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Evaluation of 1,2-Indanedione and 5,6-Dimethoxy-1,2-Indanedione for the Detection of Latent Fingerprints on Porous Surfaces

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ABSTRACT: The ability of 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione to detect latent prints on porous surfaces, as compared to DFO and ninhydrin, has been evaluated. Comparisons of prints developed under various conditions determined the optimum development conditions for the new reagents. The indanediones tested were found to have lower detection limits for glycine. The carrier solvent used was found to affect the quality of the prints developed. In Arklone, the new reagents developed prints that displayed superior luminescence to those developed with DFO. In HFE 7100, 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione gave superior luminescence to DFO after zinc salt treatment and cooling with liquid nitrogen, both of which improve the luminescence of prints developed with 1,2-indanediones. 1,2-Indanediones could offer less expensive but effective alternatives to DFO. With further optimization, the new reagents may supersede DFO as the method of choice for the detection of latent fingerprints on porous surfaces.

KEYWORDS: forensic science, fingerprints, detection techniques, porous surfaces, indanediones, DFO, ninhydrin, amino acids, luminescence

Fingerprints have long been considered as one of the most important forms of physical evidence. Most fingerprints left on an object are latent, and hence methods that will make these prints visible are required. Two chemical methods, ninhydrin (Fig. 1) and 1,8-diaza-9-fluorenone (DFO; Fig. 2), are currently widely used on porous surfaces such as paper.

A number of major developments have occurred since the use of ninhydrin was proposed by Oden and von Hofsten in 1954 (1). These developments include secondary metal salt treatment, cooling of the prints with liquid nitrogen, and the use of lasers or alternate light sources (2–4). Ninhydrin analogues have also been synthesized in attempts to enhance sensitivity (5–7). Further information on ninhydrin and analogues can be found in (8).

The next major development in the visualization of latent prints on porous surfaces occurred in 1990 when Grigg et al. (9) and Pounds et al. (10) reported on the discovery of DFO. The accepted main advantages of DFO over ninhydrin are that developed prints are luminescent without the need for secondary metal salt treatment, prints do not require cooling to reach optimum fluorescence, and DFO has greater overall sensitivity than ninhydrin. DFO has been found to reveal approximately 2–3 times more latent prints than ninhydrin (11).

In 1995, Jouillé and co-workers, synthesized a new type of latent print visualizing compound, 6-methylthio-1,2-indanedione, which was only one carbonyl group different to a ninhydrin analogue they were studying (12). A number of indanedione analogues have since been synthesized, most of which react with amino acids to give a reaction product, with a light pink initial color, that is strongly luminescent. Preliminary evaluations on both 1,2-indanedione (Fig. 3) and 5,6-dimethoxy-1,2-indanedione (Fig. 4) were carried out recently (12–15).

The practical application of these compounds in the forensic laboratory remains to be confirmed. The aim of this study was twofold: 1. To investigate the optimum conditions for the application of 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione; and 2. To evaluate these indanediones for the development of latent prints on various porous surfaces and with prints of varying ages.

Material and Methods

General Approach

A preliminary evaluation of the sensitivity of 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione was achieved by estimating the detection limit of the compounds for decreasing dilutions of glycine on filter paper. The evaluation of the ability and sensitivity of these chemical in visualizing latent prints on porous surfaces was specifically achieved by the direct comparison of latent prints developed with 5,6-dimethoxy-1,2-indanedione, 1,2-indanedione, DFO and ninhydrin. Latent prints from different donors, on different paper surfaces, and of different ages were compared. The initial color development as well as luminescence before and after metal salt treatment were considered. The effect of heat and of the carrier solvent used on the effectiveness of 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione to visualize latent prints on porous surfaces was also investigated. A preliminary evaluation of the position of these techniques in the reagent sequence for porous surfaces was also performed.

Preparation and Application of the Solutions

Ninhydrin and DFO were prepared in Arklone (1,1,3-trichlorotrifluoroethane or CFC113) solutions as described in (11).

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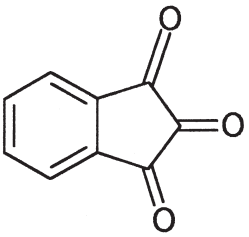

FIG. 1—*Ninhydrin.*

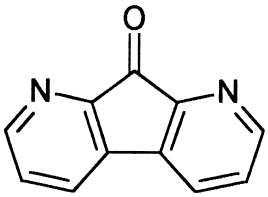

FIG. 2—*1,8-Diaza-9-fluorenone (DFO).*

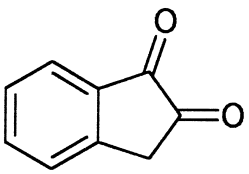

FIG. 3—*1,2-Indanedione.*

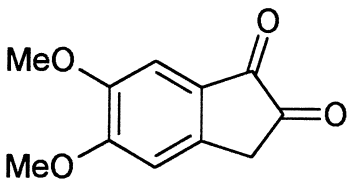

FIG. 4—*5,6-Dimethoxy-1,2-indanedione.*

The concentrations of the reagents were 0.5% w/v and 0.025% w/v for ninhydrin and DFO, respectively.

1,2-Indanedione was obtained from Dr. J. Almog (Israel National Police). A 1,2-indanedione solution using the Arklone formulation as employed for ninhydrin was attempted. Due to the lower solubility of 1,2-indanedione, extra methanol (approximately 50 mL per 100 mL of solution) had to be added to obtain a clear, single-phase solution. The final solution was 0.3% w/v 1,2-indanedione, and contained 1% v/v acetic acid.

5,6-Dimethoxy-1,2-indanedione was obtained from Dr. B. Taylor (University of Pennsylvania). As with 1,2-indanedione, a 5,6-dimethoxy-1,2-indanedione solution using the ninhydrin Arklone formulation was attempted. Due to the low solubility of 5,6-dimethoxy-1,2-indanedione, approximately four times as much methanol as Arklone had to be added to achieve a clear, single-phase solution. The final solution was 0.1% w/v 5,6-dimethoxy-1,2-indanedione, and contained 1% v/v acetic acid.

Secondary metal salt treatment was achieved using zinc nitrate in Arklone solution as described in (11).

Reagents were applied to the paper by dipping into a solution of the reagent. Fingerprints to be developed with ninhydrin, 1,2-indanedione or 5,6-dimethoxy-1,2-indanedione were dipped once in the respective solution, while fingerprints to be developed with DFO were dipped twice with air drying between each treatment.

Prints were developed using accepted optimum conditions (11). Ninhydrin prints were allowed to develop for 48 h without heat in standard laboratory conditions, while prints developed with DFO were heated for 20 min at 100°C in an oven.

In the initial stages of the project, prints developed with 1,2-indanedione or 5,6-dimethoxy-1,2-indanedione were allowed to develop for 48 h without heat before a comparison was performed. Prints were then heated for 20 min at 100°C in an oven and a second comparison performed. Later in the project, prints developed with 1,2-indanedione or 5,6-dimethoxy-1,2-indanedione were heated immediately. Some comparisons were also performed using a heat press.

After development of the fingerprints with the primary reagent was completed, prints to be treated with zinc nitrate were dipped into the zinc solution and then allowed to air dry. The effect of the use of increased humidity was not investigated in this study because standard laboratory conditions (i.e., temperature approximately 20°, humidity between 60 and 80%) were chosen as the basis for the comparison.

Visualization and Recording of the Prints

Visualization and recording of the prints were achieved using a Poliview system with a Polilight PL10 filtered light source (Rofin, Australia) and interference band-pass filters (Rofin, Australia) for luminescence visualization. Luminescence wavelengths used for each reagent are summarized in Table 1.

Comparison of Detection Limits

Using a combination of methods developed previously (7,16), testing sheets were prepared using serial dilutions of glycine spotted on a filter paper. The testing sheets containing concentrations of 10 mg/mL to 7.6×10^{-5} mg/mL glycine in distilled water were allowed to dry overnight before use. The glycine test sheets were then developed, using the different reagents and under varying conditions (Table 2). Developed sheets were viewed under white light, filtered light and under luminescence conditions. The lowest glycine concentration that gave a visible result was noted. Grids

TABLE 1—*Excitation and emission wavelengths used for the visualization of developed prints.*

Reagent	Excitation Wavelength*	Emission Wavelength*
DFO	530 & 555 nm	570-580 nm
Ninhydrin with secondary zinc treatment	450 nm	550 nm
1,2-indanedione	555 nm	610 nm
1,2-indanedione with secondary zinc treatment	555 nm	610 nm
5,6-dimethoxy-1,2-indanedione	555 nm	610 nm
5,6-dimethoxy-1,2-indanedione with secondary zinc treatment	555 nm	610 nm

* These wavelengths correspond to the values read on the Polilight lamp and on the filter. The actual wavelength within these bands might be slightly different due to the fine tuning of the lamp and to the filter tilting, both scanned to obtain the best prints.

TABLE 2—*Reagents and conditions used to develop detection limit test sheets.*

Sheet Number	Reagent	Zinc Treatment	Conditions
1	DFO	No	Heated for 20 min at 100°C
2	Ninhydrin	Yes	48 h development
3	1,2-indanedione	No	48 h development
4	1,2-indanedione	No	Heated for 20 min at 100°C
5	1,2-indanedione	Yes	48 h development
6	1,2-indanedione	Yes	Heated for 20 min at 100°C
7	5,6-dimethoxy-1,2-indanedione	No	48 h development
8	5,6-dimethoxy-1,2-indanedione	No	Heated for 20 min at 100°C
9	5,6-dimethoxy-1,2-indanedione	Yes	48 h development
10	5,6-dimethoxy-1,2-indanedione	Yes	Heated for 20 min at 100°C

were also directly compared between sheets in order to note relative brightness.

Detection limit grids were also developed with 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione in methanol, petroleum ether, HFC 4310mee (1,1,1,2,3,4,4,5,5,5-decafluoropentane; supplied by Novaline) and HFE 7100 (1-methoxynonafluorobutane; supplied by 3M). All of these grids were heated to aid development. Developed grids were also treated with zinc solution and then cooled with liquid nitrogen during luminescence visualization to see if detection limits were improved.

Comparison of Latent Print Development

Fingerprints were deposited onto three surfaces, white photocopy paper, white lined writing paper and white security business envelopes, using two different donors. One donor was a good amino acid donor and the other an average amino acid donor (based on ninhydrin development of deposited prints). The latent fingerprints were stored in envelopes in a dark cupboard, and then developed at three ages: two weeks, one and half months, and three months. Developed prints were compared under white light, filtered light, and using the optimum luminescence conditions for each reagent (Table 1). The comparisons were: 1) Ninhydrin and 1,2-indanedione, 2) Ninhydrin and 5,6-dimethoxy-1,2-indanedione, 3) DFO and 1,2-indanedione, 4) DFO and 5,6-dimethoxy-1,2-indanedione, and 5) 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione.

Late in the project, comparisons of DFO and 1,2-indanedione, DFO and 5,6-dimethoxy-1,2-indanedione, and 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione were repeated using an Elna Press Electronic to develop the prints. The heat press was set on its "wool" setting (approximately 120°C) and the samples heated for approximately 15 s. Old prints (about four months of age) and new prints (one day old) on photocopy paper, writing paper and white envelopes were developed in this manner.

Effect of Heat and Secondary Treatment on 1,2-Indanedione and 5,6-Dimethoxy-1,2-Indanedione Developed Prints

Prints developed with 1,2-indanedione which were heated, for 20 min at 100°C, were compared to prints developed with 1,2-indanedione which were allowed to develop without heat. The prints were compared after 24 h, 48 h, and 5 days, with the heated prints being reheated, for 10 min at 100°C, before each comparison. The same comparisons were carried out for 5,6-dimethoxy-1,2-indanedione. These experiments were performed on prints aged for two weeks and three months. Prints developed with each reagent were also compared with and without zinc secondary treatment.

Effect of Carrier Solvent

A comparison of Arklone, methanol, petroleum ether (30-40°C boiling point), HFC 4310mee and HFE 7100 as the carrier solvent for 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione was performed. Solutions of 1,2-indanedione, 5,6-dimethoxy-1,2-indanedione and DFO were prepared by dissolving the reagent in the minimum volume of methanol, then adding the carrier solvent and lastly acidifying the solution to 1% v/v acetic acid (or 2% v/v for DFO). 0.3 g 1,2-indanedione required 10 mL of methanol to dissolve, while 0.1 g 5,6-dimethoxy-1,2-indanedione required 65 mL of methanol and 0.025 g DFO required 5 mL of methanol. DFO solutions were 0.025% w/v, 1,2-indanedione solutions were 0.3% w/v and 5,6-dimethoxy-1,2-indanedione solutions were 0.1% w/v. The zinc nitrate solution used was made up in HFE 7100, using the same formulation as for Arklone. Fresh prints on photocopy paper, lined writing paper and security envelopes were used in the comparisons.

Comparisons were made between DFO and 1,2-indanedione, DFO and 5,6-dimethoxy-1,2-indanedione, and 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione, using each carrier solvent. Prints developed with 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione were treated with zinc solution and the comparisons repeated. Comparisons between DFO and 1,2-indanedione, and DFO and 5,6-dimethoxy-1,2-indanedione were also performed while the prints were cooled with liquid nitrogen. Comparisons of reagents formulated in HFE 7100 were repeated using development via an Elna Press Electronic as described previously. Comparisons were also made between formulations of 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione in the different carrier solvents. In this case, prints were developed in an oven for 20 min at 100°C.

Sequencing

Reagents are generally applied in sequence in order to optimize the development of latent prints. This prompted a preliminary determination of the position of 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione in the reagent sequence for paper surfaces. This was made by determining whether 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione could be used in sequence with DFO and ninhydrin. Following preliminary results, all solutions used HFE 7100 as carrier solvent. All comparisons were made on photocopy paper using fresh prints. The designation "DFO/1,2-indanedione" indicates that DFO was applied to the sample then, after the sample had been allowed to air dry, 1,2-indanedione was applied. The following comparisons were made: 1) DFO and DFO/1,2-indanedione, 2) 1,2-indanedione and DFO/1,2-indane-

dione, 3) DFO and 1,2-indanedione/DFO, and 4) 1,2-indanedione and 1,2-indanedione/DFO.

All prints that had been treated with 1,2-indanedione were also treated with zinc solution. The equivalent comparisons were also performed with 5,6-dimethoxy-1,2-indanedione. Similarly, the combination of ninhydrin and 1,2-indanedione (or 5,6-dimethoxy-1,2-indanedione) as sequential reagents (i.e., the reagents were not mixed but applied in sequence) was performed using the following comparisons: 1) ninhydrin and ninhydrin/1,2-indanedione, 2) 1,2-indanedione and ninhydrin/1,2-indanedione, 3) ninhydrin and 1,2-indanedione/ninhydrin, and 4) 1,2-indanedione and 1,2-indanedione/ninhydrin.

All prints were subsequently treated with zinc solution. The equivalent comparisons with 5,6-dimethoxy-1,2-indanedione were also performed.

Results and Discussion

Glycine Detection Limits

In agreement with previous studies (12,14,15), 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione proved to be at least as sensitive, and in some cases more sensitive, than DFO for the detection of glycine on the test sheets (Table 3). Improvements in detection limits were seen after zinc treatment and also with liquid nitrogen cooling. Similarly, 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione test sheets that had been heated gave brighter luminescence than test sheets allowed to develop at room temperature.

The impact that carrier solvent had on the effectiveness of each reagent can be seen in the different glycine detection limits (Tables 4 and 5). Overall, for both 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione, Arklone gave the best detection limits with HFE 7100 the most effective of the other solvents.

The results of the present study seem to be slightly more favorable to indanediones than those indicated elsewhere (12,13). However, it should be noted that these authors used equimolar solutions of each reagent, while a 5,6-dimethoxy-1,2-indanedione solution of 0.1%w/v (four times the concentration of the DFO solution), and a 1,2-indanedione solution of 0.3% w/v (12 times the concentration of the DFO solution) were used in this project. Although this renders an absolute comparison of the actual compounds in terms of reactivity somewhat invalid, it was felt that the comparisons had to consider optimum working solutions rather than theoretical equimolar solutions. The much better solubility of 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione in nonpolar solvents compared to DFO is an obvious advantage which has to be accounted for.

Optimum Conditions for Indanediones

The results indicated that heating produces superior prints compared to those allowed to develop for 24 or 48 h at room temperature (Fig. 5). However, it should be noted that, after five days, prints allowed to develop without heat had comparable luminescence to those developed with heat initially and then reheated at the time of observation. Better luminescence was achieved using a heat press compared to an oven. Therefore, for optimum development with 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione, prints should be developed with heat, and if possible using a heat press.

Zinc treatment improved the luminescence of prints developed with either 1,2-indanedione or 5,6-dimethoxy-1,2-indanedione. In some cases prints which were not visible before zinc treatment became visible after application of the enhancement process (Fig. 6). Relative to DFO, 1,2-indanedione and 5,6-dimethoxy-1,2-indane-

TABLE 3—*Glycine detection limits for DFO, ninhydrin, 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione in Arklone solutions; luminescence at room temperature (RT).*

	Detection Limit (mg/mL)							
	48 h Development Without Heat		Heated for 20 min at 100°C		48 h Development Without Heat with Zinc Treatment		Heated for 20 min at 100°C with Zinc Treatment	
Reagent	White Light	Luminescence (RT)	White (Light)	Luminescence (RT)	White Light	Luminescence (RT)	White Light	Luminescence (RT)
DFO	nt	nt	9.8×10^{-3}	2.4×10^{-3}	nt	nt	nt	nt
Ninhydrin	nt	nt	nt	nt	2.4×10^{-3}	9.8×10^{-3}	nt	nt
1,2-indanedione	7.8×10^{-2}	2.4×10^{-3}	7.8×10^{-2}	7.6×10^{-5}	7.8×10^{-2}	7.6×10^{-5}	7.8×10^{-2}	7.6×10^{-5}
5,6-dimethoxy-1,2-indanedione	7.8×10^{-2}	7.6×10^{-5}	7.8×10^{-2}	7.6×10^{-5}	7.8×10^{-2}	7.6×10^{-5}	7.8×10^{-2}	7.6×10^{-5}

nt = not tested under these conditions.

TABLE 4—*Glycine detection limits for 1,2-indanedione in various solvents.*

Solvent	Detection Limit (mg/mL)			
	White Light	Natural Luminescence	After Zinc Treatment	Cooled by Liquid Nitrogen
Methanol	7.8×10^{-2}	2.4×10^{-3}	6.1×10^{-4}	7.6×10^{-5}
Petroleum ether	7.8×10^{-2}	1.2×10^{-2}	3.1×10^{-4}	7.6×10^{-5}
HFC 43100mee	7.8×10^{-2}	6.1×10^{-4}	7.6×10^{-5}	7.6×10^{-5}
HFE 7100	3.9×10^{-2}	6.1×10^{-4}	1.5×10^{-4}	7.6×10^{-5}
Arklone	7.8×10^{-2}	7.6×10^{-5}	7.6×10^{-5}	nt

nt = not tested under these conditions.

TABLE 5—*Glycine detection limits of glycine for 5,6-dimethoxy-1,2-indanedione in various solvents.*

Solvent	Detection Limit (mg/mL)			
	White Light	Natural Luminescence	After Zinc Treatment	Cooled by Liquid Nitrogen
Methanol	1.6×10^{-1}	1.2×10^{-3}	3.1×10^{-4}	7.6×10^{-5}
Petroleum ether	7.8×10^{-2}	3.1×10^{-4}	1.5×10^{-4}	7.6×10^{-5}
HFC 43100mee	3.9×10^{-2}	7.6×10^{-5}	7.6×10^{-4}	7.6×10^{-5}
HFE 7100	3.9×10^{-2}	7.6×10^{-5}	7.6×10^{-4}	7.6×10^{-5}
Arklone	7.8×10^{-2}	7.6×10^{-5}	7.6×10^{-5}	nt

nt = not tested under these conditions.

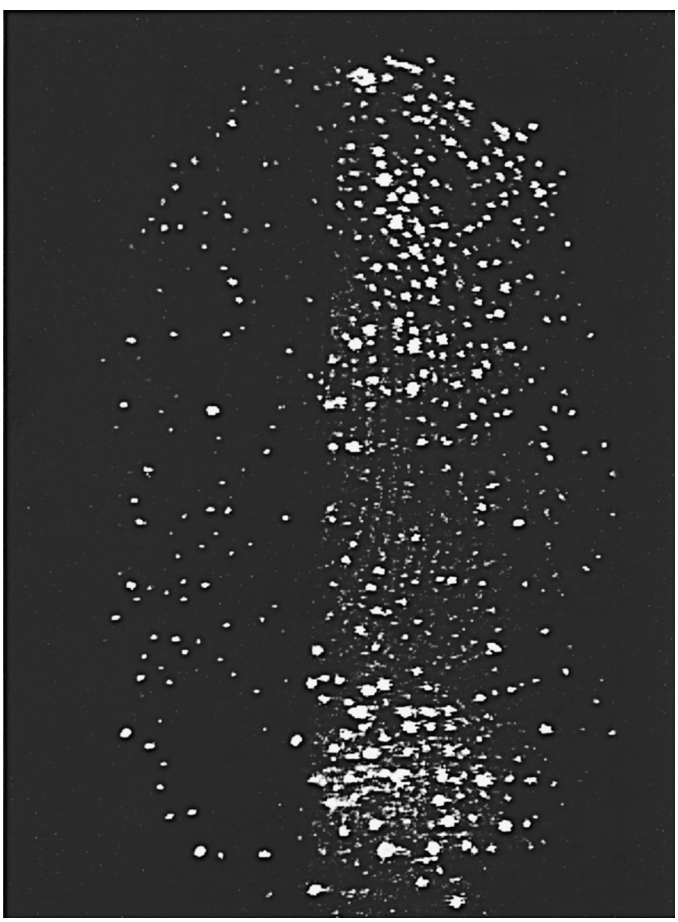

FIG. 5—*Comparison of prints heated and developed using 1,2-indanedione on photocopy paper (λex 555 nm and λem 610 nm). Left side: developed without heat for 48 h. Right side: heated in an oven.*

A

FIG. 6—*Comparison of prints with and without zinc treatment, on photocopy paper (λex 555 nm and λem 610 nm). Left side: with zinc treatment. Right side: without zinc treatment. a) 1,2-indanedione, b) 5,6-dimethoxy-1,2-indanedione.*

B

FIG. 6 *(continued)*

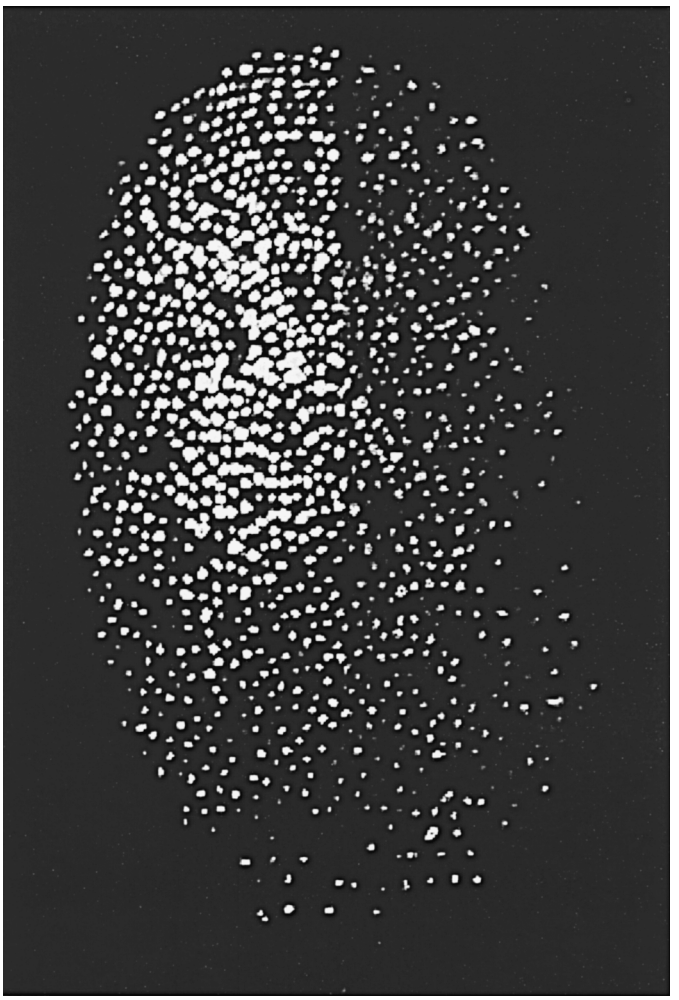

FIG. 7—*Comparison of 1,2-indanedione in HFE 7100 and petroleum ether on writing paper (λex 555 nm and λem 610 nm). Left side: HFE 7100. Right side: petroleum ether.*

dione prints with zinc treatment showed increased luminescence intensity when the prints were cooled with liquid nitrogen.

The removal of Arklone from use in fingerprint laboratories makes the choice of carrier solvent an important issue. As demonstrated by Anthonioz and Champod (13), the carrier solvent has an effect on the ability of 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione to visualize amino acids. In this study, HFE 7100 and HFC 4310mee were found to produce brighter fingerprint luminescence than petroleum ether and Arklone (Fig. 7). HFE 7100 showed slight advantages over HFC 4310mee on some surfaces. Petroleum ether and Arklone were, in turn, superior to methanol because of the smudging of prints caused by the latter. Hence HFE 7100 was found to be the best carrier solvent of those tested, for both 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione.

The combination of these factors indicates that the optimum luminescence of prints developed with 1,2-indanedione or 5,6-dimethoxy-1,2-indanedione would be achieved by using a HFE 7100 solution and then heating the prints with a heat press. After this, zinc treatment and cooling with liquid nitrogen could be used to further improve fingerprint luminescence.

Development of different formulations of indanediones or dipping the prints twice in the solution, as is presently done with DFO, may improve the fingerprint luminescence obtained. However, such modifications of the procedure were not further investigated in this study. Similarly, the effect of increased humidity on the development of 1,2-indanediones was not studied in this project. Optimization of humidity could result in further increased luminescence as suggested in (12,15).

Comparisons with Ninhydrin and DFO

Based on the initial color only, ninhydrin remains the best reagent for developing latent prints on paper. When luminescence is considered, 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione gave far superior results compared to ninhydrin with zinc secondary treatment.

Whether DFO, 1,2-indanedione or 5,6-dimethoxy-1,2-indanedione gave superior fingerprint luminescence was related to the paper type and the age of the prints, but primarily to the carrier solvent used and any secondary treatment. In Arklone and methanol, 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione were superior to DFO (Figs. 8 and 9), while in HFE 7100, HFC 4310mee and petroleum ether, DFO was superior to 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione (Fig. 10) based on initial fingerprint development. With zinc treatment of developed prints, however, 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione were generally superior, or at least equivalent, to DFO (Figs. 11 and 12). In all the solvents tested 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione were superior to DFO if zinc treatment and cooling by liquid nitrogen were employed (Fig. 13).

In general, 5,6-dimethoxy-1,2-indanedione gave brighter fingerprint luminescence than 1,2-indanedione (Fig. 14). However, it was

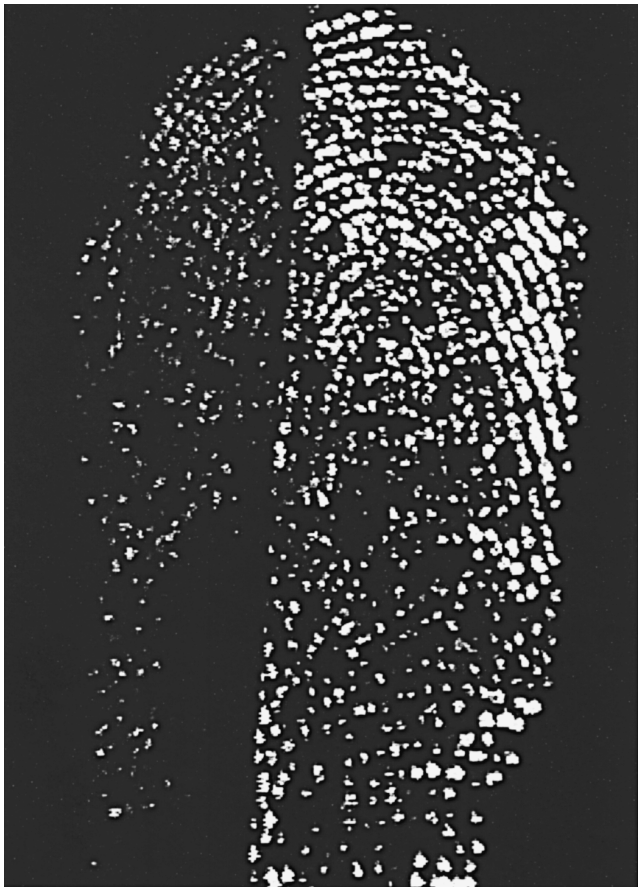

FIG. 8—*Comparison of DFO and 1,2-indanedione, on writing paper (λex 555 nm and λem 610 nm). Left side: DFO. Right side: 1,2-indanedione.*

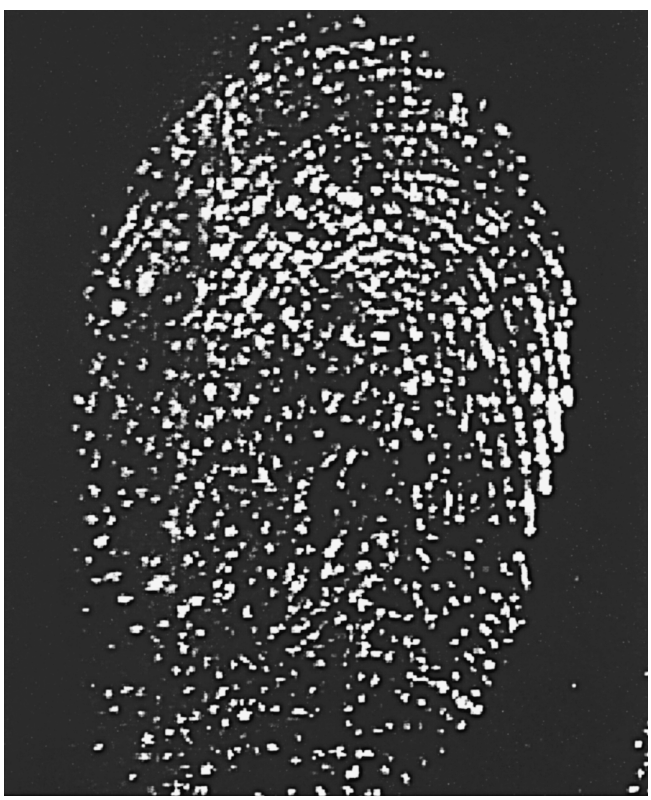

FIG. 9—*Comparison of DFO and 5,6-dimethoxy-1,2-indanedione, on white envelope. Left side: 5,6-dimethoxy-1,2-indanedione. Right side: DFO (λex 555 nm and λem 610 nm).*

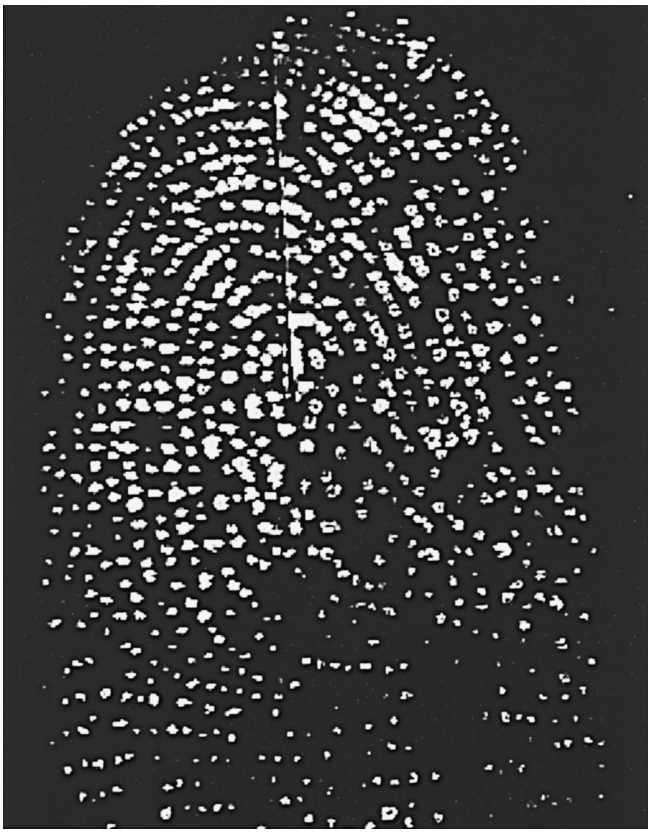

FIG. 10—*Comparison of DFO and 1,2-indanedione in Petroleum ether on photocopy paper. Left side: DFO. Right side: 1,2-indanedione (λex 555 nm and λem 610 nm).*

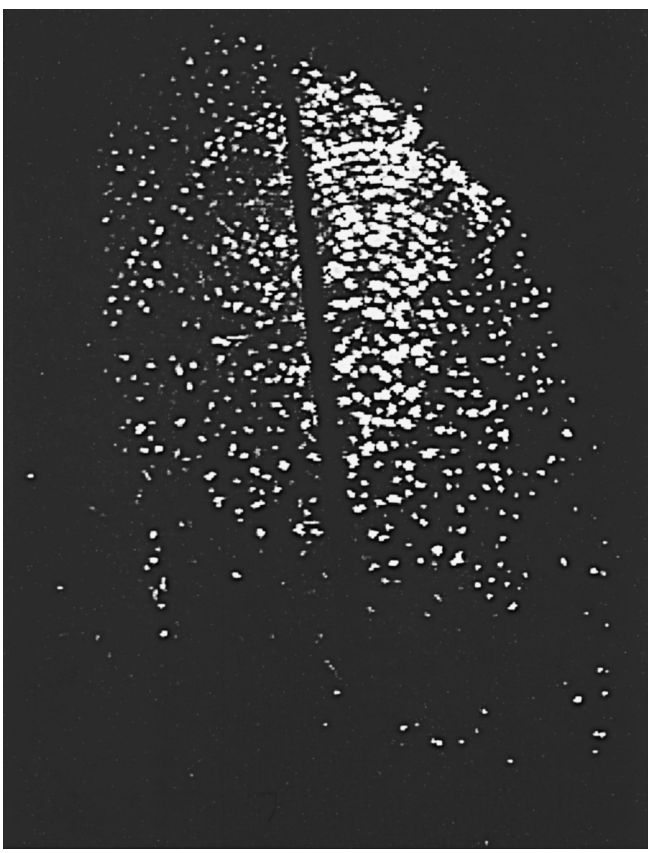

FIG. 11—*Comparison of DFO and 1,2-indanedione with zinc treatment, on yellow envelope. Left side: DFO. Right side: 1,2-indanedione with zinc treatment indanedione (λex 555 nm and λem 610 nm).*

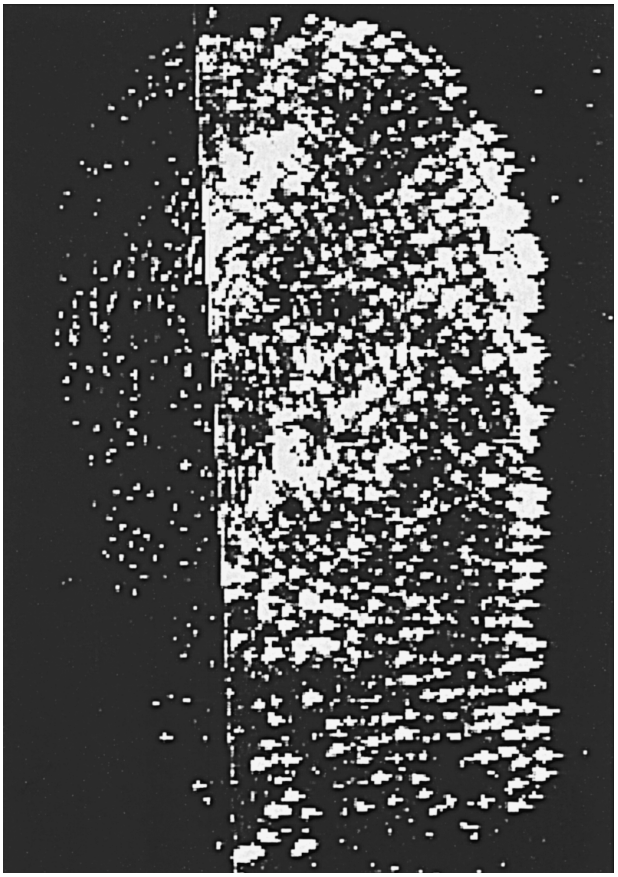

FIG. 12—*Comparison of DFO and 5,6-dimethoxy-1,2-indanedione with zinc treatment on writing paper. Left side: DFO. Right side: 5,6-dimethoxy-1,2-indanedione with zinc treatment (λex 555 nm and λem 610 nm).*

FIG. 13—*Comparison of DFO and 1,2-indanedione with zinc treatment in petroleum ether on photocopy paper cooled by liquid nitrogen. Left side: DFO. Right side: 1,2-indanedione with zinc (λex 555 nm and λem 610 nm).*

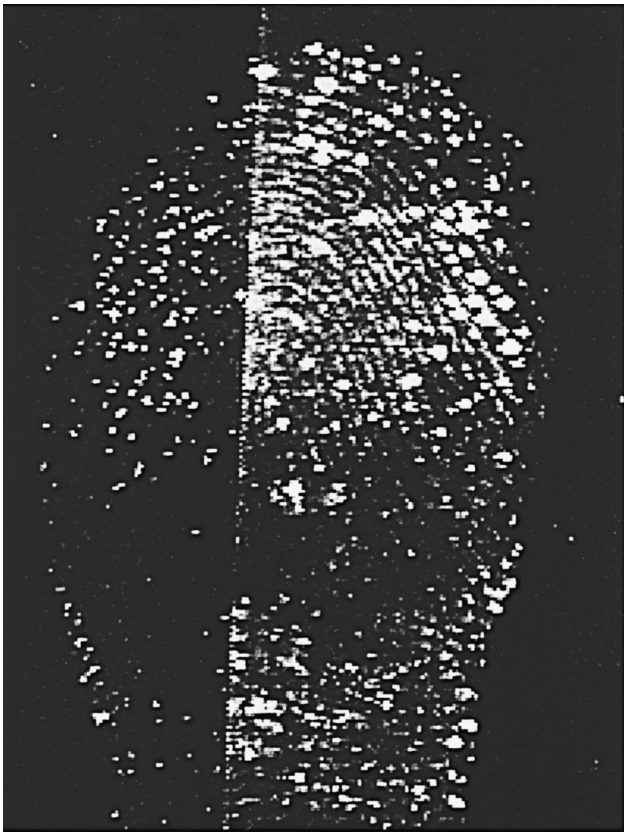

FIG. 14—*Comparison of 1,2-indanedione with zinc treatment and 5,6-dimethoxy-1,2-indanedione with zinc treatment on yellow envelope (λex 555 nm and λem 610 nm). Left side: 1,2-indanedione. Right side: 5,6-dimethoxy-1,2-indanedione.*

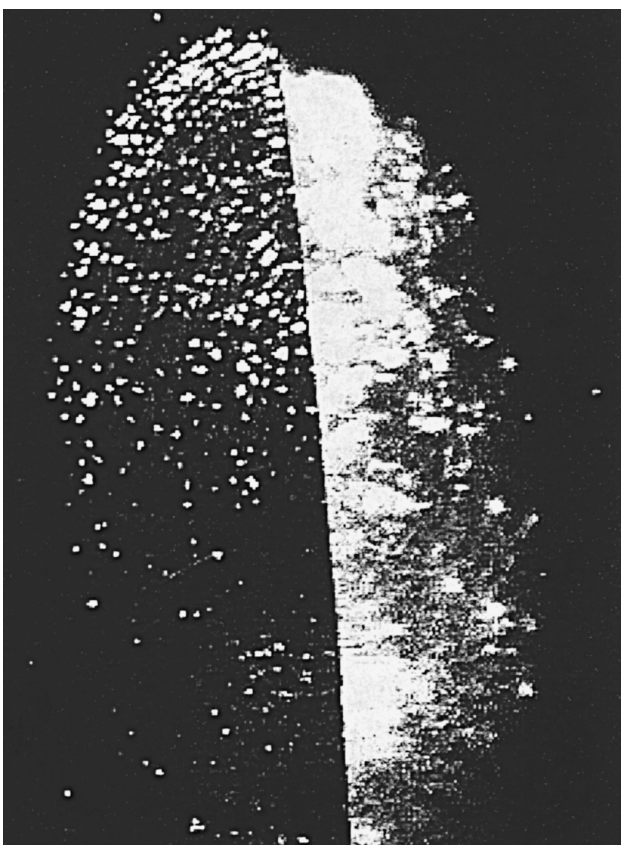

FIG. 15—*Comparison of 1,2-indanedione with zinc treatment and 5,6-dimethoxy-1,2-indanedione with zinc treatment on yellow envelope (λex 555 nm and λem 610 nm). Left side: 1,2-indanedione. Right side: 5,6-dimethoxy-1,2-indanedione.*

noted that, in some instances, prints developed with 5,6-dimethoxy-1,2-indanedione were smudged (Fig. 15). Since 5,6-dimethoxy-1,2-indanedione is a relatively polar compound, a large volume of methanol had to be used to obtain a clear, single-phase solution. The extra methanol in the 5,6-dimethoxy-1,2-indanedione solutions, as compared to solutions of the other reagents, is most likely the cause of the fingerprint diffusion. Further research is needed to optimize formulations for 5,6-dimethoxy-1,2-indanedione. Less concentrated solutions, requiring less methanol, should be investigated. A compromise needs to be found between the concentration of 5,6-dimethoxy-1,2-indanedione and the volume of methanol required in the formulation. Double dipping of samples in the solution may be a possible method to increase the fingerprint luminescence obtained from a less concentrated reagent formulation.

Sequencing

The preliminary evaluation of the position of 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione in the reagent sequence suggests that the indanediones may be used in sequence with DFO but not in sequence with ninhydrin.

The sequential combination of ninhydrin with 1,2-indanedione or 5,6-dimethoxy-1,2-indanedione, in either order, resulted in inferior initial color when compared to ninhydrin and inferior luminescence when compared to the indanediones alone.

The use of 1,2-indanedione or 5,6-dimethoxy-1,2-indanedione in sequence with DFO did display marginal advantages. After zinc treatment, DFO/indanedione sequences were generally equivalent, or superior, to 1,2-indanedione or 5,6-dimethoxy-1,2-indanedione alone. As all of the reagents considered react with amino acids producing a similar initial product (an azomethine ylide), the effect of sequencing reactions is determined by reactivity and kinetics. For example, ninhydrin being more reactive than DFO will, in theory, compete with the available amino acids more effectively. The competition between ninhydrin and 1,2-indanedione or 5,6-dimethoxy-1,2-indanedione seems to decrease the advantages of both ninhydrin and the dione. It should be pointed out that the formation of a 1,2-indanedione/ninhydrin or dione/DFO-Ruhemann's purple type product cannot be rulled out. A product of this type may be colored and/or fluorescent. Further work is obviously needed on the position of 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione within the reagent sequence, especially the order in which the indanediones should be used with DFO.

Conclusions

This study has confirmed that 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione may offer less expensive alternatives to DFO while still developing similar quality prints. The optimum development conditions were found to be the use of HFE 7100 as a carrier solvent and to heat the prints during development, preferably using a heat press rather than an oven. Secondary zinc salt treatment and cooling by liquid nitrogen have been shown to improve the luminescence of both 1,2-indanedione and 5,6-dimethoxy-1,2-indanedione developed prints. The preliminary sequencing results suggest that there may be advantages in sequencing 1,2-indanediones with DFO but not in combining 1,2-indanediones with ninhydrin.

Further research needs to be done on the conditions of use and position of 1,2-indanediones in the reagent sequence in order to achieve the best possible visualization. Further improvements could result in significant and consistent superior luminescence to DFO without metal salt treatment, and hence, become the method of choice for the detection of latent fingerprints on porous surfaces.

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References

1. Oden S, von Hofsten B. Detection of fingerprints by the ninhydrin reaction. Nature 1954;173:449.
2. Kobus HJ, Stoilovic M, Warrener RN. Simple luminescence post-ninhydrin treatment for the improved visualization of fingerprints on documents in cases where ninhydrin alone gives poor results. Forensic Sci Int 1983;22:161–70.
3. Stoilovic M, Kobus HJ, Margot PA, Warrener RN. Improved enhancement of ninhydrin developed fingerprints by cadmium complexation using low temperature photoluminescence. J Forensic Sci 1986;31:432–45.
4. Almog J. Fingerprint development by ninhydrin and its analogues. In: Advances in fingerprint technology. Lee HC, Gaensslen RE, editor, 1991, Elesvier, New York, 103–33.
5. Almog J, Hirshfeld A, Klug AT. Reagent for the chemical development of latent fingerprints: synthesis and properties of some ninhydrin analogues. J Forensic Sci 1982;27:912–7.
6. Lennard CJ, Margot PA, Stoilovic M, Warrener RN. Synthesis of ninhydrin analogues and their application to fingerprint development: preliminary results. J Forensic Sci Soc 1986;26:323–8.
7. Cantu AA, Leben DA, Jouillé MM, Heffner RJ, Hark RR. A comparative examination of several amino acid reagents for visualizing amino acid (glycine) on paper. J Forensic Ident 1993;43:44–66.
8. Jouillé MM, Thompson TR, Nemeroff NH. Ninhydrin and ninhydrin analogs. Synthesis and applications. Tetrahedron 1991;47:8791–830.
9. Grigg R, Mongkolaussavaratana T, Pounds CA, Sivagnanam S. 1,8-diazafluorenone and related compounds. A new reagent for the detection of a-amino acids and latent fingerprints. Tetrahedron 1990;31:7215–8.
10. Pounds CA, Grigg R, Mongkolaussavaratana T. The use of DFO for the fluorescent detection of latent fingerprints on paper, a preliminary evaluation. J Forensic Sci 1990;35:169–75.
11. Margot P, Lennard C. Fingerprint detection techniques. Institut de police scientifique et de criminologie, University of Lausanne, Switzerland, 6th ed, 1994.
12. Ramotowski R, Cantu AA, Jouillé MM, Petrovskaia O. 1,2-Indanediones: A preliminary evaluation of a new class of amino acid visualizing compounds. Fingerprint World 1997;23:131–40.
13. Anthonioz A, Champod C. Amino-acids reactivity to DFO and two new indanediones. 1st European Meeting of Forensic Science. Lausanne, Switzerland, 1997.
14. Hauze DB, Petrovskaia O, Taylor B, Joulliè MM, Ramotowski R, Cantu AA. 1,2-indanediones: New reagents for visualizing the amino acid components of latent prints. J Forensic Sci 1998;43:744–7.
15. Almog J, Springer M, Wiesner S, Frank A, Khodzhaev O, Lidor R, et al. Latent fingerprint visualization by 1,2-indanedione and related compounds: preliminary results. J Forensic Sci 1999;44:114–8.
16. Nielson JP. Quality control for amino acid visualization reagents. J Forensic Sci 1987;32:370–6.

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