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Till Goldmann,[1] *Ph.D.; Franco Taroni,*[1,2] *Ph.D.; and Pierre Margot,*[1] *Ph.D.*

Analysis of Dyes in Illicit Pills (Amphetamine and Derivatives)

ABSTRACT: The determination of dyes present in illicit pills is shown to be useful and easy-to-get information in strategic and tactical drug intelligence. An analytical strategy including solid-phase extraction (SPE) thin-layer chromatography (TLC) and capillary zone electrophoresis equipped with a diode array detector (CZE-DAD) was developed to identify and quantify 14 hydrosoluble, acidic, synthetic food dyes allowed in the European Community. Indeed, these may be the most susceptible dyes to be found in illicit pills through their availability and easiness of use. The results show (1) that this analytical method is well adapted to small samples such as illicit pills, (2) that most dyes actually found belong to hydrosoluble, acidic, synthetic food dyes allowed in the European Community, and (3) that this evidence turns out to be important in drug intelligence and may be assessed into a Bayesian framework.

KEYWORDS: forensic science, drug intelligence, ecstasy, color, likelihood ratio, evidence interpretation

Preparations sold as ecstasy pills (mainly 3,4-methylenedioxymethamphetamine and its congeners) are increasingly being abused as a recreational drug in Europe. Efforts are made to identify useful physical and chemical parameters that can be obtained from these pills. Strategic intelligence refers to the use of these parameters in order to identify, on a geographical macro-level, where and how a product was made (identification of producers, involved laboratories, or more generally production countries). Tactical intelligence refers to the parameters used in order to establish the structure of a traffic on a local level (1).

Producing illicit pills implies three major steps: synthesis of the active compound, addition of excipients (e.g., adulterants, diluting agents, dyes and lubricants), and compression of the pill.

Each step may supply useful data. It is worth delimiting the goals of an investigation and then to select more accurately the variables that may be useful for the purpose. To get an overview of what is locally sold, for example to target a prevention campaign, a qualitative and quantitative analysis of the active compound connected to pertinent circumstantial information may be sufficient. On the contrary, the identification of production batch[3] "A" at a given time in a "multi-producer" local traffic may require more variables, partly depending on the homogeneity of the products found on the market. Furthermore, the connection of the production batch "A" with other batches produced by the same manufacturer in a given time period may necessitate further information.

The analysis of dyes in illicitly produced tablets was first proposed by Gomm et al. (2). At the time, the context was the differentiation between illegitimate and legitimate amphetamine preparations and the comparison of illicit LSD tablets. Joyce and Sanger gave concrete results in 1979 (3) and concluded that dyes analysis achieved easy-to-get useful information for seizures comparison. No further work was done, although this subject is nowadays topical again due to the frequently colored ecstasy pills encountered. Indeed, the database from the Institut de Police Scientifique et de Criminologie (IPSC/University of Lausanne) shows that about a third of 1000 different pills were intentionally colored (i.e., 324 pills, see Table 1).

The dyes analysis, which is more informative, objective, and reliable than the color description, may give several kinds of information. According to legislation discrepancies, some food dyes allowed in the European Union are not allowed in Switzerland (4). Finding such a dye is a reasonable argument against a local fabrication (Strategic Drug Intelligence). On the other hand, the dyes-based comparison between pills (qualitative and/or quantitative), or between pills and dyes found in an illegal laboratory, is the concern of Tactical Drug Intelligence.

The aim of the paper is to propose an analytical method for the analysis of dyes in illicit pills, to present obtained results, and to assess the evidence thus collected.

Experimental

Analytical Scheme

The analytical process has been developed for 14 hydrosoluble, acidic, synthetic food dyes allowed in the European Community: C.I. 14720, C.I. 15985, C.I. 16035, C.I. 16185, C.I. 16255, C.I. 18050, C.I. 19140, C.I. 28440, C.I. 42051, C.I. 42090, C.I. 44090, C.I. 45430, C.I. 47005, and C.I. 73015.

Practically, the analysis of dyes proposed here is based on three steps: extraction of the sample (30 mg) in acidic water and purification by solid-phase extraction (SPE) on polyamide, identification by thin-layer chromatography (TLC), either on silica gel or on cellulose (2 complementary elution systems required), and confirmation of the identification and quantification by capillary zone electrophoresis coupled with a diode array detector (CZE-DAD).

The first and second steps are approved methods given by the *Swiss Handbook for Foodstuffs* (5) and their applicability has been assessed and validated for the illicit pills analysis. This is why no analytical data are detailed below; one should refer directly to MSDA.

[1] Institut de Police Scientifique, The University of Lausanne, B.C.H., 1015 Lausanne, Switzerland.
[2] Institut de Médecine Légale, The University of Lausanne, Rue du Bugnon, 21, 1005 Lausanne, Switzerland.

[3] The term "batch" is restricted here to pills produced by the same procedure, i.e., which are theoretically identical. Yet, it is still possible that the synthesis of one active compound leads to several different pills (market diversification).

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TABLE 1—*Distribution of colors between intentionally colored pills extracted from IPSC database. These pills represent about 35% of total seizures brought to the IPSC from 1995 to 2000.*

Color	Occurrence in % ($N = 324$)
Pink	32.1
Green	17.9
Blue	16.7
Yellow	15.4
Red	7.7
Orange	7.7
Purple	1.2
Bicolored	0.9
Multicolored	0.3

Concerning the analysis of synthetic acidic dyes with CZE-DAD, several buffers have been proposed in the literature. The CZE-DAD method chosen is based on the work of Schuster and Gratzfeld-Hüsgen (6) but has been modified to achieve the simultaneous separation of the 14 dyes. It allows the identification and quantitation of the dyes based on their different relative retention time and unique UV-visible spectrum.

CZE-DAD Analysis

Chemicals—Acetonitrile (puriss. p.a.), benzoic acid (puriss. p.a.), di-sodium hydrogenophosphate di-hydrated (purum p.a.), sodium hydrogenocarbonate (puriss. p.a.) and sodium hydroxide (purum p.a.) were purchased from Flucka (Switzerland). Hydroxypropyl-b-cyclodextrine was purchased from Aldrich (Switzerland). The 14 synthetic dyes have been offered by the Laboratoire Cantonal Vaudois (Switzerland).

Buffer—The buffer consists of a freshly prepared sodium hydrogenophosphate (20 mM) and sodium hydrogenocarbonate (10 mM) adjusted at pH 10.5 with NaOH 0.1 M. Ten mM hydroxypropyl-β-cyclodextrine are then added and the solution is sonicated for 15 min. Acetonitrile (4.75%) is added just before use.

Standards and Samples—The standards were diluted in the internal standard solution (benzoic acid 0.2 mg/mL bi-distilled water). After the SPE step, the sample extracts were recovered with 0.1 mL of the internal standard.

Apparatus and Operating Conditions—The apparatus used was the Hewlett-Packard HP^{3D}CE equipped with diode-array detection (190–599 nm) and HP^{3D}CE Chemstation software for instrument control, data acquisition and data analysis. The capillary was made of uncoated fused-silica (Hewlett Packard) with an internal diameter of 50 μm, a total length of 64.5 cm (56 cm to the detector), and an extended pathlength bubble cell. It was conditioned 10 min with NaOH 0.1 M followed by 10 min with buffer before each injection. The hydrodynamic injection of the sample consisted of a 6 s sample plug at 50 mbar, followed by a 4 s buffer plug at 50 mbar. The separation was performed with a 25 kV separation voltage at 25°C. Although it is possible in each spot of the electropherogram to get the entire UV-visible spectrum from 190 nm to 599 nm, the plot of the electropherogram is limited to 6 wavelengths. These detection wavelengths do not always fit with the true absorption maximum, but have been chosen as a compromise between the different absorption maxima of the dyes and the internal standard in the ultraviolet (UV) and visible region (215, 225, 425, 527, 599 nm; see Table 2*a*). The separation of the 14 dyes and the internal standard

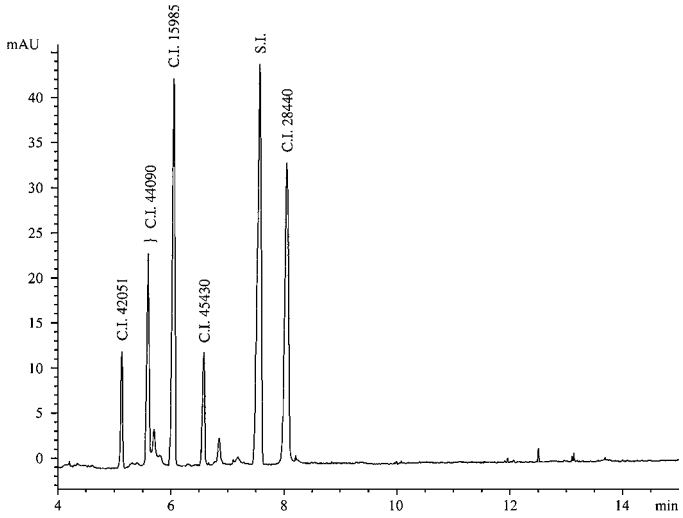

FIG. 1—*Electropherogram showing separation of five dyes (C.I. 42051, C.I. 44090, C.I. 15985, C.I. 45430, C.I. 28440, individual concentration of 0.25 mg/mL) and internal standards (S.I., concentration of 0.2 mg/mL). Absorbance was measured at 225 nm.*

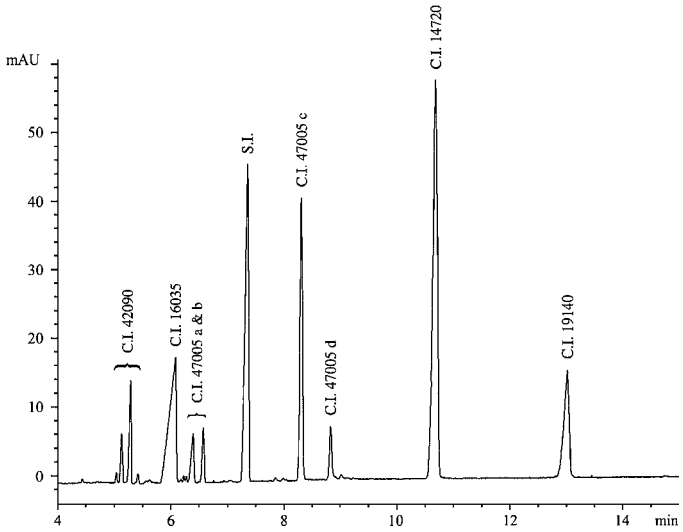

FIG. 2—*Electropherogram showing separation of five dyes (C.I. 42090, C.I. 16035, C.I. 47005, C.I. 14720, C.I. 19140, individual concentration of 0.25 mg/mL) and internal standards (S.I., concentration of 0.2 mg/mL). Absorbance was measured at 225 nm.*

is presented in Figs. 1–3 for a wavelength of 225 nm. To avoid an overload of ionic species, which reduces the column efficiency and modifies the retention times, three groups of standards in individual concentration of 0.25 mg/mL were run separately.

Validation of Method

Validation of the method has considered the three analysis steps (purification, TLC identification, and CZE-DAD confirmation and quantification) (4).

The selectivity-specificity has been evaluated: it appeared that the combination of the extraction, the separation systems, and the detection is specific to the acidic hydrosoluble dyes that may be found in illicit pills.

The qualitative accuracy of the method showed that it was not possible to mix up the identification of the 14 dyes. There is no co-elution in the two separation systems (TLC and CZE) and their

TABLE 2*a*—*Relative retention time (RRt) of dyes expressed in internal standard with relative standard deviation (RSD). Quantification wavelengths, based on a compromise between these 14 dyes, are also given (UV-vis. λ).*

Dyes	RRt	RSD %	UV-vis. λ
C.I. 42051	0.69	0.07	599 nm
C.I. 42090	0.72	0.05	599 nm
C.I.44090	0.76	0.03	599 nm
C.I. 16035	0.80	0.38	225 nm
C.I. 15985	0.81	0.56	225 mn
C.I. 73015	0.85	0.05	215 nm
C.I. 45430	0.87	0.13	527 nm
Benzoic acid	1.00	···	225 nm
C.I. 28440	1.05	0.30	215 nm
C.I. 16185	1.07	0.63	225 nm
C.I. 47005.2	1.13	0.80	425 nm
C.I. 18050	1.24	1.04	215 nm
C.I. 14720	1.39	0.40	215 nm
C.I. 16255	1.64	0.30	225 nm
C.I. 19140	1.76	1.17	425 nm

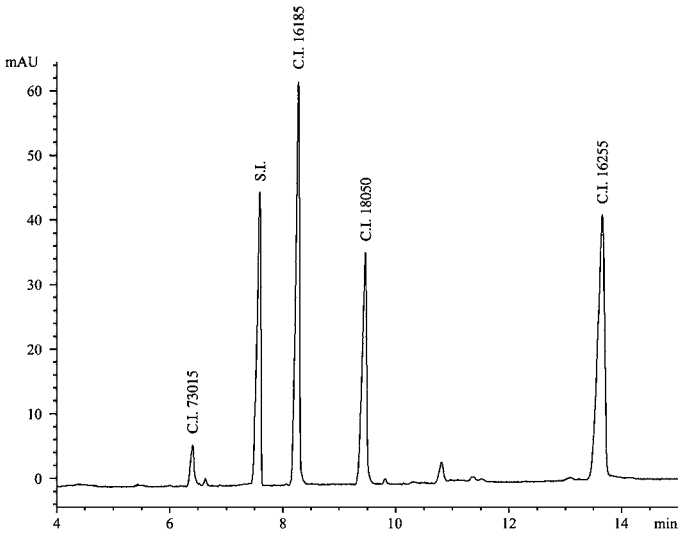

FIG. 3—*Electropherogram showing separation of five dyes (C.I. 73015, C.I. 16185, C.I. 18050, C.I. 16255, individual concentration of 0.25 mg/mL) and internal standards (S.I., concentration of 0.2 mg/mL). Absorbance was measured at 225 nm.*

TABLE 2*b*—*Numeral characteristics of CZE-DAD analysis for some dyes.*

Parameter	Value	Remarks
Repeatability of injection (RSD)	~1.5%	Evaluated for C.I. 14720
Repeatability of extraction and injection (RSD)	~2.0%	Evaluated for C.I. 14720
Detection limit (signal/noise ≥ 3)	~0.008 mg/mL	Evaluated for C.I. 42051, C.I. 44090, C.I. 15985, C.I. 45430, and C.I. 28440
Quantitation limit (RSD ≤ 5%)	~0.015 mg/mL	Evaluated for C.I. 42051, C.I. 44090
	~0.03 mg/mL	Evaluated for C.I. 15985, C.I. 28440
	~0.06 mg/mL	Evaluated for C.I. 45430
Linearity	0.008–0.25 mg/mL	Evaluated for C.I. 42051, C.I. 44090, C.I. 15985, and C.I. 28440
	0.016–0.25 mg/mL	C.I. 45430

UV-visible spectrum turned out to be different. The main problem regarding the quantitative accuracy is the extraction loss. For example, a loss of 13% has been observed after the extraction of a C.I. 14720 solution. However, the real concentration in a comparative approach is not so important so long as the extraction procedure is precise and allows comparisons.

The qualitative precision of the TLC systems may be enhanced by weighting the retention time with two reference dyes (10). The CZE qualitative precision turned out to be good with the use of the internal standard (see Table 2*a*). Yet, small differences of pH or the use of different batches of hydroxypropyl-b-cyclodextrine may induce the retention time of some dyes to change. This may explain the difference noted for the dye C.I 16255 between Fig. 2 (RRT ~ 1.94) and Table 2*a* (RRT ~ 1.64). It implies that standards should be run each time a new buffer is prepared. The quantitative precision has been evaluated with the CZE-DAD method for the extraction and the injection steps (see Table 2*b*).

The quantitation limit, detection limit, linearity, and robustness have also been evaluated for some dyes (see Table 2*b*) and it appears that the proposed method is well adapted to the analytical expectations.

Results and Discussion

Two kinds of samples have been measured. The first sample consisted of ten pills belonging apparently to the same batch (same seizure, no visual differentiation, seized at the same time, by the same police force). It was tested for qualitative and quantitative homogeneity (2 analyses per pill). The second sample consisted of 43 pills coming from 43 different seizures and upon which only a qualitative analysis was done.

Batch Homogeneity

The method used in this work allowed identification of the dye C.I. 14720 in each of the ten pills, with a mean concentration of 0.14% and with a relative standard deviation of 8.2%. As the extraction precision (RSD) for one of these pills turned out to be about 2%, the 8.2% observed variation may be considered as information about the batch homogeneity and allows a distribution to be represented. This variation is not perceptible to the naked eye and, in this sense, seems independent of the manufacturer.

Inter-Seizure Qualitative Variability

Between the 43 selected pills, the color distribution was the following : 12 green, 12 pink, 7 yellow, 4 blue, 4 orange, 3 red, and 1 purple. The results are given in Table 3.

Each dye identified belongs to the class of hydrosoluble, acidic, synthetic food dyes, except for C.I. 75470, which is an hydrosoluble, acidic, but natural dye. The dyes of two pills (a blue and a pink one) have not been identified by this method. The blue pill presents a

TABLE 3—*Dyes analysis: qualitative results of 43 colored illicit pills (number in brackets in column 1 is the occurrence of similar cases).*

Color (Occurrence)	Logo	Identification by TLC and CZE-DAD (C.I. Name)
bicolored white-purple	none	75470
blue	none	42051
blue	none	73015
blue	star	28440, 16185
blue	Tom (and Jerry)	not identified
yellow [3]	none	19140, 15985
yellow	none	19140, 15985, 14720
yellow	none	19140, 15985 (traces)
yellow	none	19140
yellow	CD/125 Mg	19140, 47005
orange	none	19140, 15985
orange [2]	hammer and sickle	15985
orange	smile	15985
pink [2]	none	14720
pink [6]	none	45430
pink	none	19140, 16255
pink [2]	heart arrowed	14720
pink	heart-shaped pill	15985 traces, pink dye observed only with TLC but not identified
red	none	19140, 16255
red	none	16255, 19140
red	swallow	16255, 19140
green [2]	none	19140, 44090
green	Adidas	19140, 42051
green	clover	19140, 42051
green	clover	42051, 19140
green	clover	19140, 73015, 42051
green [4]	sparrow	19140, 42051
green	star	19140, 42051
green	5 5 5	42051

blue hydrosoluble basic and acidic dyes mixture. The pink one is distinguished by an hydrosoluble pink dye which is fluorescent under UV (366 nm). Despite the nonidentification, the physical properties of these dyes may be used for subsequent comparison.

Dyes and Strategic Drug Intelligence

As mentioned in the introduction, the pills presenting dyes that are not authorized in the country where the seizure is made will support a foreign production or delimit a geographical production. Regulation of the use of synthetic food dyes in several countries is presented in Table 4. This is, for example, the case of the pills containing the dyes C.I. 16135, C.I. 19140 or C.I. 42090, which are allowed in the European Community but not in Switzerland. One could reasonably then think of a "European" rather than a Swiss production.

Another possible case regarding strategic intelligence could be the comparison of dyes found in pills with dyes found in an illicit laboratory. In a case of a match between the pills and the raw material, the strength of this link is dependent on the particularity of the dyes; its value could be assessed.

Dyes and Tactical Drug Intelligence

Tactical drug intelligence generally requires a comparison between samples. This comparison is often based on chemical profiles, themselves defined by quantitative and/or qualitative data. Yet, the way the data are compared, how the results are expressed and the meaning of the conclusions are not an easy task. Some possible situations including qualitative or quantitative comparisons are given below. However, the way the results and the conclusion are given is fixed; it is included in a Bayesian framework.

The value of the information derived by chemical analysis is estimated using a likelihood ratio, LR (7). A Bayesian model permits the revision, based on new information, of a measure of uncertainty about the truth or otherwise of an issue (for example, the common origin of two seizures). This perspective is common to numerous scientific fields where data are combined with prior, or background, information (for example, information such as characteristics coming from the three production steps and the circumstantial elements) to give posterior probabilities for particular outcomes or issues.

(Note that different LRs connected with fabrication steps of illicit pills may be evaluated; notably, the comparison of the active compound could be then seen at the "synthetic route" level, at the "producer" level, or at the "batch" level.)

Example 1: Dyes as a Qualitative Variable

Examples presented below do not involve precise data, but sketch four situations that may occur while considering qualitative data. The comparison of the variables inherent to the second step of illicit pills fabrication may lead to the following results:

1. different excipients, different dyes,
2. same excipients, different dyes,
3. different excipients, same dyes, or
4. same excipients, including dyes.

The first situation tends to indicate the absence of an objective link between the two pills, and an exclusion that it may have come from the same batch.

The second situation may indicate either an absence of link, especially if the other excipients are common, or a link if they are particular. In this last case the use of different dyes could be imputed to market diversification.

The third situation may indicate either a link, especially if the dye(s) is particular, or the absence of link. If a link is considered, the two pills could not have the same batch as origin (temporary modification of the receipt).

The last situation indicates a positive link between the two pills, but any inference that they are truly linked must be evaluated. Cases presenting same excipients, but where a link was excluded based on other information, help to measure this risk. Another way to evaluate more precisely the link between two samples is to employ some judicious qualitative parameters in a quantitative way. The use of quantitative values in a comparative approach usually increases the discrimination power of the method and allows the conclusion to be refined. This is demonstrated in Example 2.

Example 2: Dyes as Quantitative Variable

When based on quantitative values, the comparison between two samples is rather complex and depends mainly on the samples size, on the number of variables, and also on the statistical approach used. For example, the classical inferential approach, based on hypothesis tests, may lead to several problems. One of them—the so-called "fall-off-the-cliff effect"—is due to the dichotomous nature of the approach (8) and creates logical problems for combining evidence. A continuous approach avoids this problem.

In a comparison between two samples, a quantitative variable of interest is generally characterized by statistical criteria (e.g., mean and variance). Walsh et al. (9) propose a continuous methodology

TABLE 4—*Use of synthetic food dyes in several European and extra-European countries in Year 2000 (O = use allowed, X = use forbidden).*

Dyes	Ukraine	Norway	Poland	USA	Switzerland	Japan	Moldavia	Rumania	Russia	Cyprus	Czechia	Estonia	Latvia	Malta	Turkey	**EU countries**	Yugoslavia	Frequency
CI44044	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**X**	O	1
CI44045	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**X**	O	1
CI42040	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**X**	O	1
CI15850	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**X**	O	1
CI42735	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**X**	O	1
CI42170	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**X**	O	1
CI10020	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**X**	O	1
CI19235	X	X	X	O	X	X	X	X	X	X	X	X	X	X	X	**X**	X	1
CI12156	X	X	X	O	X	X	X	X	X	X	X	X	X	X	X	**X**	X	1
CI75100	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**X**	X	1
CI75300	X	X	X	X	X	X	X	X	X	O	X	X	X	X	X	**X**	X	1
CI45410	X	X	X	X	X	O	X	X	X	O	X	X	X	X	X	**X**	X	1
CI45440	X	X	X	X	X	O	X	X	X	X	X	X	X	X	X	**X**	X	1
CI45100	X	X	X	X	X	O	X	X	X	X	X	X	X	X	X	**X**	X	1
CI27755	O	X	X	X	X	X	X	X	O	X	O	X	X	X	X	**X**	X	3
CI42535	O	X	X	X	X	X	X	X	X	X	X	X	X	X	X	**X**	O	3
CI42053	X	X	X	O	X	O	O	X	O	X	X	X	X	X	X	**X**	X	4
CI18050	X	X	X	X	X	X	X	X	X	X	O	O	O	O	O	**O**	X	19
Brown FK	X	X	X	X	X	X	X	X	X	X	O	O	O	O	O	**O**	X	19
CI20285	X	X	X	X	X	X	X	O	X	X	O	O	O	O	O	**O**	X	20
CI16185	X	X	X	X	O	O	X	X	X	X	O	O	O	O	O	**O**	O	22
CI44090	X	X	X	X	X	O	X	O	O	O	O	O	O	O	O	**O**	X	24
CI16035	X	X	X	O	X	O	O	O	O	O	O	O	O	O	O	**O**	X	25
CI42090	X	X	X	O	X	O	O	O	O	O	O	O	O	O	O	**O**	X	25
CI19140	X	X	X	O	X	O	O	O	O	O	O	O	O	O	O	**O**	O	26
CI14720	X	X	O	X	O	X	O	O	O	O	O	O	O	O	O	**O**	O	26
CI45430	X	O	X	O	O	O	X	O	X	O	O	O	O	O	O	**O**	O	26
CI42051	X	X	O	X	O	X	O	O	O	O	O	O	O	O	O	**O**	O	26
CI28440	X	X	O	X	O	X	O	O	O	O	O	O	O	O	O	**O**	O	26
CI47005	X	O	O	X	O	X	O	O	O	O	O	O	O	O	O	**O**	O	27
CI75470	X	O	O	X	O	X	X	O	O	O	O	O	O	O	O	**O**	O	27
CI16255	X	X	O	X	O	O	O	O	O	O	O	O	O	O	O	**O**	O	27
CI15985	X	X	O	O	O	O	O	O	O	O	O	O	O	O	O	**O**	O	28
CI73015	X	O	O	O	O	O	O	O	O	O	O	O	O	O	O	**O**	O	29
Frequency	2	4	8	9	11	12	14	14	14	16	17	17	17	17	17	17	19	

to compare two samples having different mean and variance and which are not normally distributed. This approach was proposed for the evaluation of glass evidence in forensic science but turns out to be useful here. The reader is referred to the Appendix of the original paper for the mathematical development.

The following case presents the estimation of the likelihood ratio based on one variable, notably the concentration of the dye C.I. 14720 found in illicit pills. The sample, say Y (N = 5 pills), is compared with a specific batch X (N = 20 pills) and with other batches attributed to the same producer Z (N = 100 pills coming from 20 batches).

Two couples of hypotheses are considered, notably, H_1, the sample Y comes from batch X, and H_2, the sample Y does not come from batch X (it comes from a different batch), and H_3, the sample Y comes from a batch produced by Z, and H_4, the sample Y does not come from a batch produced by Z.

The population parameters (see Table 5) have been defined as follows: Degrees of freedom and pooled standard deviations of Y with X and Y with Z are, respectively: $\varphi_{y,x} = 4.50$, $S_{pool.y,x} = 0.0092$, and $\varphi_{y,z} = 5.75$, $S_{pool.y,z} = 0.0098$. The t-distribution of Y based on X and on Z are presented in Figs. 4 and 5.

Considering the first couple of hypotheses, H_1 and H_2, the likelihood ratio is obtained by balancing the probability density of finding $\bar{y}$ in the batch X as a function of Y (hypothesis H_1) and the probability density of finding $\bar{y}$ in the population P unrelated to X (hypothesis H_2). The value of the evidence under these two hypotheses is 5.4. Such a result supports slightly the hypothesis that sample Y comes from batch X. In fact, it is approximately five times more likely to observe a C.I. 14720 concentration of 0.165% if sample Y does come from batch X rather than from an unknown batch.

Considering the second couple of hypotheses, H_3 and H_4, the likelihood ratio becomes 23.3; it clearly supports that sample Y comes from a batch produced by Z.

Note that for investigative purposes it could be more appropriate to assess the value of the evidence (C.I. 14720 concentration of

TABLE 5—*Population parameters.*

Sample	Sample Y	Batch X	Producer Z	General Population*
Mean (%)	$\bar{y} = 0.165$	$\bar{x} = 0.140$	$\bar{z} = 0.180$	$\bar{p} = 0.300$
Standard deviation	$S_y = 0.02$	$S_x = 0.01$	$S_z = 0.04$	$S_p = 0.06$

* This population is characterized by illicit pills colored with the dye C.I. 14720. It is normally distributed, $P \sim N(0.3, 0.06^2)$.

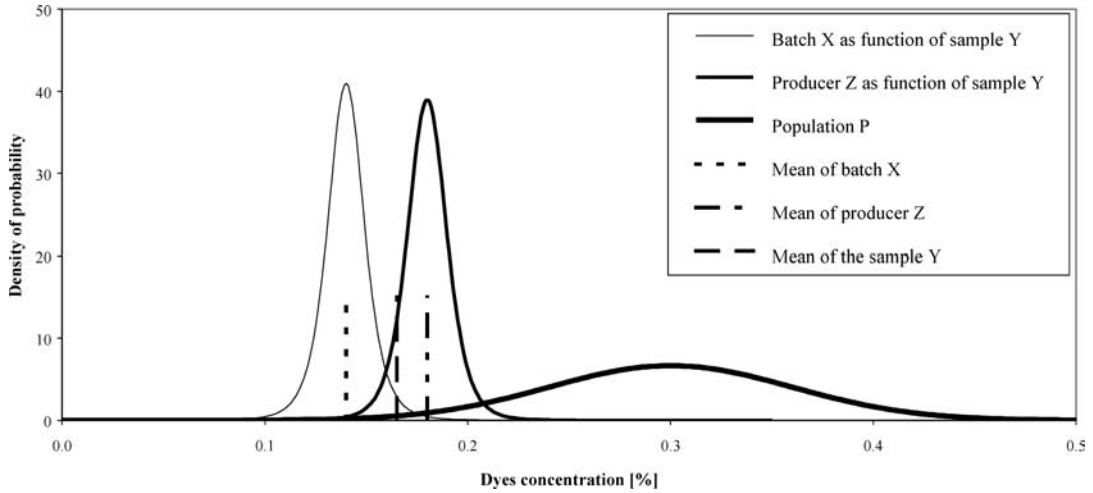

FIG. 4—t-*density functions for sample Y as function of batch X and Z, and density function of population.*

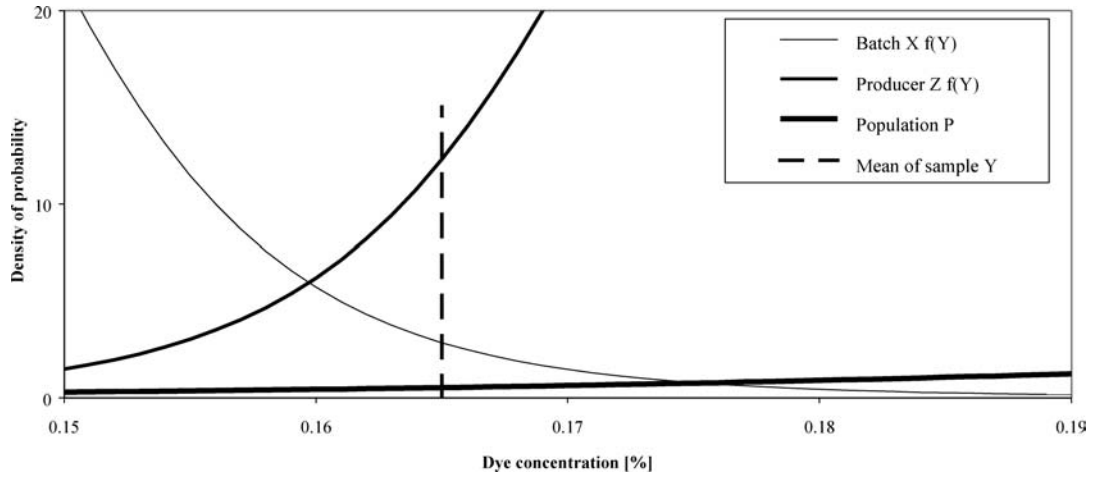

FIG. 5—*Detailed view of Fig. 4 showing mean of sample Y in relationship with distribution of batch X as function of Y, of producer Z as function of Y, and of population P.*

0.165%) according to the two other hypotheses, H_1 (the sample Y does come from batch X) and H_3 (the sample Y does come from a batch produced by Z). Note also that even if this example approaches a simple univariate case, it illustrates the utility of such a continuous assessment approach in drug intelligence.

Conclusion

A method for the analysis of 14 hydrosoluble, acidic, synthetic food dyes allowed in the European Community has been developed (C.I. 14720, C.I. 15985, C.I. 16035, C.I. 16185, C.I. 16255, C.I. 18050, C.I. 19140, C.I. 28440, C.I. 42051, C.I. 42090, C.I. 44090, C.I. 45430, C.I. 47005 and C.I. 73015). Among the 43 colored pills, 40 contained exclusively dyes belonging to the aforementioned list, one contained a natural dye (C.I. 75470), and two contained dyes that were not identified.

Such a method applied to illicit pills implies that the dye evidence may play a relevant role in drug analysis by giving additional information for drug intelligence.

Actually, the information derived by dyes analysis of illicit pills offers a contribution to both tactical and strategic drug intelligence; the way to use this information could be modeled through a quantitative evaluation using a continuous likelihood ratio assessment methodology.

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Additional information and reprint requests:
Franco Taroni, Ph.D.
Institut de Médecine Légale
The University of Lausanne
Rue du Bugnon 21
1005 Lausanne, Switzerland