

Analysis of Cannabis and its Products in the Context Forensic Science

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Legalization of low-tetrahydrocannabinol-high-cannabidiol cannabis plants is gaining momentum due to growing demand for these products. In some countries, the testing of cannabis and products containing it is a legal requirement: cannabis is identified, the amount of tetrahydrocannabinol or cannabidiol and their precursor acids is assessed. Current research requires more sensitive and reliable analytical methods for accurate identification and quantification of cannabis components. This article purpose is to review the latest advances in the scientific literature on the isolation and analysis of cannabis and cannabis-containing products in the context of forensic science. Research methods included analysis of information on this topic using search engines, including Google, Google Scholar, Web of Science, PubMed, and ScienceDirect. Search requests took into account scientific, analytical and statistical reports in the field of forensic research. Since the forensic expert must be well-versed in modern trends in the analysis of prohibited substances and use the latest data from the analytical and forensic literature in his work, such information will help them choose research methods, taking into account the actual resources and equipment of forensic laboratories. According to the article purpose, advantages and disadvantages of existing methods of extraction and analysis of objects containing cannabis for identification,

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quantification, profiling and age estimation of cannabis are considered.

Keywords: *cannabis; phytocannabinoids; extraction; identification; quantitative definition; gas chromatography; liquid chromatography; nuclear magnetic resonance method; methods of vibrational spectroscopy.*

Research Problem Formulation

Illegal circulation of narcotic drugs, psychotropic substances, their analogues and precursors is one of the leading social problems. Cannabis remains the most widely used illicit substance. Cultivation and production of hemp covers all regions of the world, the main emphasis is on achieving a high content of tetrahydrocannabinol (hereinafter referred to as *THC*) in plants. According to the report of the European Monitoring Centre for Drugs and Drug Addiction (*EMCDDA*) for 2023, in the countries of the European Union in 2021, the average *THC* content in herbal cannabis was 9.5 %, in cannabis resin – 20 %¹.

Cannabis regulation is increasingly confronted with new forms and ways of its use. Currently, cannabis products are represented by substances with a high *THC* content or contain cannabidiol (hereinafter referred to as *CBD*) against the background of low levels of *THC* in oils or tinctures. These products are used in food production (such as pastries, candies, chocolate, marmalade, potato chips, pies, soups, drinks of various colors and flavors), as well as in electronic cigarettes and

vaping liquids. Traditional cannabis resin is increasingly found in loose form, and there are known cases of cannabis resin being produced from plant material with a high *CBD* content.

The increase in the number of such materials and their various characteristics requires forensic experts to revise analysis methods of in order to prevent unreliable results. In addition, forensic experts (in particular, in EU countries) often have to not only detect, but quantify low levels of *THC*, differentiate its isomers, in particular delta-9-tetrahydrocannabinol (hereinafter referred to as Δ^9 -*THC*) and delta-8-tetrahydrocannabinol (hereinafter referred to as Δ^8 -*THC*), as well as to identify other cannabinoids present. Solving such a large number of analytical problems requires reliable, reproducible and sensitive analytical methods. At the same time, the lack of reference materials for Δ^9 -*THC*, its isomers and other cannabinoids is hindering quality results of forensic laboratories.

Plants of the Cannabis genus contain approximately 500 compounds, of which more than 144 are classified as phytocannabinoids (natural cannabinoids), while others are represented by flavonoids,

1 European Drug Report 2023: Trends and Developments. Lisbon : EMCDDA, 2023. URL: https://www.emcdda.europa.eu/index_en (date accessed: 25.09.2023).

fatty acids, and phenols. Among the chemical components, the most famous in plants of the genus *Cannabis*, THC and CBD are distinguished. Due to complexity of terpenophenolic composition of plants and the investigated matrix, for example, products containing cannabis extracts, their analysis and quantification require the use of multi-step sample preparation protocols with subsequent validation of each new method that will be implemented in the laboratory.

This topic is relevant for Ukraine, as cannabis and products containing cannabis are actively promoted on the market of recreational products. The speed of spread of these substances (against the fact that their psychoactivity is not always known, insufficient research and lack of control) gives them the status of high social danger and requires further research, which is already being conducted in EU countries.

Article Purpose

Review of the latest advances of scientific literature on isolation and analysis of cannabis and cannabis-containing products in a forensic context. Since the forensic expert must be well-versed in modern trends in the analysis of prohibited substances and use the latest data from the analytical and forensic literature in his work, such information will help them choose research methods, taking into account the actual resources and equipment of forensic laboratories.

Research Methods

Research on information according to the topic in question was carried out by studying search engines, in particular *Google*, *Google Scholar*, *Web of Science*, *PubMed*, *ScienceDirect*. Search requests took into account scientific, analytical and statistical reports in the field of forensic research.

Analysis of Essential Researches and Publications

Analysis of the special scientific literature of recent years indicates an active interest in the analysis of the complex matrix of cannabis plants. Many studies are aimed at studying the processes of phytocannabinoid extraction for further analysis. A study by G. Micalizzi and colleagues of the properties of solvents (methanol, ethanol, acetone, hexane) demonstrated that ethanol exhibits the best extraction properties against cannabinoid acids in their decarboxylated forms; on the other hand, the use of hexane reduces the extraction results of cannabinoids².

N. Christinat et al. studied the properties of a mixture of water and acetonitrile as extraction reagents for the determination of various types of cannabinoids in samples of hempseed oil, milk, various beverages and food³. In other similar studies, isopropanol was recognized as the most effective extractant (compared to methanol and acetonitrile) during the extraction

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- 2 Micalizzi G., Vento F., Alibrando F., Donnarumma D., Dugo P., Mondello L. Cannabis Sativa L.: A comprehensive review on the analytical methodologies for cannabinoids and terpenes characterization. *Journal of Chromatography A*. 2021. Jan 25:1637:461864. DOI: [10.1016/j.chroma.2020.461864](https://doi.org/10.1016/j.chroma.2020.461864) (date accessed: 27.09.2023).
 - 3 Christinat N., Savoy M.-C., Mottier P. Development, Validation and Application of a LC-MS/MS Method for Quantification of 15 Cannabinoids in Food. *Food Chemistry*. 2020. Vol. 318. Art. 126469. DOI: [10.1016/j.foodchem.2020.126469](https://doi.org/10.1016/j.foodchem.2020.126469) (date accessed: 27.09.2023).

of the phytocannabinoid composition of hemp seeds ⁴.

V. Brighenti and colleagues compared extraction methods, their parameters and solvents, studying the composition of cannabinoids in cannabis flowers; dynamic maceration in ethanol at room temperature demonstrated the highest efficiency for the further study of the total amount of cannabinoids, as well as their neutral and acidic forms ⁵.

Investigating the effect of extraction conditions on the release of cannabinoids and cannabis flowers, E. M. Mudge et al demonstrated that ultrasonic extraction was more effective than shaking, but that enhanced sonication for 15 minutes caused some cannabinoid degradation ⁶.

The advantages of microwave extraction for decarboxylated forms of

cannabinoids were noted by D. de Vita and her colleagues ⁷.

L. J. Rovetto and N. V. Aieta developed a supercritical fluid extraction strategy with pulsating carbon dioxide and ethanol as co-solvents, which increased the extraction rate and total cannabinoid yield, reduced solvent consumption and analysis time; this method proved useful for extracting total THC or CBD in neutral and acidic forms ⁸.

M. A. ElSohly and C. Cuttler report a tendency to increase THC concentration in hemp plants from 10-14 % ⁹ to 20 % ¹⁰. Quantification of cannabis is usually performed using gas chromatography (GC) with a flame ionization detector (GC-FID), as noted in G. R. Borges et al ¹¹.

V. Cardenia and his colleagues compared the methods of GC-FID and

- 4 Chang Ch.-W., Tung Ch.-W., Tsai Ch.-Ch., Wu Yu-T., Hsu M.-Ch. Determination of Cannabinoids in Hemp Nut Products in Taiwan by HPLC-MS/MS Coupled with Chemometric Analysis: Quality Evaluation and a Pilot Human Study. *Drug Testing and Analysis*. 2017. No. 9. Pp. 888–897. DOI: [10.1002/dta.2062](https://doi.org/10.1002/dta.2062) (date accessed: 29.09.2023).
- 5 Brighenti V., Pellati F., Steinbach M., Maran D., Benvenuti S. Development of a New Extraction Technique and HPLC Method for the Analysis of Non-Psychoactive Cannabinoids in Fibre-Type Cannabis Sativa L. (Hemp). *Journal of Pharmaceutical and Biomedical Analysis*. 2017. Vol. 143. Pp. 228–236. DOI: [10.1016/j.jpba.2017.05.049](https://doi.org/10.1016/j.jpba.2017.05.049) (date accessed: 21.09.2023).
- 6 Mudge E. M., Murch S. J., Brown P. N. Leaner and Greener Analysis of Cannabinoids. *Analytical and Bioanalytical Chemistry*. 2017. Vol. 409. Pp. 3153–3163. DOI: [10.1007/s00216-017-0256-3](https://doi.org/10.1007/s00216-017-0256-3) (date accessed: 22.09.2023).
- 7 De Vita D., Madia V. N., Tudino V., Saccoliti F., De Leo A., Messori A., Roscilli P., Botto A., Pindinello I., Santilli G. et al. Comparison of Different Methods for the Extraction of Cannabinoids from Cannabis. *Natural Product Research*. 2019. Vol. 34 (20). Pp. 2952–2958. DOI: [10.1080/14786419.2019.1601194](https://doi.org/10.1080/14786419.2019.1601194) (date accessed: 23.09.2023).
- 8 Rovetto L. J., Aieta N. V. Supercritical Carbon Dioxide Extraction of Cannabinoids from Cannabis Sativa L. *The Journal of Supercritical Fluids*. 2017. Vol. 129. Pp. 16–27. DOI: [10.1016/j.supflu.2017.03.014](https://doi.org/10.1016/j.supflu.2017.03.014) (date accessed: 22.09.2023).
- 9 ElSohly M. A., Chandra S., Radwan M., Majumdar Ch. G., Church J. C. A Comprehensive Review of Cannabis Potency in the United States in the Last Decade. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*. 2021. Vol. 6. No. 6. Pp. 603–606. DOI: [10.1016/j.bpsc.2020.12.016](https://doi.org/10.1016/j.bpsc.2020.12.016) (date accessed: 22.09.2023).
- 10 Cuttler C., LaFrance E. M., Stueber A. Acute effects of high-potency cannabis flower and cannabis concentrates on everyday life memory and decision making. *Scientific Reports*. 2021. Vol. 11. No. 1. Art. 13784. DOI: [10.1038/s41598-021-93198-5](https://doi.org/10.1038/s41598-021-93198-5) (date accessed: 24.09.2023).
- 11 Borges G. R., Birk L., Scheid C., Morés L., Carasek E., Kitamura R. O. S., Roveri F. L. et al. Simple and Straightforward Analysis of Cannabinoids in Medicinal Products by Fast-GC-FID. *Forensic Toxicology*. 2020. Vol. 38. Pp. 531–535. DOI: [10.1007/s11419-020-00522-1](https://doi.org/10.1007/s11419-020-00522-1) (date accessed: 22.09.2023).

gas chromatography with a mass detector (hereinafter referred to as GC-MS), showed the interchangeability of detectors in the case of the study of cannabis and products containing it, and developed a GC-MS method for the quantitative determination of cannabinoids, approved for use in European countries, on a quadrupole GC-MS with electron impact ionization¹².

C. Citti and colleagues noted that the GC-MS method for quantification requires the use of expensive deuterated standards, which are not available for all cannabinoids¹³. L. A. Ciolino and her colleagues recommend using N,O-bis(trimethylsilyl)trifluoroacetamide for the derivatization process that occurs during the identification of phytocannabinoid acids¹⁴. G. R. Borges and his co-authors compared several chromatographic methods using Δ⁹-THC as an example and determined a significant amount of Δ⁸-THC and cannabiniol (hereinafter referred to as CBN), which are known products of the breakdown of Δ⁹-THC and are present in

the GC chromatograms, in contrast to the results obtained by the methods of high-performance Liquid chromatography-mass spectrometry (hereinafter referred to as HPLC)¹⁵, nuclear magnetic resonance (hereinafter referred to as hereinafter referred to as) and thin-layer chromatography (hereinafter referred to as TLC). M. M. Delgado-Povedano, together with co-authors, described a method for research on extracts of plants of the genus Cannabis using quadrupole time-of-flight mass detectors in combination with GC for non-polar compounds or the method of liquid chromatography (hereinafter referred to as LC) for more polar cannabinoids and their acids¹⁶.

L. Calvi and colleagues evaluated the potential of HPLC with an Orbitrap detector for the study of cannabinoids in commercial cannabis extracts and investigated the degradation of these extracts under different storage conditions¹⁷.

N. Christinat et al. tested a variety of edible products sold in the EU for the presence and quantitative content of

- 12 Cardenia V., Toschi T. G., Scappini S., Rubino R. C., Rodriguez-Estrada M. T. Development and Validation of a Fast Gas Chromatography/Mass Spectrometry Method for the Determination of Cannabinoids in Cannabis Sativa L. *Journal of Food and Drug Analysis*. 2018. Vol. 26 (4). Pp. 1283–1292. DOI: [10.1016/j.jfda.2018.06.001](https://doi.org/10.1016/j.jfda.2018.06.001) (date accessed: 25.09.2023).
- 13 Citti C., Russo F., Sgrò S., Gallo A., Zanutto A., Forni F., Vandelli M. A., Laganà A., Montone C. M., Gigli G., Cannazza G. Pitfalls in the analysis of phytocannabinoids in cannabis inflorescence. *Analytical and Bioanalytical Chemistry*. 2020. Vol. 412. No. 17. Art. 4009–4022. DOI: [10.1007/s00216-020-02554-3](https://doi.org/10.1007/s00216-020-02554-3) (date accessed: 25.09.2023).
- 14 Ciolino L. A., Ranieri T. L., Taylor A. M. Commercial cannabis consumer products part 1: GC-MS qualitative analysis of cannabis cannabinoids. *Forensic Science International*. 2018. Vol. 289. Pp. 429–437. DOI: [10.1016/j.forsciint.2018.05.032](https://doi.org/10.1016/j.forsciint.2018.05.032) (date accessed: 24.09.2023).
- 15 Borges G. R., Birk L., Scheid C., Morés L., Carasek E., Kitamura R. O. S., Roveri F. L. et al. Op. cit. DOI: [10.1007/s11419-020-00522-1](https://doi.org/10.1007/s11419-020-00522-1) (date accessed: 28.09.2023).
- 16 Delgado-Povedano M. M., Sánchez-Carnerero Callado C., Priego-Capote F., Ferreiro-Vera C. Un-targeted Characterization of Extracts from Cannabis Sativa L. Cultivars by Gas and Liquid Chromatography Coupled to Mass Spectrometry in High Resolution Mode. *Talanta*. 2020. Vol. 208. Art. 120384. DOI: [10.1016/j.talanta.2019.120384](https://doi.org/10.1016/j.talanta.2019.120384) (date accessed: 27.09.2023).
- 17 Calvi L., Pentimalli D., Panseri S., Giupponi L., Gelmini F., Beretta G., Vitali D., Bruno M., Zilio E., Pavlovic R., Giorgi A. Comprehensive Quality Evaluation of Medical Cannabis Sativa L. Inflorescence and Macerated Oils Based on HS-SPME Coupled to GC-MS and LC-HRMS (q-ex-active Orbitrap) Approach. *Journal of Pharmaceutical and Biomedical Analysis*. 2018. Vol. 150. Pp. 208–219. DOI: [10.1016/j.jpba.2017.11.073](https://doi.org/10.1016/j.jpba.2017.11.073) (date accessed: 28.09.2023).

cannabinoids using ultra-efficient liquid chromatography with a hybrid triple quadrupole-linear ion trap. Studies have shown that the concentration of CBD in the milk of cows fed with hemp reaches 10 mg/kg. In their studies, the authors also noted the excess of permissible levels of toxicity and concentration of THC in some products containing cannabis extract¹⁸.

G. R. Borges and colleagues developed a fast (5 minutes) method of high-performance liquid chromatography in combination with a diode detector for the quantitative determination of THC without loss of resolution of the main cannabinoids¹⁹.

Application of liquid chromatography method with ultraviolet detection to classify cannabis samples in order to distinguish them into recreational and fibrous, was proposed by M. Mandrioli et al²⁰.

M. Deville and her colleagues noted the existence of a significant metabolic difference between plants grown indoors and outdoors: outdoor cultivars had significantly higher concentrations of THC, CBD, and CBN²¹.

G. Stefkov and his co-authors investigated phytocannabinoids from plants of the genus *Cannabis* using UV detection²². At the same time, a team of Italian researchers published a report on the difficulties of joint elution of cannabinoid peaks and their low sensitivity to UV radiation, which makes it difficult to quantify THC and CBD during one analytical cycle²³.

C. Duchateau and colleagues described the difficulties of identifying and distinguishing between legal and illegal (legal and illegal) cannabis inflorescences encountered by law enforcement agencies in the field (outside laboratories), and developed an innovative approach to the classification of cannabis samples (in accordance with European and Swiss laws) using stationary and portable near-infrared (hereinafter referred to as NIR) analyzers and chemometric methods for determining the concentration of THC on GC-FID²⁴.

C. Sánchez-Carnerero Callado and co-authors reported obtaining acceptable prognostic results in the estimation of

- 18 Christinat N., Savoy M.-C., Mottier P. Op. cit. DOI: [10.1016/j.foodchem.2020.126469](https://doi.org/10.1016/j.foodchem.2020.126469) (date accessed: 27.09.2023).
- 19 Borges G. R., Birk L., Scheid C., Morés L., Carasek E., Kitamura R. O. S., Roveri F. L. et al. Op. cit. DOI: [10.1007/s11419-020-00522-1](https://doi.org/10.1007/s11419-020-00522-1) (date accessed: 28.09.2023).
- 20 Mandrioli M., Tura M., Scotti S., Toschi T. G. Fast Detection of 10 Cannabinoids by RP-HPLC-UV Method in *Cannabis sativa* L. *Molecules*. 2019. Is. 24. No. 11. Art. 2113. DOI: [10.3390/molecules24112113](https://doi.org/10.3390/molecules24112113) (date accessed: 10.10.2023).
- 21 Deville M., Dubois N., Denooz R., Charlier C. Validation of an UHPLC/DAD Method for the Determination of Cannabinoids in Seized Materials: Analysis of 213 Samples Sold in Belgian CBD shops. *Forensic Science International*. 2020. Vol. 310. Art. 110234. DOI: [10.1016/j.forsciint.2020.110234](https://doi.org/10.1016/j.forsciint.2020.110234) (date accessed: 06.10.2023).
- 22 Stefkov G., Cvetkovikj Karanfilova I., Stoilkovska Gjorgievska V., Trajkovska A., Geskovski N., Karapandzova M., Kulevanova S. Analytical Techniques for Phytocannabinoid Profiling of Cannabis and Cannabis-Based Products — A Comprehensive Review. *Molecules*. 2022. Vol. 27. Is. 3. Art. 975. DOI: [10.3390/molecules27030975](https://doi.org/10.3390/molecules27030975) (date accessed: 11.10.2023).
- 23 Citti C., Russo F., Sgrò S., Gallo A., Zanotto A., Forni F., Vandelli M. A., Laganà A., Montone C. M., Gigli G., Cannazza G. Op. cit. DOI: [10.1007/s00216-020-02554-3](https://doi.org/10.1007/s00216-020-02554-3) (date accessed: 07.10.2023).
- 24 Duchateau C., Kauffmann J.-M., Canfyn M., Stévigny C., De Braekeleer K., Deconinck E. Discrimination of legal and illegal *Cannabis* spp. according to European legislation using near infrared spectroscopy and chemometrics. *Drug Testing and Analysis*. 2020. Vol. 12. No. 9. Pp. 1309–1319. DOI: [10.1002/dta.2865](https://doi.org/10.1002/dta.2865) (date accessed: 12.10.2023).

cannabinoid concentration using NIR and NIR with Fourier transformation and the use of mathematical and statistical models: in their opinion, this analytical method simplifies the estimation of the quantitative content of cannabinoids in plants of the genus *Cannabis* compared to traditional GC method ²⁵.

L. Sanchez and colleagues used Raman spectroscopy to investigate cannabis with high CBD content, achieving 100 % accuracy through the use of chemometric methods ²⁶.

J. A. de Leite and her colleagues noted difficulty of isolating cannabinoids from a complex plant matrix using the NMR method: they used preparative high-pressure liquid chromatography to isolate and purify the samples ²⁷.

C. Citti ²⁸, G. Stefkov ²⁹ and J. A. de Leite ³⁰ in their research papers described the use of the NMR method for qualitative and quantitative research of cannabis components.

Chemometric analysis for estimating the age of herbal cannabis was used by K. C. Mariotti and co-authors ³¹. G. R. Borges and his co-authors used chemometric methods to differentiate the fibrous and recreational types of cannabis ³². A. Slosse processed data during cannabis profiling using chemometric methods ³³.

Main Content Presentation

Development of analytical methods for the identification and quantification of cannabinoids in various matrices is a special

- 25 Sánchez-Carnerero Callado C., Núñez-Sánchez N., Casano S., Ferreiro-Vera C. The potential of near infrared spectroscopy to estimate the content of cannabinoids in *Cannabis sativa* L.: A comparative study. *Talanta*. 2018. Vol. 90. No. 1. Pp. 147–157. DOI: [10.1016/j.talanta.2018.07.085](https://doi.org/10.1016/j.talanta.2018.07.085) (date accessed: 11.10.2023).
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- 27 De Leite J. A., de Oliveira M. V. L., Conti R., de S. Borges W., Rosa Th. R., Filgueiras P. R., Lacerda Jr. V., Romão W., Neto Á. C. Extraction and isolation of cannabinoids from marijuana seizures and characterization by 1H NMR allied to chemometric tools. *Science & Justice*. 2018. Vol. 58. Is. 5. Pp. 355–365. DOI: [10.1016/j.scijus.2018.06.005](https://doi.org/10.1016/j.scijus.2018.06.005) (date accessed: 01.10.2023).
- 28 Citti C., Russo F., Sgrò S., Gallo A., Zanutto A., Forni F., Vandelli M. A., Laganà A., Montone C. M., Gigli G., Cannazza G. Op. cit. DOI: [10.1007/s00216-020-02554-3](https://doi.org/10.1007/s00216-020-02554-3) (date accessed: 07.10.2023).
- 29 Stefkov G., Cvetkovikj Karanfilova I., Stoilkovska Gjorgievska V., Trajkovska A., Geskovski N., Karapandzova M., Kulevanova S. Op. cit. DOI: [10.3390/molecules27030975](https://doi.org/10.3390/molecules27030975) (date accessed: 11.10.2023).
- 30 De Leite J. A., de Oliveira M. V. L., Conti R., de S. Borges W., Rosa Th. R., Filgueiras P. R., Lacerda Jr. V., Romão W., Neto Á. C. Op. cit. DOI: [10.1016/j.scijus.2018.06.005](https://doi.org/10.1016/j.scijus.2018.06.005) (date accessed: 12.10.2023).
- 31 Mariotti K. C., Marcelo M. C. A., Ortiz R. S., Borille B. T., dos Reis M., Fett M. S., Ferrão M. F., Limberger R. P. Seized Cannabis Seeds Cultivated in Greenhouse: A Chemical Study by Gas Chromatography-Mass Spectrometry and Chemometric Analysis. *Science & Justice*. 2016. Vol. 56. Pp. 35–41. DOI: [10.1016/j.scijus.2015.09.002](https://doi.org/10.1016/j.scijus.2015.09.002) (date accessed: 10.10.2023).
- 32 Borges G. R., Birk L., Scheid C., Morés L., Carasek E., Kitamura R. O. S., Roveri F. L. et al. Op. cit. DOI: [10.1007/s11419-020-00522-1](https://doi.org/10.1007/s11419-020-00522-1) (date accessed: 28.09.2023).
- 33 Slosse A., Van Durme F., Samyn N., Mangelings D., Vander Heyden Yv. Gas Chromatographic Fingerprint Analysis for the Comparison of Seized Cannabis Samples. *Molecules*. 2021. Vol. 26. Is. 21. Art. 6643. DOI: [10.3390/molecules26216643](https://doi.org/10.3390/molecules26216643) (date accessed: 10.10.2023).

challenge. In nature, THC is found in plants of the genus *Cannabis*, it is considered the main psychoactive component of cannabis. The *tetrahydrocannabinol* term includes all stereochemical variants unless otherwise specified. For forensic investigations, the following components of cannabis are important: tetrahydrocannabinolic acid (hereinafter referred to as THCA), CBN, CBD, cannabigerol, cannabivarin, cannabichromene (hereinafter referred to as CBC).

THC, CBD and CBC are the main phytocannabinoid components of cannabis. In fresh biomass, approximately 95% of these components exist in the form of starting compounds: THCA, cannabidiolic acid (hereinafter referred to as CBDA) and cannabichromic acid. All of them are formed as a result of the enzymatic catalysis of cannabigerolic acid. The corresponding THC, CBD and CBC are formed by light and heat decarboxylation.

Decarboxylation rarely comes to an end, so both forms remain present in the matrix. CBN is a product of unnatural decomposition of THC, therefore, when processing cannabis and products containing it, it is necessary to take into account factors that affect the stability of cannabinoids and the consequences of sample storage conditions, laboratory analysis and interpretation of results (such as decarboxylation of THCA, oxidation of THC to CBN, CBD to THC isomers, isomerization of Δ^9 -THC in Δ^8 -THC).

Decarboxylation of THCA to form THC occurs during harvesting and drying of hemp, heating of the sample, for example, during smoking, under the influence of light, and during chemical research. Under similar conditions, THC can independently turn into CBN. Therefore, the correct

storage of samples and products containing hemp, as well as the choice of appropriate methods for their chemical analysis, are of crucial importance.

Important factor in determining total THC content is also the stability of cannabinoids in the studied object. Based on the THC and CBN content, the age of a particular cannabis sample can be determined, so comparative analysis is usually impractical three months after material extraction.

Cannabis resin is usually in the form of large, dense blocks; the degree of decarboxylation and degradation of cannabinoids, and therefore the profiles of cannabinoids, differ in different parts of such blocks due to different exposure to light and heat (cannabis resin is sensitive to heat and light during storage).

CBN and Δ^8 -THC have recently received increasing attention: Δ^8 -THC, which is a secondary component naturally occurring in the *Cannabis* plant, has been found as a major component in vaping liquids, chewing gum and tinctures.

In addition to Δ^8 -THC, THC isomers such as delta-6a- and delta-10a-tetrahydrocannabinol have been found in vaping liquids³⁴.

For routine analysis (identification and quantification) of cannabis samples and products containing it, it is important to use representative material. General aspects of representative sampling of narcotic substances for analysis are presented in the European Network of Forensic Institutes (ENFSI) Narcotics Working Group Guidelines on Sampling of Illicit Drugs for Quantitative Analysis.

It is important to maintain the best storage conditions for the herb, including a dark place at -20 °C, as THC at this stage

34 European Drug Report 2023 URL: https://www.emcdda.europa.eu/index_en (date accessed: 25.09.2023).

is still sensitive to air and UV (light) that can cause THC to oxidize to CBN. Fresh plant material should be stored in paper bags, as polymer packaging can cause decomposition and the appearance of mold due to the high moisture content.

Samples must be dried. There are different approaches to drying *Cannabis* plants, for example, at temperatures below 70 °C to constant weight and a moisture content of 8% to 13%³⁵, or at 40 °C in an oven for 12 hours³⁶. The dried material has a heterogeneous composition: it should be crushed. Grinding helps to release the oily resin containing cannabinoids, terpenes and other secondary plant metabolites, increases the surface area and increases the extraction efficiency³⁷.

Homogenization of plant cannabis is not required for qualitative chromatographic analysis when using plant parts with the highest THC levels. Drying cannabis resin is not necessary. However, due to the nature of the matrix, the grinding process is complicated, and freezing the samples can facilitate grinding with a mortar and pestle³⁸.

Objects in the form of food, beverages, or supplements require preparation

for a specific analytical method before analytical testing. For research on of liquid samples containing cannabinoids, they are mixed with a selected solvent, homogenized and (if necessary) decarboxylated³⁹. This method of sample preparation is simple and straightforward, but can lead to overloading of the analyzer and unreliable results.

The extraction procedure is an important step in the preparation of samples containing cannabis. Extraction of samples should be simple, selective and reproducible⁴⁰. Depending on the lipophilicity of the extracted cannabis components, solvents from polar to non-polar are used⁴¹. Non-polar solvents (hexane, petroleum ether) extract neutral cannabinoids well, but acidic cannabinoids (for example, THCA) poorly. Therefore, the extracts obtained in this way do not satisfy the requirements of quantitative THCA analysis the sum of THC and THCA. To extract acidic cannabinoids, polar solvents are used (isopropyl alcohol, ethanol, methanol, mixtures of methanol with chloroform and acetonitrile)⁴².

Common methods are liquid-liquid extraction, which is used to extract

- 35 Recommended methods for the identification and analysis of Cannabis and Cannabis products / United Nations Office on Drugs and Crime. March 2022. 82 p. URL: <https://www.unodc.org/unodc/en/scientists/recommended-methods-for-the-identification-and-analysis-of-cannabis-and-cannabis-products.html> (date accessed: 13.10.2023).
- 36 Slosse A., Van Durme F., Samyn N., Mangelings D., Vander Heyden Yv. Op. cit. DOI: 10.3390/molecules26216643 (date accessed: 10.10.2023).
- 37 Citti C., Russo F., Sgrò S., Gallo A., Zanutto A., Forni F., Vandelli M. A., Laganà A., Montone C. M., Gigli G., Cannazza G. Op. cit. DOI: 10.1007/s00216-020-02554-3 (date accessed: 12.10.2023).
- 38 Recommended methods for the identification and analysis URL: <https://www.unodc.org/unodc/en/scientists/recommended-methods-for-the-identification-and-analysis-of-cannabis-and-cannabis-products.html> (date accessed: 13.10.2023).
- 39 Borges G. R., Birk L., Scheid C., Morés L., Carasek E., Kitamura R. O. S., Roveri F. L. et al. Op. cit. DOI: 10.1007/s11419-020-00522-1 (date accessed: 13.10.2023).
- 40 Micalizzi G., Vento F., Alibrando F., Donnarumma D., Dugo P., Mondello L. Op. cit. DOI: 10.1016/j.chroma.2020.461864 (date accessed: 13.10.2023).
- 41 Rovetto L. J., Aieta N. V. Op. cit. DOI: 10.1016/j.supflu.2017.03.014 (date accessed: 13.10.2023).
- 42 Citti C., Russo F., Sgrò S., Gallo A., Zanutto A., Forni F., Vandelli M. A., Laganà A., Montone C. M., Gigli G., Cannazza G. Op. cit. DOI: 10.1007/s00216-020-02554-3 (date accessed: 13.10.2023).

bioactive substances from oils or other liquids containing CBD, and solid-liquid extraction, where an organic solvent is added to the plant material⁴³.

In addition to the solvent type, total cannabinoid yield is affected by the number of consecutive extractions, particle size, and temperature. Extraction at elevated temperatures causes the decarboxylation of cannabinoid acids to neutral compounds, which distorts the results for each cannabinoid present, so extraction methods using ultrasound, microwave radiation, pressurized liquid extraction and supercritical liquid extraction are recommended⁴⁴.

The choice of appropriate method for research on cannabis and products containing it depends on the goals of the analysis, the characteristics of the objects and the analytical requirements (qualitative and/or quantitative data, determination of low levels of Δ^9 -THC, differentiation of Δ^9 -THC isomers, detection of other cannabinoids present in the sample).

Thin-layer chromatography is often used for the initial qualitative screening of cannabinoids: it is a simple and affordable method for pre-screening for the presence of acidic and neutral cannabinoids.

GC is a rapid method with excellent resolution properties used for the analysis of cannabinoids in plant materials and biological matrices. However, due to the thermolability of acidic forms of phytocannabinoids, this method does not work for the identification of cannabinoid acids (THCA and CBDA), since their

decarboxylation occurs in the high-temperature injector of gas chromatograph.

In default of specific legal requirements, it is established practice to determine the total THC content, as this best reflects the pharmacological activity of the material, but even then, elevated temperatures may lead to THC decomposition (to CBN). For non-smoking products containing THC, THC and THCA should be identified and quantified separately. THC, like cannabis, unlike THCA, is subject to international control. Total THC findings are common practice when the material is intended for smoking, as this process converts THCA to THC. In test materials that are not heated during use, THC does not convert to THC (e.g. in foodstuffs) and should therefore be identified and described separately.

In order to preserve the acid structure and evaluate all cannabis components separately, derivatization is carried out before starting the research, which helps to obtain a more detailed profile of cannabinoids (although this procedure lengthens sample preparation and increases analysis cost). There can be difficulty in achieving complete derivatization, leading to inaccurate results due to the possibility of thermal degradation of cannabinoids in the injection port and column.

Despite the above issues, GC method remains useful for the analysis of cannabinoids. The most common detectors for GC analysis of cannabinoids are mass spectrometric (MS) and flame ionization (FID) detectors. The gold standard for identification is the GC-MS method, which

43 Deidda R., Dispas A., De Bleye Ch., Hubert Ph., Ziemons É. Critical review on recent trends in cannabinoid determination on cannabis herbal samples: From chromatographic to vibrational spectroscopic techniques. *Analytica Chimica Acta*. 2021. May 29:1209:339184. DOI: 10.1016/j.aca.2021.339184 (date accessed: 10.10.2023); Valizadehderakhshan M., Shahbazi A., Kazem-Rostami M., Todd M. S., Bhowmik A., Wang L. Extraction of Cannabinoids from *Cannabis sativa* L. (Hemp) — Review. *Agriculture*. 2021. Vol. 11. Is. 5. Art. 384. DOI: 10.3390/agriculture11050384 (date accessed: 11.10.2023).

44 Delgado-Povedano M. M., Sánchez-Carnerero Callado C., Priego-Capote F., Ferreira-Vera C. Op. cit. DOI: 10.1016/j.talanta.2019.120384 (date accessed: 09.10.2023).

uses electron ionization, which provides a high level of fragmentation of compounds together with the use of commercial and proprietary libraries for the qualification of cannabis products. There is no such possibility in GC-FID ⁴⁵, since the identification of substances depends on the retention time, and reference standards are used to identify components. At the same time, GC-FID offers a simple and relatively economical detection method with high resolution and a wider linear dynamic range, which ensures accurate quantification of cannabinoids ⁴⁶.

For accurate identification and quantification of the most common cannabinoids (Δ^9 -THC, Δ^8 -THC, CBD, CBC, cannabicyclol and their acid precursors that have the same molecular weight and identical mass fragments) during testing using mass spectrometric detectors, it is necessary to carefully choose an initial chromatographic separation method combined with sensitive detection methods.

Liquid chromatography (hereinafter referred to as LC) is an advanced method for separating complex cannabinoid samples. The main methods used for this are HPLC and ultra-efficient LC.

Advantages of LC compared to GC: reduced separation time and the ability to analyze all cannabinoids directly, including acid precursors, bypassing the derivatization process. The use of this method is not accompanied by heating of the samples, therefore decarboxylation of natural acids does not occur. This ensures the preservation of the authentic composition and allows detection of acids and their corresponding neutral forms, which contributes to a more complete profile ⁴⁷.

Diode array detectors and UV detectors are often used in conjunction with HPLC to quantify cannabinoids in complex extracts of Cannabis plants, simple and relatively inexpensive methods that provide accurate results. Diode array detectors have the advantage of simultaneously measuring a wide range of wavelengths (compared to UV scanning, which uses one fixed wavelength per cycle). Published HPLC analytical methods are fully ⁴⁸ or partially ⁴⁹ validated for various matrices ⁵⁰ and meet the requirements of the international standard ISO/IEC 17025 ⁵¹, that stipulates general requirements for testing and calibration laboratories. However, the authors note different values of detection

45 Slosse A., Van Durme F., Samyn N., Mangelings D., Vander Heyden Yv. Op. cit. DOI: [10.3390/molecules26216643](https://doi.org/10.3390/molecules26216643) (date accessed: 09.10.2023).

46 Stefkov G., Cvetkovikj Karanfilova I., Stoilkovska Gjorgievska V., Trajkovska A., Geskovski N., Karapandzova M., Kulevanova S. Op. cit. DOI: [10.3390/molecules27030975](https://doi.org/10.3390/molecules27030975) (date accessed: 12.10.2023).

47 Micalizzi G., Vento F., Alibrando F., Donnarumma D., Dugo P., Mondello L. Op. cit. DOI: [10.1016/j.chroma.2020.461864](https://doi.org/10.1016/j.chroma.2020.461864) (date accessed: 11.10.2023).

48 Mudge E. M., Murch S. J., Brown P. N. Op. cit. DOI: [10.1007/s00216-017-0256-3](https://doi.org/10.1007/s00216-017-0256-3) (date accessed: 13.10.2023).

49 Brighenti V., Pellati F., Steinbach M., Maran D., Benvenuti S. Op. cit. DOI: [10.1016/j.jpba.2017.05.049](https://doi.org/10.1016/j.jpba.2017.05.049) (date accessed: 13.10.2023).

50 Deville M., Dubois N., Denooz R., Charlier C. Op. cit. DOI: [10.1016/j.forsciint.2020.110234](https://doi.org/10.1016/j.forsciint.2020.110234) (date accessed: 13.10.2023).

51 ДСТУ EN ISO/IEC 17025:2019 Загальні вимоги до компетентності випробувальних та калібрувальних лабораторій (EN ISO/IEC 17025:2017, IDT; ISO/IEC 17025:2017, IDT) : затв. наказом ДП «УкрНДНЦ» від 23.12.2019 р. № 483 [Чинний з 01.01.2021]. URL: https://online.budstandart.com/ua/catalog/doc-page.html?id_doc=88724 (date accessed: 12.10.2023).

levels, quantification, linear range, and repeatability due to matrix, instrument, and detector design properties.

Lack of selectivity of diode-array detectors when analyzing complex matrices of cannabinoid extracts, where other cannabinoid-absorbing compounds at the detection wavelength may co-elute with the same retention time and distort analytical results, has prompted the scientific community to investigate more sensitive and specific MS detectors.

LC-MS is the preferred method for cannabinoid analysis using ionization modes (electrospray ionization or atmospheric pressure chemical ionization). Cannabinoids can be analyzed in any type of mass detector because they contain ionized hydroxyl and carboxyl groups. Most of these mass detectors and their combined systems have been successfully used to determine cannabinoids in cannabis plant material⁵².

A time-of-flight mass detector (alone or in combination with a quadrupole) is used to identify and quantify cannabinoid compounds in complex plant mixtures and matrices: such as food products containing cannabis (e.g. cannabis chocolate)⁵³.

Because the mass-to-charge ratio of cannabinoids and the nature of fragmentation are similar, experts use a dual approach to their quantification: chromatographic separation using a diode detector combined with quadrupole

quantitative analysis. Two separate LC-MS instruments can be used in research to effectively identify and quantify all cannabinoids in their extracts.

Triple quadrupole mass detector is particularly useful for the quantification of compounds with very low cannabinoid concentrations (e.g. hemp seed extracts and human body fluids) in positive ionization mode⁵⁴.

Ion trap mass detectors (such as the *Orbitrap*) are often combined with a quadrupole mass detector to form a *QTrap*. Detectors of this type perform multi-stage mass spectroscopic analysis with high resolution and selectivity. Orbitrap type mass detectors, as well as LC with triple quadrupole mass spectrometer (*LC-QqQ*), are used to study products with low cannabinoid content (food and beverages)⁵⁵.

In order to meet the high demand for the analysis of cannabis and products containing it, today special analytical tools are being developed to test such samples. For example, an HPLC analyzer from Shimazu is already available, designed exclusively for the quantification of cannabinoid content, which comes with a column, mobile phase and standard material and does not require laborious method development.

High-resolution mass spectrometry with direct real-time analysis (*DART-HRMS*) is used to screen products

52 Citti C., Russo F., Sgrò S., Gallo A., Zanutto A., Forni F., Vandelli M. A., Laganà A., Montone C. M., Gigli G., Cannazza G. Op. cit. DOI: [10.1007/s00216-020-02554-3](https://doi.org/10.1007/s00216-020-02554-3) (date accessed: 12.10.2023).

53 McRae G., Melanson J. E. Quantitative Determination and Validation of 17 Cannabinoids in Cannabis and Hemp Using Liquid Chromatography-Tandem Mass Spectrometry. *Analytical and Bioanalytical Chemistry*. 2020. Vol. 412. No. 27. Pp. 7381–7393. DOI: [10.1007/s00216-020-02862-8](https://doi.org/10.1007/s00216-020-02862-8) (date accessed: 12.10.2023).

54 Chang Ch.-W., Tung Ch.-W., Tsai Ch.-Ch., Wu Yu-T., Hsu M.-Ch. Op. cit. DOI: [10.1002/dta.2062](https://doi.org/10.1002/dta.2062) (date accessed: 29.09.2023).

55 Aizpurua-Olaizola O., Omar J., Navarro P., Olivares M., Etxebarria N., Usobiaga A. Identification and Quantification of Cannabinoids in *Cannabis Sativa* L. Plants by High Performance Liquid Chromatography-Mass Spectrometry. *Analytical and Bioanalytical Chemistry*. 2014. Vol. 406. Pp. 7549–7560. DOI: [10.1007/s00216-014-8177-x](https://doi.org/10.1007/s00216-014-8177-x) (date accessed: 11.10.2023).

containing cannabis (eg., leaves, stems, roots, powders, tinctures, capsules, and other plant products) for forensic purposes. This method makes it possible to quickly identify the required substance in complex matrices without pre-treatment of samples ⁵⁶.

The NMR method is a powerful tool for the analysis of chemical compounds, including cannabinoids. In forensic laboratories, the NMR method is used to identify and quantify cannabinoids in samples of narcotic drugs and psychotropic substances. NMR is based on the reaction of nuclei with a magnetic field and measures the emission of electromagnetic signals that provide information about the structure and amount of substances in the sample. Derivatization is a necessary step in the study of some samples to obtain reliable analysis results, especially for cannabidiol acids, which acquire a neutral form during decarboxylation. Direct measurement is possible for cannabis oils. One of the main advantages of the NMR method is that its use does not require the use of standard samples for calibration. This method makes it possible to quickly and reliably determine the composition of complex mixtures by measuring the interactions of nuclei with a magnetic field, which is especially important for the study of complex substances that contain many different compounds and in which it is difficult to determine the

standard concentrations of each individual component.

In recent years, methods of vibrational spectroscopy, in particular infrared and Raman, have been actively used to analyze cannabis. NIR method is considered the most common in the spectral range of infrared spectroscopy. The main advantages of these methods are ease of use, speed of measurements, as well as non-invasive and non-destructive analysis of plant material without the need for pre-treatment of the sample ⁵⁷.

The availability of portable devices makes it possible to conduct testing outside the laboratory ⁵⁸. Despite the mentioned advantages, it is worth noting the low sensitivity of this method compared to LC and GC. The interpretation of such spectra requires a multidimensional analysis of the obtained data due to a significant amount of information ⁵⁹. It is worth noting that the results of Raman spectroscopy can be affected by molecules that cause fluorescence (for example, chlorophyll) ⁶⁰.

Analytical methods provide a large and complex volume of data that requires multidimensional analysis to obtain the necessary information. These data can be processed to select optimal measurement procedures, explore patterns, or predict certain properties. Chemometrics methods are used to obtain the most valuable information. Recently, for processing complex matrices (as in the case of

56 Appley M. G., Chambers M. I., Musah R. A. Quantification of Hordenine in a Complex Plant Matrix by Direct Analysis in Real Time-High-Resolution Mass Spectrometry: Application to the "Plant of Concern" *Sceletium Tortuosum*. *Drug Testing and Analysis*. 2021. Vol. 14. Is. 4. Pp. 604–612. DOI: [10.1002/dta.3193](https://doi.org/10.1002/dta.3193) (date accessed: 07.10.2023).

57 Deidda R., Dispas A., De Bleye Ch., Hubert Ph., Ziemons É. Op. cit. DOI: [10.1016/j.aca.2021.339184](https://doi.org/10.1016/j.aca.2021.339184) (date accessed: 12.10.2023).

58 Sanchez L., Filter C., Baltensperger D., Kurouski D. Op. cit. DOI: [10.1039/C9RA08225E](https://doi.org/10.1039/C9RA08225E) (date accessed: 11.10.2023).

59 Citti C., Russo F., Sgrò S., Gallo A., Zanutto A., Forni F., Vandelli M. A., Laganà A., Montone C. M., Gigli G., Cannazza G. Op. cit. DOI: [10.1007/s00216-020-02554-3](https://doi.org/10.1007/s00216-020-02554-3) (date accessed: 12.10.2023).

60 Deidda R., Dispas A., De Bleye Ch., Hubert Ph., Ziemons É. Op. cit. DOI: [10.1016/j.aca.2021.339184](https://doi.org/10.1016/j.aca.2021.339184) (date accessed: 07.10.2023).

Cannabis), chemometric tools are used, which make it possible to obtain necessary information from sample data⁶¹.

Given that the results provided by forensic laboratories are part of law enforcement investigations and can be used as evidence in court, it is important to provide reliable and reproducible data. To confirm the technical competence of forensic laboratories, accredited ISO/IEC 17025 methods should be used. The main parameter is the measurement uncertainty, especially for the quantitative determination of Δ^9 -THC and other prohibited cannabinoids to check their legality (0.08% is the maximum permissible rate of THC in vegetable raw materials in Ukraine). This parameter should be kept in mind as it reflects the variance of the results and has a significant impact on the interpretation of the results under applicable law. Without considering this parameter, there is a risk of misinterpretation and wrongful prosecution⁶².

Analytical standards are a cornerstone of quantitative cannabinoid analysis. Today, there are several manufacturers and distributors of single-component and multi-component analytical standards for cannabinoids: *Cayman*, *Cerilliant*, *Accu Standard*, *Merck*, *Restek* (USA), *LGC Standards*, *Reagecon Diagnostics* (EU). The most available is an analytical standard that contains 10 different cannabinoid compounds. However, in order to obtain a standard material, experts must pay

attention to the legislation that regulates the purchase and import of such materials.

Morphological and chemical analytical methods for the study of cannabis and products containing it are usually sufficient for its identification. However, in situations where the sample does not have distinct morphological characteristics of cannabis plant material or contains low levels of THC (for example, if it is highly fragmented material, young seedlings, seeds, roots or bare branches), the identification of cannabis based on DNA analysis is more efficient and effective for species-level identification⁶³.

Conclusions

Highly professional forensic examination of narcotic drugs, psychotropic substances and precursors plays an important role for judicial system in particular and society as a whole. Most current research focuses on the three or four major cannabinoids and their precursor acids. With the expansion of knowledge about other cannabinoids, the demand for their research as additives to many consumer goods is likely to increase, which necessitates the development of identification protocols and quantification methods.

There are at least 16 to 20 different cannabinoids that require immediate development of procedures for their extraction and analysis due to the fact that interest in them as products for consumption is growing day by day.

61 Duchateau C., Kauffmann J.-M., Canfyn M., Stévigny C., De Braekeleer K., Deconinck E. Op. cit. Pp. 1309—1319. DOI: [10.1002/dta.2865](https://doi.org/10.1002/dta.2865) (date accessed: 13.10.2023).

62 Sgrò S., Lavezzi B., Caprari C., Polito M., D'Elia M., Lago G., Furlan G., Girotti S., Ferri E. N. Delta9-THC Determination by the EU Official Method: Evaluation of Measurement Uncertainty and Compliance Assessment of Hemp Samples. *Analytical and Bioanalytical Chemistry*. 2021. Vol. 413. No. 13. Pp. 3399—3410. DOI: [10.1007/s00216-021-03283-x](https://doi.org/10.1007/s00216-021-03283-x) (date accessed: 13.10.2023).

63 CBOL Plant Working Group, Hollingsworth P. M., Forrest L. L., Little D. P. A DNA Barcode for Land Plants. *Proceedings of the National Academy of Sciences USA*. 2009. Vol. 106. Is. 31. Pp. 12794—12797. DOI: [10.1073/pnas.0905845106](https://doi.org/10.1073/pnas.0905845106) (date accessed: 10.10.2023).

The present review of cannabis-containing object analysis methods shows that for the correct separation and identification of phytocannabinoids from the plant matrix and/or matrix of edible or other cannabis-derived products, various chromatographic methods offer different possibilities in terms of detection limits, linearity, reproducibility, and specificity. They depend on particular device parameters (type of detector, availability of ionization, capabilities of data collection and analysis software). Therefore, in order to choose the most appropriate analytical method, it is important to apply a balanced approach, which should be based on the volume of analysis and analytical capabilities of a particular laboratory.

While developing analysis procedures, it is necessary to take into account the storage conditions and the influence of various factors on composition of cannabis containing objects, as well as on the analytical research standards. This is especially important because cannabinoids by their nature can decompose or turn one into the other under the influence of light, heat, or oxidation.

With development of cannabinoid extract analysis, it is important to harmonize standardized research methods that will contribute to harmonization of testing methods and harmonization of analytical results.

Chemometrics is becoming an important and powerful forensic tool, especially when it comes to cannabis profiling or while working with spectroscopic data, where multivariate data analysis is commonly used.

Despite the rather complex modern approaches to cannabis research procedures and products containing it, they may not be needed for routine research. The choice of method of and decision on the need to apply additional methods

remains at discretion of forensic expert and depends on availability of appropriate laboratory equipment and legal specifics.

This list of research methods for cannabis and cannabis containing products is not exhaustive. Within one article, it is impossible to cover all the analytical methods for research on plant material and products based on it used in forensic research: we have focused only on the leading ones.

Аналіз канабісу та його продуктів у контексті судової експертизи

Ірина Кучинська

Легалізація вирощування рослин роду Cannabis із низьким умістом тетрагідроканабінолу й високим умістом канабідіолу набирає обертів через зростання попиту на ці продукти. У деяких країнах тестування канабісу та продуктів, що його містять, є юридичною вимогою: канабіс ідентифікують, оцінюють кількість у ньому тетрагідроканабінолу або канабідіолу та їхніх кислот-попередників. Сучасні дослідження потребують більш чутливих і надійних аналітичних методів для точної ідентифікації та кількісного визначення компонентів канабісу. Мета цієї статті — огляд представлених у наукових джерелах останніх досягнень щодо виокремлення й аналізу канабісу та продуктів, які його містять, у контексті судової експертизи. Методи дослідження містили аналіз інформації із цієї тематики за допомогою пошукових систем, зокрема Google, Google Scholar, Web of Science, PubMed і ScienceDirect. Пошукові запити враховували наукові, аналітичні та статистичні звіти в галузі судово-експертних досліджень. Оскільки судовий експерт має добре орієнтуватися в сучасних тенденціях аналізу заборонених речовин і посприяти своїй роботі останніми даними аналітичної та судово-криміналістичної літератури, така інформація

допоможе їм обирати методи проведення досліджень, зважаючи на фактичні ресурси й обладнання судово-криміналістичних лабораторій. Згідно з метою статті розглянуто переваги і недоліки наявних методів екстрагування й аналізу об'єктів, що містять канабіс, для ідентифікації, кількісного визначення, профілювання та оцінювання віку канабісу.

Ключові слова: канабіс; фітоканабіноїди; екстрагування; ідентифікація; кількісне визначення; газова хроматографія; рідинна хроматографія; метод ядерного магнітного резонансу; методи коливальної спектроскопії.

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Declaration of Competing Interest

Author declare no conflict of interest.

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