An Assessment of a Portable Cyanoacrylate Fuming System (LumiFume™) for the Development of Latent Fingermarks

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Conflict of interest

The authors have no conflict of interest to declare.

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Highlights

- LumiFume™ with Lumicyano™ is an effective crime scene cyanoacrylate fuming system.
- LumiFume™ with Lumicyano™ was at least as effective as traditional cabinet fuming.
- As in previous work, the use of BY40 after Lumicyano™ detected additional new marks.
- A pseudo-operational trial of 300 items demonstrated the effectiveness of LumiFume™.

Abstract

The effectiveness and suitability of a portable cyanoacrylate fuming system (LumiFume™) with Lumicyano™ at detecting latent fingermarks was assessed. The first phase of the study compared the LumiFume™ system with traditional cabinet fuming and black/white powder suspension for the development of latent fingermarks on a variety of surfaces (glass, plastic bin bag, laminated wood and tile) by means of depletion series' from 10 donors and four ageing periods (1, 7, 14 and 28 days). The portable fuming system provided superior quality of developed marks on glass and laminated wood whereas powder suspension was better on bin bags and all three techniques were comparable on tile. A decrease in mark quality was recorded from 1-14 days for the fuming techniques before an increase at 28 days. Lumicyano™ fluorescence stability studies over a 28 day period by means of depletion series' on glass slides and plastic bin bags revealed better quality marks for the portable system LumiFume™; however, storing marks under light conditions expedited deterioration for both systems. All marks developed with Lumicyano™ were subsequently treated with BY40 resulting in further improvement in mark quality for all substrates and ageing periods, with the exception of laminated wood which absorbed the fluorescent stain reducing the contrast in the process. The second phase of the study consisted of a pseudo-operational trial on 300 various substrates (e.g. glass bottles, aluminium cans, plastic bags) recovered from recycling bins. LumiFume™ and Lumicyano™ yielded 1,469 marks whereas Lumicyano™ cabinet fuming and powder suspension yielded 1,026 and 641 marks respectively. Similar to the first phase of the study, further treatment of the Lumicyano™ treated marks with BY40 resulted in further quality improvement as well as additional new marks. The LumiFume™ system produced results at least equivalent to the traditional cabinet fuming with Lumicyano™ highlighting its potential for implementation into casework to process crime scenes.

Keywords: Lumicyano™; crime scene; fingerprints; enhancement; superglue; pseudo-operational trials.

1. Introduction

Cyanoacrylate fuming is a routine enhancement technique for the development of latent fingermarks. The mechanism of cyanoacrylate polymerisation is well documented; however, the precise mechanism of the interaction between the cyanoacrylate and the residue of the fingermark is less understood. It is generally agreed that when cyanoacrylate monomers, released via the heating of the cyanoacrylate, diffuse into the mark and encounter nucleophilic initiators, the anionic polymerisation ensues and a white polymer develops on the ridges of the deposited fingermark, but not on the surface the mark was deposited on, leaving a distinct cyanoacrylate coating of the mark's ridge detail [1–3]. It is debated that water is crucial for this polymerisation and that moisture in the mark is of more importance to the reaction than moisture in the air [4,5]. Other studies have dismissed the importance of water and report that the carboxylate ion is required for the reaction and polymer propagation [1]. The polymer formed is hardened and the resultant polymerised mark features a fibrous polymer that can scatter light. A wide range of molecules present in fingermark residues have been identified as nucleophilic initiators, including sodium hydroxide, amines, carboxylate ions, fatty acids, amino acids, chlorides and sulphates [6]. Other studies have investigated the use of acetic acid, lactic acid, ammonia, alkanes and alanine and lactate amino acids specifically as initiators [5,7]. The initiating nucleophile can also affect whether the polymerisation is fast or gradual [6]. Studies have also indicated the importance of an optimum relative humidity of 80% during the fuming of latent fingermarks [8,9]. At this optimum humidity, sodium chloride residues in the mark absorb moisture, enhancing the polymerisation process. It also aids the formation of the ideal noodle-like morphology for a cyanoacrylate developed fingermark and is thought to maintain the two electron withdrawing groups in a solvated state, enabling the diffusion of the cyanoacrylate monomers.

1.1. One-step fluorescent cyanoacrylate process

A two-step process is generally required to improve the contrast of the developed white ridges after cyanoacrylate fuming. This is typically done with powdering or a fluorescent stain such as basic yellow 40 (BY40) and Rhodamine 6G. Over the last decade, investigations and comparisons with one-step fluorescent cyanoacrylates, Lumicyano™, PolyCyano, CN Yellow and PECA Multiband, have taken place [10–17]. One-step cyanoacrylates feature cyanoacrylates with a fluorescent dye or fluorophore conjugated to the glue [18]. The aim of such processes is to save time, space, reduce costs and eliminate the use of toxic or flammable solvents which may affect DNA or other types of evidence [19]. In 2016, a review of one-step fluorescent cyanoacrylate processes discussed such advantages and potential issues [15]. Lumicyano™ is the only one-step process that requires the same temperature (120^0C) as the two-step process whereas other one-step processes require 230^0C. A major drawback for some one-step processes is that the fluorescence will decay over a period of a few days/weeks although this decay can be limited by storing samples in the dark. Furthermore, for some of these one-step processes, re-fuming the samples can restore some of the original fluorescence and subsequent treatment with a fluorescent stain can detect additional new marks. The one-step fluorescent cyanoacrylate processes are currently classified as a Category C in the UK Home Office Fingermark Visualisation Manual highlighting that there is a need for further research and that it is less thoroughly tested than the two-step method [20].

1.2. Cyanoacrylate fuming at crime scenes

A desire to create devices capable of fuming at scenes was borne of necessity to avoid the costs, labour and time that transporting scene items back to the laboratory can bring as well as the degradation due to friction that may be incurred on samples during transit [21,22]. Such devices must be safe and produce similar results at scenes as would be achieved in a laboratory [21]. There are several limitations to fuming at scenes such as the lack of control over humidity and temperature; difficulty in monitoring development thus preventing overdevelopment; calculating the volume of cyanoacrylate required to fume a given area; time-consuming equipment and enclosure setup. There are also health and safety concerns such as the effective clean-up of cyanoacrylate vapours and deposits as well as the potential exposure of hydrogen cyanide when using high temperatures to evaporate cyanoacrylate [22,23]. Primitive portable systems used cars or aquarium tanks as an enclosure [24,25] followed by wand devices using styryl dye cartridges for handheld convenience at scenes [26]. An evaluation [27] of fuming wands reported the rapid consumption of cyanoacrylate and that the generated high temperatures could damage evidence and synthesise toxic gases, although a later study [28] with modern models of fuming wands revealed some success at developing fluorescent marks.

1.3. Portable crime scene cyanoacrylate fuming system

The SUPERfume® is a complete crime scene cyanoacrylate fuming system described by its manufacturer, Foster and Freeman, as a “kit designed as individual components that are easily transported and deployed, comprising a humidifier, two cyanoacrylate evaporators with integral dispersing fans, and an activated carbon filter unit”. A UK Home Office evaluation of this system involving 6000 fingermarks revealed that fingerprint powders were at least as effective as SUPERfume® on most surfaces except for textured surfaces, although in general, cyanoacrylate treatment of all surfaces in a controlled environment in a laboratory chamber was more effective [21]. A later study by Fieldhouse [22] using 5400 fingermarks and SUPERfume® reported that the portable fuming system was more effective than aluminium powder at developing latent fingermarks on textured and smooth plastic surfaces. A recently developed portable fuming system called LumiFume™, developed by Crime Science Technology™, is in wide use by the French police. It claims to turn a scene into a fuming cabinet and develop marks in minutes using the "cyclone effect" of its fume dispersing fans.

This study aims to evaluate the use of LumiFume™ with a one-step fluorescent cyanoacrylate, Lumicyano™, as a portable crime scene cyanoacrylate fuming system for the development of latent fingermarks on non-porous surfaces by means of a split depletion series' and a pseudo-operational trial.

2. Methodology

The first phase of the study compared the LumiFume™ portable crime scene cyanoacrylate fuming system with traditional cabinet fuming and powder suspensions (black iron-oxide and white titanium dioxide) for the development of latent fingermarks on a variety of surfaces by means of depletion series' from 10 donors and four ageing periods. The second phase of the study consisted of a pseudo-operational trial using the same three enhancement techniques on 300 various substrates recovered from recycling bins. A PVC, black cyanoacrylate fuming tent (Tetra Scene of Crime Ltd.) measuring 2.5 x 2.5 x 2.4 m and with a volume of approximately 13 m^3 was erected for use with LumiFume™ (figure 1).

(a) (b)

Figure 1 - Cyanoacrylate Fuming Tent: (a) exterior and (b) interior set-up example

2.1 Humidity profiling

The humidity in the tent was profiled by measuring the humidity at various locations, including the ground, corners and upper areas, for 80 minutes (humidification and fuming cycle) using an external device (Extech Instruments Digital Psychometer RH305 kit). The same device was also used to calibrate humidity in various locations in the traditional fuming cabinet. A major difference between the LumiFume™ and the fuming cabinet is that once the crime scene system reaches 80% humidity, the hot plate switches on but the humidifier switches off for the remainder of the cycle whereas the fuming cabinet's humidifier switches on if the humidity goes below 80% during the fuming cycle.

2.2 Phase 1: Comparison of LumiFume™ performance with fuming cabinet and powder suspension development

Ten donors were recruited and issued project descriptors as well as participation consent forms. The collection of marks occurred in two separate sessions, five days apart. Four substrates (glass, white tile, black plastic bin bag and laminated wood) sourced locally were used in the study. Session 1 obtained marks that were to be aged for 1 day or 28 days on all four substrates and session 2 collected marks to be aged for 1 or 2 weeks. The items were aged on an open bench and exposed to sunlight and other ambient conditions in the laboratory. Due to the volume of substrates and techniques, donors were asked to deposit marks once in the morning and again in the afternoon. For each session, donors were asked not to wash their hands at least 30 minutes prior to deposition, then prior to deposition to rub their hands together to distribute residues evenly across all fingers. They were then asked to press a finger down a column of a grid to form a depletion series of 10 marks. The process continued, using a different finger, until each substrate had marks for each series [29,30].

2.3 Phase 2: Pseudo-operational trial

Various items such as shopping plastic bags, confectionery wrappers, aluminium cans as well as plastic and glass bottles of unknown history were collected from work colleagues and various recycling bins. To avoid any bias, the maximum number of items taken from any one person was limited to five. The 300 collected items were divided equally amongst the three enhancement techniques so that each technique processed 100 items: 44 confectionery wrappers, 21 plastic bags, 14 each of plastic and glass bottles and 7 cans.

2.4 LumiFume™

The LumiFume™ system (CST, France) was set up in the fuming tent as per the guidance of the user manual [31]. The system is comprised of a humidification device, four hygrometry sensors to monitor humidity, a fuming device, a carbon air-recycling device and a control touch tablet (figure 2). The temperature of the hotplate was set to reach a maximum of 140°C and verified with a digital thermometer/thermocouple (RS 206-3738). The humidity was set to 80% with preliminary work involving humidity profiling inside the tent. The manufacturer's guidelines stipulated 1 g of Lumicyano™ product per 1 m^3 and a 10% w/v solution of Lumicyano™ powder (CST, France) in Lumicyano™ solution (CST, France). This was prepared by dissolving 1.3 g of the powder in 13 g of the solution in an aluminium dish of diameter 10 cm, ready for the fuming cycle. The weight of any remaining product in the foil dish was measured before and after each cycle to ensure efficient evaporation. An average rate of 98% evaporation was achieved across 10 runs. Under these conditions, a typical LumiFume™ cycle has a duration of 3hr 48m (~28 minutes humidity, ~55 minutes fuming and ~2hr 25m purging cycle).

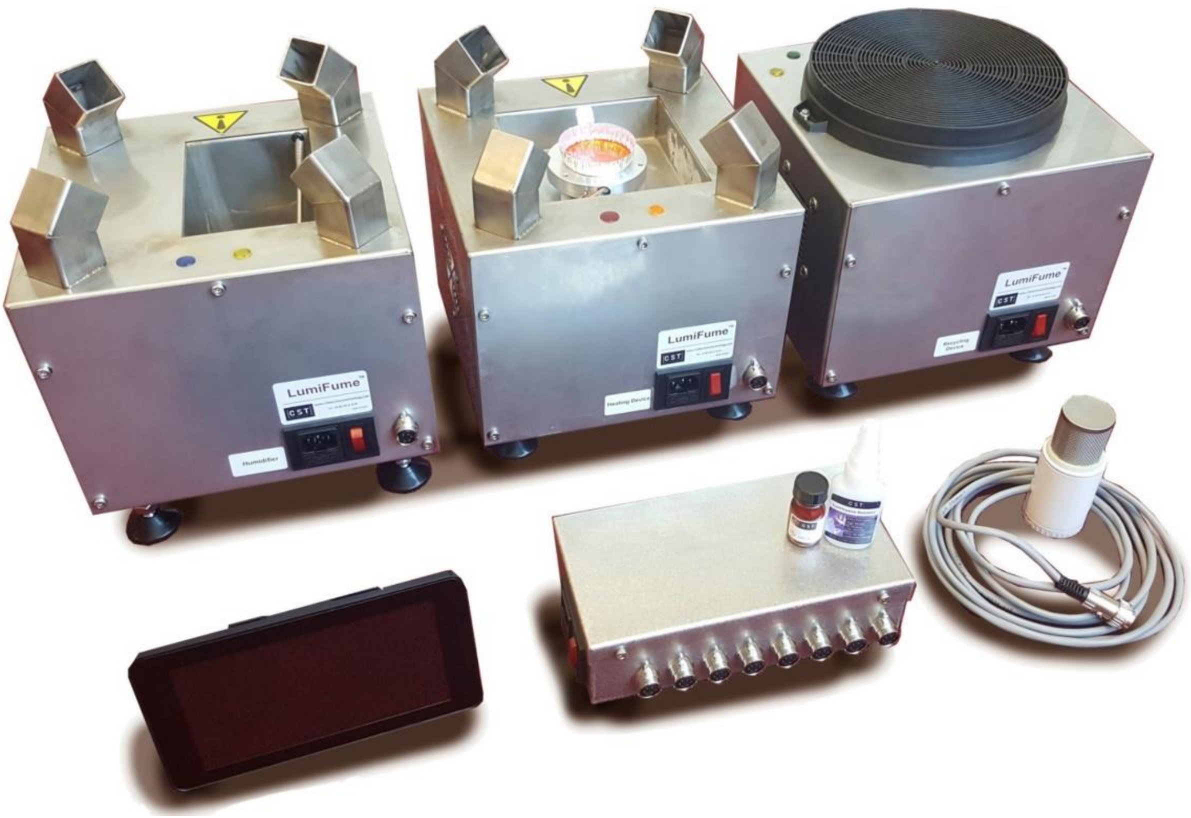


Figure 2 – The LumiFume™ crime scene cyanoacrylate fuming system [31].

2.5 Cyanoacrylate Fuming Chamber

An Air Science (model number CA60T) fuming chamber was employed with a volume of approximately 1.5 m^3. The chamber is fitted with a temperature hot plate (set to 120^{o}C) and a humidifier (set to 80%). The correct operation of the hot plate and humidifier were verified by means of a digital thermometer/thermocouple (RS 206-3738) and a humidity meter (Fluke 971). A 10% w/v solution of Lumicyano™ powder (0.4 g, CST, France) in Lumicyano™ solution (4.0g, CST, France) was prepared with a heat source of 120^{0}C, relative humidity of 80% and a running time of 60 minutes. A cycle time of 60 minutes ensured that 99% of the cyanoacrylate had evaporated as checked by the weight difference before and after the cycle.

2.6 Basic Yellow 40 (BY40)

After observation and photography of any marks developed by Lumicyano™ from both the tent and the chamber, the articles were immersed in a BY40 solution for 15 s followed by thorough rinsing under running water and left to dry at room temperature before fluorescence examination. The staining solution was prepared by dissolving BY40 (2g, Sirchie) in ethanol (1 L, Fisher). BY40 dyeing on fumed items was always performed the day after fuming and items were allowed to dry overnight before fluorescence examination.

2.7 Powder suspensions (PS)

A black powder suspension was prepared by the addition of iron (II/III) oxide powder (20 g, I/1100/53, Fisher Scientific) to a stock detergent solution (20 mL) and stirred with a glass rod until a paste-like consistency was observed. The stock detergent solution was created by mixing Triton X-100 (250 mL, Acros), ethylene glycol (350 mL, Acros) and deionised water (400 mL). The suspension was applied to pre-wetted substrates with a large soft bristle brush, left for 20 seconds and rinsed off under running water. To gain contrast on black bin bags, a white powder suspension, Wetwop™ (CSI Equipment), was employed. This commercial product was applied and rinsed as described above for black powder suspension. Substrates were then allowed to dry overnight before examination.

2.8 Fluorescence examination, photography and grading of developed marks

Fluorescence was observed using a Mason Vactron Quaser 2000/30, Crime Lites 82S and a UV Labino light. Marks treated with Lumicyano™ were observed by exciting with a blue/green excitation source (band pass filter 468–526 nm at 1% cut-on and cut-off points respectively) and viewed with an orange long pass 529 nm filter (1% cut-on point). Furthermore, UV examination was carried out using a 50 W Labino® SuperXenon Lumi Kit (peak excitation at 325 nm) and viewed with a UV face shield for UV protection. BY40 fluorescence was observed with violet-blue light (band pass filter 400-469nm at 1% cut on and cut off points) and viewed with a yellow long pass 476nm filter (1% cut on point). Photography was performed within a few hours using a Nikon D5100 equipped with a 60 mm micro Nikon lens. Marks 1, 2, 5 and 10 of the depletion series' were graded from 0 to 4 as per the UK Home Office CAST guidelines [29] followed by statistical analysis, such as analysis of variance and Mann-Whitney test, using Minitab (v18). For the phase 2 pseudo-operational trial, marks with an area of discernible ridge detail area greater than $64mm^2$ were counted as a detected mark and tallied by substrate and technique [29].

2.9 *Evaluation of the stability of Lumicyano™ fluorescence*

Two additional depletion series' on plastic bin bags and glass slides, deposited by a donor previously identified as a 'good donor', were prepared for treatment with both Lumicyano™ techniques (LumiFume™ and cabinet fuming). The marks were deposited at a junction of two separate glass slides placed next to each other, and the series on the bag split in two, to enable comparison of the two techniques on the same mark. After fuming, fluorescence examination took place at 1, 2 and 5 days and then weekly for 4 weeks. Both runs, consisting of a depletion series of 10 split marks on glass slides and plastic bin bags, were assessed on a comparative scale where "+", "-" or "=" symbols were used to represent which of the two techniques being compared had produced the better, worse or equivalent result, respectively. The samples were then re-fumed to assess if it was possible to restore fluorescence. Furthermore, a number of the developed marks (square root of the total number) from phase 2 were divided in half, where one half was stored in a brown envelope in a dark room and the other half stored on a windowsill of a bright room. The marks were re-examined under fluorescence after 1, 7 and 14 days.

3. Results and Discussion

3.1 Humidity Profiling

Initial trial runs of the LumiFume™ device with no cyanoacrylate or substrates present established variability in the percentage relative humidity of the tent throughout a fuming cycle (as described in section 2.4) between 80 – 97% depending on where the humidity sensor was situated within the tent (figure 3). As relative humidity above 90% can cause over-development [9], the maximum water temperature was reduced from 95°C to 80°C. A number of runs were carried out with these settings and the relative humidity range dropped to between 80 and 90% (as read by the external device). All runs demonstrated a steady incline for the first 40 minutes as the device increased humidity within the tent to 80% before slowly increasing still for the remainder of the run. This was contrary to expectations as crime scene fuming devices are generally described as inconsistent in the literature due to difficulties in maintaining a relative humidity of 80% once the fuming cycle starts [21,32]. The further humidity increase during the fuming stage and after the initial humidification was thought to be due to the exposed water tank incorporated into the LumiFume™ humidifier, which was still releasing steam into the tent. The location of the humidity probe had little to no effect on the relative humidity range observed. Both LumiFume™ software and an external handheld device confirmed the results. The external device consistently provided higher humidity measurements; however, these readings were more reliable due to its calibration. LumiFume™ readings were then correlated to these values.

3.2 Phase 1 Results

3.2.1 Fingermark grading and donor variation

Figure 4 represents the percentage of marks graded as 3 or 4 per donor across all substrates types and ageing periods. The use of BY40 after Lumicyano yielded additional new marks for both the cabinet and LumiFume™. Additionally, marks developed with powder suspension were generally of an inferior quality to marks detected with fuming techniques. A one-way ANOVA was applied to the full data set for all donors (including grade 0, 1 and 2 marks) where $p < 0.001$, suggesting there is a significant difference between the different donors. A Mann-Whitney U test was then applied to discern between which donors the variance was significant. All comparisons returned a significant result ($p = 0.005$) except for comparisons between donors; 2 with 5, 7 and 8; 3 with 6 and 9; 5 with 7, 8 and 10; 6 with 9; 7 with 8, where $p = >0.005$. Grade and quality of fingermark is affected by the deposition of the mark, which in turn can be affected by donor and environmental characteristics.

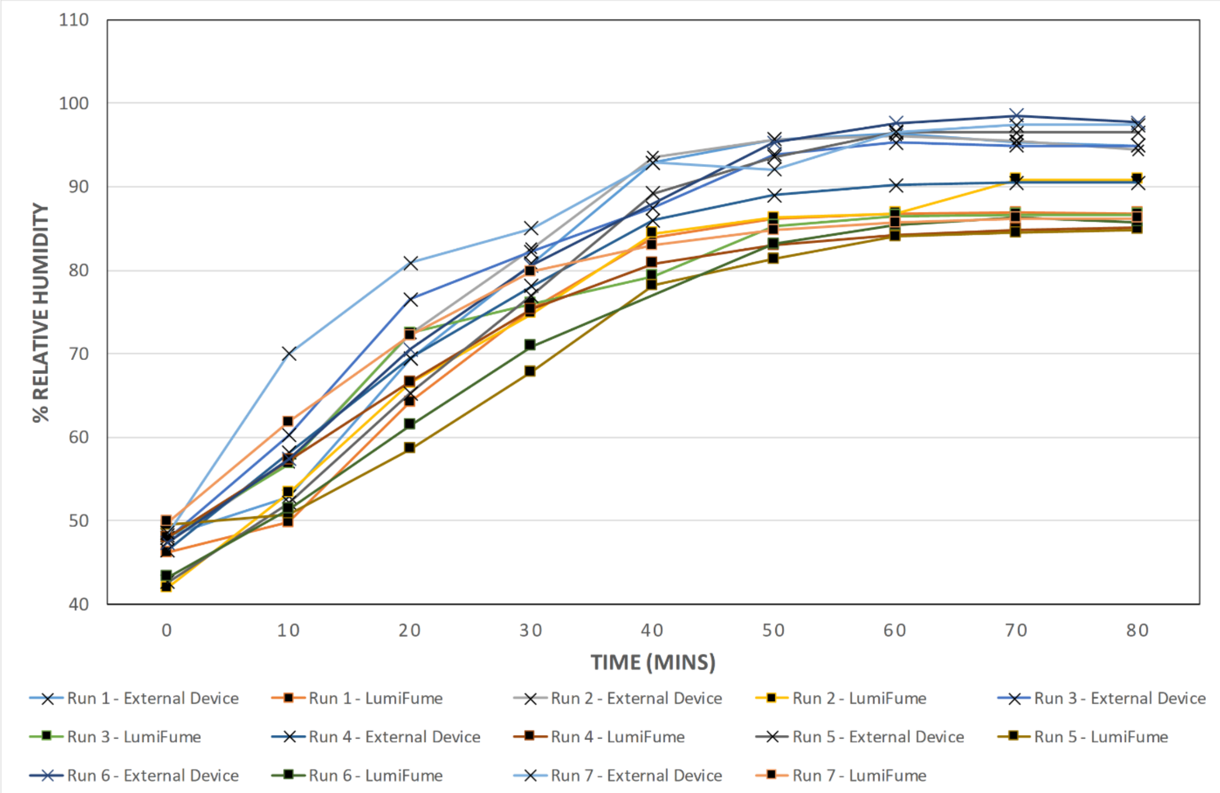
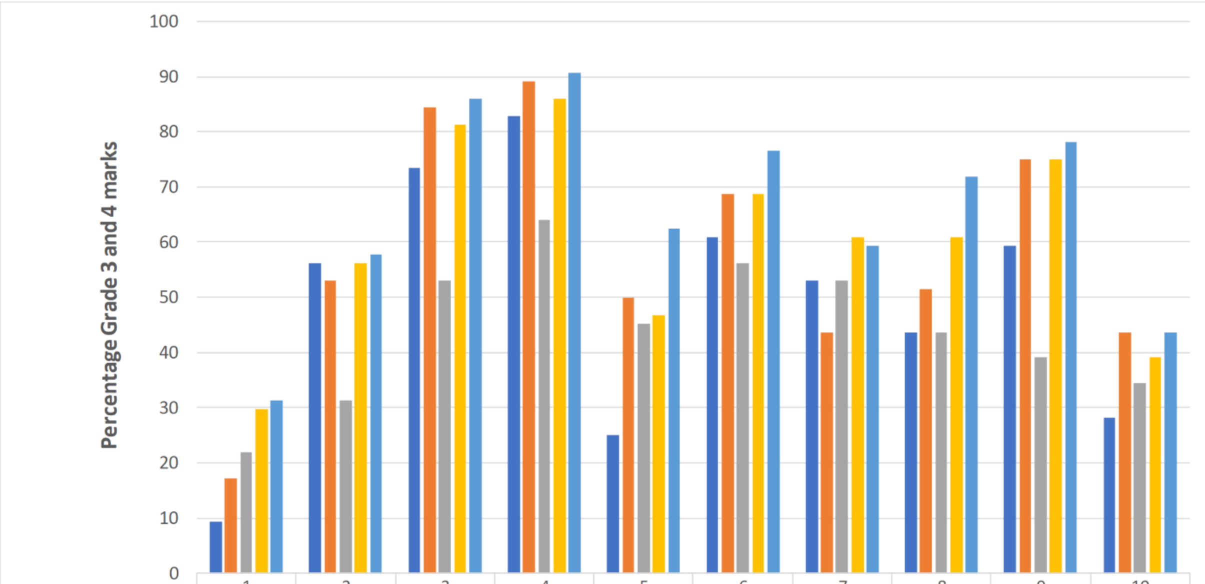


Figure 3 - Humidity profiling results of tent housing LumiFume™ system over different runs with maximum water temperature set at 80°C. External device denotes Extech sensor readings and LumiFume™ denotes its own sensor readings.



	1	2	3	4	5	6	7	8	9	10
Cabinet	9	56	73	83	25	61	53	44	59	28
LumiFume	17	53	84	89	50	69	44	52	75	44
Powder Suspension	22	31	53	64	45	56	53	44	39	34
Cabinet + BY40	30	56	81	86	47	69	61	61	75	39
LumiFume + BY40	31	58	86	91	63	77	59	72	78	44

Donor Number

Figure 4: Percentage Grade 3 and 4 marks for each donor per technique across all ageing periods and substrates.

3.2.2 The effects of different substrates

The quality of marks developed by the techniques was assessed based on the four substrates used in this study. Figure 5 depicts the average grade for all donors and ageing periods by technique and substrate. The results generally show that LumiFume™ in the tent and cabinet fuming produced marks of similar grading (figure 6). The use of BY40 after Lumicyano™ increased the average grade on all substrates except for laminate due to background staining. All three techniques produced fingermarks with third level detail such as pores. Two-sample paired t-tests were used to assess any significant differences between techniques for each substrate. Significant differences ($p= <0.05$) were observed for the bag substrate when comparing cabinet fuming with both LumiFume™ and powder suspension as well as for glass when comparing cabinet fuming and powdering suspension. The difference in average grades for tile substrate as well as for the fuming techniques on glass were not significant.

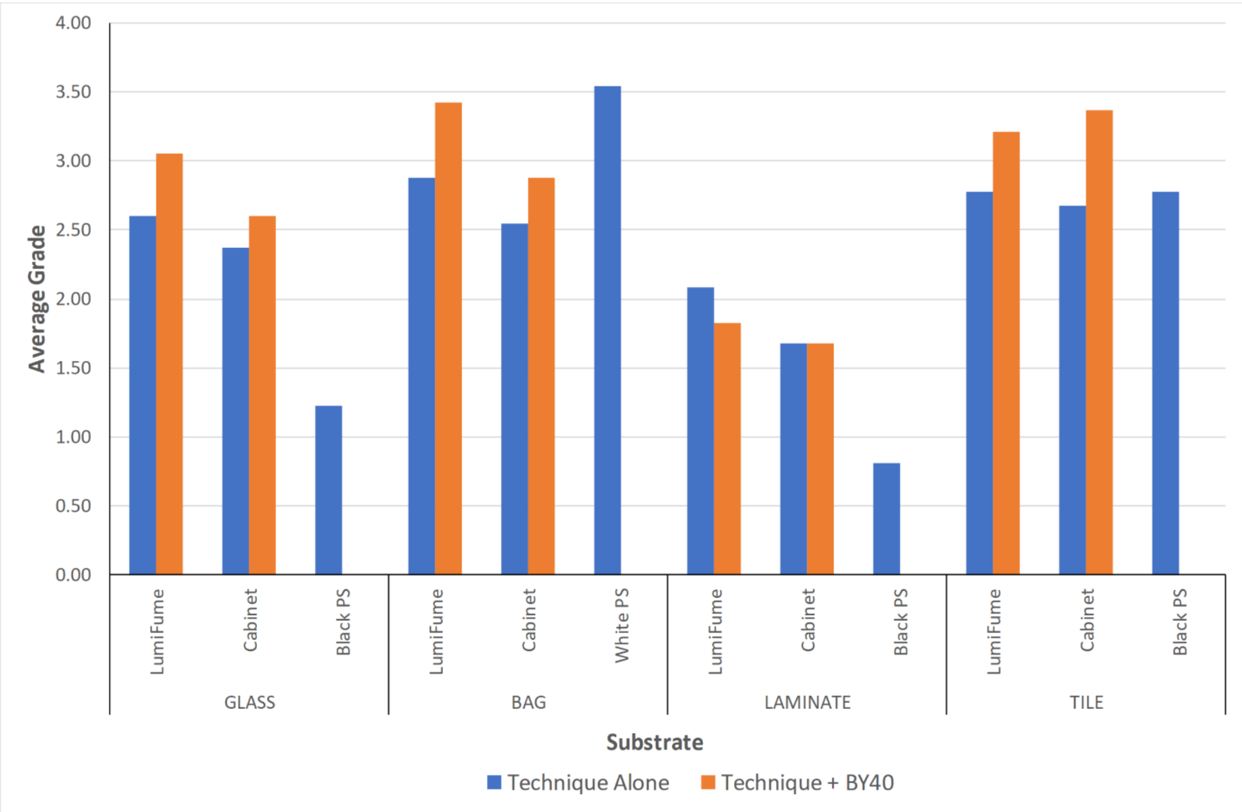


Figure 5: Average fingermark grade per substrate across all ageing periods and donors by substrate and technique with subsequent BY40 staining for the fuming techniques.

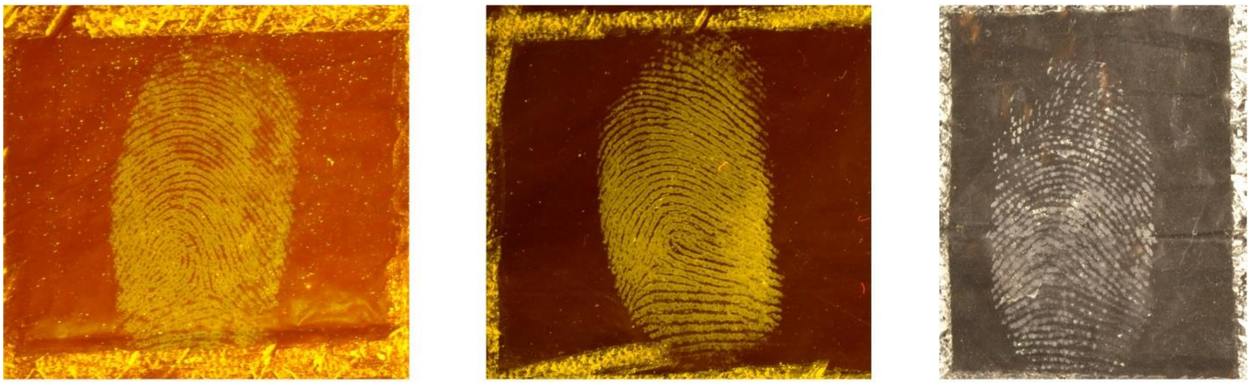
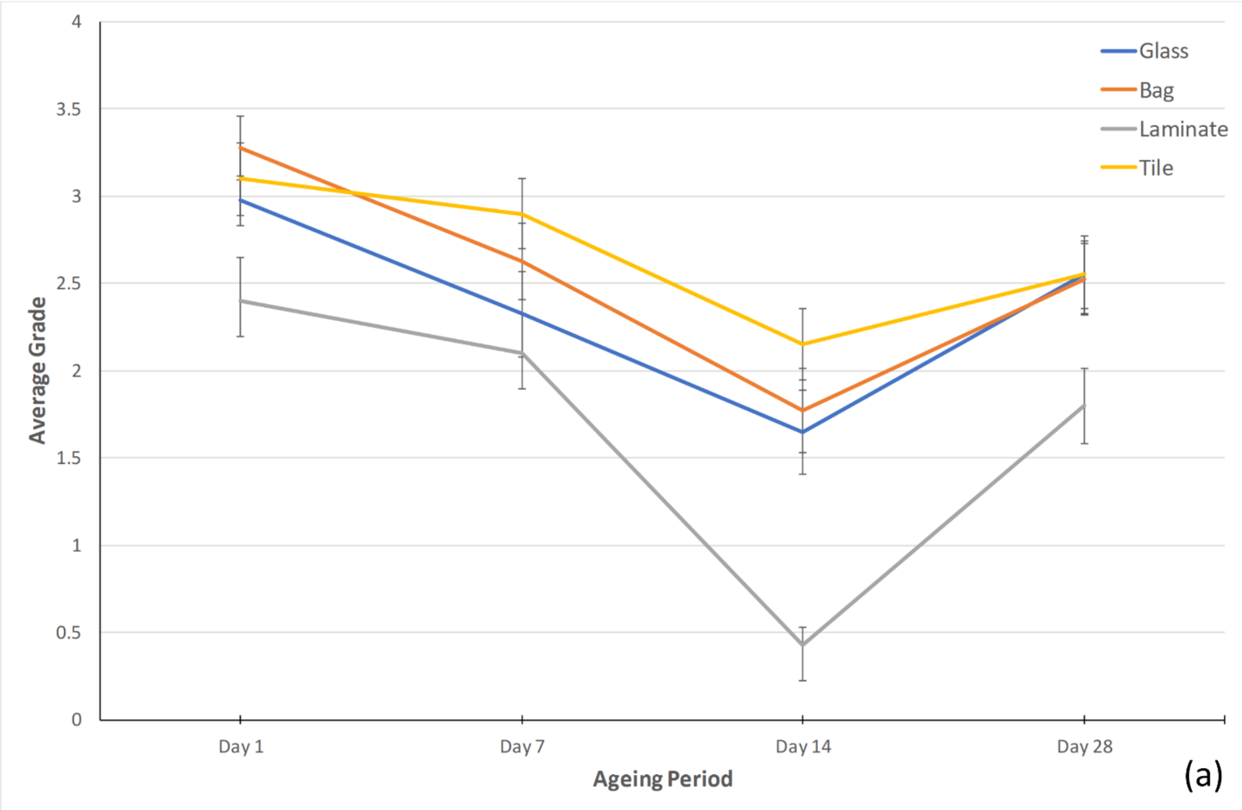


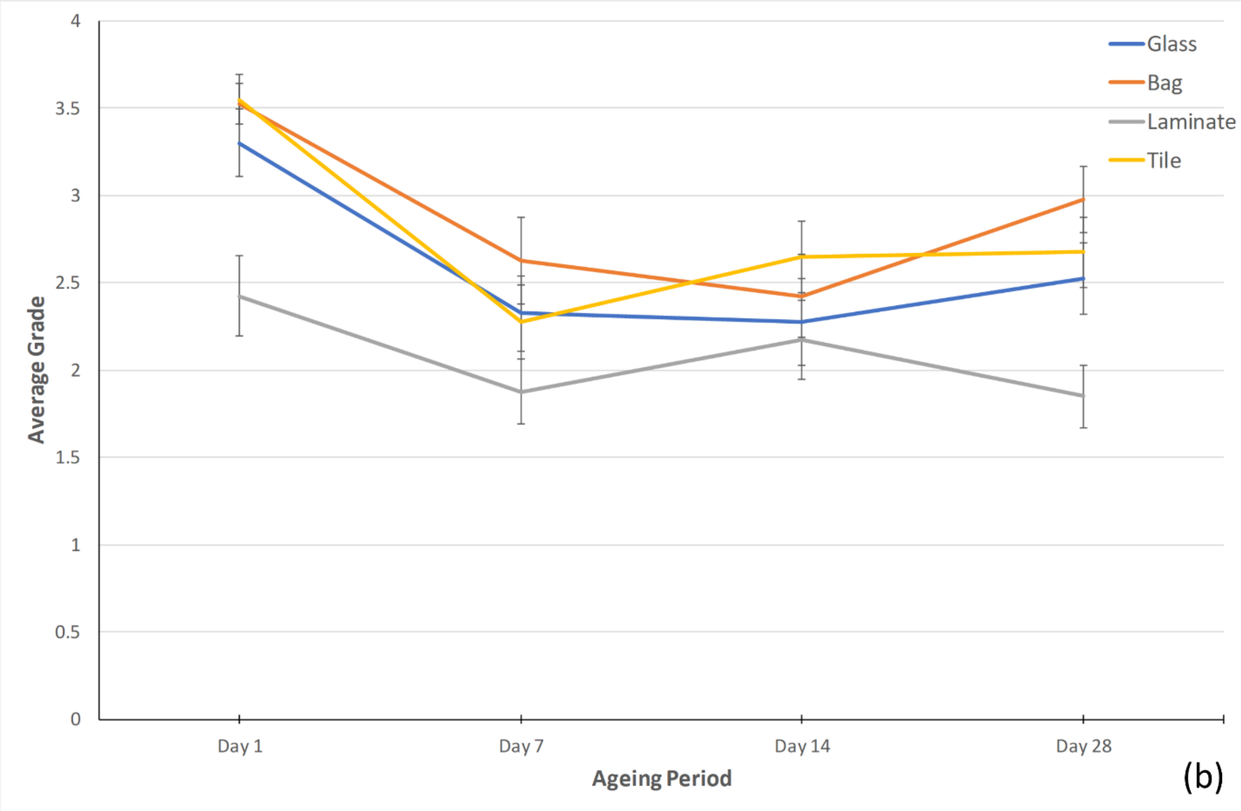
Figure 6 – Fingermark enhancement (donor 4, depletion 3) on a black plastic bin bag with Lumicyano™ cabinet (a), LumiFume™ (b) and TiO_2 powder suspension (c).

3.2.3 The effects of different ageing periods

This part of the study aged donor fingermarks for 1,7,14 and 28 days. Figure 7 summarises the average grade across all donors for each ageing period and substrate. From the Lumicyano™ cabinet and LumiFume™ graphs it is observed that the average grade generally decreases from 1 day to 7 days, thereafter, the cabinet grades continue to decrease to 14 days whilst the LumiFume™ grades slightly increase, before both techniques increase at 28 days. As reported in the literature [33,34] substrate type affects rate of degradation, with aged marks on glass noted to be of lower quality as water evaporation is faster. The increase in grade at 28 days was unexpected, as degradation would be expected to continue. This may be due to the different collection day/times for the different ageing periods. Environmental temperature and humidity are listed as factors that affect deposition in several sources, with a decreased temperature causing decreased skin elasticity and surface contact also cited [33]. The average grades for powder suspensions are consistent for both plastic bag and tile but variable for glass and laminate, with no substrate showing the decrease in grade over time expected.

All results were statistically analysed using a two-sample t-test which compared 1 day with each 7, 14 and 28 day results, 7 day with 14 and 28 day results and 14 day with 28 day results, for each substrate and technique. There were few clear significant trends apparent and most significant results appeared random and scattered throughout the comparisons. The complex results are attributable to the difficulty of applying statistical analysis to fingermark experiments due to the expansive list of variables that can occur between donors, substrates and techniques and due to the number of marks required for a robust comparison. Significant differences ($p= <0.05$) were observed between cabinet fumed bag and LumiFume™ fumed glass, bag and tile when comparing their respective 1 day grades with their 7,14 and 28 day grades, indicating differences in grade as time period increased was of importance. Additional significant differences were also obtained for cabinet fumed glass, bag and laminate substrates when comparisons were made between day 14 and day 28 grades. Trends were difficult to ascertain regarding the powder suspension technique though some significant results were obtained when comparisons were made between less aged marks and 28 day aged marks, again emphasising age as an important factor on grade. Treatment of Lumicyano fumed substrates with BY40 resulted in the same general trend as figure 7; an increased average grade with the exception for laminate, due to background staining.





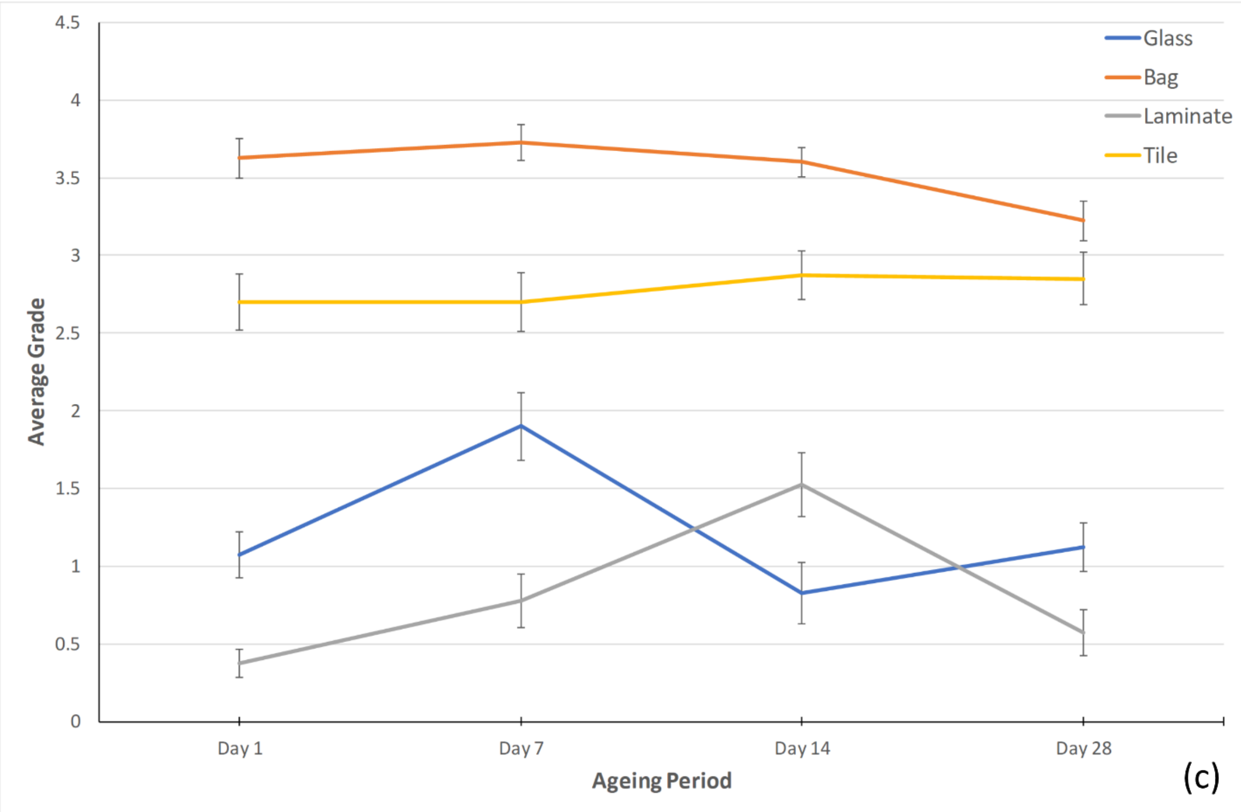


Figure 7 - Average fingermark grade across all 10 donors for each fuming technique per substrate and ageing period: (a) Lumicyano™ cabinet; (b) Lumicyano™ LumiFume™ and (c) powder suspensions

3.2.4 Evaluation of the stability of Lumicyano™ fluorescence

Two runs were carried out to evaluate Lumicyano™ fluorescence stability (cabinet and LumiFume™) and assessed over a period of days up to a total 28 days. Fluorescence observations were strong after 28 days reflecting previous studies [11,12,14,15]; however, the 10% Lumicyano™ concentration allows for a higher dye concentration providing more time for visualisation before the complete decay of fluorescence (figure 8). Fingermarks developed on glass slides in the cabinet were noted to feature overdeveloped marks (figure 9); however, no overdeveloped marks were observed with the LumiFume™ device which addresses a concern of previous studies that being unable to monitor the mark development (due to the tent) may lead to unintended overdeveloped marks [22]. Furthermore, and in general, marks treated with LumiFume™ appeared brighter when compared to marks treated in the cabinet (Table 1). For Lumicyano™ developed marks stored under light or dark conditions, it was noted that over time the brightness and visibility of ridge detail decreased, where the effect under light conditions was much more pronounced (figure 10) as observed in previous studies [11,12,14,15]. Furthermore, Figure 8 demonstrates that re-fuming the samples after 28 days, using both fuming techniques, provides fluorescence visualisation and mark quality that is at least as good as that observed within hours of fuming.

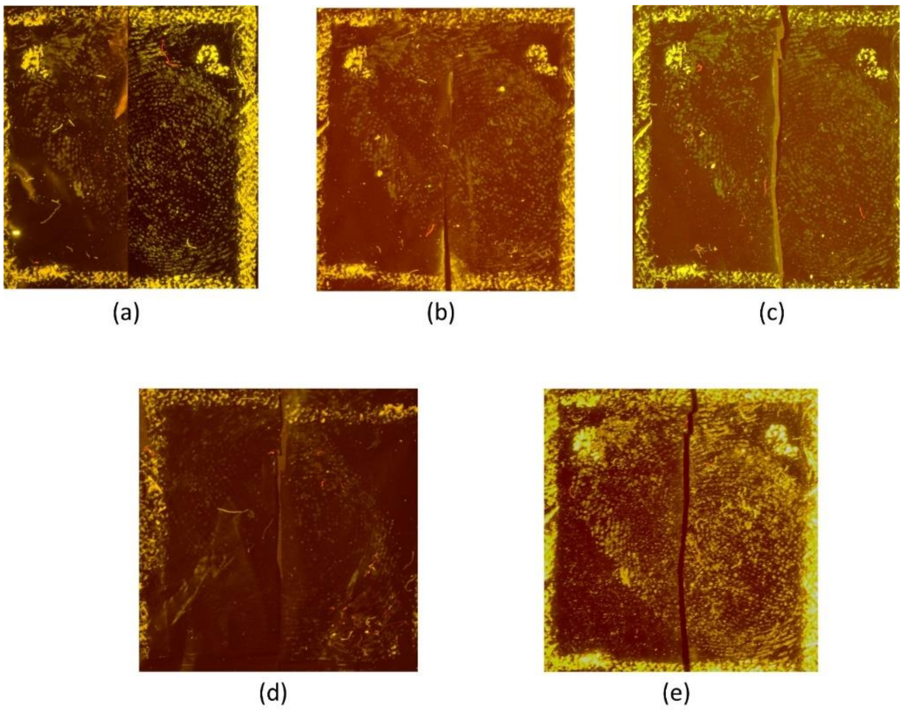


Figure 8 - A fingermark on a plastic bin bag (depletion 2) treated with Lumicyano™ observed with blue/green light (orange filter): (a) within a few hours of fuming; and after (b) 7 days; (c) 21 days; (d) 28 days; (e) re-fuming with Lumicyano™ [left part fumed in a cabinet, right part fumed in a tent with LumiFume™].

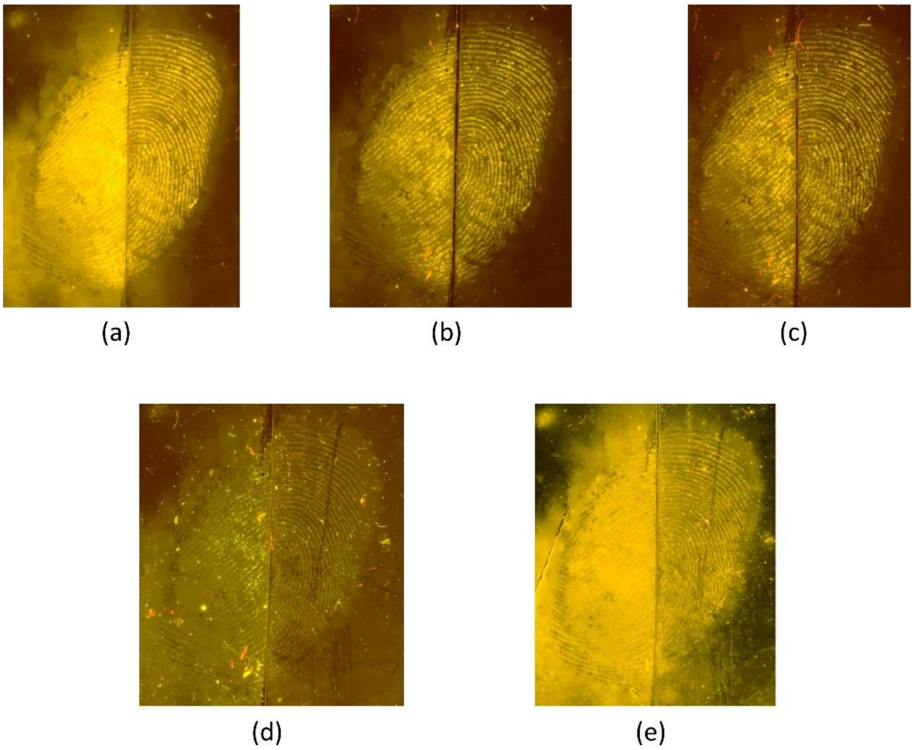


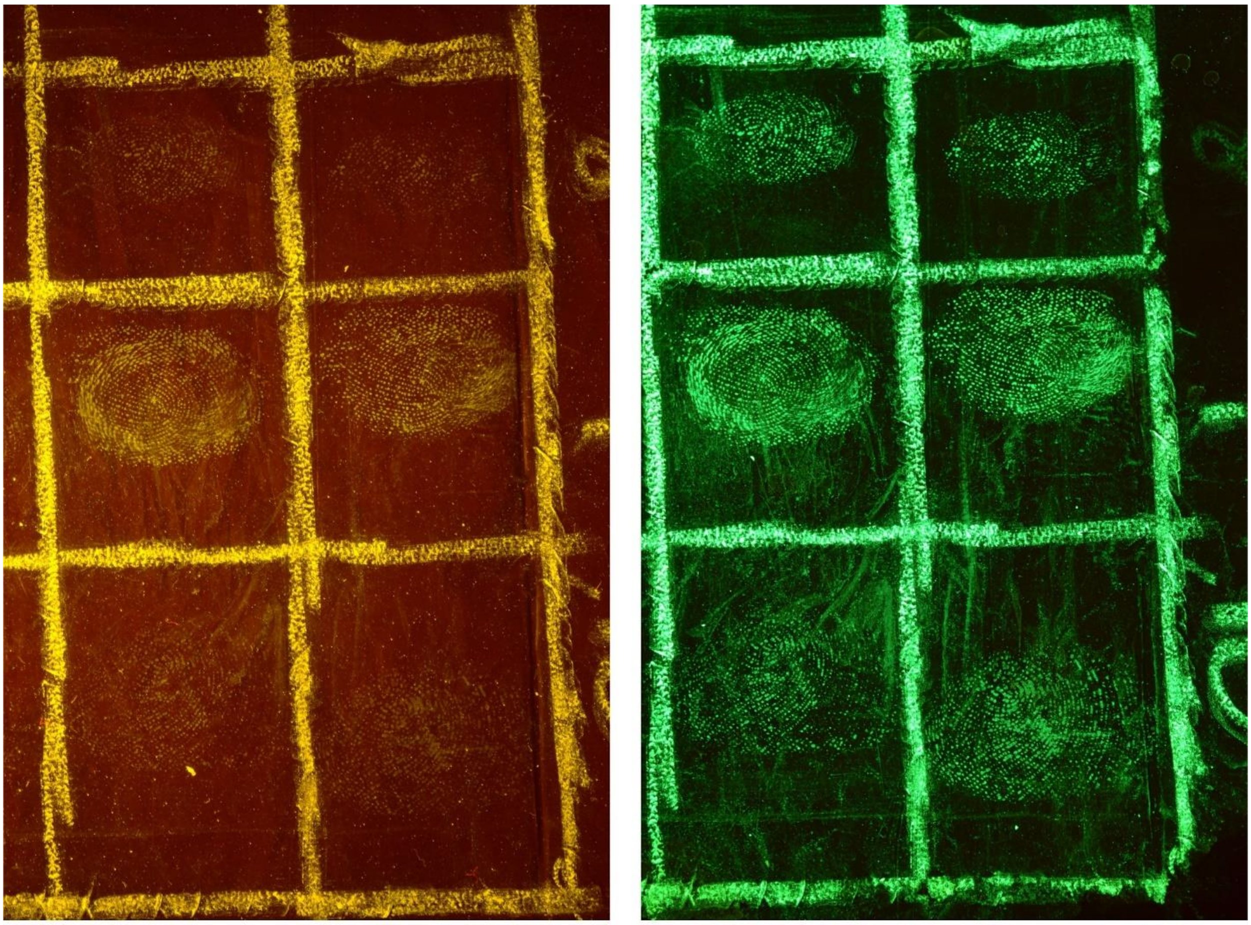
Figure 9 - A fingermark on a glass slide (depletion 2) treated with Lumicyano™ observed with blue/green light (orange filter): (a) within a few hours of fuming; and after (b) 7 days; (c) 21 days; (d) 28 days; (e) re-fuming with Lumicyano™ [left part fumed in a cabinet, right part fumed in a tent with LumiFume™].

Table 1 – Fluorescence stability runs for Lumicyano™ treated marks in cabinet and LumiFume™

		Bag		Glass	
		Cabinet	LumiFume	Cabinet	LumiFume
Mark 1	Day 0	-	+	-	+
	Day 1	+	-	-	+
	Day 2	=	=	-	+
	Day 5	=	=	-	+
	Day 7	=	=	-	+
	Day 14	+	-	-	+
	Day 21	=	=	-	+
	Day 28	=	=	-	+
	REFUME	=	=	-	+
Mark 2	Day 0	-	+	-	+
	Day 1	-	+	-	+
	Day 2	-	+	-	+
	Day 5	-	+	-	+
	Day 7	=	=	-	+
	Day 14	=	=	-	+
	Day 21	=	=	-	+
	Day 28	-	+	-	+
	REFUME	=	=	-	+
Mark 5	Day 0	=	=	+	-
	Day 1	-	+	-	+
	Day 2	-	+	-	+
	Day 5	-	+	-	+
	Day 7	-	+	-	+
	Day 14	-	+	-	+
	Day 21	-	+	-	+
	Day 28	-	+	-	+
	REFUME	-	+	-	+
Mark 10	Day 0	-	+	-	+
	Day 1	+	-	-	+
	Day 2	=	=	-	+
	Day 5	-	+	-	+
	Day 7	+	-	-	+
	Day 14	=	=	-	+
	Day 21	-	+	-	+
	Day 28	-	+	-	+
	REFUME	-	+	-	+

3.2.5 Evaluation of subsequent BY40 dyeing on marks visualised with Lumicyano™

Throughout the study and for each variable considered, BY40 staining further improved mark quality and visualisation (figure 10); however, background staining was observed, particularly on the laminate substrate. Furthermore, there is additional time required for dyeing and drying of samples overnight as well as the use of flammable ethanol, which may affect other types of evidence such as DNA [19]. This study supports previous findings that BY40 marks are brighter than Lumicyano™ alone and that BY40 can reveal further additional marks [11,12,14,15]. Two-sample t-tests assessed if the improvement in mark quality with BY40 was significant. The results were mixed though it was noted that improvement in grade for 14 and 28 day cabinet fumed bag and tile marks and 14 and 28 day LumiFume™ fumed glass and bag marks was significant.



(a) (b)

Figure 10 – Sequential enhancement of Lumicyano™ developed marks on a plastic bag with: (a) LumiFume™ and (b) followed by BY40 staining

3.3 Phase 2 Results

The most successful technique of the pseudo-operational trial was Lumicyano™ with LumiFume™ on all substrates except plastic bags, which Lumicyano™ in the cabinet was better. Figure 11 summarises the number of marks detected by technique and substrate. In total, Lumicyano™ with LumiFume™ (figure 12) and subsequent BY40 yielded 1,946 marks whereas Lumicyano™ in the cabinet and BY40 provided 1,574 marks. The use of powder suspensions resulted in the lowest number of marks (641). The use of titanium dioxide and iron oxide powder suspension was dependent on the substrate colour; however, results were poor in comparison to the fuming techniques. Nonetheless, the detection of marks on plastic bags was comparable for all three processes (excluding BY40) in line with previous studies on the same substrate [11,12]. A recent study [35] also reported that the iron oxide currently recommended in the Fingermark Visualisation Manual (Fisher Scientific, Product code: I/1100/53) was less effective than another alternative iron oxide nanopowder (50-100 nm) due to variations between batches. Sequential treatment with BY40 after fuming with Lumicyano™ yielded additional new marks.

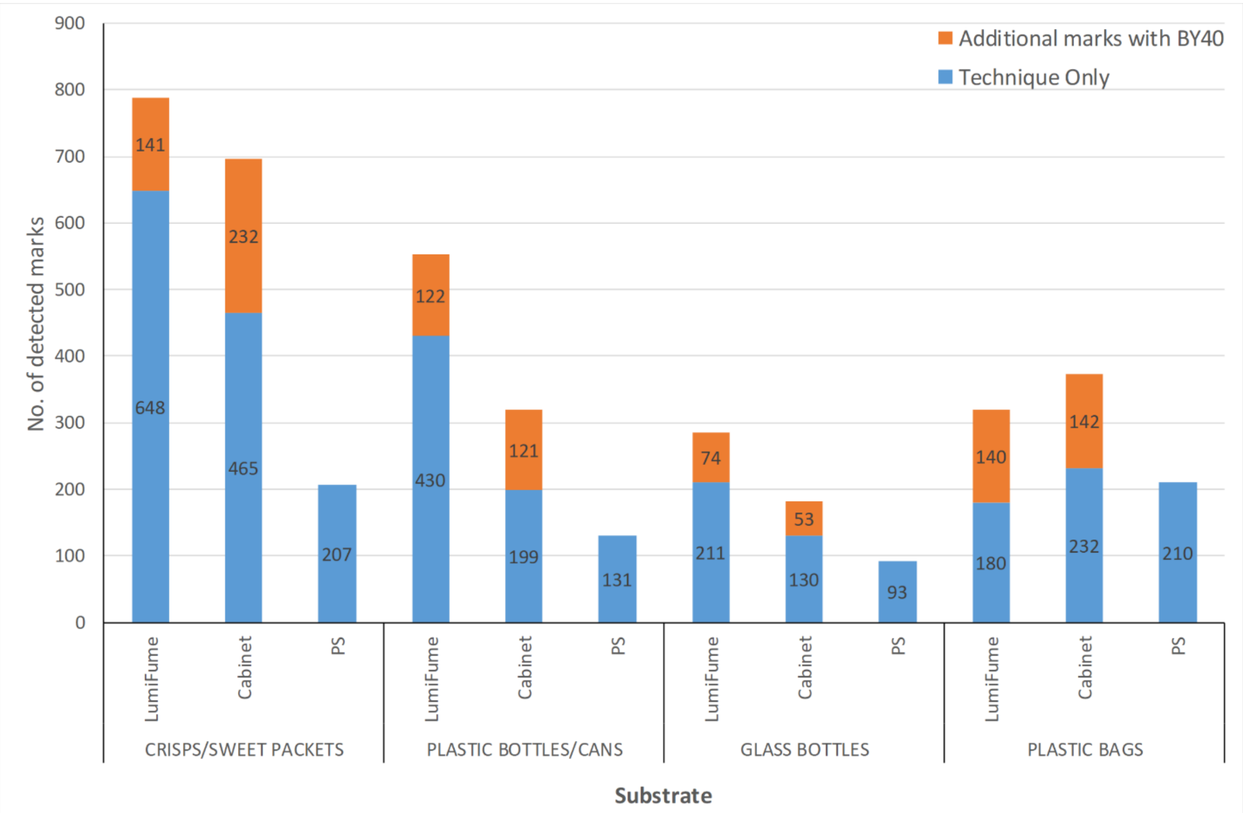
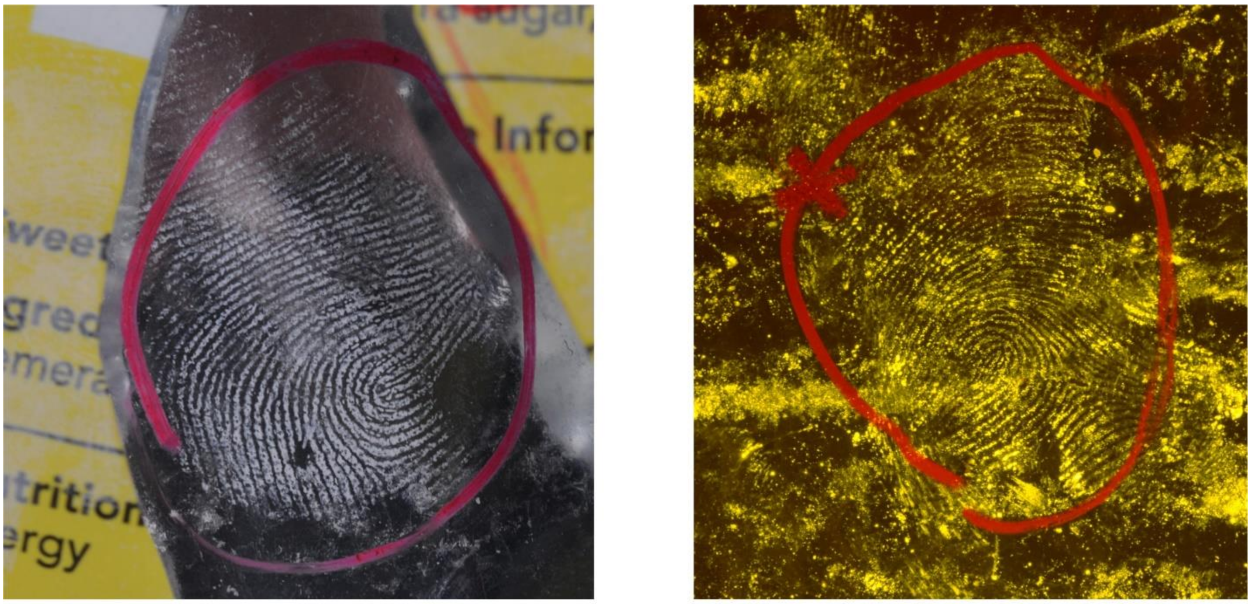


Figure 11 – Number of detected marks for each enhancement process in the pseudo-operational trial.



(a) (b)

Figure 12 - Example images of recovered LumiFume™ marks on items used in the pseudo-operational trial: (a) a popcorn packet observed under white light and (b) a biscuit packet observed under blue/green light (orange filter).

4. Conclusion

The effectiveness and suitability of LumiFume™ with Lumicyano™ at detecting latent fingermarks was assessed. LumiFume™ was compared with both laboratory cabinet fuming and iron oxide/titanium dioxide powder suspensions. The portable fuming system LumiFume™ provided superior quality of developed marks on glass and laminated wood whereas powder suspension was better on bin bags and all three techniques were comparable on tile. Furthermore, for all three techniques, the quality of developed marks was affected by donor, substrate, ageing period and background staining. As reported in previous studies, storing fumed samples under dark conditions slows down the fluorescence decay. BY40 improved mark quality on all substrates for both fuming techniques except for laminated wood. Results from a pseudo-operational trial of 300 non-porous items showed that the highest number of marks was detected by LumiFume™, although cabinet fuming yielded the highest number of marks on plastic bags. It is not clear why a cyanoacrylate portable system in a tent, which does not control humidity, provides overall better results than a humidity-controlled cabinet.

The study has contributed additional information and builds upon previous research on the use of portable cyanoacrylate fuming systems. Further research of the LumiFume™ device is recommended and future work can assess its performance within a room including furnishings (no tent) or outdoors within a tent. The LumiFume™ device produced results at least equivalent to the traditional cabinet fuming with Lumicyano™ highlighting its potential for implementation into casework to process crime scenes.

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