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CHEMICAL AND PHARMACEUTICAL RESEARCH OF CANNABINOIDS AS OBJECTS OF FORENSIC EXAMINATION

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Synthetic cannabinoids are a group of psychoactive compounds that mimic the effects of Δ9-tetrahydrocannabinol, the main psychoactive component of marijuana. Today, the most important task in forensic science is to establish the chemical structure of new psychoactive compounds that appear in illicit trafficking promptly in order to respond quickly and stop their distribution. Less important is the development of methodological support for expert activity, including analysis methods and reference data on the analytical characteristics of compounds.

The aim. *To develop stages of the forensic analysis of objects containing synthetic cannabinoids and propose methods for determining 5 new synthetic cannabinoids for forensic pharmaceutical purposes.*

Materials and methods. *The study was conducted as part of the identification of cannabinoids for forensic purposes at the National Scientific Centre "Bokarius Institute of Forensic Examination". As part of the study, 5 new synthetic cannabinoids were identified for forensic analysis using the following methods: infrared spectroscopy, thin-layer chromatography, and gas chromatography with a mass detector. The algorithm for the forensic analysis of cannabinoid derivatives was developed based on the requirements of Ukraine's current legislation.*

Results*. Spectral and chromatographic methods of determination of 5 new synthetic cannabinoids for forensic purposes were proposed, and during research and elaboration of the current legislation of Ukraine, an algorithm for forensic investigation of objects containing synthetic cannabinoids has been developed.*

Conclusions*. The stages of the forensic analysis of objects containing synthetic cannabinoids meet the requirements of the current legislation of Ukraine and the Ministry of Justice of Ukraine. The obtained data prove the high sensitivity and reproducibility of the methods and prove the possibility of their introduction into the practice of forensic examination*

Keywords*: synthetic cannabinoids, forensic analysis, spectral analysis, chromatography*

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1. Introduction

Today, synthetic cannabinoids are very widely available on the illicit market of psychoactive substances and pose a serious threat to society as they are abused to achieve euphoria [1, 2].

Cannabinoids are a group of more than 66 biologically active terpenophenolic compounds, derivatives of 2-substituted 5-amylresorcin, found in the cannabis plant (Cannabis sativa) [3] and its preparations, such as marijuana and hashish [4], as well as their synthetic analogues capable of binding to cannabinoid receptors [5].

One of the most important goals in understanding the properties of cannabis and its preparations has been to establish the structures of its main constituents (Fig. 1), such as Δ9-tetrahydrocannabinol (THC), its isomer D8-tetrahydrocannabinol, cannabinol and cannabidiol [6, 7].

As the distribution and abuse of narcotic drugs, including cannabis derivatives containing the natural cannabinoid tetrahydrocannabinol, is prohibited and is penalized by law, there is a certain interest for the drug business in the search for new types of narcotic drugs, so-called "designer drugs" – synthetic substances obtained by a certain modification of the chemical structure of already known drugs for the purpose of their further "legal" distribution [8]. Smoking mixtures, so-called "spice", purportedly consisting of exotic and medicinal herbs that, when used together, produce similar effects to cannabis herb, have been available in several European Union countries since 2004 [9]. The true reason for the psychoactive properties of the smoking mixtures, namely the presence of synthetic cannabinoids, mainly JWH-018 (Table 1), was identified only in 2008, primarily because of the lack of information on the analytical characteristics of these compounds [10].

Representing a long-standing legal alternative to cannabis preparations, synthetic cannabinoids have become popular for both consumers and drug dealers. As a result, in a historically short period of time, many synthetic cannabinoids have moved from objects of scientific research and pharmacological testing to legally prohibited drugs in many countries of the world. Nevertheless, the drug business is seriously searching for new types of psychoactive substances, often using the scientific pharmacological literature and offering consumers new compounds with modified structures compared with those already forbidden [11].

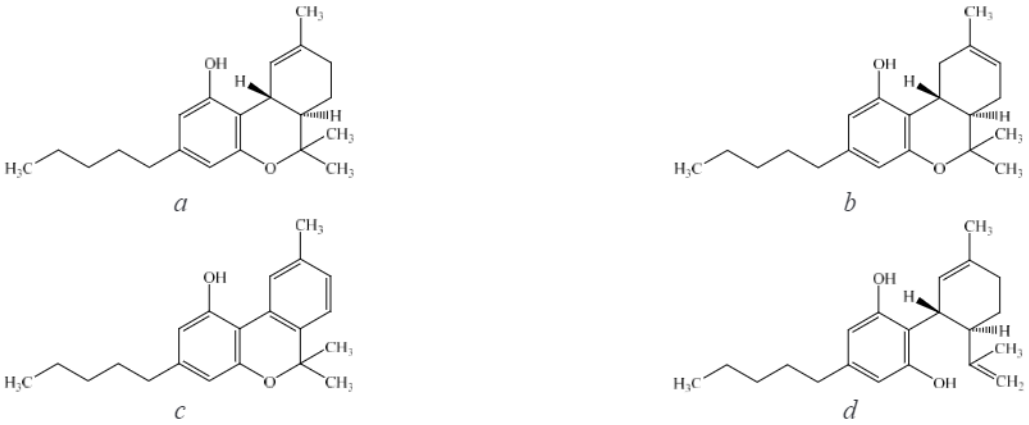


Fig. 1. Structural formulas of: *a* – THC; *b* – D8-tetrahydrocannabinol; *c* – cannabinol; *d* – cannabidiol

Thus, the identification of narcotic drugs remains one of the most pressing problems of modern analytical chemistry in the field of forensics [12]. Many Decrees of the Cabinet of Ministers of Ukraine between 2008 and 2021 included most synthetic cannabinoids in the lists of narcotic substances prohibited on the territory of Ukraine [13]. However, almost immediately after their inclusion in the relevant schedules of narcotic drugs, laboratories of expert institutions faced the problem of a lack of analytical methods and, for several synthetic cannabinoids, a lack of published analytical data to identify those compounds. The problem of providing information on the analytical characteristics of synthetic cannabinoids became particularly acute following the emergence of new types of compounds that regularly replaced illicit ones. In Ukraine, new types of cannabinoids began to appear, as a rule, earlier than in foreign countries and long before the first publications on their analytical characteristics [14].

At the same time, if the individual substance is unknown, i.e. its analytical characteristics and identifiers are not described, the establishment of the structure of the substance is one of the tasks of the speciality "organic chemistry".

In that connection, the most important task is, first and foremost, to establish the chemical structure of new psychoactive compounds appearing in illicit traffic, which is one of the most difficult problems in modern chemistry. Equally important is the development of methodological support for expert activities, including methods of analysis and reference data on the analytical characteristics of compounds [15]. Analytical identification - assignment of an object or its components to a specific individual substance, material, class of substances or materials [16].

Thus, the aim of this work is to determine the chemical structure and identify new synthetic cannabinoids, which most often appear in illicit traffic, register their analytical signals and create information support for qualitative chemical analysis of objects containing synthetic cannabinoids in the form of reference data of analytical characteristics of identified compounds and unified methodology for their determination.

2. Planning (methodology) of research

The methodological approach we proposed for qualitatively analysing objects containing synthetic cannabinoids is presented in Fig. 2.

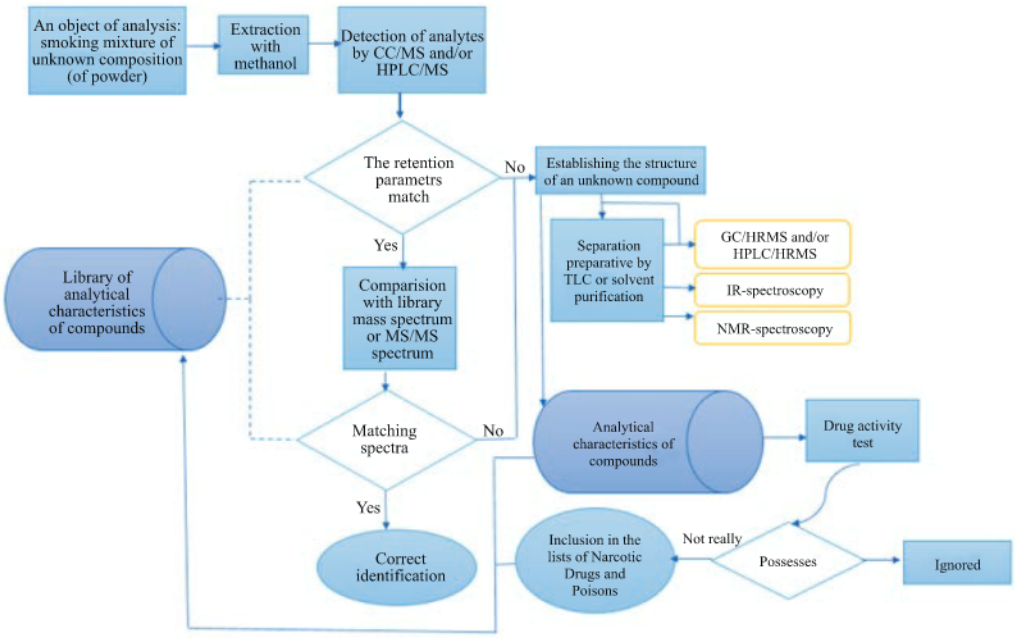


Fig. 2. Stages of the forensic analysis of objects containing synthetic cannabinoids

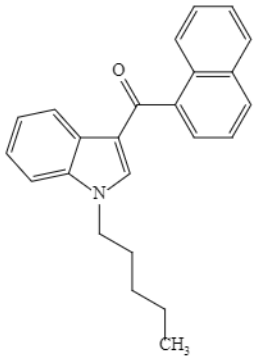
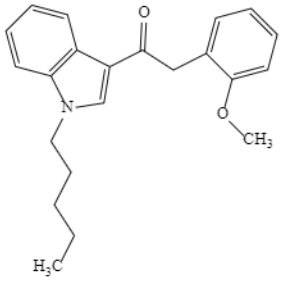
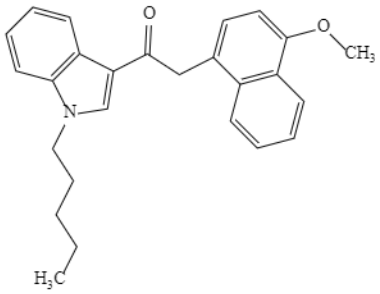
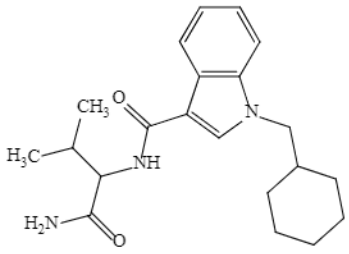
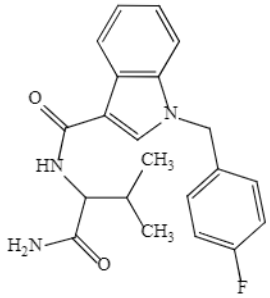
3. Materials and methods

The study was conducted from 2021 to 2023. Samples of synthetic narcotic drugs were selected for experimental studies and presented both as individual powdered microcrystalline substances and as smoking mixtures prepared for use in abuse. The samples were taken from the collection of the laboratory of the National Scientific Centre "Bokarius Institute of Forensic Examination" (Merck, Sigma-Aldrich). Preliminary control of homogeneity of objects for structural studies, including IR spectroscopy methods, was carried out using gas-liquid chromatography by mass spectrometric (GC/MS) detection and thin-layer chromatography.

The structural formulas of the synthetic cannabinoids studied, their chemical names, and brief conventional names are given in Table 1.

Table 1

Structural formulas and names of research objects

No.	Name	Structural formula	Chemical name (IUPAC)	M. w.
1	JWH-018		naphthalen-1-yl(1-pentyl-1H-indol-3-yl)methanone	341.45
2	JWH-250		2-(2-methoxyphenyl)-1-(1-pentyl-1H-indol-3-yl)ethanone	335.44
3	JWH-081		(4-Methoxynaphthalen-1-yl) (1-pentyl-1H-indol-3-yl) methanone	371.47
4	AB-CHMICA		N-(1-amino-3-methyl-1-oxobutan-2-yl)-1-(cyclohexylmethyl)-1H-indole-3-carboxamide	355.47
5	AB-FUBICA		N-(1-amino-3-methyl-1-oxobutan-2-yl)-1-(4-fluorobenzyl)-1H-indole-3-carboxamide	367.42

For analysis by chromatographic methods, solutions of the individual compounds under study were prepared by dissolving accurate suspensions in methanol followed by dilution to the required concentration. For this purpose, 1 ml of solvent (methanol) was added to 2 mg of the studied samples. When determining the components applied to the plant matrix, the obtained extract was ultrasonicated and filtered through a paper filter.

TLC was carried out on Silica gel 60 GF_{254} plate (Merck): silica gel G layer 0.25 mm thick containing an inert indicator fluorescing under the UV light with a wavelength of 254 nm. The dimensions of the plates were 20×10 cm. Before use, the plates were activated in a desiccator at 120 °C for 20 min. The study was carried out in the following systems:

A – n-hexane:diethylether (2:1);

B – toluene:diethylamine (9:1);

C – ethyl acetate:methylene chloride:methanol: concentrated ammonia solution (18.5:18:3:1).

After preparation of the system, the elution system was left in the TLC chamber for 10 min to saturate the mobile phase vapour before analysis. Reference solutions were prepared with a 0.5 mg/ml concentration in the appropriate solvent. Samples were applied to the TLC plate in separate spots (1 µl aliquots), reference solutions (2 µl) and solvent (2 µl, as a negative control sample). Detection of the results obtained was performed by:

a) UV light at 254 nm (dark spots on a green background are observed);

b) freshly prepared Fast Blue RR reagent (when the reagent is sprayed over the plate, classical or non-classical cannabinoids appear as orange-red spots);

c) iodine (synthetic cannabinoids appear as yellow spots;

d) iodoplatinate (Synthetic cannabinoids appear as green/yellow, white/pink or purple spots).

Analysis by absorption spectroscopy in the infrared region was carried out on a Thermo Fisher Scientific (USA) Nicolet 380 FTIR spectrometer. Absorption spectra were recorded using a Smart Perfomer with a ZnSe crystal. Parameters of the analysis: measurement area – 500–4000 cm^{-1}; resolution – 4; recording speed – 0.6329; amplification – 4; number of scans – 32.

Determination of compounds by GC/MS method was carried out in their methanol solutions with the content of the studied powdered sample about 1 mg/ml on a gas chromatograph "Shimadzu GCMS" with a quadrupole mass-selective detector "Shimadzu QP2020" (Shimadzu, Japan).

HP-5 quartz capillary chromatographic column was used for chromatographic separation of the compounds. The column length was 30.0 m, the column inner diameter was 0.25 mm, and the film thickness of the fixed liquid phase was 0.25 µm. The chromatograph evaporator temperature was 280 °C; the detector interface temperature was 290 °C. The column temperature programming was carried out in the following mode:

1) holding at 100 °C for 2 min;

2) temperature rise from 100 to 290 °C at a rate of 20 °C per minute;

3) holding at 290 °C for 25 minutes.

The total analysis time was 36.5 minutes.

Helium was used as carrier gas, and the constant flow mode was 1.0 ml/min.

The sample solution of 1 µl was injected manually with a Shimadzu microsyringe with a working range of 0–10 µl and a division value of 0.2 µl.

Dosing of the sample solution was carried out with a flow division of 1:50. The detector was equipped with an electron ionization source, the energy value of ionizing electrons was chosen to be 70 eV. The ion source temperature is 230 °C; the quadrupole temperature is 150 °C. The mass spectra were scanned by the total ion current in the range of m/z 30–550.

Instrument setup, control and processing of the obtained results were performed using the software of the instrument "Shimadzu LabSolution" (Shimadzu).

4. Research results

The TLC method is widely used for the separation and detection of illicitly manufactured drugs. This low-budget and rapid method allows the choice of both stationary and mobile phases and is suitable for the examination of a wide range of substances, both as bases and as salts, from the most polar to non-polar compounds. Since the TLC plates are recyclable after analysis, there are no problems associated with contamination of the stationary phase with matrix compounds (e.g. fatty acid derivatives), which are often observed in HPLC columns.

The results of the *Rf* values of the proposed systems are presented in Table 2.

Table 2

Rf TLC values for selected synthetic cannabinoids using different elution systems

Compound	*Rf* value		
	System A	System B	System C
JWH-018	0.27	0.74	0.93
JWH-250	0.24	0.71	0.88
JWH-081	0.42	0.73	0.90
AB-CHMICA	–	0.90	–
AB-FUBICA	–	0.85	–

According to the data in Table 2, most of the studied compounds have satisfactory R_f values in the proposed solvent systems, but the most suitable for the identification of all the determined samples is the toluene-diethylamine 9:1 system.

For synthetic cannabinoids seized in powder form, qualitative infrared spectroscopic analysis is easier. Infrared spectroscopy can also be a useful tool for the identification of new substances [4].

The presence and structure of selected synthetic cannabinoids was determined by the characteristic absorption bands using IR spectroscopy: JWH-018 (Fig. 3), JWH-250 (Fig. 4), JWH-081 (Fig. 5), AB-FUBICA (Fig. 6), AB-CHMICA (Fig. 7).

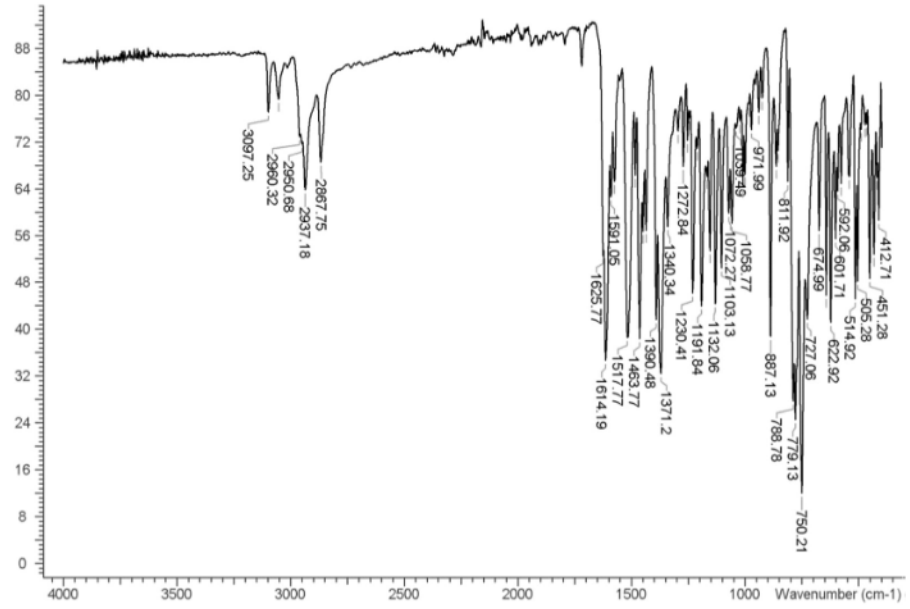


Fig. 3. IR spectrum of the investigated compound JWH-018

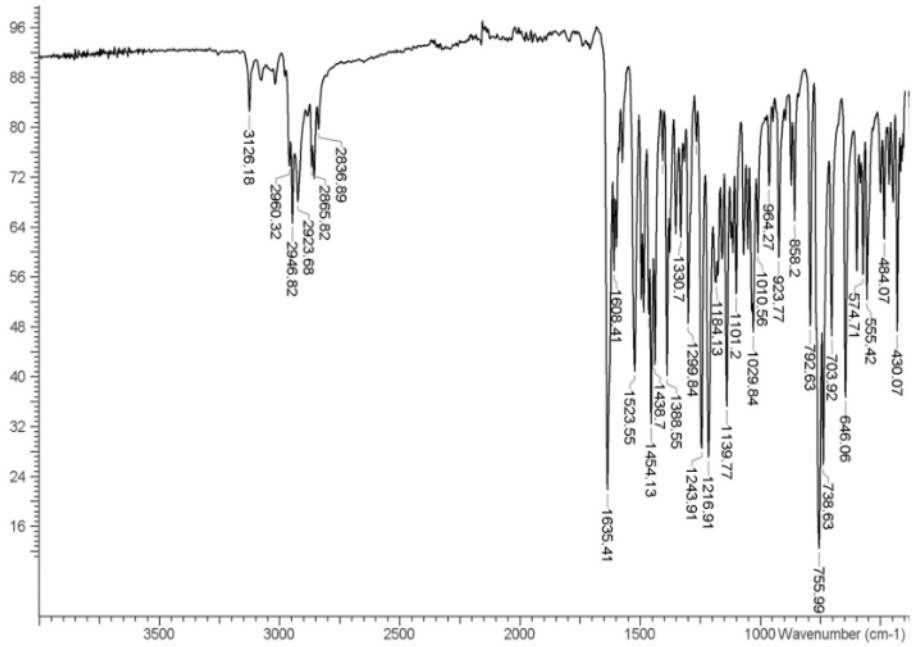


Fig. 4. IR spectrum of the investigated compound JWH-250

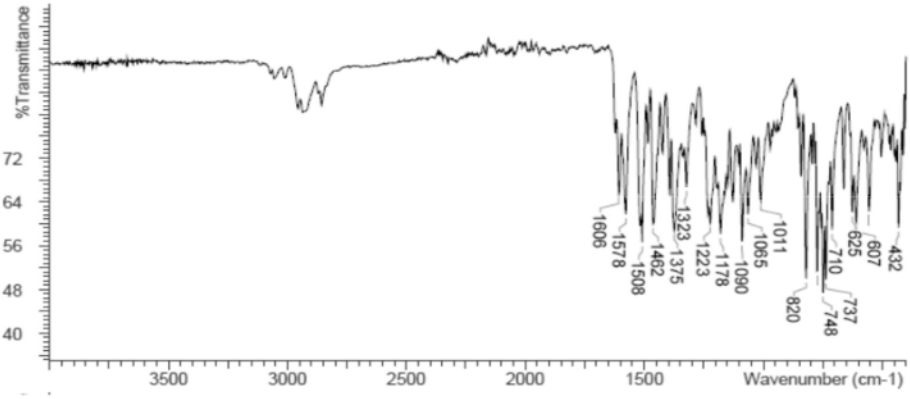


Fig. 5. IR spectrum of the investigated compound JWH-081

Gas chromatography-mass spectrometry is one of the most widely used methods for the identification of drug samples in forensics [17]. Being a hyphenated method, it combines the separation ability and sensitivity of

GC with the analytical specificity of a spectrometric method. It provides highly specific spectral data for individual compounds in a complex mixture [18].

The results of the conducted studies by gas chromatography with mass selective detection are given in Table 3.

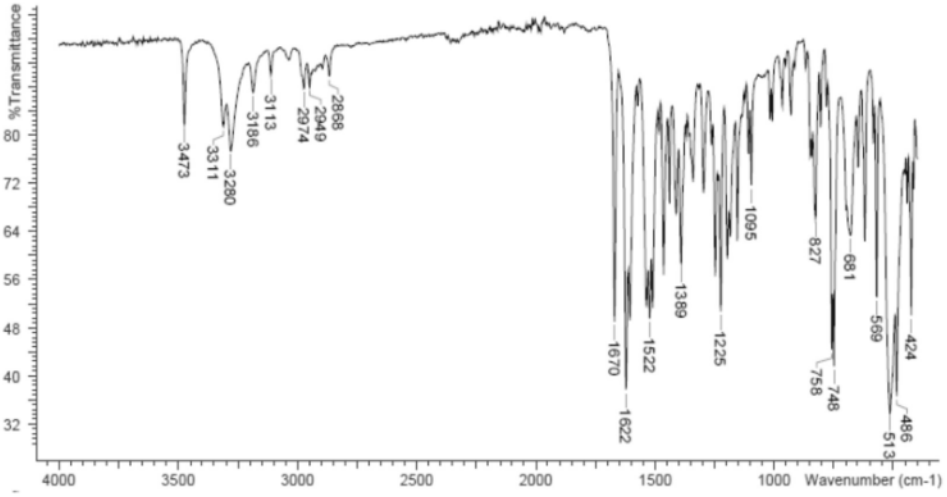


Fig. 6. IR spectrum of the investigated compound AB-FUBICA

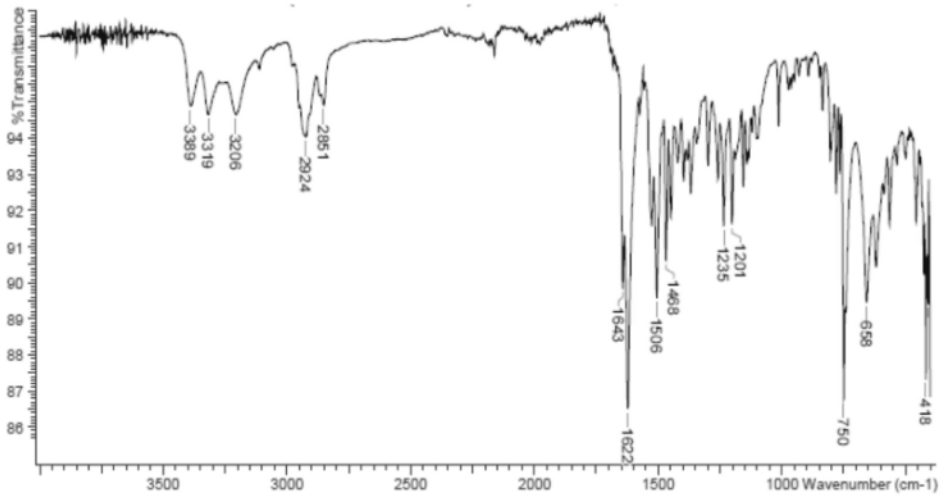


Fig. 7. IR spectrum of the investigated compound AB-CHMICA

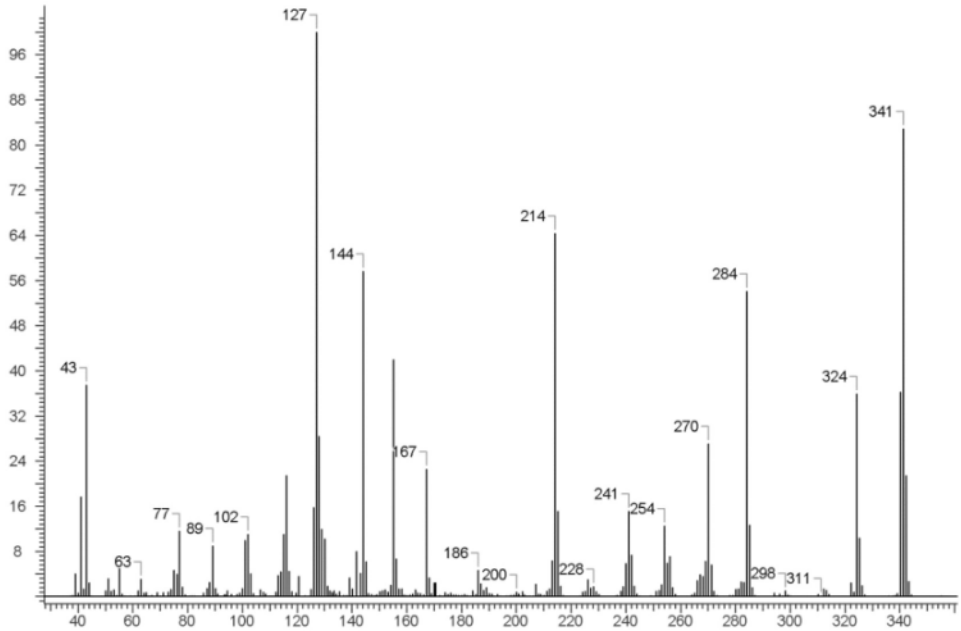


Fig. 8. Mass spectrum of the investigated substance JWH-018

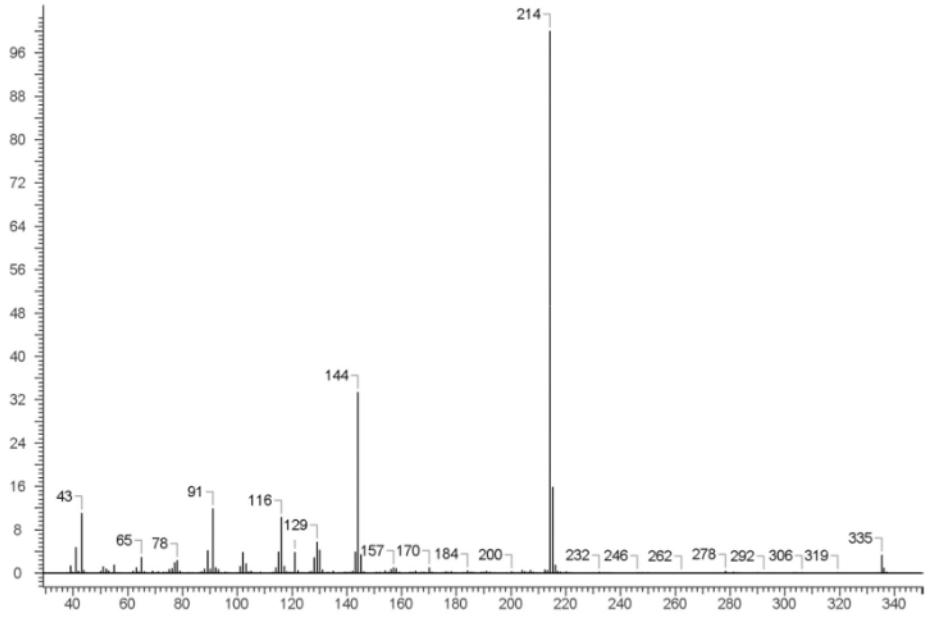


Fig. 9. Mass spectrum of the investigated substance JWH-250

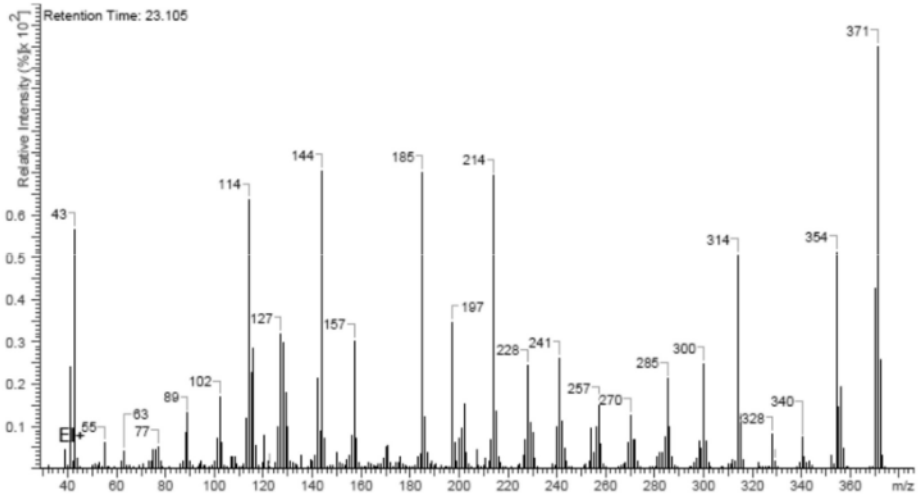


Fig. 10. Mass spectrum of the investigated substance JWH-081

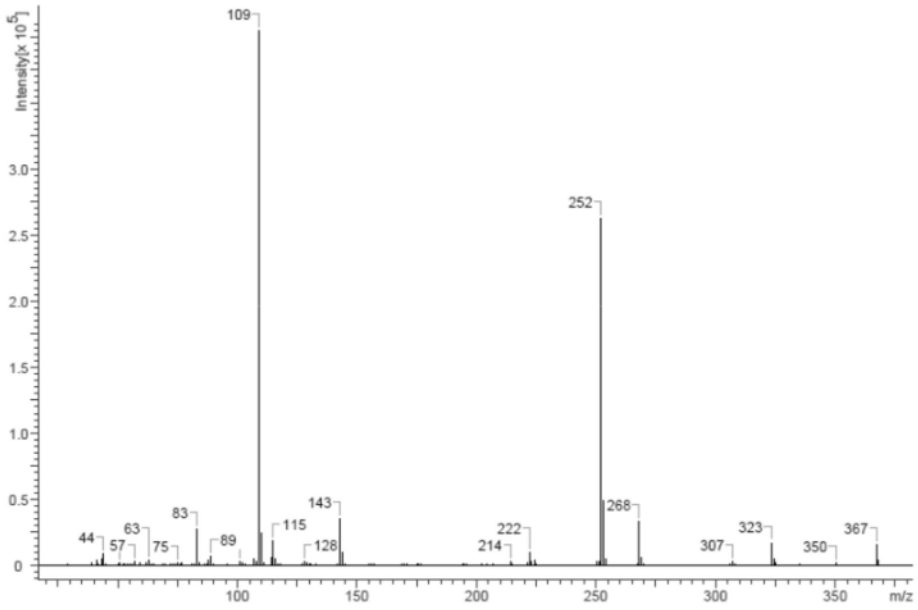


Fig. 11. Mass spectrum of the investigated substance AB-FUBICA

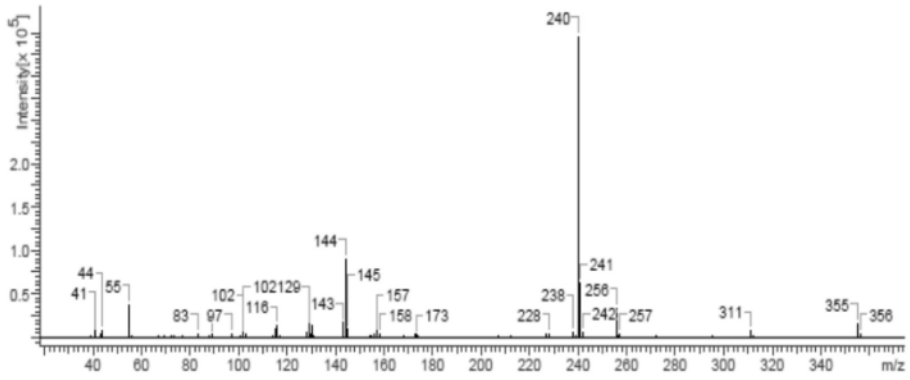


Fig. 12. Mass spectrum of the investigated substance AB-CHMICA

Table 3

Results of gas chromatography method with mass selective detection

Compound	Retention time	Characteristic m/z ions
JWH-018 (Fig. 8)	20.011	127, 144, 214, 284, 341
JWH-250 (Fig. 9)	18.249	144, 214, 146, 91, 41
JWH-081 (Fig. 10)	23.105	114, 144, 185, 214, 314, 354, 371
AB-FUBICA (Fig. 11)	23.196	83, 109, 115, 143, 252
AB-CHMICA (Fig. 12)	24.282	44, 55, 144, 240, 241

5. Discussion of research results

The qualitative analysis of narcotic drugs, including synthetic cannabinoids, is characterized not only by the fact that the composition of the analyzed object is unknown prior to analysis but also by the fact that it may include psychoactive compounds that either have no described analytical characteristics or are not described at all in the scientific literature, so-called designer drugs [19]. In the qualitative determination of unknown components of the samples analyzed, the most important thing is the availability of experimental and reference analytical data for the compounds to be identified. In this case, the reliability of identification can be expressed in the form of similarity indices of analytical data [20]. Such indicators can be chromatographic retention parameters, the similarity criterion for which is the evaluation of the difference between the obtained and reference values within a certain interval (search window). Another, more reliable indicator of identification is the mass spectrum and (or) MS/MS spectrum of the compound, the coincidence of any of which with reference data can be assessed both using probabilistic criteria in the course of an automatic library search according to the algorithms of the applied software and by visual assessment of the degree of coincidence of spectra using non-numerical expressions for the formulation of analysis results based on the personal experience of the mass spectrometer analyst [21]. In the case of high-resolution mass spectrometry, the measured values of the exact ion masses and the gross formulas calculated on their basis act as an additional indicator of identification, with the reliability of identification being determined by the measurement error of the instrument. The combined use of chromatographic and mass spectrometric methods allows unambiguous identification of synthetic cannabinoids, as the combination of these methods is characterized by a large number of identification points [22].

Our studies on the determination of the structures of synthetic cannabinoids have provided a reference set of analytical characteristics of compounds in the form of chromatographic and mass spectrometric data, allowing for reliable identification of synthetic cannabinoids in the analyzed samples.

The proposed methods are characterized by low detection limits for cannabinoids and depend on the chosen analysis methodology and equipment used.

It has been experimentally proven that the limit of detection of the studied cannabinoids by TLC using the toluene – diethylamine 9:1 system and the proposed developers is 0.015 μg/ml and can be used for forensic analysis in the presence of witness samples or by Rf value, as the method is accurate, reliable and reproducible.

The proposed and used GC-MS method is characterized by simple sample preparation, relatively short analysis time, and the ability to detect the substances without the use of standard samples due to the presence of electronic libraries of mass spectra. The detection limit is 30 ng of the analyzed sample.

The combination of signals of characteristic fragments in the mass spectrum and retention time in the column provides a fairly high selectivity of identification of analyzed compounds by GC-MS and proves that the method can be used to detect and quantify cannabinoid samples during forensic examination.

Study limitations. The proposed methods for the determination of synthetic cannabinoids in objects of forensic analysis can be used taking into account the modern equipment of laboratories.

Prospects for further research. The proposed methods for determining synthetic cannabinoids will be submitted for consideration for further us in forensic examination.

6. Conclusions

Classification and general characterization of narcotic drugs – cannabinoids are considered. The conditions for the determination of synthetic narcotic drugs by thin-layer chromatography were proposed. It was found that the investigated substances have satisfactory R_f values in the proposed solvent systems, but the most suitable for the identification of all the studied compounds is the toluene-diethylamine 9:1 system. Methods of identification of synthetic narcotic drugs as objects of forensic examination using modern instrumental methods – IR spectroscopy and gas chromatography with mass spectrometric detection are developed for the stage of confirmatory studies. A scheme for analyzing forensic objects suspected of containing synthetic cannabinoids is proposed.

Conflict of interests

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this article.

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Data availability

Data will be made available on reasonable request.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

References

1. Auwärter, V., de Morais, J., Gallegos, A., Evans-Brown, M., Christie, R., Jorge, R., Sedefov, R. (2021). Synthetic cannabinoids in Europe – a review. European Monitoring Centre for Drugs and Drug Addiction. Lisbon, 70.

2. Soria, M. L. (2018). New psychoactive substances: Popular and dangerous. Spanish Journal of Legal Medicine, 44 (2), 64–72. https://doi.org/10.1016/j.remle.2017.11.005

3. Pertwee, R. G. (2004). Pharmacological and therapeutic targets for Δ9 tetrahydrocannabinol and cannabidiol. Euphytica, 140 (1-2), 73–82. https://doi.org/10.1007/s10681-004-4756-9

4. Recommended methods for the identification and analysis of cannabis and cannabis products (2022). Vienna: United Nations, United Nations Office on Drugs and Crime (UNODC), 72.

5. Synthetic cannabinoids in herbal products (2011). Vienna: United Nations, 26.

6. Atakan, Z. (2012). Cannabis, a complex plant: different compounds and different effects on individuals. Therapeutic Advances in Psychopharmacology, 2 (6), 241–254. https://doi.org/10.1177/2045125312457586

7. Simon, T. A., Simon, J. H., Heaning, E. G., Gomez-Caminero, A., Marcu, J. P. (2023). Delta-8, a Cannabis-Derived Tetrahydrocannabinol Isomer: Evaluating Case Report Data in the Food and Drug Administration Adverse Event Reporting System (FAERS) Database. Drug, Healthcare and Patient Safety, 15, 25–38. https://doi.org/10.2147/dhps.s391857

8. The challenge of new psychoactive substances (2013). United Nations Office on Drugs and Crime, 122.

9. Ujváry, I. (2014). Psychoactive natural products: overview of recent developments. Annali dell'Istituto Superiore di Sanità, 50 (1), 12–27. https://doi.org/10.4415/ANN_14_01_04

10. EMCDDA 2009 Thematic paper Understanding the 'Spice' phenomenon (2009). Luxembourg: Office for Official Publications of the European Communities, 37.

11. Tai, S., Fantegrossi, W. E. (2016). Pharmacological and Toxicological Effects of Synthetic Cannabinoids and Their Metabolites. Current Topics in Behavioral Neurosciences, 249–262. https://doi.org/10.1007/7854_2016_60

12. Tai, S., Fantegrossi, W. E. (2014). Synthetic Cannabinoids: Pharmacology, Behavioral Effects, and Abuse Potential. Current Addiction Reports, 1 (2), 129–136. https://doi.org/10.1007/s40429-014-0014-y

13. Zakonodavstvo Ukrainy. Verkhovna rada Ukrainy. Available at: https://zakon.rada.gov.ua/laws/main/index

14. Navarro-Tapia, E., Codina, J., Villanueva-Blasco, V. J., García-Algar, Ó., Andreu-Fernández, V. (2022). Detection of the Synthetic Cannabinoids AB-CHMINACA, ADB-CHMINACA, MDMB-CHMICA, and 5F-MDMB-PINACA in Biological Matrices: A Systematic Review. Biology, 11 (5), 796. https://doi.org/10.3390/biology11050796

15. Muscat, R., Mheen, D., Barendregt, C. (2010). Towards an integrated policy on psychoactive substances: a theoretical and empirical analysis. Council of Europe Publishing, 75.

16. Gehl R., Plecas D. (2016). Introduction to Criminal Investigation: Processes, Practices and Thinking. New Westminster: Justice Institute of British Columbia, 191.

17. Mogollón, N. G. S., Quiroz-Moreno, C. D., Prata, P. S., de Almeida, J. R., Cevallos, A. S., Torres-Guiérrez, R., Augusto, F. (2018). New Advances in Toxicological Forensic Analysis Using Mass Spectrometry Techniques. Journal of Analytical Methods in Chemistry, 2018, 1–17. https://doi.org/10.1155/2018/4142527

18. Harrison, S., Gas, L. (2011). GC-MS: an ideal tool for forensic analysis. Hydrocarbon Engineering, 33–36.

19. Luethi, D., Liechti, M. E. (2020). Designer drugs: mechanism of action and adverse effects. Archives of Toxicology, 94 (4), 1085–1133. https://doi.org/10.1007/s00204-020-02693-7

20. Sliwoski, G., Kothiwale, S., Meiler, J., Lowe, E. W. (2013). Computational Methods in Drug Discovery. Pharmacological Reviews, 66 (1), 334–395. https://doi.org/10.1124/pr.112.007336

21. Sleeman, R., Carter, J. F. (2005). Mass spectrometry: Overview. Encyclopedia of Analytical Science. Elsevier, 337–344. https://doi.org/10.1016/b0-12-369397-7/00342-3

22. Scientific Working Group for Forensic Toxicology (SWGTOX) Standard Practices for Method Validation in Forensic Toxicology (2013). Journal of Analytical Toxicology, 37 (7), 452–474. https://doi.org/10.1093/jat/bkt054

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