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METABOLOMIC PROFILING OF MEDICINAL PLANTS AND RELATED FOOD PRODUCTS USING COUPLED MASS SPECTROMETRY METHODS

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Introduction and aims

Despite the fact that plants produce a wide variety of secondary metabolites with significant ecological, toxicological, and pharmacological significance, only a small portion of the world's plant species has been thoroughly studied by scientists. These compounds are vital for defense, signaling, and interactions with the environment even though they are not necessary for basic plant physiology. When consumed or otherwise absorbed, a variety of secondary metabolites, including alkaloids, flavonoids, and terpenoids, show “bioactivity” both in humans and animals and can have an impact on health. The focus of their analysis has shifted from preventing deficiencies to comprehending the biological impacts of non-nutrient bioactive substances as nutritional science has developed over the past few decades, revealing that diet influences almost all physiological systems. This has blurred the boundary between nutrition and medicine and increased interest in plant-derived compounds as potential therapeutic agents.

Throughout history, medicinal plants have been crucial to healthcare and continue to be so today. The WHO estimates that over 25% of pharmaceuticals are derived from plants or their synthetic analogues, and that about 80% of the world's population still uses plant-based medicines for primary healthcare. This dependence emphasizes the continued pharmacological value of medicinal plants as well as their cultural significance. However, quality control is severely hampered by the chemical complexity and variability of plant compounds. Both national and international regulatory frameworks have been developed to address these problems. While herbs used as food ingredients are governed by food safety and hygiene laws, including HACCP-based quality systems, herbal medicinal products in the EU are governed by directives and guidelines created by

organizations like the European Medicines Agency and the Committee on Herbal Medicinal Products.

Standardized cultivation and processing conditions are necessary to guarantee consistent quality in plant-derived products, which is especially difficult for wild-harvested plants. Plants may contain ten thousands of secondary metabolites with widely differing chemical characteristics and quantities, even in controlled environments, making qualitative and quantitative experiments much more challenging. In light of this, the current study sought to enhance the quality of raw materials and processing methods for plant-based products by characterizing the metabolome of specific medicinal plants.

Only a small percentage of plant species have undergone thorough analysis, despite notable advancements in phytochemistry. Chromatographic separation coupled with spectroscopic methods - specifically, nuclear magnetic resonance spectroscopy and high-resolution mass spectrometry - is a key component of modern plant metabolomics. Although NMR is still the highest-level technique for conclusive (ultimate) structural elucidation, it is not suitable for low-abundance plant metabolites due to its high analyte needs. As a result, multivariate statistical analysis and achieving high confidence levels for compound identification have made liquid chromatography – high-resolution mass spectrometry the main instrument for the profiling of plant metabolomes.

Catharanthus roseus (L.) G. Don (Madagascar periwinkle) is a medicinal plant with significant pharmaceutical values since it produces anticancer indole alkaloids like vinblastine and vincristine. With around 200 monoterpenoid indole alkaloids discovered to date, *C. roseus* is known for its complicated alkaloid metabolism. Its therapeutically significant dimer alkaloids' production is tightly controlled, spatially segregated within plant

tissues, and heavily impacted by environmental and developmental stage. Alkaloid production has been improved through cultivation techniques, tissue cultures, semi-synthesis, and controlled environmental cultivation, including LED lighting, due to their extremely low natural abundance and the high commercial value. In this current work, various LED light spectra effects were examined in the accumulation of pharmaceutically valuable alkaloids using targeted and untargeted metabolomics techniques based on ultra-high-performance liquid chromatography combined with high-resolution mass spectrometry and ion mobility separation. The research sought to increase the supply of valuable secondary metabolites in plant leaves by tuning cultivation and illumination conditions.

Taraxacum officinale (L.) Weber ex F.H. Wigg, or dandelion, is a plant that is commonly utilized for both medicinal and culinary purposes. Sesquiterpenes, phenolic acids, and flavonoids – which have hepatoprotective, anti-inflammatory, antioxidant, and perhaps anticancer properties – are mainly responsible for its bioactivity. Despite its widespread use, formerly reported quantitative data are frequently inconsistent, and the chemical composition of dandelion and the effects of processing technologies on its metabolome are still little understood. The need for further metabolomics-based research is highlighted by this dearth of trustworthy, consistent data. The secondary metabolite composition of dandelion leaf-root drug and flowers was investigated, and the production and maturation of a dandelion-based liqueur were tracked using metabolomic fingerprinting. Understanding how processing technologies impact the qualitative and quantitative metabolomic profiles and optimizing extraction efficiency during product development were also targeted.

This work is situated at the nexus of food science, pharmaceutical research, analytical chemistry, and plant biology. By using cutting-edge

metabolomics techniques on medicinal plants grown in controlled conditions and processed into consumer goods, it advances our understanding of plant-derived bioactive compounds and helps create more standardized, high-quality food and medicine products.

Materials and methods

Plant materials and growth conditions of *C. roseus*

In a PGR-15 growth chamber (Conviron Ltd., Winnipeg, Canada), 300 seedlings (Rédei Kertimag Zrt., Réde, Hungary; cultivar undisclosed) were grown for two months under controlled conditions (26/20 °C day/night temperature, 300 μmol $m^{-2} \cdot s^{-1}$ light intensity from metal halide lamps, 16/8 h photoperiod, and 70–75% relative humidity). After that, seedlings were moved to LED chambers and provided two weeks of exposure to various light treatments (Table 1), involving twelve plants per treatment. Following exposure, five plants per group were chosen for vinca alkaloid analysis and four completely developed leaves were taken from each plant's apical region. Prior to analysis, samples were promptly frozen in liquid nitrogen and kept at -80 °C.

Table 1. Experimental settings of the LED treatment

No.	Type	SUM PPFD* (μmol $m^{-2} \cdot s^{-1}$)	Blue %	Green %	Red %	Far-red %
1	High blue	350	43	15	41	1
2	High red	350	11	15	73	1
3	High far-red	350	20	15	44	21
4	Medium light (control)	350	20	15	64	1
5	Low light	115	20	15	64	1

* Photosynthetic photon flux density

Plant materials and product samples of *T. officinale*

The dried dandelion leaf-root drug (*Taraxaci herba cum radice*), which is composed of the roots and rosettes harvested prior to blossoming, was purchased from a nearby market (Mecsek-Drog Kft., Pécsvárad, Hungary). In the spring of 2023, dandelion flowers were collected in Gyömrő, Hungary (47°25′05.5°N, 19°23′54.8°E), mechanically cleaned, and kept at –80°C. The same flower batch was used to make liqueur samples, which were aged for two months before being bottled after maceration in 40% (v/v) ethanol at room temperature in the dark. To maximize extraction and track maturation, a second test batch was made with 70% (v/v) ethanol and sampled every week for two months.

Sample preparation for *C. roseus* samples

After powdering the leaf samples in liquid nitrogen, 0.2 g subsamples were extracted twice using a MiniG® automated tissue homogenizer (SPEX, Rickmansworth, UK) at 1250 rpm and 1.0 mL methanol–water (2:1, v/v) for two minutes. Carotenoids were eliminated by partitioning supernatants with 1.0 mL n-hexane following centrifugation at 16,500 *g* for 10 minutes at 4 °C. After filtering the methanol–water phase (0.22 µm pore sized PTFE), it was diluted either ten-fold with Milli-Q water containing 0.11 v/v% formic acid or two-fold with Milli-Q water containing 0.2 v/v% formic acid. Before LC-MS analysis, diluted samples were filtered once more (0.22 µm hydrophilic PTFE).

Sample preparation for *T. officinale* samples

Fresh flowers were ground in liquid nitrogen, while dried leaf-root drug samples were ground in an electric grinder. 0.5 g subsamples were

extracted with ultrasonication using 8.0 mL of 80% (v/v) ethanol for one hour and for three minutes with shaking in a MiniG® homogenizer running at 1250 rpm. Supernatants were evaporated following centrifugation (20 minutes, 4 °C, 8000 *g*), residues were taken up in 0.8 mL methanol, and Milli-Q water containing 0.1% (v/v) formic acid was used to adjust the volume to 2.0 mL. Samples were filtered (0.22 µm PTFE) after centrifugation (10 min, 4 °C, 16,000 *g*).

Metabolomics and multivariate statistical analysis

A Vion ESI-IMS-QTOF-MS instrument (Waters; Milford, MA, USA) and equipped with a Z-spray ion source was connected to a Waters Acquity I-Class ultra-performance liquid chromatography (UPLC) system equipped with a PDA detector to perform the analyses. A BEH-C_{18} reversed-phase UPLC column (100 mm × 2.1 mm, 1.7 µm; Waters) kept at 40 °C was used for the separation. Acetonitrile and water [both with 0.1% (v/v) formic acid] were used for gradient elution.

Validation of specificity/selectivity, linearity, accuracy, analytical range, LOD, LOQ, and matrix effects proved the method's applicability for *C. roseus* studies. Quantification was carried out using the standard addition method with authentic vinblastine and vincristine standards. Determination of 3′,4′-anhydrovinblastine using the vinblastine standard was semi-quantitative.

Thirty of the detected compounds in *T. officinale* samples were quantified by standard addition using authentic standards; the remaining 38 compounds were evaluated in relation to the most suitable standard and their quantification was therefore regarded as semi-quantitative. To account for deviations in sample preparation, only normalized intensity values were presented for the remaining 16 components. LOQs were defined at a S/N ratio of 10:1 and expressed as corresponding concentrations; for the semi-

quantitatively determined compounds, the LOQ of the actual authentic standard used for quantification was applied. The analytical range for standard addition was 25–1000 $\mu g \cdot L^{-1}$.

Data processing and multivariate analyses were performed using UNIFI (v1.9.4), Waters Connect (v3.4.0.19), Progenesis QI (PCA; v27.26.1020), EZinfo (PLS-DA, S-plot, VIP; v3.0.3), R (v4.1.2) and IBM SPSS (v29). Data were presented as the mean ± SD.

For periwinkle samples, plant height (n = 12 per group) was analyzed by one-way ANOVA after confirming normality and variance homogeneity using Shapiro–Wilk and Levene's tests ($p > 0.05$). The effects of LED treatments on vinca metabolites were assessed by one-way MANOVA; vinblastine data were transformed [1/sqrt(x)] to meet distribution assumptions. Residual normality was confirmed (Shapiro–Wilk, $p > 0.05$), while variance homogeneity was violated for catharanthine and vincristine. Following significant MANOVA results, one-way ANOVA with Bonferroni correction was applied, and pairwise comparisons were conducted using the Games–Howell post hoc test.

In the case of dandelion samples, one-way ANOVA with Welch correction was used to compare the mean values of the samples of the leaf-root drug, the flowers, and the liqueur samples as the three levels of the independent factor variable. When ANOVA yielded a significant result ($p < 0.05$), the Games-Howell post hoc test was employed to separate the homogeneous groups of means. The maturation process was analyzed by repeated-measures ANOVA across three time points. The within-subject effects were tested using Greenhouse-Geisser Type I error correction. The estimated marginal means were then compared across the three time points using Sidak's confidence interval adjustment. Normality was verified for all models using the Shapiro–Wilk test ($p > 0.05$).

Results and discussion

Catharanthus roseus

Morphological response to LED treatments

Plant height varied among LED light treatments, with far-red-enriched illumination showing the greatest elongation. Nevertheless, these variations were not significant (one-way ANOVA: $F(4,55) = 2.12$, $p = 0.09$). Due to variations in cultivar and experimental methodology, the results could not be directly compared with previous investigations, despite the trend being consistent with a shade-avoidance-type response.

Metabolite identification and multivariate discrimination

Vinca alkaloid biosynthesis-related compounds were the subject of both targeted and untargeted metabolomic investigations. Based on authentic standards, accurate mass, fragmentation patterns, database searches, and literature data, 14 compounds were identified from a panel of 64 targeted analytes. These included intermediates, dimeric alkaloids, and monomers.

The LED treatments could be statistically discriminated, according to PLS-DA modeling. Several metabolites, including 3′,4′-anhydrovinblastine (variable importance of projection /VIP/ = 32.3), vinblastine, vincristine, vindolinine, and 19-*S*-vindolinine, were found to be significant contributors to group discrimination (VIP > 2). The reliable identification and quantification of vincristine isomers required authentic standard.

Quantitative changes and statistical evaluation

The standard addition method was used to quantify vincristine and vinblastine in order to account for low matrix effects (<10%). A highly significant overall effect of LED treatment on vinca alkaloid profiles was confirmed by one-way MANOVA (Wilks' lambda < 0.001, $p < 0.001$). For

loganic acid, 3′,4′-anhydrovinblastine, vinblastine, vincristine, vindolinine, and 19-*S*-vindolinine, further univariate ANOVA testing showed significant light-dependent changes ($p < 0.01$). Vindoline and catharanthine, on the other hand, did not exhibit significant differences between treatments.

High blue light caused a significant rise in pharmaceutically relevant alkaloids - compared to the control group, concentrations of vinblastine, vincristine, and 3′,4′-anhydrovinblastine rose up to 15-fold. Maximum concentrations exceeded several previously reported values for leaf tissue, reaching 961 $mg \cdot kg^{-1}$ DW for 3′,4′-anhydrovinblastine, 33.8 $mg \cdot kg^{-1}$ DW for vinblastine, and 11.7 $mg \cdot kg^{-1}$ DW for vincristine.

Dimer alkaloids were among the most powerful discriminating variables in multivariate analyses (PCA and PLS-DA), which consistently distinguished the high-blue treatment from all others. These results imply that blue light selectively increases metabolic flux toward dimerization, relieving a known bottleneck in the production of vinblastine and vincristine. Overall, the findings show that LED spectral composition is an important environmental element affecting *C. roseus*'s qualitative and quantitative alkaloid profile.

Taraxacum officinale

Metabolomic characterization

The leaf-root drug, flower, and liqueur samples had significantly different compositions, according to UPLC-HRMS analysis. A total of 84 metabolites were found in all matrices; 30 of these were quantified using authentic standards, and 38 were determined semi-quantitatively. Terpenoids, hydroxylated fatty acids, coumarins, flavonoids, and derivatives of caffeic acid predominated among the assigned compounds.

24 compounds, including taraxinositol A and B, various hydroxylated fatty acids, caffeoylsucrose, and several caffeic acid derivatives, were initially identified in *T. officinale*. Characteristic fragmentation patterns, such as neutral losses diagnostic for sulfate and sugar moieties, could contribute to the identification.

Highlighted compound classes

Derivatives of caffeic acid constituted the largest chemical group. These were identified by their characteristic fragment ions and included free acids, glycosides, derivatives of tartaric and quinic acids, and sulfated derivatives.

Extensive structural variety was found by flavonoid profiling, especially among derivatives of luteolin, quercetin, and isorhamnetin, which are usually found as glycosides. In the absence of available authentic standards, a number of flavonoids could only be identified on a low level due to isomerism. Based on similar fragmentation characteristics, five hydroxylated C18 fatty acids were also tentatively identified.

Leaf-root drug samples had the greatest quantities of the majority of known polyphenols, including rosmarinic acid and chlorogenic acids, according to the quantitative comparison. Due to dilution and production effects, liqueur samples showed much lower total metabolite levels, but flower samples were especially enriched in chicoric acid and chrysoeriol. However, other chemicals were more easily detected or selectively concentrated in the liqueur matrix, such as sulfated derivatives.

A number of metabolites showed distinct matrix specificity. Some compounds, like hesperidin and robinin, were only found in leaf-root drug samples, whereas others, like chrysin and fraxin, were only found in flowers. These variations show that the secondary metabolism of dandelion varies significantly and depends on the plant organ and the production technology.

Maturation dynamics of the liqueur

Dynamic chemical changes during liqueur aging were monitored on a test batch over a two-month period. Esculetin derivatives were a good example of the occurring changes: esculin concentrations gradually dropped as esculetin levels rose, esculetin sulfate formed and its concentration rose, and esculetin partially degraded. Caffeic acid and quercetin derivatives showed similar trends, generally rising in the first month and then falling. A smaller portion of the 67 compounds under observation displayed temporary maxima or minima, whereas 32 showed a steady reduction, 16 rose over time, and 13 stayed practically stable. For a number of important phenolic compounds, substantial temporal effects were confirmed by repeated-measures ANOVA ($p < 0.05$). Overall, the findings show that dandelion liqueur's chemical profile is very dynamic, with an apparent peak around one month of maturation, after which the concentration of a number of bioactive metabolites decreases.

Conclusion and recommendations

Indole alkaloid production in *C. roseus* is significantly influenced by LED lighting. Vinblastine, vincristine, and 3′,4′-anhydrovinblastine were measured and overall, 14 pathway-related metabolites were identified using UPLC-ESI-IMS-QTOF-MS. Without changing plant height, high blue light dramatically enhanced these important alkaloids – up to even 15-fold. Optimizing plant-derived active pharmaceutical ingredients by spectral composition modification is a promising approach given the ubiquitous availability of LED systems in vertical farming.

Because secondary metabolites naturally vary and affect both composition and sensory qualities, it is difficult to maintain constant quality in plant-based products like liqueurs. High chemical complexity, including previously unnoticed or production-specific metabolites (such as taraxinositol

A/B and sulfated caffeic acid derivatives), was discovered through the metabolomic profiling of *T. officinale* plant parts and its flower-based liqueur. The appearance of highly concentrated and formerly unreported compounds, such as caffeoylsucrose (5.34 ± 0.81 $g \cdot kg^{-1}$ DW), might call the attention to the possibility that producers might not be aware of even major metabolites in their final products. The majority of compounds under investigation peaked after a month during the liqueur maturation process, highlighting the difficulty of precise optimization because of maceration parameters and enzymatic reactions. Therefore, untargeted metabolomics is useful for the quality monitoring of especially high-end plant-based products.

Further experiments should be considered in the following areas:

- To confirm the effects of light spectrum on alkaloid production in *C. roseus* plants by conducting extensive research in controlled vertical farm settings under production-relevant settings.
- To extend the number of identified metabolites by working with more authentic standards through the collaboration with organic chemistry research groups to synthesize standard materials that are not commercially available – both for *C. roseus* and *T. officinale*.
- To fingerprint genetic and environmental diversity by conducting comprehensive metabolomic investigations of *T. officinale* from various geographic origins.
- To determine and confirm which compounds are principally responsible for the therapeutic benefits of the dandelion plant. To establish standardized analytical techniques and concentration thresholds for inclusion in pharmacopoeias or food-quality related documentations.

New scientific results

1. I developed a comprehensive targeted and untargeted metabolomic analysis using UPLC–ESI–IMS–QTOF–MS for the simultaneous identification and measurement of vinca alkaloids in *Catharanthus roseus* leaves. I identified 14 alkaloid compounds in total, vinblastine and vincristine confirmed by authentic standards, and 12 other was tentatively identified based on retention time order, accurate mass and fragmentation spectra.
2. I demonstrated that the concentration of pharmaceutically important bisindol alkaloids could be significantly (up to 15-fold) increased by exposing the *C. roseus* plant to blue LED illumination without requiring UV stress.
3. I established a comprehensive metabolomic profile of *Taraxacum officinale*, covering the leaf–root drug, flowers, and a commercially available dandelion flower–based liqueur. I identified 84 compounds, out of which 24 were first reported, which considerably increased the species' known metabolome.
4. I tentatively identified taraxinositol A and B for the first time in *T. officinale*, reported their ESI '-' MS/MS fragmentation spectra together with their possible fragmentation patterns.
5. I described the maturation process of a dandelion flower-derived liqueur through the UPLC–ESI–IMS–QTOF–MS based monitoring of 60 known and 24 formerly unreported secondary metabolites. I described a complex accumulation/decomposition pattern for all the 84 compounds for a period of two months and I could suggest an optimal maturation period of one month for this food product.

Publications

Journal articles linked to the thesis:

Nagy K., Darkó É., Szalai G., Janda T., Jókai Zs., Ladányi M., Rady M. R., Dernovics M. (2023) UPLC-ESI-QTOF-MS assisted targeted metabolomics to study the enrichment of vinca alkaloids and related metabolites in *Catharanthus roseus* plants grown under controlled LED environment. Journal of Pharmaceutical and Biomedical Analysis. 235 Paper: 115611 https://doi.org/10.1016/j.jpba.2023.115611
Norwegian list: 1, IF: 3.1, **Q2**

Gholizadeh F., Darkó É., Benczúr K., Hamow K.Á., Dernovics M., Nagy K., Janda T., Rady M.R., Gohari G., Pál M., Le V.N., Szalai G. (2023) Growth light substantially affects both primary and secondary metabolic processes in *Catharanthus roseus* plants. Photosynthetica. 61 (SI): 47-56. https://doi.org/10.32615/ps.2023.037
Norwegian list: 1, IF: 2.1, **Q2**

Nagy K., Jókai Zs., Ladányi M., Kovács V., Dernovics M. (2026) Maturation of *Taraxacum officinale* (dandelion) flower-based liqueur: comprehensive targeted, semi- and untargeted metabolomic fingerprinting. *(Submitted manuscript*)

Journal articles:

Gell Gy., Nagy K., Dernovics M., Birinyi Zs., Nagy-Réder D., Békés F., Veisz O. (2025) Combined effects of genotype and harvest year on the distribution patterns of avenanthramide forms in oat varieties: considerations regarding the classification of “major” and “minor” forms. Applied Food Research. 5:2 Paper: 101432 https://doi.org/10.1016/j.afres.2025.101432
Norwegian list: 1, IF: 6.2, **Q1** (2024)

Szalai G., Dernovics M., Gholizadeh F., Pál M., Darkó É., Nagy K., Peeva V., Doneva D., Janda T. (2025) Exploring the impact of blue light on cold acclimation mechanisms in wheat: A comparative analysis of leaf and root responses. Plant Physiology and Biochemistry. 227 Paper: 110078 https://doi.org/10.1016/j.plaphy.2025.110078
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Pál M., Rahman A., Hamow K.Á., Nagy K., Janda T., Dernovics M., Szalai G. (2025) Genotype-specific and light dependence of polyamine uptake and metabolism in wheat plants. Plant Physiology and Biochemistry. 222 Paper: 109659 https://doi.org/10.1016/j.plaphy.2025.109659
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Rahman A., Nagy K., Hamow K.Á., Pál M., Janda T., Dernovics M., Szőke Cs., Szalai G. (2024) Cadmium stress responses under white or blue light are influenced by putrescine pre-treatment in wheat. Environmental and Experimental Botany. 222 Paper: 105746 https://doi.org/10.1016/j.envexpbot.2024.105746
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Norwegian list: 1, IF: 4.0, **Q1**

Zin M. M., Nagy K., Bánvölgyi S., Abrankó L., Nath, A. (2022) Effect of microwave pretreatment on the extraction of antioxidant-rich red color betacyanin, phenolic, and flavonoid from the crown of Cylindra-type beetroot (*Beta vulgaris* L.). Journal of Food Process Engineering. e14175 https://doi.org/10.1111/jfpe.14175
Norwegian list: 1, IF: 3.0, **Q2**

Conference material – full paper, in Hungarian:

Nagy K., Darkó É., Janda T., Szalai G., Dernovics M.: „A rózsameténg alkaloidtartalmának vizsgálata – metabolomikai megközelítés" Hagymási K., Janda T., Poór P. (Eds.) A reaktív oxigénformákkal és az antioxidáns védekezéssel kapcsolatos újdonságok. Magyar Szabadgyök-Kutató Társaság (2024) 162 p. pp. 59-68.

Conference material – summary, in Hungarian:

Tormási J., Nagy K., Abrankó L.: „Élelmi tápanyagok biológiai hozzáférhetőségének vizsgálata *in vitro* emésztésszimulációval" METT 25 a Magyar Elválasztástudományi Társaság jubileumi konferenciája
Egerszalók, 2021. 10. 18.-20.

Nagy K., Zubay P., Szabó K., Oláh Cs., Ablonczy A., Abrankó L.: „Táplálékkiegészítő urzolsav hozzáférhetőségének vizsgálata *in vitro* emésztésszimuláció során – analitikai módszerfejlesztés" – Poster award. METT 25 a Magyar Elválasztástudományi Társaság jubileumi konferenciája Egerszalók, 2021. 10. 18.-20.

Nagy K., Darkó É., Janda T., Rady M.R., Dernovics M.: „A rózsameténg LED fénnyel történő kezelésének hatása a vinca alkaloid bioszintézisútra: metabolomikai megközelítés" MKE 4. Nemzeti Konferencia
Eger, 2023.07.10.-12.

Conference material – full paper, in English:

Andráskó D., Varga E., Balázs V. B., Nagy K., Üveges M.: „Development and optimization of an UHPLC-MS/MS method for the determination of mycotoxins from vanilla spice samples" Proceedings of János Lippay – Imre Ormos – Károly Vas (LOV) Scientific Meeting, 2021

Conference material – summary, in English:

Janda T., Darkó É., Gholizadeh F., Gondor O.K., Hamow K.Á., Dernovics M., Nagy K., Rady M.R., Pál M., Szalai G.: „Anyagcsere-változások különböző erősségű megvilágítás mellett rózsás meténg (*Catharanthus roseus* L.) leveleiben." 12th Congress of the Hungarian Free Radical Society, Martonvásár, 2023.08.24.-25.

Nagy K., Dernovics M.: „Analytical challenges in the determination of conjugated polyamines" 2nd Hungarian Polyamine Research Workshop, Szeged, 2022.12.02.

Tormási J., Nagy K., Abrankó L.: „Emésztés során megmutatkozó tápanyag kölcsönhatások feltárása *in vitro* emésztésszimulációval" Lippay János – Ormos Imre – Vas Károly Scientific Congress, Budapest, 2021. 11. 29.

Rahman A., Nagy K., Hamow K.Á., Pál M., Janda T., Dernovics M., Szalai G.: „Different responses of wheat to cadmium stress under white and blue light, modulated by pre-treatment with putrescine" 7th Conference on Cereal Biotechnology and Breeding, Wernigerode (Germany), 2023.11.07.-09.

Nagy K., Janda T.: „Plant Based Products Intended for Authentication vs. Limited Set of Known Discriminating Metabolites: Hungarian Liquors in the Crosshair of Untargeted Metabolomics" 33rd International Symposium on Chromatograpy, Budapest, 2022. 09. 18-22.

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Andráskó D., Varga E., Balázs V. B., Nagy K., Üveges M.: „Development and optimization of an UHPLC-MS/MS method for the determination of mycotoxins from vanilla spice samples" Lippay János – Ormos Imre – Vas Károly Scientific Congress, Budapest, 2021. 11. 29.

Tormási J., Nagy K., Tömösköziné Farkas R., Abrankó L.: „Rozmaring fűszer szerepének feltárása sült ponty étel emészthetőségében *in vitro* emésztésszimulációs modell alkalmazásával" Lippay János – Ormos Imre – Vas Károly Scientific Congress, Budapest, 2021. 11. 29.