard packaging using 4% Lumicyano, black iron-oxide powder suspension, and magnetic powder also provided a low detection rate. Trial 7, using 4% Lumicyano → BY40, solvent black 3, and iron-oxide powder suspensions on cardboard packaging from a fast food chain, indicated that 4% Lumicyano → BY40 might be a suitable alternative to solvent black 3 and iron-oxide powder suspensions for suspected greasy marks.

Introduction

There are several products that are marketed as providing a one-step fluorescent cyanoacrylate process and are thus alternatives to the conventional two-step cyanoacrylate fuming and dyeing. Examples of such one-step fluorescent products include Polycyano (Cyano UV, Foster and Freeman, U.K.), Lumicyano (Crime Scene Technology, France), and CN Yellow (Aneval, Inc., IL). Such products, although currently expensive when compared to traditional cyanoacrylate fuming followed by staining, might be suitable alternatives that can save time and space as well as reduce interference with subsequent DNA analysis from the dyeing procedure [1].

An evaluation of Polycyano revealed that the quality of enhanced fingermarks is comparable to those developed by the conventional two-step fuming and staining method [2]. A later study reflected similar findings, however argued that the cost and weaker fluorescence (when compared to staining with rhodamine 6G) of Polycyano was a “costly alternative that is not justified by the results observed on common non-porous substrates” [3]. Additionally, this technique (in addition to CN Yellow [4]) requires a modification of existing cabinets because the product is a solid powder and requires heating temperatures of up to 230 °C. This high temperature may also produce toxic hydrogen cyanide gas [5]. Nonetheless, it has been reported that Polycyano might be more effective on semiporous substrates and that in some cases, marks treated with Polycyano followed by rhodamine 6G staining provided better results than the conventional two-step process of cyanoacrylate fuming followed by rhodamine 6G [3]. The use of basic yellow 40 (BY40) may be a suitable alternative stain to the suspected carcinogenic rhodamine 6G.

Lumicyano is another fluorescent one-step cyanoacrylate process, but it does not require any modifications to the fuming chamber cabinet and can operate at heating temperatures of 120 °C. Prete et al. [6] reported that Lumicyano offers equal or better sensitivity for the detection of fingermarks when compared to traditional cyanoacrylate processes. A further study [7] compared cyanoacrylate → BY40, 1% Lumicyano, and iron-oxide powder suspension to investigate the suitability and effectiveness of each technique for the visualization of fingermarks on plastic carrier bags by means of pseudo-operational trials. A similar number of fingermarks were detected by the three techniques; however, 1% Lumicyano did not require any dyeing or drying facilities or times. Furthermore, sequential BY40 treatment of 1% Lumicyano-treated marks provided an additional 15% detection rate [7]. The fluorescence of 1% Lumicyano decayed almost completely after a period of 7 days. However, it was possible to re-fume the articles under examination to restore fluorescence. If fluorescence examination cannot be done immediately after fuming, it is recommended to store treated articles in a cool, dark, and dry place, ideally sealed in a brown paper envelope. If necessary, further treatment with BY40 ensures that the fluorescence does not degrade on exposure to light. Both the U.K. Home Office Centre for Applied Science and Technology (CAST) [8] and the International Fingerprint Research Group [9] describe pseudo-operational trials as stage or phase 3 out of 4 in fingermark research, and CAST [8] describes the process as one to "establish whether the results obtained in laboratory trials are replicated on articles/surfaces typical of those that may be submitted to a fingerprint laboratory, or to distinguish between closely equivalent formulations that cannot be separated in laboratory trials".

Current methodologies by CAST recommend either the use of cyanoacrylate followed with BY40 dyeing or iron-oxide-based powder suspension as the primary method for the enhancement of latent fingermarks on plastic packaging material [10, 11]. This study [11] revealed that, contrary to previous trials, the effectiveness of vacuum metal deposition on this substrate has diminished relative to that of cyanoacrylate fuming followed by BY40; however, the sequential treatment of VMD after cyanoacrylate → BY40 may detect additional marks. Solvent black 3 (Sudan black) is a fat-soluble diazo dye that reacts with fats and lipids to produce a blue-black staining [12]. This technique "is less sensitive than some other processes for latent fingerprint detection but is of particular use on surfaces which are contaminated with, e.g. grease, foodstuffs or dried deposits of soft drinks" [10]. Recent studies [13, 14] have demonstrated that using 1-methoxy-2-propanol (PGME) as the primary solvent for the solvent black 3 formulation provides superior enhancement than the previously recommended ethanol formulation. An additional advantage of the PGME formulation is the lower flammability of the solvent when compared to ethanol. Research by CAST [15] assessed the suitability of black powder suspensions for enhancing footwear marks made in a wide range of contaminants (e.g., milk, beer, baby oil, soft drinks) on different nonporous substrates commonly encountered at crime scenes, with suitable enhancement results obtained on more than 50% of all contaminants tested. The major drawback for powder suspension is the excessive rinsing required after application, potentially making the technique unsuitable for porous surfaces and large, fixed, horizontal surfaces.

Ninhydrin, 1,8-diazofluoren-9-one (DFO), and 1,2-indanedione (1,2-IND) are generally employed for the detection of latent fingermarks on papers because of a reaction with amino acids, which may result in a visual or fluorescent reaction [16–18]. The addition of zinc chloride to the 1,2-IND formulation improves the fluorescence [19, 20]. The efficiency of amino acid reagents on semiporous substrates, such as cardboard and glossy magazines, appears to be less successful possibly because of the amino acids and fingermark residues not being absorbed into the substrate [21]. The use of a one-step fluorescent cyanoacrylate process may provide a viable alternative to fingermark enhancement on semiporous substrates. Current recommendations and comparisons between DFO and 1,2-indanedione vary between countries, and variable climatic conditions between different countries (and even within) may have an effect on the performance of 1,2-IND and DFO [22]. The U.K. CAST currently recommends the use of DFO; however, research in countries such as Israel, the United States of America, and Australia has shown that 1,2-IND is superior to DFO [22, 23].

This current study aims to follow up the previous pseudo-operational trials on plastic carrier bags with further trials on a variety of substrates using 4% Lumicyano where the cyanoacrylate and the dye have been separated. Additional trials were set up to assess the efficiency of 4% Lumicyano on substrates such as food and cosmetic cardboard packaging, junk mail, magazines, and fast food containers.

Methodology

Collection of Items

Plastic carrier bags (mixture of HDPE, LDPE, recycled, and bio), junk mail, magazines, and food or cosmetic cardboard packaging were collected from family, friends, and colleagues to obtain different types of items with varying ages and fingermark donors. The maximum number of an item from any one person was limited to five to increase the variability of donors as well as the origin and type of substrates. Used fast food containers were collected in four batches from rubbish bins from two local establishments of the same fast food chain. Each trial consisted of 100 items so as to be in line with other studies [7, 11], and the description (e.g., color and material type) for each item was recorded. All items were treated with the appropriate technique within three weeks of collection.

Trials 1 and 2

For trials 1 and 2, plastic carrier bags were split into quarters and the opposite sides were labeled either A or B in an attempt to eliminate bias, as shown in Figure 1 (left for trial 1 and right for trial 2). The first trial used the latest version of Lumicyano (CST) consisting of a clear cyanoacrylate solution (Lumicyano solution) and a bright red-orange powdered dye (Lumicyano powder), added at the 4% level (by weight). This mixture shall be referred to here as 4% Lumicyano. After fuming with 4% Lumicyano and recording of any detected marks, BY40 was used in sequence, and any additional marks were recorded. The other technique in trial 1 involved conventional two-step cyanoacrylate fuming followed by BY40 staining. The second trial used Lumicyano solution without the use of the powdered dye but treated with BY40 and compared to a conventional two-step cyanoacrylate fuming followed by BY40 staining.

Trials 3 through 5

These trials involved the use of food or cosmetic cardboard packaging (e.g., cereal boxes, cardboard sleeves for dips), junk mail, and magazines. The cardboard packaging and junk mail were split into three equal parts (left to right) and labeled A, B, and C. The glossy magazines were split into three equal parts (top to bottom), as shown in Figure 2. Glossy magazines differed in the methodology because they are handled differently because of the inner part of the page being bound and therefore were handled more at one edge in contrast to the two other substrates. Five pages were taken from each magazine–the front and back pages in addition to three other pages at random. The three techniques employed for these trials included 4% Lumicyano, ninhydrin, and 1,2-indanedione-zinc. For

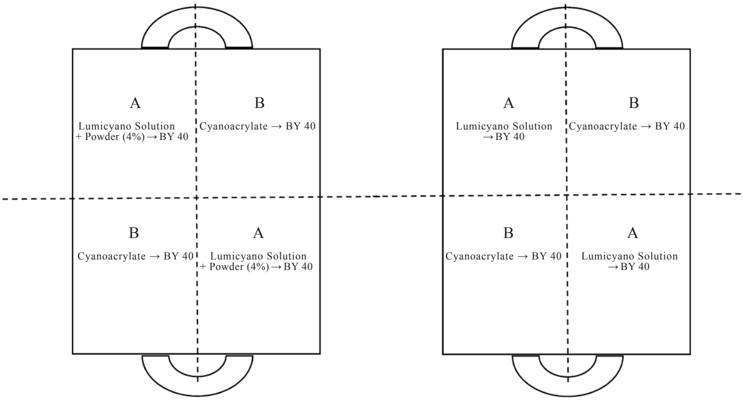


Figure 1

Sample division for a plastic carrier bag in trial 1 (left) and trial 2 (right).

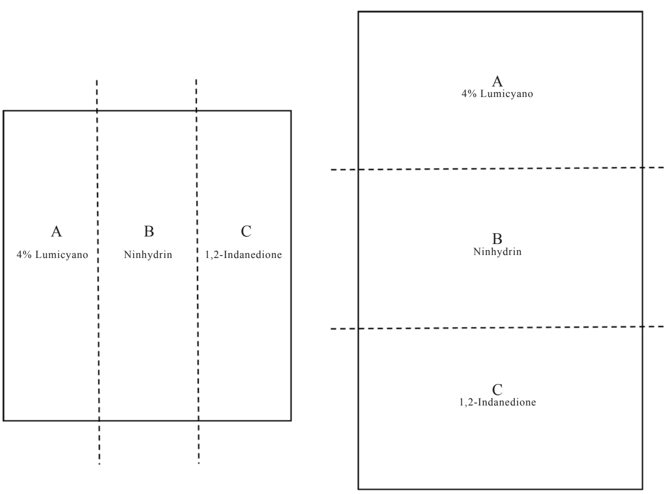


Figure 2

Sample division for substrates in trials 3–7 for cardboard packaging and junk mail (left) and glossy magazines (right).

trials 3 through 5, BY40 staining was not attempted after fuming with 4% Lumicyano because of extensive background staining observed during preliminary testing. Item 1 was labeled as part A corresponding to 4% Lumicyano, part B to ninhydrin, and part C to 1,2-indanedione-zinc. To eliminate any bias, the techniques were rotated for each third of the item throughout the trial. For example, item 2 part A corresponded to 1,2-indanedione-zinc, part B to 4% Lumicyano, and part C to ninhydrin.

Trial 6

This trial involved 4% Lumicyano, black iron-oxide powder suspension, and black magnetic powder (CSI Equipment Ltd.) as enhancement techniques on the cardboard packaging, as described above for trials 3 through 5.

Trial 7

Used fast food packaging was sorted to include food and drink packaging or containers, but paper bags and clear plastic were not included. The enhancement techniques employed for this trial were 4% Lumicyano, iron-oxide black powder suspension, and solvent black 3. After treatment with 4% Lumicyano and recording of any detected marks, BY40 was used in sequence, and any additional marks were recorded. All items were split (from top to bottom) into three equal sections and labeled, as described for previous trials.

Cyanoacrylate Fuming Chamber, Photography, and Fluorescence

A fuming chamber (model number CA305, Air Science) was employed with an approximate volume of about 450 liters. The chamber is fitted with a fixed temperature hot plate (internally set to 100 °C) and a humidifier (set to 80%). The correct operation of the hot plate and humidifier were verified by means of a digital thermometer (RS 206-3738, RS Components Ltd, Corby, U.K.) and a humidity meter (Fluke 971). Fluorescence examination was performed using a Mason Vactron Quaser 2000/30, and photography was carried out using a Nikon D5100 equipped with a 60 mm micro Nikon lens. UV examination was carried out using a 50W Labino SuperXenon Lumi Kit (peak excitation at 325 nm) and viewed with a clear UV filter.

Cyanoacrylate → BY40 [10]

Cyanoacrylate (2 g) (CSI Equipment Ltd, U.K.) was placed into a new foil dish and positioned on a clean support ring on a heat source of about 100 °C in the fuming chamber. The relative humidity level within the chamber was set at 80%, with a running time of 45 minutes. A cycle time of 45 minutes ensured that 99.99%

of the cyanoacrylate had evaporated, as checked by the weight difference before and after the cycle. The fuming process was followed by immersion of the items under examination in a BY40 solution for 1 minute followed by thorough rinsing under running tap water and left to dry at room temperature before fluorescence examination. BY40 dyeing on fumed items was performed the following day after fuming. Basic yellow 40 (Sirchie) dye was prepared by dissolving 2 g in 1 L of ethanol (Fisher). Fluorescence was observed using a Quaser 2000/30 by exciting with a violet-blue excitation source (bandpass filter 400–469 nm at 1% cut-on and cut-off points) and viewed with a yellow longpass 476 nm filter (1% cut-on point). Other light sources may use wavelengths representing the 50% point or the peak wavelength.

4% Lumicyano

The manufacturer recommends a maximum concentration of 4% of powder by weight of cyanoacrylate solution, thus 0.08 g of dye was added to 2 g Lumicyano cyanoacrylate solution, which readily dissolved to create a pink solution. A previous Lumicyano product involved a ready-mixed pink 1% Lumicyano solution, which has now been superseded by Lumicyano solution and Lumicyano powder. The foil dish was positioned on a clean support ring on a heat source of about 100 °C in the fuming chamber. The relative humidity level within the chamber was set at 80%, with a running time of 45 minutes. A cycle time of 45 minutes ensured that 99.99% of the glue → dye mixture had evaporated, as checked by the weight difference before and after the cycle. After fuming, in this study, fluorescence was observed using the Quaser 2000/30 by exciting with a blue-green light (bandpass filter 468–526 nm at 1% cut-on and cut-off points) and viewed with an orange longpass 529 nm filter (1% cut-on point). UV examination was carried out using a 50W Labino SuperXenon Lumi Kit (peak excitation at 325 nm) and viewed with a UV face shield for UV protection.

Ninhydrin [10]

A concentrated solution was prepared by dissolving ninhydrin (25 g, Sigma) in absolute ethanol (225 mL, Sigma). Ethyl acetate (10 mL, Sigma) followed by acetic acid (25 mL, Sigma) were added to the slurry and stirred until a clear yellow solution was produced. A working solution was then prepared by measuring ninhydrin concentration solution (52 mL) together with HFE7100 (1L, 3M Novec) while stirring with a magnetic stirrer. The articles to be examined were immersed in the working solution for a maximum of 5 seconds. The excess solution was allowed to drain back in the tray, and the item was allowed to dry completely before being placed in a humidity oven for 4 minutes at 80 °C and a 65% relative humidity. Observations of developed marks were checked immediately and over the next 10 days.

1,2-Indanedione-Zinc [24]

A working solution was prepared by weighing 1,2-indanedione (0.25 g, BVDA) and dissolved using a magnetic stirrer in ethyl acetate (90 mL, Sigma), acetic acid (10 mL, Sigma), and zinc stock solution (1 mL). Finally, HFE-7100 (1L, 3M Novec) was added to the mixture and stirred. The zinc stock solution was prepared by dissolving anhydrous zinc chloride (0.2 g, Sigma) in ethyl acetate (5 mL, Sigma) and acetic acid (1 mL, Sigma). The articles to be treated were treated in the working solution by immersion for a maximum of 5 seconds. After the excess solution was allowed to drain, the items were allowed to dry completely in a fume hood before heating in a dry oven at 100 °C for 10 minutes. Fluorescence examination was performed by using a green excitation source (bandpass filter 473–548 nm at 1% cut-on and cut-off points) and viewed with a bandpass 549 nm filter (1% cut-on point).

Black Magnetic Powder

Black magnetic powder (CSI Equipment Ltd.) was applied by means of a magnetic fingerprint brush.

Solvent Black 3 [13]

Solvent black 3 (10 g, Sigma Aldrich) was added to 1-methoxy-2-propanol (500 mL, Sigma) and stirred vigorously for 1 hour. Distilled water (500 mL) was added and stirred for another hour. The articles to be treated were immersed in this working solution for 2 minutes followed by gentle rinsing under cold, running tap water until the excess dye was removed from the background. The items were allowed to dry at room temperature prior to examination. (The working solution was kept for a maximum of 1 month.)

Iron-Oxide Black Powder Suspension [10]

Iron (II/III) oxide (20 g, Fischer I/1100/53) was weighed and poured into a 100 mL glass beaker. Stock detergent solution (20 mL) was added slowly while stirring with a soft, squirrel-hair brush until no lumps remained. The stock detergent solution was prepared by measuring Triton X100 (250 mL, Acros) and adding ethylene glycol (350 mL, Acros) while stirring slowly for 10 minutes. Distilled water (400 mL) was added and stirred for a further 10 minutes. The articles to be treated were wetted with tap water prior to the application of the powder suspension with a small, animal-hair brush. The working suspension was left for a few seconds and then was washed under slowly running cold tap water until all the excess powder was removed from the background. The articles were allowed to dry at room temperature before examination.

Evaluation of the Number and Quality of Latent Marks Recovered by Each Process

Any prints developed with continuous ridge detail and an area greater than 64 mm^2 were counted [8, 11]. Each of these marks was graded "a" for good contrast or "b" for poor contrast as well as assessed for the quality of pore and ridge detail (the presence of third-level detail or not). Marks that showed signs of overfuming or overdevelopment were also noted.

Evaluation of the Stability of Lumicyano Fluorescence

Eighteen marks[1] developed with 4% Lumicyano from trial 1 were investigated further for the stability of fluorescence [7]. This was assessed prior to subsequent treatment with BY40. Photographs of these marks were taken 1 day, 1 week, 4 weeks, and 8 weeks after development. Each sample was stored in a sealed brown paper envelope at room temperature in a cool, dry, and dark cupboard. The representative samples were then re-fumed with 4% Lumicyano to restore fluorescence, followed by subsequent BY40 dyeing.

Results and Discussion

An evaluation of the number and quality of latent marks recovered by each process and trial was performed. For trials using cyanoacrylate fuming and fluorescence, the enhancement techniques yielded a small percentage (<5%) of marks with poor contrast (grade "b") where subsequent fluorescence removed the poor contrast issues and marks could then be graded as "a". Although over half of the marks could be seen visually, the use of fluorescence provided a quicker visualization method with less stress on the eye. The exception was trial 7, where less than 30% of the marks developed with 4% Lumicyano → BY40 could be observed visually. The 4% Lumicyano fluorescence appeared visually stronger on light-colored items when compared to darker items; however, with BY40-stained marks, the difference between light and dark items was not as apparent. All enhancement techniques used in the trials

[1] The quantity of marks (18) was equal to the square root of the total number of marks developed. The square root method is a nonstatistical approach to examine a random representative sample from a larger sample [25].

provided third-level ridge details, and there was no observation of overdeveloped marks; however, there were many instances of scuffed marks where the level of detail was not suitable enough to be counted as a detection. The many instances of scuffed marks were not due to the development technique but rather to the fingermark residue transfer.

Trial 1

Figure 3 demonstrates graphically that the two techniques employed in trial 1 detected a similar number of fingermarks: conventional cyanoacrylate → BY40 detected 295 marks and 4% Lumicyano detected 299 marks. Both the UV light and the Quaser used in this trial found the same number of marks after treatment with 4% Lumicyano; however, in general, the blue-green light and orange filter combination (Quaser) provided better contrast (Figure 4), specifically on white and highly reflective backgrounds. The fact that both techniques detected almost the same number of fingermarks suggests that 4% Lumicyano is a viable alternative to the conventional two-step cyanoacrylate fuming followed by dye staining. An added advantage is that the articles could be examined immediately and did not require any dyeing or drying facilities or times, thus saving time and lab space. Furthermore, sequential treatment of 4% Lumicyano-enhanced marks with BY40

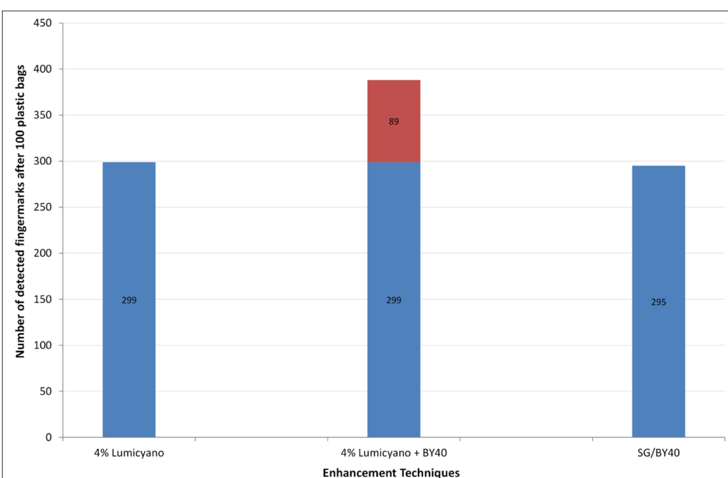
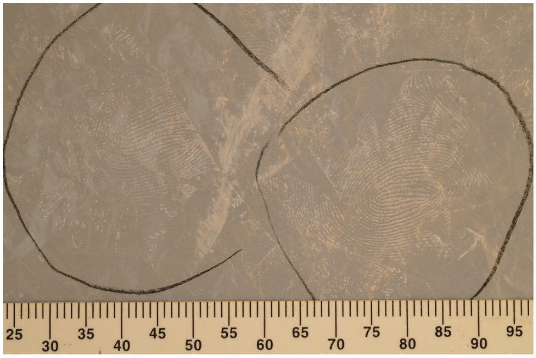
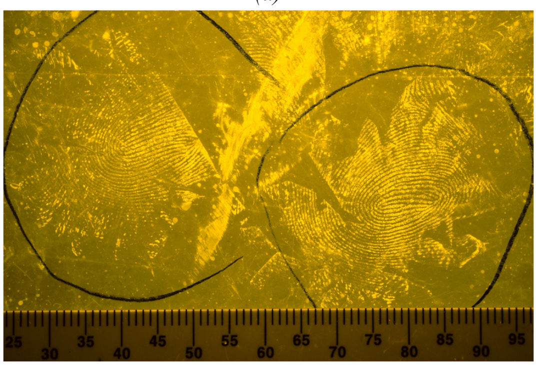


Figure 3

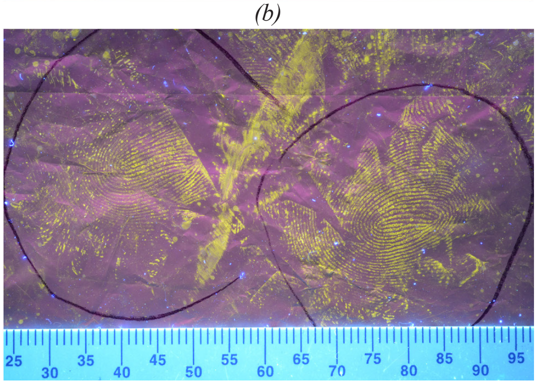
Number of detected latent fingermarks for each enhancement process in trial 1.



(a)



(b)



(c)

Figure 4

Latent fingermarks on a plastic carrier bag after treatment with 4% Lumicyano (trial 1) observed under (a) white light; (b) blue-green light (orange filter); (c) UV light (clear UV filter).

detected an additional 89 new marks, which is an increased detection rate of about 30%. Although the 4% Lumicyano-treated marks fluoresced strongly, the color perception of BY40 fluorescence was more prominent.

Trial 2

Figure 5 demonstrates that the Lumicyano solution followed by BY40 staining detected 565 marks and conventional cyanoacrylate fuming → BY40 detected 489 marks (Figure 6). Lumicyano solution detected about 16% more latent fingermarks, which may be due to the higher quality of the cyanoacrylate polymer when compared to conventional cyanoacrylate products. Other studies [26] and analyses have reported that the Lumicyano polymer appears to have a "slightly better developed polymeric nanofiber morphology in comparison with the traditional method".

A previous pseudo-operational trial [7] using the older formulation of Lumicyano (supplied as a 1% by weight of powder dye dissolved in cyanoacrylate solution) has reported an increased rate of about 15%, which aligns with the results of trial 2. The increased 30% detection rate from trial 1 does not align with the 16% detection rate in trial 2 and the 15% detection rate from a previous study [7]. The increased percentage rate is a reference to the increased rate from the Lumicyano → BY40 process when compared to the two-step cyanoacrylate process and BY40 dyeing. After looking closer at the individual data for each plastic carrier bag, four outliers from trial 1 were removed because many more marks were detected after dyeing 4% Lumicyano-treated marks with BY40 on these bags. An average percentage, from all the bags in the particular trial, was then taken for the number of extra marks detected after dyeing Lumicyano treated marks with BY40. The increased detection rate from trial 1 (4% Lumicyano) was calculated at a 20% detection rate, which is closer to the 15% detection rate from trial 2. Data from a previous study [7] using a 1% Lumicyano solution was treated in the same way as described above and an increased detection rate of 20% was also calculated. This data appears to suggest that the increased detection rate is more due to the quality of the cyanoacrylate used in the Lumicyano cyanoacrylate product. An added advantage of the 4% formulation is the higher dye concentration, which slows down the rate of fluorescence decay.

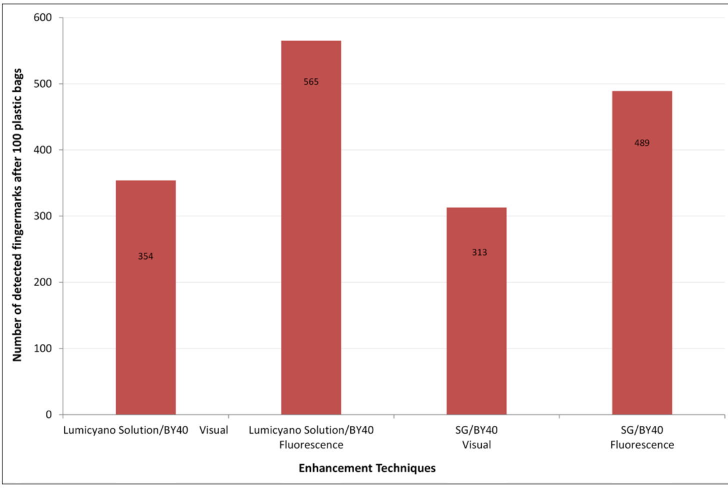
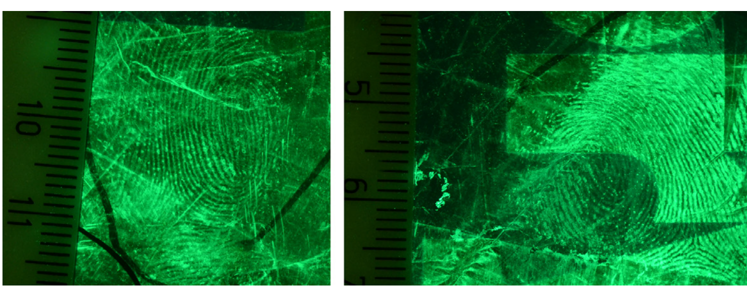


Figure 5

Number of detected latent fingermarks for each enhancement process in trial 2.



(a) *(b)*

Figure 6

Latent fingermarks on a plastic carrier bag under violet-blue light (yellow filter) after treatment with (a) Lumicyano solution → BY40; (b) cyanoacrylate → BY40.

Evaluation of the Stability of 4% Lumicyano Fluorescence

Several fingermarks developed with 4% Lumicyano from trial 1 were investigated further for the decay of fluorescence. For the previous 1% Lumicyano solution, the manufacturer's guidelines state that examination and photography should take place within 48 hours of treatment to ensure the quality of the fluorescence. Additionally, other studies [6, 7] into the use of 1% Lumicyano demonstrated a considerable decay in fluorescence after 48 hours, more so when the marks were stored on an open bench rather than in the dark. In this study, using a 4% concentration of Lumicyano resulted in the observation of fluorescence after at least 4 weeks (Figure 7) of storage in the dark, whereas storage on an open bench demonstrated time periods of up to 1 week. As described in previous work [7], it was possible to restore the decayed fluorescence by re-fuming with 4% Lumicyano (Figure 7f); however, it was not always as bright as the original attempt. Subsequent treatment with BY40 can ensure that the fluorescence will not decay again. Manipulation with computer software of the acquired images is likely to enhance the fluorescence further; however, none of the images presented in this study have been enhanced with computer software to improve fluorescence.

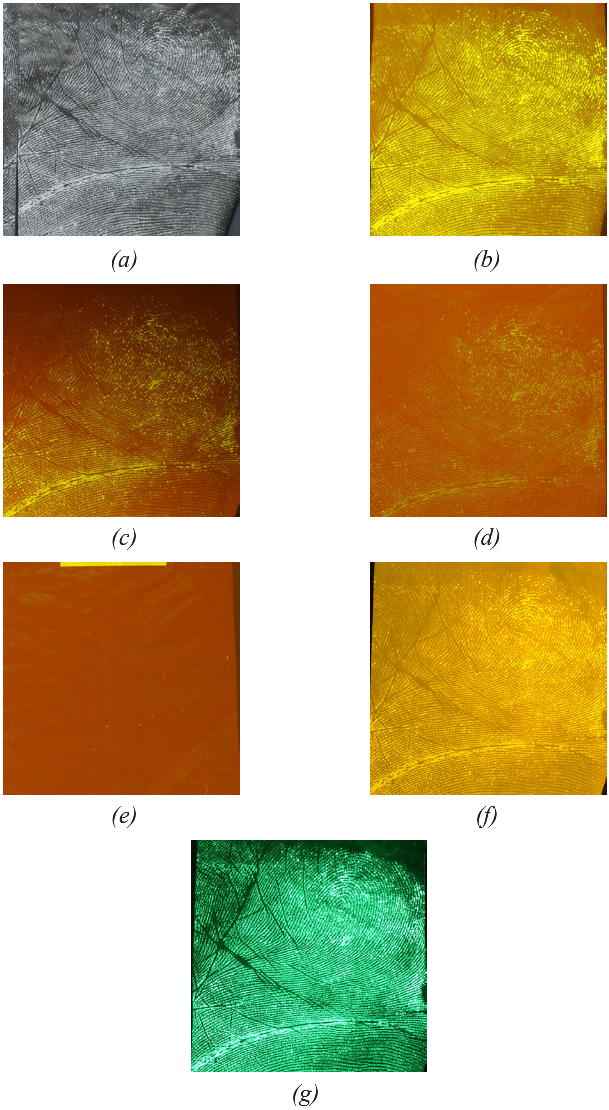


Figure 7

A mark on a black plastic carrier bag treated with 4% Lumicyano under (a) white light and blue-green light (orange filter) after (b) 1 day; (c) 1 week; (d) 4 weeks; (e) 8 weeks followed by (f) 4% Lumicyano re-fuming and (g) BY40 staining viewed under violet-blue light (yellow filter).

Trials 3 through 5

The detection of latent fingermarks on semiporous items (cardboard packaging, junk mail, and glossy magazines) was poor across the three enhancement techniques used in these trials (4% Lumicyano, ninhydrin, and 1,2-indanedione), as revealed in Figure 8. The amino acid reagents performed better than 4% Lumicyano on junk mail; this was not expected because the junk mail used in this study had a high proportion of glossy leaflets in comparison to envelopes and paper. It was hypothesized that 4% Lumicyano would be able to provide suitable enhancement results on these difficult surfaces in comparison to the amino acid reagents because of the lack of solvents involved in the process. The efficiency of amino acid reagents may also be limited on semiporous items because of the amino acids not being absorbed into the surface during deposition. Contrary to the plastic carrier bags, the use of a UV light source provided very poor visualization for marks treated with 4% Lumicyano, most notably on cardboard packaging. The use of a blue-green light and orange filter combination provided superior contrast and visualization (Figure 9).

1,2-Indanedione-zinc provided a low detection rate on the cardboard packaging but overall performed best out of the three techniques on junk mail and glossy magazines, with the added advantage of fluorescence examination (Figure 10). Ninhydrin, on the other hand, performed consistently across the three substrates used in this study and over half of the marks detected were recorded 48 hours after treatment rather than immediately (Figure 11).

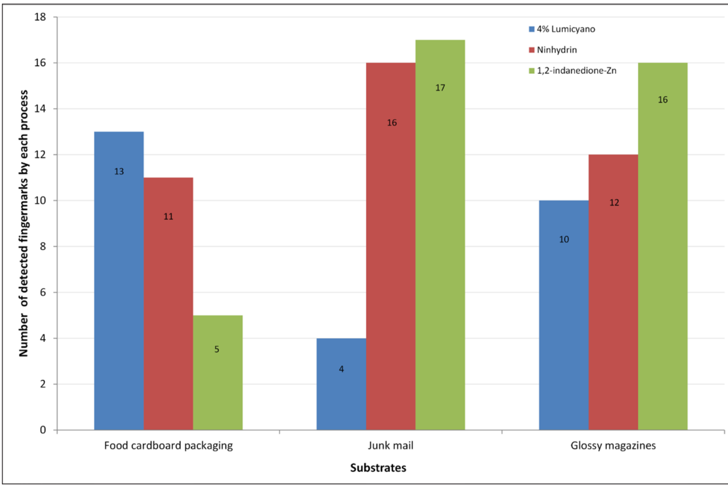
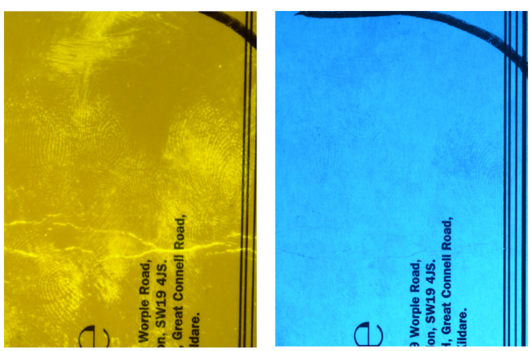


Figure 8

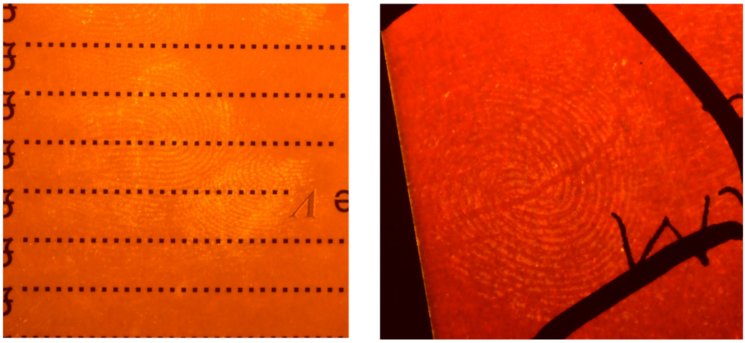
A comparison of the number of detected fingermarks on cardboard packaging, junk mail, and glossy magazines (trials 3–5) after enhancement with 4% Lumicyano, ninhydrin, and 1,2-indanedione-zinc.



(a) *(b)*

Figure 9

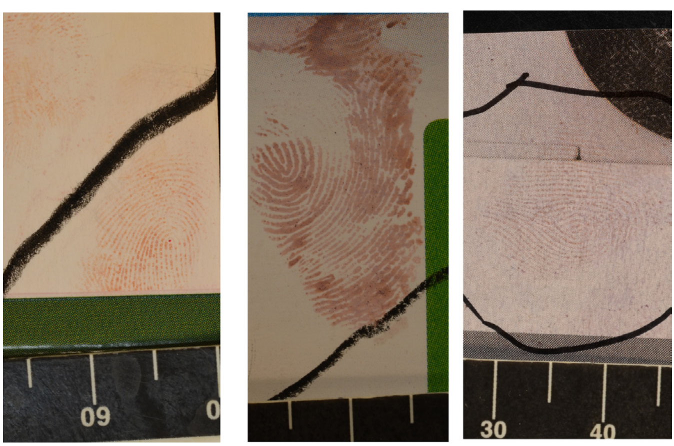
Latent fingermarks on cardboard packaging after treatment with 4% Lumicyano and observed under (a) blue-green light (orange filter); (b) UV light (clear UV filter).



(a) *(b)*

Figure 10

Latent fingermarks after treatment with 1,2-indanedione-zinc and observed under green light (orange filter) on (a) junk mail; (b) glossy magazine.



(a) *(b)* *(c)*

Figure 11

Latent fingermarks after treatment with ninhydrin on (a) cardboard packaging; (b) junk mail; (c) glossy magazine.

Trial 6

Similar to trials 3 through 5, the detection of latent fingermarks on the cardboard packaging was poor across the three enhancement techniques used in this trial (4% Lumicyano, black iron-oxide powder suspension, and black magnetic power). For marks treated and detected with 4% Lumicyano, fluorescence was observed using a blue-green excitation source (orange 529 nm filter) but not under UV light. Figure 12 represents the number of latent fingermarks detected in trial 6, and Figure 13 illustrates some of the developed marks using iron-oxide powder suspension and black magnetic powder. This trial, in conjunction with trials 3 through 5, demonstrates further the difficulties involved in the detection of latent fingermarks on semiporous surfaces such as the cardboard packaging used in this study.

Trial 7

Figure 14 demonstrates that iron-oxide powder suspension provided the highest detection rate of latent fingermarks (96 marks) in this pseudo-operational trial involving packaging from a fast food chain. After rinsing under running tap water, some background staining with iron-oxide powder suspension still remained; however, it did not hinder the detection of the marks. The use of 4% Lumicyano, prior to subsequent BY40 dyeing, provided a low detection rate of 23 marks. Sequential BY40 treatment revealed an additional 58 marks, an increase rate of about 250%, to give a total of 81 marks. This is because most of the marks treated with 4% Lumicyano could only be visualized with fluorescence after treatment with BY40. An explanation for this difference is that the background fluorescence from the substrate under examination is masking the 4% Lumicyano fluorescence. The use of solvent black 3 gave a detection rate of 75 marks, which is similar to the detection rate of 4% Lumicyano in sequence with BY40 staining. Figure 15 represents examples of developed fingermarks with the various enhancement techniques.

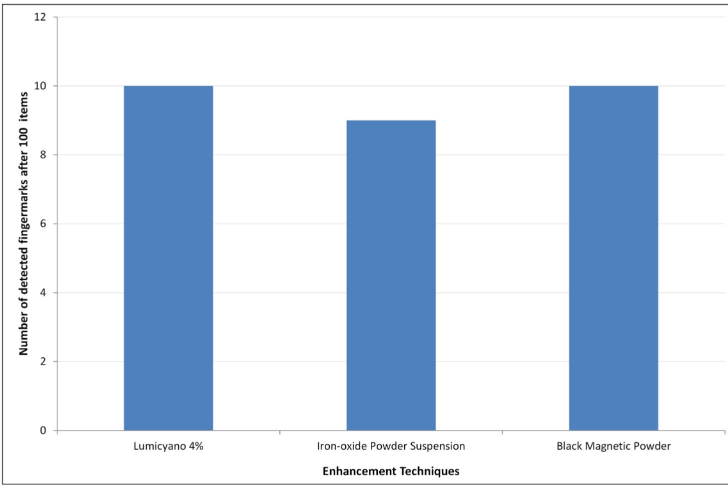
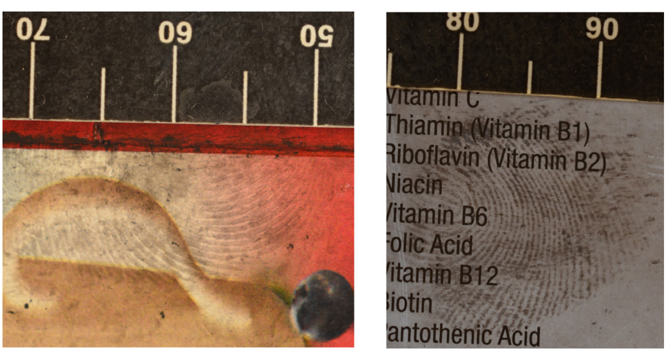


Figure 12

Number of detected latent fingermarks for each enhancement process in trial 6.



(a) *(b)*

Figure 13

Latent fingermarks developed on cardboard packaging after treatment with (a) black iron-oxide powder suspension; (b) black magnetic powder.

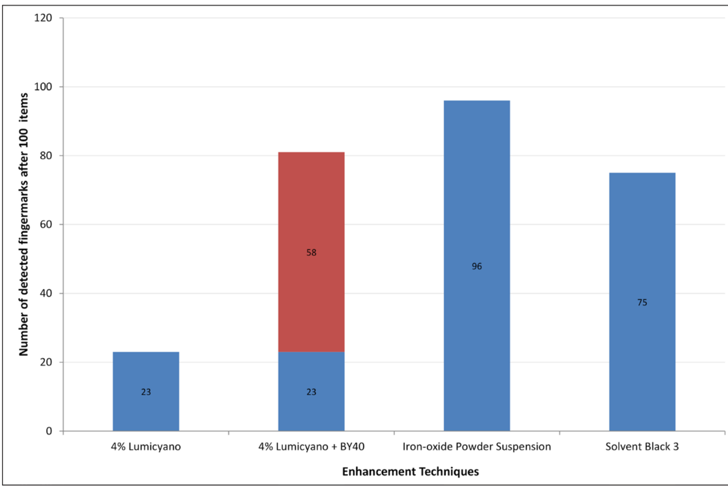


Figure 14

Number of detected latent fingermarks for each enhancement process in trial 7.

(a)

(b)

(c)

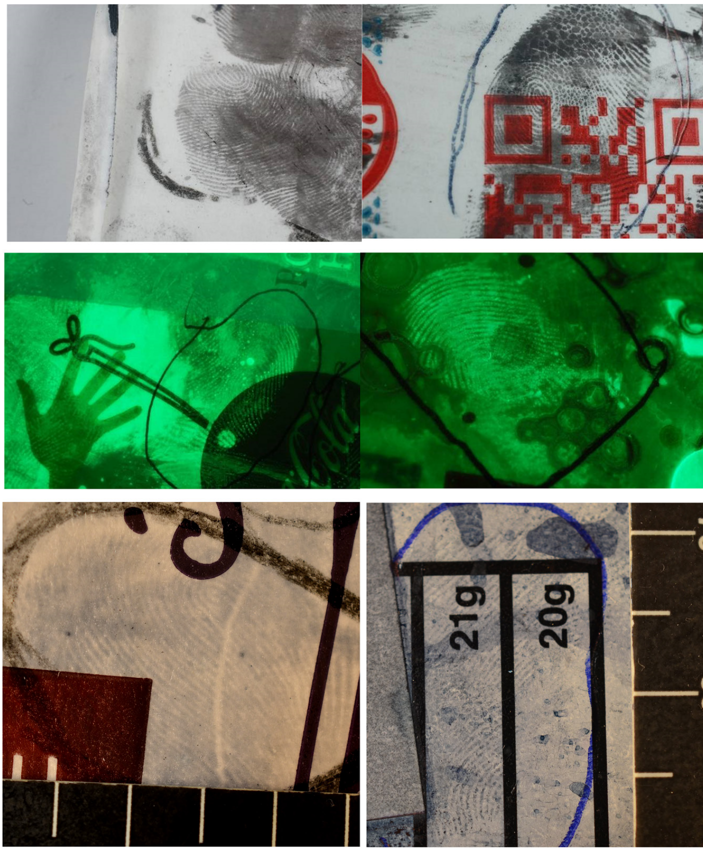


Figure 15

Latent fingermarks developed on fast food packaging after treatment with (a) black iron-oxide powder suspension; (b) 4% Lumicyano → BY40; (c) solvent black 3.

Conclusion

4% Lumicyano formulation has a higher dye concentration of four times when compared to previous formulations. This provides an increased timeline for the observation of fluorescence of at least four weeks when stored in the dark. These trials have demonstrated that the use of 4% Lumicyano provides a detection rate similar to the two-step conventional cyanoacrylate fuming followed by BY40 staining; however, subsequent BY40 treatment of 4% Lumicyano-enhanced marks resulted in an increased detection rate of about 20%. This may be due to the higher quality of the cyanoacrylate solution in Lumicyano. Other advantages of a one-step fluorescent cyanoacrylate process include decreased treatment times without the need of dyeing or drying facilities in a cyanoacrylate chamber that does not require any modifications. A high detection rate of fingermarks was observed on plastic carrier bags; however, this rate was much lower on semiporous surfaces such as magazines, leaflets, and cardboard used for food or cosmetic packaging. Although 4% Lumicyano fluorescence lasts longer, it is still recommended to perform fluorescence examination immediately after fuming and if this is not possible, the fumed articles should be stored in a cool, dark, and dry place, ideally sealed in a brown paper envelope and checked for fluorescence at the earliest opportunity.

The detection rate of latent fingermarks on semiporous surfaces was low with all the techniques used in this study, indicating that further research is required. For suspected greasy fingermarks on semiporous items, 4% Lumicyano → BY40 might be a suitable alternative to solvent black 3 and iron-oxide powder suspensions. Further research will assess the use of 4% Lumicyano on other surfaces and under vacuum conditions.

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