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TECHNICAL NOTE

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An Amino Acid Model for Latent Fingerprints on Porous Surfaces*

ABSTRACT: Analytical standards are needed in latent fingerprint detection for research and development as well as for quality control in routine work because normal fingerprints are too varied for comparison studies and tests. One way is to create latent fingerprints. For the amino acid sensitive detection method this can be achieved by coating test items with an amino acid solution using a modified commercial office bubble jet printer. Besides low costs, fast and easy preparation, the main advantage of a bubble jet printer is that the amino acid loading per area on the test item can be calculated by weighing the cartridge on a balance. This opens the possibility to determine the deviation for every printing series. The reproducibility of prints in a printing series made by one cartridge has a deviation of 2–16% and of prints made by different cartridges 20–25%.

KEYWORDS: forensic science, latent, fingerprint, detection, model, amino acid

The aim of latent fingerprint detection is to make prints of friction ridge skin visible by chemical and physical methods in high contrast to the background and with high sensitivity to develop very weak prints also.

From the analytical point of view, latent fingerprint detection is a complicated field with many unknown parameters. Fortunately, what is involved is qualitative and not quantitative analytic science. The aim is to get a visible spatial distribution of the fingerprint residue (the analyte) on the item's surface (the matrix). Because of this, it is not possible to separate the matrix from the analyte before starting the detection and so the matrix is interacted into the analytical process too.

In the research and development of latent fingerprint detection a big problem occurs due to the differences in quality and quantity of fingerprint residue. Comparing two detection methods by using two fingerprints on the same item material, the resulting difference can be caused by the methods or by the fingerprints used. To reduce this irregularity, the test must be repeated with more fingerprints and the results must be analyzed statistically. This is very time-consuming and impractical at the beginning of research where a lot of different parameters are of interest. Another common way is to split a fingerprint and compare the different treated segments. But there is also no guarantee that the resulting differences are caused by the treatment because the process of fingerprint generation is complex and can result in inhomogenity in the prints. To verify the results, repeating the test with several fingerprints is also necessary and time-consuming as well. Splitting fingerprints is also limited if the influence of multi parameters or parameters with gradual steps, e.g., temperature, humidity, concentration, are focal points of interest.

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A third way is to work with models as artificial fingerprints. The advantage of artificial fingerprints is that all examples of one series are almost identical. So this is an easy method and the differences in the test results can only be caused by the different treatments and parameters. But in practice artificial fingerprints are not easy to produce. The main questions are:

- What compounds and what amounts of these must be present in an artificial fingerprint to correspond to reality?
- How to apply these compounds onto test items in a reproducible way?
- How to determine the amounts of compounds applied?

In general, a model must not represent every aspect of reality but it must be adapted to suit the question or problem which is to be solved.

Because of our interest in amino acid sensitive detection methods we use models with amino acids on paper obtained by printing solutions of amino acids with a bubble jet printer system. The advantages of models developed in this way are that

- the quality of the analyte can be changed by mixing different amino acids,
- the quantity of the analyte can be changed by using different concentration of the amino acid solution,
- the matrix can be changed by using different types of paper or cardboard,
- the pattern can be changed easily,
- a high number of prints can be produced in a short time,
- the loading of amino acids per unit area on the test items can be calculated by weighing the printer cartridge,
- the amino acid distribution is homogenous because of the application as micro drops (minimization of drying effects),
- the reproducibility of the print can be checked,
- the set-up is very easy and inexpensive.

In 2007, in this journal we reported on the development of a new method for fingerprint detection on thermal paper using such a model but without details (1). Now we want to give some more detailed information including results in respect of reproducibility. In the meantime, we use this type of model in other examinations

(2), to prepare an interlaboratory test in Germany (3) and to take an initial step towards quality assurance in case work.

Experimental Set-up

The amino acid models are obtained by using a HP Deskjet 550C (Hewlett Packard GmbH, Böblingen, Germany) bubble jet printer with 300 dpi controlled by a standard office PC system with Windows XP and MS Word. For printing, a clean HP type 26 (51626A) cartridge is filled with an aqueous solution of amino acids instead of the black ink. The different master patterns are easily saved as black-and-white information in MS Word files. The printing options used are: printing modus "black-and-white," printing quality "normal," paper quality "normal." As the matrix of the model we use paper or flexible cardboard in DIN A4 format or thermal paper strips which are affixed onto DIN A4 sheets for the printing process.

Amino Acid Solutions

The qualitative and quantitative composition of the amino acid solutions used depends on the problem to be solved. At the moment we use a main solution (1/1) with a ratio of the amino acids that is based on information given in chapter 3 of "Advances in Fingerprint Technology" (4). For the preparation of 500 mL of this 1/1-solution, 490 mg Serine (9.3 mM), 294 mg glycine (7.8 mM), 147 mg alanine (3.3 mM), 195 mg lysine (2.7 mM), 73 mg threonine (1.2 mM), 73 mg asparagin acid (1.1 mM), 73 mg histidine (0.9 mM), 49 mg Valine (0.8 mM), 49 mg leucine (0.7 mM), and 3300 mg sodium chloride (113 mM) are dissolved in osmosis water by stirring at room temperature. The resulting concentration of the amino acids is 28 mM in total.

Further diluted solutions are made by a dilution series: e.g., 1/10 solution is made by diluting 50 mL of 1/1 solution up to 500 mL with osmosis water; 1/50 solution is made by diluting 100 mL of 1/10 solution up to 500 mL with osmosis water; 1/100 solution is made by diluting 50 mL of 1/10 solution up to 500 mL with osmosis water, and so on.

Master Pattern

The choice of the pattern to be printed also depends on the questions and problems which are to be dealt with. We use scanned fingerprints just like geometric figures, e.g., small completely filled fields or characters. It is imperative that the scanned patterns are saved as 1 bit (black-and-white) information. Gray scale information will be printed in halftone and the results are worthless with one exception: Halftone printed gray scale fields (e.g., 50% and 25% gray) are used to get a better impression of sharpness on the developed prints (Fig. 1).

Printing Process

The first step is a system control and printing check by printing the desired master pattern with a normal cartridge filled with black ink. If this print looks good, the cartridge is replaced by a cartridge containing amino acid and a 19.35 cm × 25.95 cm completely filled field is printed. By viewing the print in the glancing angle during the printing process it is possible to check that all nozzles of the printing head are working.

After the system has passed this test the determination of the printed solution can begin. For that the cartridge filled with amino acid is first weighed on a precision balance to get the weight

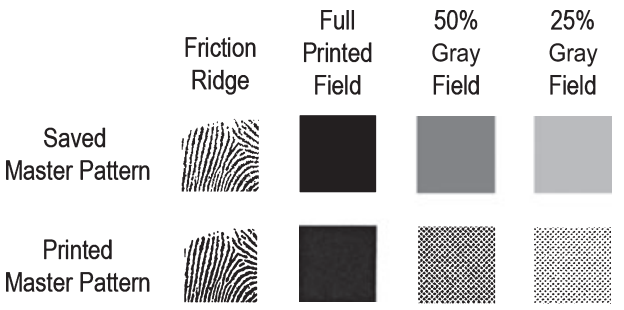

FIG. 1—*Pattern in use, the printed patterns are displayed by black ink.*

before printing (m_b). Then an area of 502 cm^2 (A) is printed as a 19.35 cm × 25.95 cm completely filled field. After that the weight of the cartridge after printing (m_a) is also determined. This process is repeated twice. After printing the model pattern to produce the test items, the printed amount is determined three times again using the methodology already described.

By using the corresponding weights before (m_b) and after (m_a) printing the applied mass can be calculated by $m = m_b\text{-}m_a$. With the average of this mass, the printed area (A = 502 cm^2), the concentration of the amino acid solution (c_x), and the assumption that 1 mL of the solution is the equivalent of 1000 mg (this causes a very small error which is less than 1% for the 1/1 solution and much less for lower concentrated solutions) the amino acid loading per area (L_x) can be calculated: $L_x \cong (m_b - m_a) \cdot c_x / A$

Test items with zones of different loading per area are made by repeating the printing process described with solutions of different concentrations.

Reproducibility

Firstly, one cartridge of type HP 26 filled with deionized water is used to print a completely filled field of 19.35 cm × 25.95 cm 42 times and the weight of the cartridge is determined between the prints by a precision balance.

Secondly, 21 cartridges of type HP 26 filled with different concentrated solutions (1/1, 1/50, 1/100, 1/500, 1/1000, 1/5000, 1/10,000, and deionized water) are used to print three times each a completely filled field of 19.35 cm × 25.95 cm and the weight of the applied solution is determined. Then, a series of test items are printed and at the end the weight determination process of the applied solution for a 19.35 cm × 25.95 cm field is again repeated three times. Average, standard deviation, maximum, minimum, range of variation and loading per area are calculated by the six prints of each cartridge.

Results and Discussion

Printing amino acid solution by a bubble jet printer as a model of latent fingerprints for amino acid sensitive methods proves to be a good method for creating analytical standards. The resulting test items do not represent the whole reality of latent fingerprints but it is an easy way to get test items in a fast, flexible, inexpensive way, and provides the possibility of calculating the amino acid loading per area on individual measured data for a printing series. In contrast to applying solutions on paper using pipettes, bigger areas can be loaded homogenously because of the smaller printing drop size (big drops tend to bring about inhomogenity through the drying). It takes about 4 min to print a field of 19.35 cm × 25.95 cm using the HP DeskJet 550C printer. A line, one centimeter in width, is

printed within 15 to 20 sec, including indentation and ejection of the paper sheet. Reproducibility test items with zones of different amino acid loading per area are more time-consuming because the sheet must be run through this process again (indentation—printing—ejection) for each different loading. The disadvantages are that the printed image can be blurred on some paper qualities and that the printer used is unable to process inflexible and thicker materials as matrix.

The printing head of the bubble jet system used and the "ink" tank are integrated into the cartridge. So it is easy and inexpensive to replace the head if the printing quality does not come up to the required standard, and it opens up the possibility of weighing the whole printing unit to calculate the printed loading per area on experimental data for each cartridge and printing series. This information is hard to get for real fingerprints and artificial prints produced by other methods. It also provides the opportunity of using these measured weights for quality assurance and determining reproducibility. The bubble jet working principle is based on heating up a part of the "ink" to form and eject the micro drops. This heating is considered noncritical because most amino acids have a good temperature resistance.

As shown in Table 1 the average printed amount of deionized water for a 19.35 cm × 25.95 cm completely printed field (502 cm^2) printed 42 times by one cartridge is 986.1 mg with a standard deviation of 21 mg (2%). The maximum printed amount is 1027.9 mg and the minimum amount 958.2 mg, so the range of variation is 69.7 mg (7%). This result shows a good reproducibility for the printed amount of solution made by the cartridge used over most of the solution capacity of about 40 mL.

In Table 2 data relating to reproducibility of printings made by different cartridges are shown. Here the procedure outlined for determining the printed solution for a completely printed 502 cm^2 field is carried out on 21 different cartridges filled with 1/1, 1/10, 1/50, 1/100, 1/500, 1/1000, 1/5000 1/10,000, or deionized water six times each (three times before and three times after printing a bunch of test items).

The recorded weights vary much more than in Table 1. The average per cartridge comes to a maximum with 1075.9 mg in cartridge no. 12 and with 862.0 mg to a minimum in cartridge no. 14 (range: 213.9 mg). There is no indication of a relationship between the concentration used and amount printed. A glance at the range of variation of each cartridge shows the highest value at 153.7 mg (16%) in cartridge no. 7 and the lowest in cartridge no. 12 at 18.5 mg (2%). Related to all single measured weights of all

TABLE 1—*Reproducibility test of one cartridge type 26 filled with deionized water.*

Printing No.	Cartridge Weight (in g)	Printed Amount (in mg)
Start	61.5590	
1	60.5674	991.6
2	59.5891	978.3
3	58.6193	969.8
4	57.6453	974.0
5	56.6728	972.5
6	55.7058	967.0
7	54.7476	958.2
8	53.7880	959.6
9	52.8239	964.1
10	51.8621	961.8
11–20	42.1403	9721.8
21	41.1550	985.3
22	40.1688	986.2
23	39.1902	978.6
24	38.2071	983.1
25	37.2213	985.8
26	36.2361	985.2
27	35.2441	992.0
28–37	25.2399	10,004.2
38	24.2370	1002.9
39	23.2146	1022.4
40	22.1895	1025.1
41	21.1661	1023.4
42	20.1382	1027.9
Average per printing		986.1
Standard deviation		21
Maximum		1027.9
Minimum		958.2
Range of variation		69.7

TABLE 2—*Reproducibility test of different cartridges of type 26 filled with different concentrated amino acid solutions or deionized water.*

Cartridge No.	Printed Solution	Number of Prints	Average per Printing (in mg)	Standard Deviation (in mg)	Maximum (in mg)	Range of Variation (in mg)	Minimum (in mg)	Resulting Loading per Area
1	1/1	6	1030.0	28	1065.0	66.9	998.1	57 ± 2 nmol/cm^2
2	1/1	6	997.4	12	1012.3	34.1	978.2	56 ± 1 nmol/cm^2
3	1/10	6	934.3	15	949.2	37.2	912.0	5 ± 0.1 nmol/cm^2
4	1/10	6	1008.2	28	1051.3	77.5	973.8	6 ± 0.2 nmol/cm^2
5	1/10	6	1004.0	17	1040.9	65.0	975.9	6 ± 0.2 nmol/cm^2
6	1/50	6	984.3	24	1008.7	59.4	949.3	1 ± 0.04 nmol/cm^2
7	1/50	6	992.2	63	1053.6	153.7	899.9	1 ± 0.10 nmol/cm^2
8	1/100	6	966.6	30	998.2	72.4	925.8	539 ± 23 pmol/cm^2
9	1/100	6	1031.8	38	1066.4	84.5	981.9	576 ± 28 pmol/cm^2
10	1/100	6	1002.3	42	1067.5	124.0	943.5	559 ± 36 pmol/cm^2
11	1/500	6	1071.1	8	1080.3	21.6	1058.7	119 ± 1.4 pmol/cm^2
12	1/500	6	1075.9	7	1086.4	18.5	1067.9	120 ± 1.0 pmol/cm^2
13	1/1000	6	994.9	10	1004.2	24.0	980.2	55 ± 0.8 pmol/cm^2
14	1/1000	6	862.0	30	892.3	62.8	829.5	48 ± 1.8 pmol/cm^2
15	1/1000	6	924.3	39	961.6	75.4	886.2	52 ± 2.1 pmol/cm^2
16	1/5000	6	1039.7	40	1092.9	99.9	993.0	12 ± 0.6 pmol/cm^2
17	1/5000	6	1017.9	45	1069.6	107.2	962.4	11 ± 0.6 pmol/cm^2
18	1/10,000	6	1027.6	16	1043.5	36.0	1007.5	6 ± 0.11 pmol/cm^2
19	1/10,000	6	866.3	10	877.7	22.6	855.1	5 ± 0.06 pmol/cm^2
20	1/10,000	6	880.7	17	907.4	52.0	855.4	5 ± 0.15 pmol/cm^2
21	Deion. aq.	6	887.4	29	922.8	73.5	849.3	
22	Deion. aq.	42	986.1	21	1027.9	69.7	958.2	

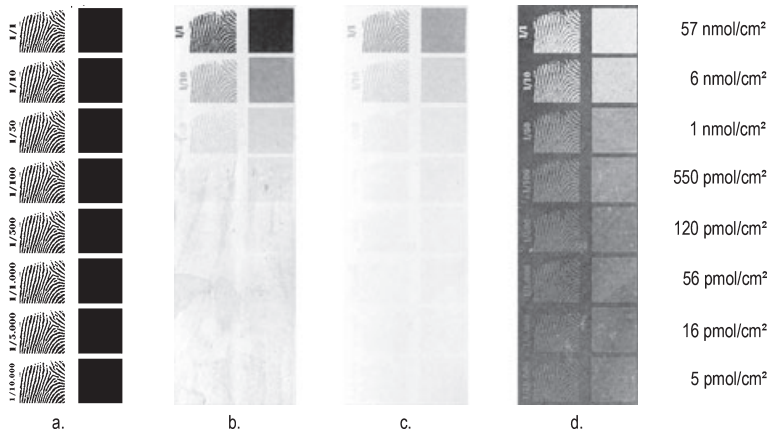

FIG. 2—*(a-d) Sample of a test item with 8 different amino acid loadings per area treated in different ways: (a) saved master pattern, (b) test item developed by Ninhydrin, (c) test item developed by DFO (day light view), (d) test item developed by DFO (fluorescence mode).*

tested cartridges (n = 126) the average is 969.9 mg with a standard deviation of 69 mg (7%) (maximum at 1092.9 mg, minimum at 829.9 mg, and a range of 263 mg).

This shows that the range of variation is much higher when different cartridges are used (27%) than when a single cartridge is used (2–16%). In practice, it is useful to perform comparison tests only by using test items of the same printing series (made by using the same cartridge for each concentration). The loading per area can be calculated and given individually for each printing series and is no higher than 16% in the tests conducted. A look at column "Resulting Loading per Area" in Table 2 indicates that the deviation is much smaller than the distance between the various desired loadings.

In general, the amino acid loading is by printing an average of 1000 mg to an area of 502 cm^2 using the 1/1 solution (28 mM amino acids) 56 nmol/cm^2 (558 pmol/mm^2) and the 1/10,000 solution (2.8 μM) 5.6 pmol/cm^2 (56 fmol/mm^2).

The method of preparing models which was outlined can be applied to accelerate research and development in the field of latent fingerprint detection, to compare the sensitivity of different detection methods or conditions, as well as to produce items for process control in case work and for interlaboratory tests. An impression of such test items and their use is given in Fig. 2. The production method using a bubble jet printer is easy, fast, and inexpensive. The cartridge containing the printing unit provides the opportunity of calculating the loading per area by weighing the cartridge. Nevertheless, it will not replace real fingerprints totally in experiments and examinations for research and development. Especially when studies have been completed, real fingerprints are needed before application to case work.

Further experiments with regard to adopting that method to substrates other than amino acids are planned, e.g., solutions of blood and its components like hemoglobin. Also tests are planned to replace the printer used in order to accelerate the printing speed and facilitate printing onto flat and nonflexible substrates.

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