Further Pseudo-Operational Trials with the Lumicyano Double- and Co-Fuming Process for the Detection of Latent Fingermarks

Kevin J. Farrugia
Danielle Hunter
Clarice Wilson
Stef Hay
Paul Sherriffs
Paul Deacon

Further pseudo-operational trials with the Lumicyano double and co-fuming process for the detection of latent fingermarks

Journal:	*Journal of Forensic Sciences*
Manuscript ID	JOFS-19-300.R1
Manuscript Type:	Technical Note
Keywords:	forensic science, cyanoacrylate, superglue, fingerprint, latent mark, fluorescence

Further pseudo-operational trials with the Lumicyano double and co-fuming process for the detection of latent fingermarks

ABSTRACT

This study presents a number of pseudo-operational trials on plastic bags investigating the double and co-fuming process of a one-step fluorescent cyanoacrylate (Lumicyano™) with comparisons to the two-step process with basic yellow 40 (BY40) staining for the detection of latent fingermarks. The results demonstrate that both the Lumicyano solution and dye contribute to the increased detection of latent fingermarks during the double fuming process (trial 1). Co-fuming the Lumicyano solution and dye separately (at a concentration of 8%) but simultaneously was less effective than 8% Lumicyano (trial 2). Co-fuming Lumicyano 8% and an additional 8% Lumicyano dye by weight was more effective than Lumicyano 8% (trial 3), possibly due to increased fluorescent material deposition during co-fuming allowing for better visualisation. The use of BY40 after Lumicyano resulted in a considerable increase of detected fingermarks. luorescence

KEYWORDS

Forensic science, cyanoacrylate, superglue, fingerprint, latent mark, fluorescence

One-step fluorescent cyanoacrylates have a number of potential advantages such as a decrease in processing time and the absence of solvents helps to reduce interference with subsequent DNA analysis and other forensic evidence. Examples of one-step fluorescent cyanoacrylates include Lumicyano, Polycyano, CN Yellow, Fuming Orange and PECA Multiband in addition to other fluorescent cyanoacrylates synthesised in the laboratory (1-8). Although such products have a number of advantages, their fluorescence is generally weaker and can degrade with time. The subsequent use of a fluorescent stain, such as basic yellow 40 (BY40) and Rhodamine 6G will often reveal additional new detections of latent marks (9). Fluorescent cyanoacrylates, with the exception of Lumicyano, require a temperature of 230^{o}C. The use of higher temperatures for evaporating cyanoacrylates may require cabinet modification and produce toxic hydrogen cyanide gas (10).

A study (3) investigating the sequential double process of Lumicyano fuming, whereby items are fumed followed by another fuming cycle, reported that the second fuming cycle resulted in the detection of marks that were not observed after the first fuming cycle. This increased detection rate was due to a break between the two fuming cycles rather than due to the double amount of cyanoacrylate/dye and fuming time. In 2005, the UK Home Office Centre for Applied Science and Technology (CAST) investigated the co-polymerisation of cyanoacrylate and solvent yellow 43 that was heated to a temperature range of 170–185^{0}C. The resultant fluorescence was weak; however, subsequent staining with basic yellow 40 provided fluorescence that was 5-10 times brighter (Vaughn Sears, CAST, personal communication, 11/11/2015).

This current study aims to follow up on previous pseudo-operational trials (3) on plastic carrier bags to further evaluate the Lumicyano double fuming process. The methodology is based on guidelines recommend by CAST (11) and the International Fingerprint Research Group (IFRG) (12). Both CAST and the IFRG describe pseudo-operational trials as stage or phase 3 out of 4

in fingermark research. These trials are defined as a process 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" (11). CAST classifies fluorescent superglue fuming at low to medium maturity and as a category C process with niche applications. As more peer-reviewed articles are published around the topic, the technique may be upgraded to a category B process which is defined as a process that is generally less effective but has not been fully evaluated by the Home Office CAST (11).

Methodology

Sample collection and preparation.

The collection of plastic carrier bags (mixture of HDPE, LDPE, recycled and bio) from work colleagues, family and friends became more difficult since a recent change in UK law (Wales 2011, Northern Ireland 2013, Scotland 2014 and England 2015) requiring large retailers to charge a small fee for all single-use plastic barrier bags. Plastic carrier bags were therefore collected from dedicated plastic bag recycling centres at big supermarkets. This increased the variation of donors, plastic bag types and fingermark age. Each trial consisted of 100 items in line with other studies (1-3,13) and the description (e.g. colour and material type) for each item was recorded. All items were treated with the required technique within three weeks of collection. For the three pseudo-operational trials, all items were split into three equal parts and labelled Process A, B and C from left to right as shown in figure 1. To eliminate any bias, samples were rotated whereby sample 1 was A-B-C; sample 2 was B-C-A; sample 3 was C-B-A and so on.

Pseudo-operational trials

Trial 1 used Lumicyano™, supplied by Crime Science Technology (CST) consisting of a clear cyanoacrylate solution (Lumicyano™ Solution) and a bright red-orange powdered dye (Lumicyano™ Powder), added at the 5% level (by weight). Process A consisted of a double fuming treatment with Lumicyano 5% followed by basic yellow 40 (BY40) staining. At least six hours had passed before the second fuming treatment and in general, it was done within 24 hours of the first treatment. Any detected fingermarks were counted between each process (Lumicyano 5%-Lumicyano 5%-BY40). Processes B and C were similar to process A; however, the second treatment was replaced with Lumicyano solution only and Lumicyano dye only respectively (figure 1). Trials 2 and 3 used co-fuming of the Lumicyano solution and dye.

Trial 2 treatment A involved 8% Lumicyano treatment (manufacturer's instructions at the time of trial increased dosage to 8%) followed by BY40 staining whereas treatment C was the conventional two-step cyanoacrylate fuming followed by BY40 staining. For treatment B, a co-fuming process was carried out where the Lumicyano solution and the Lumicyano dye (8%) were evaporated separately, but simultaneously, before BY40 staining. Trial 3 differed only from trial 2 with treatment B (figure 1), where this process involved a co-fuming process of Lumicyano 8% and Lumicyano dye only at 8%. For all three trials, BY40 staining was performed the day after fuming. A small trial of 25 recycled bags (trial 4) was performed to investigate the effect of the change in Lumicyano concentration from 5 to 8%.

Cyanoacrylate Fuming Chamber, Photography and Fluorescence

An Air Science fuming chamber (model number CA60T) was employed with an approximate volume of about 1500 L (1.5 m^3). The chamber is fitted with two independent hot plates capable of reaching 400^0C (both set at 120^0C) and a humidifier (set to 80%). The two hot plates can start simultaneously once a humidity of 80% is reached or the second hot plate can turn on at a pre-determined time after the first hot plate (figure 2). For trials 2 and 3, the second hot plate was set to come on 15 minutes after the first one. The hot plate and humidifier were calibrated by means of a digital thermometer/thermocouple (RS 206-3738) and a Hygro-Thermometer Psychrometer (Extech RH300). Fluorescence examination was carried out using Crime-Lites and a Mason Vactron Quaser 2000/30 whereas UV examination was carried out using a 50W Labino® SuperXenon Lumi Kit (peak excitation at 325nm) and viewed with a clear UV filter. Photography was performed with a Nikon D5100 and a 60mm micro Nikon lens.

Cyanoacrylate

4 g of cyanoacrylate (CSI equipment Ltd, UK) was required for the volume of the cabinet. A cycle time of 60 minutes ensured that 99.99% of the cyanoacrylate had evaporated as checked by the weight difference before and after the cycle.

5% and 8% Lumicyano™

The manufacturer recommends a concentration of 5% and 8% of powder by weight of cyanoacrylate solution. For example, 5% solution was prepared by adding 0.2g of Lumicyano dye to 4 g Lumicyano cyanoacrylate solution. After fuming, fluorescence was observed using the Quaser 2000/30 by exciting with a blue/green light (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). UV examination was carried out using a 50W Labino® SuperXenon Lumi Kit (peak excitation at 325nm) and viewed with a UV face shield for UV protection.

BY40 staining (14)

The BY40 solution was prepared by dissolving 2 g of BY40 (Sirchie) in 1 L of ethanol (Fisher). The items to be processed were submerged in the BY40 solution for 15-20 seconds before rinsing off the excess dye with running tap water and allowed to dry at room temperature overnight prior to fluorescence examination. BY40 dyeing on fumed items was performed the following day after fuming. BY40 fluorescence was observed using a Quaser 2000/30 by exciting with a violet/blue excitation source (band pass filter 400-469 nm at 1% cut-on and cut-off points respectively) and viewed with a yellow long pass 476 nm filter (1% cut-on point). A blue Crime-Lite® 82S [10% band width 420–470 nm with a 445 nm peak and viewed with a yellow long pass 476 nm filter (1% cut-on point)] was also used.

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 64mm^2 were counted. Each of these marks was graded 'a' for good contrast or 'b' for poor contrast. The quality of the marks was assessed after each treatment in the sequence. Marks that showed signs of over-developed were also noted.

Results and Discussion

In general, a high number of recycled and life-long plastic bags were observed which differed significantly from previous studies (1-3). An evaluation of the number and quality of latent marks recovered by each treatment in each process and trial was performed. For all trials, there was some marks with poor contrast (grading b); however, subsequent fluorescence examination improved the contrast and almost all marks were graded as 'a'. Although a considerable number of marks were observed visually, the use of fluorescence provided a quicker visualisation method with less stress on the eye. In general, for Lumicyano, the blue-green excitation source (orange filter) provided better contrast than UV fluorescence. Over-fuming of marks was rarely observed with all fuming techniques.

Trial 1

Figure 3 summarises the number of marks detected for each treatment with each process as observed visually (V) and under fluorescence (F). The double fuming process (process A) resulted in an increased detection rate after the initial fuming cycle from 153 marks to 209 marks. This is in line with a previous study (3) which reported that the increased detection rate during the Lumicyano double fuming process was not due to the amount of cyanoacrylate or the fuming time but rather the break in the two fuming cycles. A similar pattern was reported for other one-step fluorescent cyanoacrylates, such as Polycyano and PECA Multiband, but not for the traditional two-step cyanoacrylate process (9). The increased detection rate may be due to Lumicyano targeting cyanoacrylate deposits and the marks undetected from the first fuming cycle could be acting as activation points for the polymer growth in the second fuming cycle (3). Processes B and C from trial 1 appear to suggest that the increased detection rate for the double fuming process A is due to both the Lumicyano solution and dye since both the

secondary treatments of process B (solution) and process C (dye) resulted in an increased detection rate after treatment with 5% Lumicyano. A higher number of marks was reported for the double fuming process of 5% Lumicyano - 5% Lumicyano (209 marks) compared to 192 marks (process B) and 184 marks (process C). The final BY40 staining step resulted in additional marks for all treatments as reported in other studies for BY40 (1-3) and Rhodamine 6G (4-5).

Trial 2

Figure 4 demonstrates that the number of marks, visually and fluorescent, detected for each treatment with each process. Process A resulted in a significantly increased detection rate after BY40 staining marks previously treated with Lumicyano 8%. It is important to note that trials 2 and 3 were performed about six months after trial 1 and, in that time, the recommended concentration of Lumicyano changed from 5% to 8%. This increased detection rate after BY40 is higher than the 15-25% in trial 1 and previous studies (1-3). The high increase in the number of recycled bags in trials 2 and 3 (>90%) when compared to trial 1 and previous studies may explain this. The increased concentration of Lumicyano from 5% to 8% did not appear to influence the results (small scale study of 25 plastic bags in trial 4); however, the increased detection after BY40 was evidenced again. A recent study (15) reported that substrate characteristics play a significant role in determining the number and quality of marks developed. Furthermore, another study (11) on the detection of fingermarks on plastics by the UK Home Office CAST highlighted a change in the relative performance of enhancement techniques from trials done in 1986 and 2009 due to changes in the manufacturing process of plastics. Process B, involving the co-fuming of the Lumicyano solution and dye (8%), revealed a lower detection rate by about a third than when Lumicyano was mixed at a concentration of 8% (Process A). This suggests that Lumicyano is more effective when the solution and dye are

mixed together rather than co-fumed separately. Process C, two-step cyanoacrylate followed by BY40, resulted in a lower detection rate when compared to process A and B, but only after the use of BY40 on these two processes.

Trial 3

Figure 5 demonstrates that, as per trial 2, Process A resulted in a significantly increased detection rate after BY40 staining marks previously treated with Lumicyano 8%. The co-fuming of Lumicyano 8% and Lumicyano dye (8%) resulted in an increased detection rate (85 marks) when compared to only using Lumicyano 8% (63 marks). This may be because more dye material is present resulting in a prolonged strong fluorescence. As per the previous trial, Process C (two-step process) resulted in less marks than processes A and B; however, the two-step process detected a similar number of marks (64 marks) when taking into consideration only the one-step process (without the additional step of BY40) for processes A (63 marks). This trial suggests that the use of co-fuming Lumicyano 8% in addition to more dye (Process B) may result in the detection of more marks. For both trials 2 and 3, the increased dye concentration of 8% did not result in an increase in background development during fluorescence examination.

Trial 4

This small pseudo-operational trial of 25 recycled bags (not a double fuming process) confirmed that the change in Lumicyano concentration did not have a detrimental effect on the number of marks detected (figure 6). This also reflected the increased detection rate of BY40 after Lumicyano with recycled bags. As in previous studies (1-3), the two-step process of 5% and 8% Lumicyano (71 and 83 marks respectively) is comparable to the two-step process with

BY40 (72 marks); however, the use of BY40 after Lumicyano treatment can result in a considerable increase in detected marks.

Conclusion

This study has demonstrated that the increased detection rate during the double fuming cycle of Lumicyano is due to both the solution and the dye part of the product. Further trials revealed that the detection rate of latent fingermarks is reduced if the two Lumicyano components are used separately (but simultaneously) when compared to mixing the two components together. On the other hand, the simultaneous co-fuming of Lumicyano 8% with extra dye at a concentration of 8% was more effective due to an increased in fluorescent material. In summary, the use of a double fuming cycle can result in a higher detection rate; however, co-fuming of Lumicyano 8% with additional Lumicyano dye can produce similar or a higher detection rate during one cycle rather than two. Furthermore, the use of BY40 dye staining resulted in a pronounced increased detection rate (more than previous studies), which may be explained by the fact that most plastic bags currently in circulation are recyclable. Future work will need to address the effect of substrate composition on latent fingermark detection due to the increased circulation of recyclable, compostable and biodegradable plastic bags. There is no doubt about the advantages of a one-step fluorescent cyanoacrylate process; however, extensive further research by the forensic community is required to improve the maturity level of these processes.

References

1. Farrugia KJ, Deacon P, Fraser J. Evaluation of Lumicyano™ cyanoacrylate fuming process for the development of latent fingermarks on plastic carrier bags by means of a pseudo operational comparative trial. Sci Justice 2014;54(2):126–32.
2. Farrugia KJ, Fraser J, Calder N, Deacon P. Pseudo-Operational Trials of Lumicyano Solution and Lumicyano Powder for the Detection of Latent Fingermarks on Various Substrates. J Forensic Identif 2014;64(6):556–82.
3. Farrugia KJ, Fraser J, Friel L, Adams D, Attard-Montalto N, Deacon P. A comparison between atmospheric/humidity and vacuum cyanoacrylate fuming of latent fingermarks. Forensic Sci Int 2015;257:54-70.
4. Chadwick S, Xiao L, Maynard P, Lennard C, Spindler X, Roux C. PolyCyano UV: an investigation into a one-step luminescent cyanoacrylate fuming process. Aust J Forensic Sci 2014;46(4):471–84.
5. Khuu A, Chadwick S, Spindler X, Lam R, Moret S, Roux C. Evaluation of One-Step Luminescent Cyanoacrylate Fuming. Forensic Sci Int 2016;263:126–31.
6. Khuu A, Chadwick S, Moret S, Spindler X, Gunn P, Roux C. Impact of one-step luminescent cyanoacrylate treatment on subsequent DNA analysis. Forensic Sci Int 2018;286:1–7.
7. Bentolila A, Totre J, Zozulia I, Levin-Elad M, Domb AJ. Fluorescent cyanoacrylate monomers and polymers for fingermark development. Macromolecules 2013;46(12):4822–8.
8. Groeneveld G, Kuijer S, de Puit M. Preparation of cyanoacrylate derivatives and comparison of dual action cyanoacrylate formulations. Sci Justice 2014;54(1):42–8.
9. Stewart V, Deacon P, Farrugia K. A review of one-step fluorescent cyanoacrylate techniques. Fingerprint Whorld 2016;41(162):6–29.

10. Fung TC, Grimwood K, Shimmon R, Spindler X, Maynard P, Lennard C, et al. Investigation of hydrogen cyanide generation from the cyanoacrylate fuming process used for latent fingermark detection. Forensic Sci Int 2011;212(1–3):143–9.

11. Sears VG, Bleay SM, Bandey HL, Bowman VJ. A methodology for finger mark research. Sci Justice 2012;52(3):145–60.

12. IFRG. Guidelines for the Assessment of Fingermark Detection Techniques. J Forensic Identif 2014;64(2):174–200.

13. Downham R, Mehmet S, Sears VG. A Pseudo-Operational Investigation into the Development of Latent Fingerprints on Flexible Plastic Packaging Films. J Forensic Identif 2012;62(6):661–82.

14. Centre for Applied Science and Technology (CAST). Fingermark Visualisation Manual. Home Office U.K, 2014.

15. Chadwick S, Moret S, Jayashanka N, Lennard C, Spindler X, Roux C. Investigation of some of the factors influencing fingermark detection. Forensic Sci Int 2018;289:381–9.

List of Figures

FIG. 1 - Sample division for a plastic carrier bag in the three trials.

441x246mm (300 x 300 DPI)

FIG. 2 – The two hot plates in the CA fuming chamber used during co-fuming.

350x241mm (300 x 300 DPI)

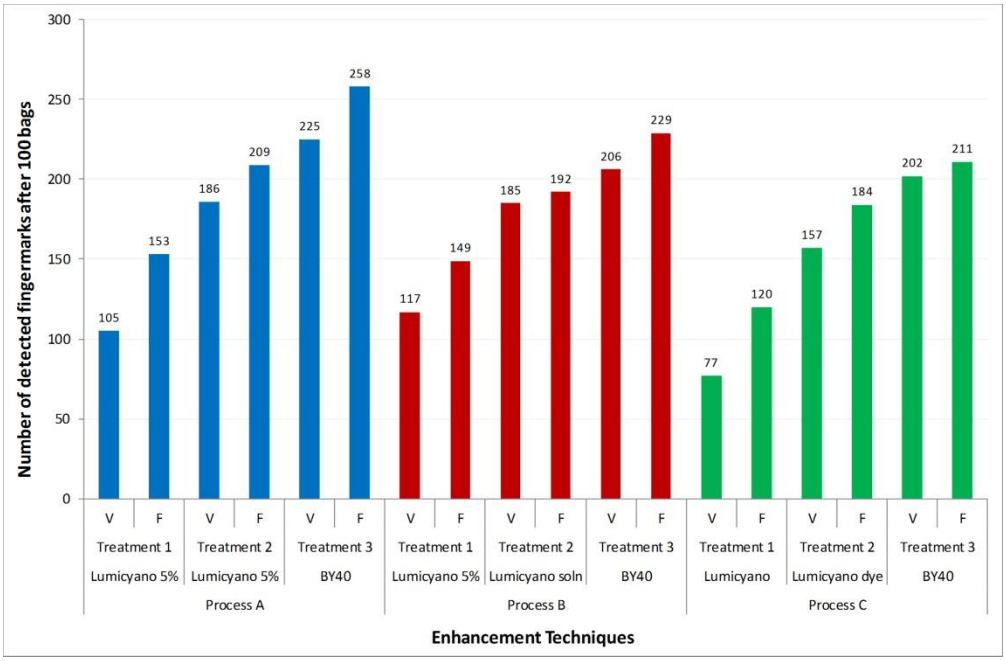

FIG. 3 - Number of detected latent fingermarks in pseudo-operational trial 1.
393x256mm (300 x 300 DPI)

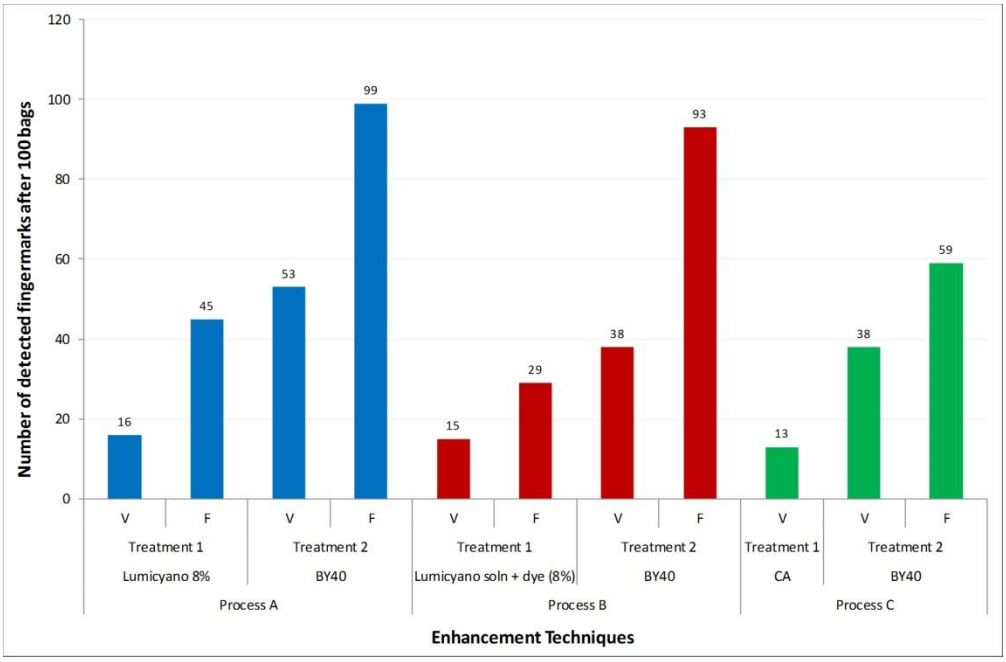

FIG. 4 - Number of detected latent fingermarks in pseudo-operational trial 2.
370x242mm (300 x 300 DPI)

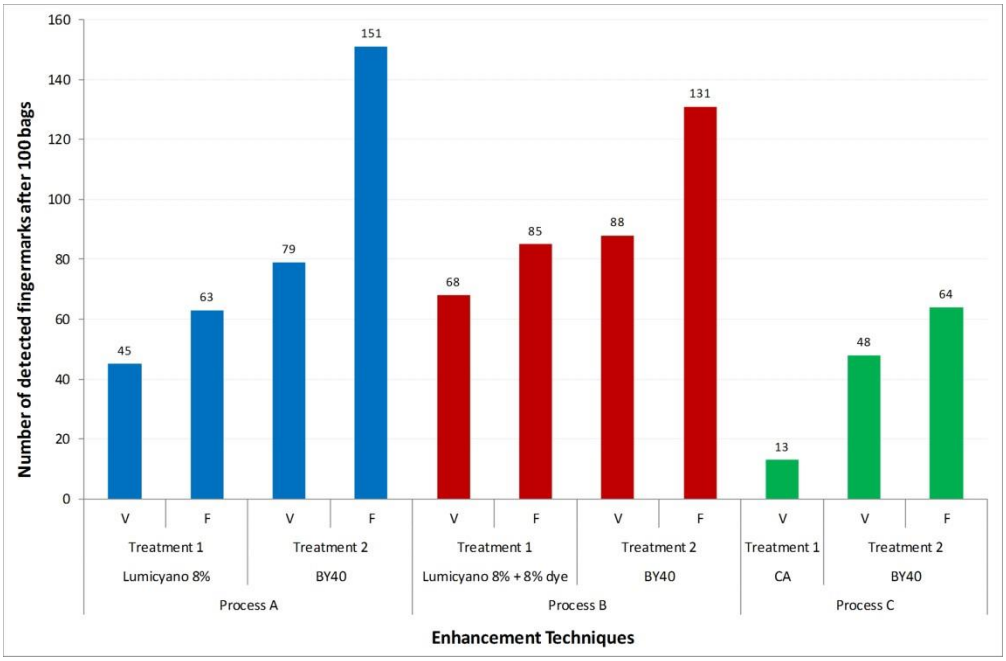

FIG. 5 - Number of detected latent fingermarks in pseudo-operational trial 3.
376x246mm (300 x 300 DPI)

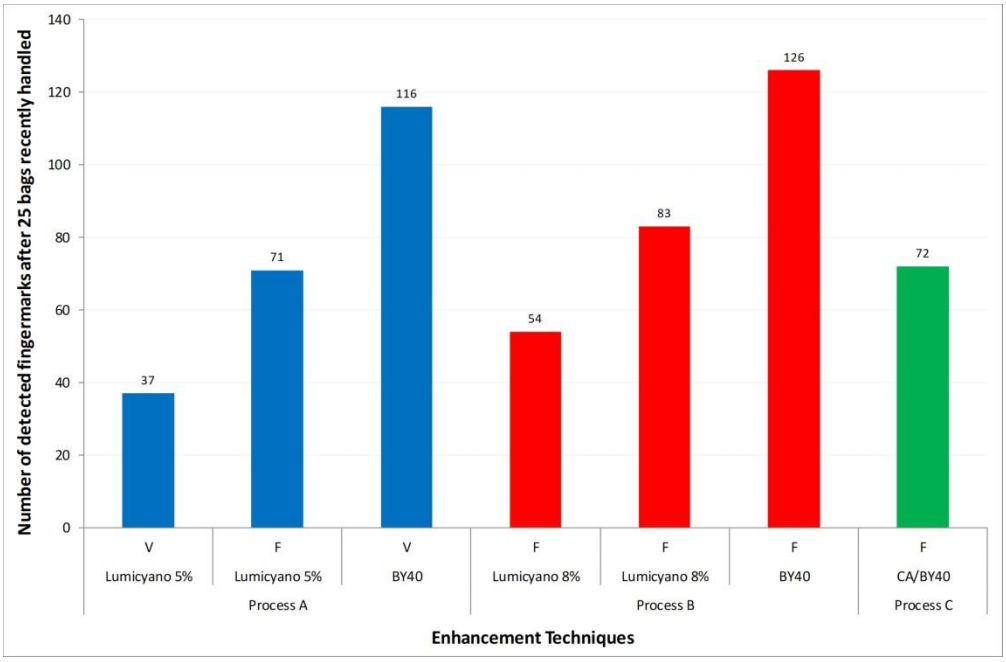

FIG. 6 - Number of detected latent fingermarks in pseudo-operational trial 4.
362x236mm (300 x 300 DPI)