EXPERIMENTAL ARTICLES

UDC 577.25:612.8:620.3 https://doi.org/10.15407/biotech19.05.057

EFFECT OF SUNFLOWER SEED HUSK BIOCHAR ON HIGH-KCL -INDUCED L-[^{3}H] GLUTAMATE RELEASE FROM BRAIN NERVE TERMINALS

N. G. POZDNYAKOVA[1] *(https://orcid.org/0000-0001-9922-5389)*
A. O. PASTUKHOV[1] *(https://orcid.org/0000-0001-5837-6412)*
A. V. TEREBILENKO[2] *(https://orcid.org/0000-0002-8956-8713)*
M. O. IVANYTSYA[2] *(https://orcid.org/0009-0003-0590-8720)*
S. V. KOLOTILOV[2] *(https://orcid.org/0000-0002-4780-4378)*
T. A. BORISOVA[1] *(https://orcid.org/0000-0002-6533-1420)*
N. V. KRISANOVA[1] *(https://orcid.org/0000-0001-5208-2982)*

[1]Palladin Institute of Biochemistry of the National Academy of Sciences of Ukraine, Kyiv
[2]Pisarzhevskii Institute of Physical Chemistry of the National Academy of Sciences of Ukraine, Kyiv

E-mail: nataly.pozdniakova@gmail.com

Aim. The actual task of modern biotechnology is the search for efficient adsorbents, which have the capacity: 1) to detoxicate heavy metals, 2) are biocompatible, and 3) do not influence homeostasis of physiological metals in the nerve cells. Earlier, we demonstrated that pyrolysis biochar from sunflower seed husk with a non-modified surface was biocompatible and contained carbon (89.5%) and calcium (0.4%). The aim was to analyze whether internal biochar calcium (0.4%) influences L-[^{3}H] glutamate release from nerve terminals.

Methods. Key parameters of synaptic transmission were analyzed using presynaptic rat cortex nerve terminals (synaptosomes) and radiolabelled excitatory neurotransmitter L-[^{3}H] glutamate.

Results. It was demonstrated that the biochar did not influence unstimulated tonic release of L-[^{3}H] glutamate from synaptosomes in Ca^{2+}-free medium. Stimulated by membrane depolarisation with high KCl, L-[^{3}H]glutamate release from synaptosomes measured in the presence of the biochar in Ca^{2+}-free medium was higher in the medium without EGTA than in the presence of EGTA. Whereas membrane depolarisation-induced L-[^{3}H]glutamate release from the nerve terminals measured in Ca^{2+}- containing medium was not changed in the presence of the biochar as compared to the control (without biochar).

Conclusion. Internal Ca^{2+} contained in the biochar can be released to the synaptosomal incubation medium. In contrast, this Ca^{2+} content was insufficient to affect the Ca^{2+}-dependent release of L-[^{3}H] glutamate from nerve terminals, thereby confirming the biocompatibility of biochar and its prospects for medical application.

Keywords: agricultural waste, sunflower seed husk, pyrolysis biochar, glutamate, presynaptic nerve terminals, brain cortex.

Heavy-metal contamination remains a major environmental and biomedical challenge because heavy metals such as cadmium (Cd), lead (Pb), mercury (Hg), and arsenic (As) are persistent, non-biodegradable contaminants that can accumulate in biological systems and interfere with essential cellular processes. Adsorption-based remediation has therefore attracted considerable attention as a relatively simple, scalable, and cost-effective approach for removing toxic metal ions from contaminated water, soil, and biological matrices. Among the diverse classes of adsorbents, biochar has emerged as a particularly promising material because it can be produced from abundant agricultural and other biomass wastes and possesses a porous carbon-rich structure, mineral components,

Citation: Pozdnyakova, N. G., Pastukhov, A. O., Terebilenko, A. V., Ivanytsya, M. O., Kolotilov, S. V., Borisova, T. A., Krisanova, N. V. (2026). Effect of sunflower seed husk biochar on high-KCl-induced L-[^{3}H] glutamate release from brain nerve terminals. *Biotechnologia Acta*, 19(5), 57–64. https://doi.org/10.15407/biotech19.05.057

and surface functional groups capable of binding metal ions through ion exchange, electrostatic interactions, surface complexation, cation–π interactions, pore filling, and precipitation [1–4]. Recent studies have demonstrated that the adsorption performance of biochar depends strongly on feedstock, pyrolysis temperature, surface chemistry, porosity, and the environmental conditions under which adsorption occurs [2, 5, 6].

However, high adsorption capacity alone is insufficient for the development of a biologically applicable adsorbent. A critical challenge of modern biotechnology is to identify materials that combine efficient detoxification of hazardous metals with a high degree of biological compatibility. This requirement is particularly important when adsorbents are considered for applications in biological systems where they may come into direct contact with cells or tissues. Biochar is generally regarded as a low-cost and environmentally favorable material. However, its biological effects are not necessarily negligible and can vary substantially depending on biomass origin, production conditions, particle size, and surface chemistry [7–9]. Indeed, recent assessments emphasize that biochar should be evaluated not only for pollutant-removal efficiency but also for its potential ecological risks, including changes that occur during aging, migration, and interactions with biological systems [8, 9]. Thus, the development of a biocompatible adsorbent requires a simultaneous assessment of its sorption performance and biological activity.

An important requirement is the selectivity of the biochar for toxic metals without disrupting the homeostasis of physiologically essential metals. Consequently, an adsorbent intended for biomedical or neurobiotechnological applications should not disturb the homeostasis of physiological ions. Excessive redistribution of essential metals could itself become biologically detrimental. This consideration introduces an important distinction between conventional environmental remediation, where maximal removal of a contaminant is usually the primary objective, and biologically compatible detoxification, where selective removal of toxic metals while preserving physiological metal homeostasis is required.

Biochar is particularly attractive in this context because its surface chemistry can potentially be tuned to provide selective interactions with different metal species. At the same time, modification of biochar surfaces, although often increasing adsorption capacity, may introduce additional functional groups, inorganic phases, or nanoscale components that can alter its biological activity. Recent meta-analyses and reviews indicate that activation and functionalization can substantially enhance heavy-metal adsorption. However, the magnitude of this effect depends on the preparation procedure and physicochemical characteristics of the resulting material [3, 5]. Therefore, an important research direction is to determine whether non-functionalized biochar produced directly from inexpensive agricultural residues via controlled pyrolysis can provide an advantageous balance between metal-binding capacity and biological inertness. Such materials may avoid some of the additional toxicological uncertainties associated with chemically modified or highly engineered adsorbents.

Agricultural residues are especially attractive feedstocks because their conversion into biochar simultaneously addresses waste valorization and environmental remediation. Sunflower seed husk represents an abundant lignocellulosic agricultural residue and can be converted by pyrolysis into a carbonaceous material with potential adsorption properties [10–12].

Recently, we have demonstrated that pyrolysis biochar from sunflower seed husk with a non-modified surface contained carbon (89.5%) and calcium (0.4%) and was biocompatible [13]. The latter was shown in radiolabelled experiments where the biochar (0.25–1.0 mg/ml) did not change the extrasynaptosomal levels of the excitatory neurotransmitter L-[^{3}H] glutamate and inhibitory neurotransmitter [^{3}H] GABA. In fluorimetric experiments with the dye JC-1, biochar (1.0 mg/ml) did not alter the mitochondrial membrane potential of nerve terminals. It was concluded that the biochar showed no signs of neurotoxicity and high biocompatibility, and therefore has potential for use as an adsorbent in biotechnology and medicine. These findings support the concept that a non-functionalized agricultural-waste-derived biochar can act as a biologically inert carbonaceous platform.

Taking into account the above facts, this study aimed to analyze whether internal biochar calcium (0.4%) influences L-[^{3}H] glutamate release stimulated by membrane depolarisation with high KCl in presynaptic rat brain nerve terminals (synaptosomes).

The synaptosome model provides a sensitive experimental system for detecting disturbances in neurotransmitter homeostasis, plasma and mitochondrial membrane function, and oxidative processes. Accordingly, the evaluation of biochar in this model can provide complementary information not obtained from conventional adsorption experiments performed solely in aqueous solutions. Such an integrated approach may contribute to the development of a new generation of bio-based adsorbents characterized by three essential properties: 1) efficient detoxification of hazardous heavy metals, 2) high biocompatibility, and 3) preservation of physiological metal homeostasis and neuronal function (Fig. 1).

Materials and Methods

Materials

HEPES, EGTA, EDTA, salts of the analytical grade, High Performance LSC Cocktail were obtained from Sigma, USA; L-[^{3}H] glutamate was from Revvity, Waltham, MA, USA.

Synthesis of the biochar from sunflower seed husk

Synthesis of the biochar (SHB) was carried out in Pisarzhevskii Institute of Physical Chemistry of the National Academy of Sciences of Ukraine, as described in our recent publication [13].

Experiments using brain nerve terminals

Ethics

Male Wistar rats were housed at 22–23 °C in a quiet, temperature-controlled room in the vivarium of the Palladin Institute of Biochemistry of the National Academy of Sciences of Ukraine. Animals had free access to standard dry pellet food and water ad libitum. All animal experiments were performed in accordance with the European Community Directive 2010/63/EU, the relevant scientific and research ethics requirements, the principles of the Declaration of Helsinki, the ARRIVE Guidelines for reporting animal research [14, 15], and applicable Ukrainian legislation and institutional policies. Experimental protocols were reviewed and approved by the Animal Care and Use Committee of the Palladin Institute of Biochemistry of the National Academy of Sciences of Ukraine (Protocol No. 1, approved January 12, 2026). A total of 12 animals were used in the study.

Isolation of nerve terminals from the rat cortex (rat cortex synaptosomes)

Presynaptic nerve terminals (synaptosomes) were isolated from the cerebral cortex of male Wistar rats. Cortical tissue was homogenized at 4 °C in an ice-cold medium containing 0.32 M sucrose, 5 mM HEPES-NaOH (pH 7.4), and 0.2 mM EDTA. Synaptosomes were isolated according to the method originally described by Cotman, with minor modifications [16,17]. All isolation procedures were performed at 4 °C.

The standard saline solution used for synaptosome experiments contained 126 mM NaCl, 5 mM KCl, 2.0 mM $MgCl_2$, 1.0 mM NaH_2PO_4, 20 mM HEPES (pH 7.4), and 10 mM D-glucose. Protein concentration was determined according to the method of Larson [18] using a Shimadzu UV-1900i spectrophotometer.

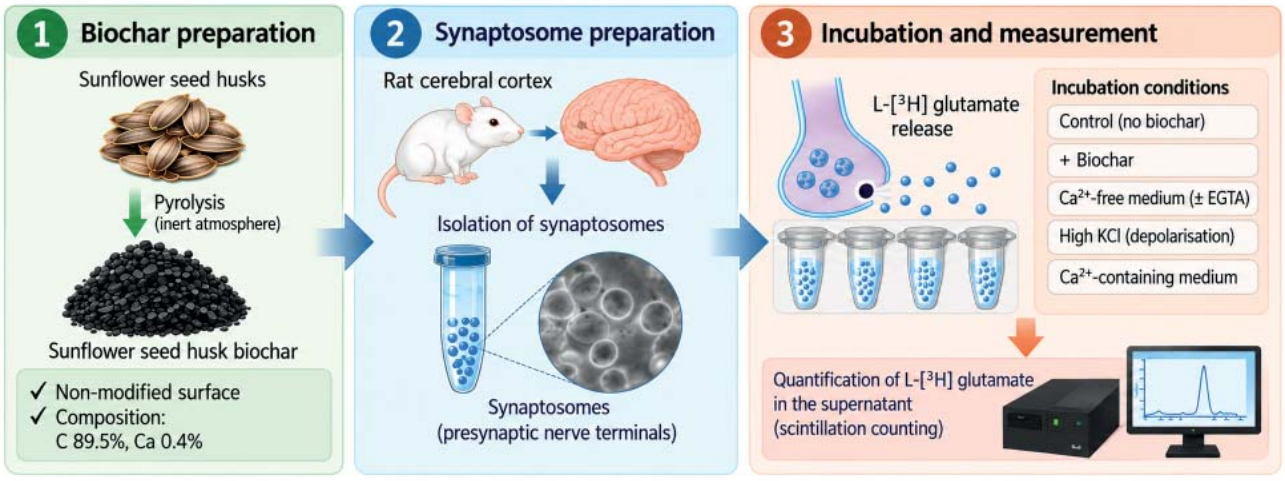


Fig. 1. **Experimental workflow diagram**

The release L-[^{3}H] glutamate from synaptosomes

Synaptosomal suspensions were adjusted to a protein concentration of 2 mg/ml and preincubated at 37 °C for 10 min. The preparations were subsequently loaded with L-[^{3}H]glutamate (1 μCi/ml) and incubated for an additional 10 min at 37 °C. The suspension was then diluted with a 10-fold standard saline solution and centrifuged at 10,000 × g for 20 s. The resulting pellets were resuspended in standard saline solution to a final protein concentration of 1 mg/ml

To determine the extrasynaptosomal level of L-[^{3}H]glutamate, 125-μl aliquots containing 0.5 mg/ml protein were preincubated for 8 min. Following the addition of the tested biochar, the samples were incubated at 37 °C for 0 or 6 min and subsequently centrifuged at 10,000 × g for 20 s. Radioactivity was determined separately in the supernatant and synaptosomal pellet.

To assess L-[^{3}H] glutamate release in nerve terminals, the following parameters were measured: L-[^{3}H] glutamate release in Ca^{2+}-containing and Ca^{2+}-free medium; the latter was recorded without and in the presence of EGTA.

Before scintillation counting, the pellets were solubilized with 10% SDS (100 μl of stock solution). Radioactivity was measured using Sigma-Fluor® High Performance LSC Cocktail and a Hidex 600SL liquid scintillation counter (Finland).

Data were obtained from *n* independent experiments performed in triplicate using independently prepared synaptosomal preparations.

Statistical analysis

The experimental results were expressed as the mean ± SEM. of *n* independent experiments. One-way ANOVA was used with a significance level of $P < 0.05$.

Results and Discussion

To analyze whether or not internal calcium (0.4%) of the sunflower seed husk biochar influences Ca^{2+}-dependent cellular processes, the following parameters were recorded in nerve terminals: unstimulated tonic L-[^{3}H] glutamate release in Ca^{2+}-free medium, membrane depolarisation-induced L-[^{3}H] glutamate release in Ca^{2+}-containing and Ca^{2+}-free medium, the latter was recorded without and in the presence of EGTA. L-[^{3}H] glutamate release from nerve terminals in Ca^{2+}-free medium and in Ca^{2+}-containing medium was stimulated by membrane depolarisation with high KCl (35 mM) in the presence of the biochar. The high KCl-induced L-[^{3}H]glutamate release in Ca^{2+}-free medium reflected, in particular, transporter-mediated release [19, 20].

In the first set of experiments with synaptosomes, the unstimulated tonic release of L-[^{3}H]glutamate was assessed in Ca^{2+}-free medium in the presence of biochar.

As shown in Figure 2, the biochar (SHB) did not change the unstimulated tonic release of L-[^{3}H] glutamate from synaptosomes, which reflected unchanged membrane integrity and biocompatibility of the biochar.

In the second set of experiments, we revealed an SHB-stimulated increase in high-KCl-induced L-[^{3}H]glutamate release from

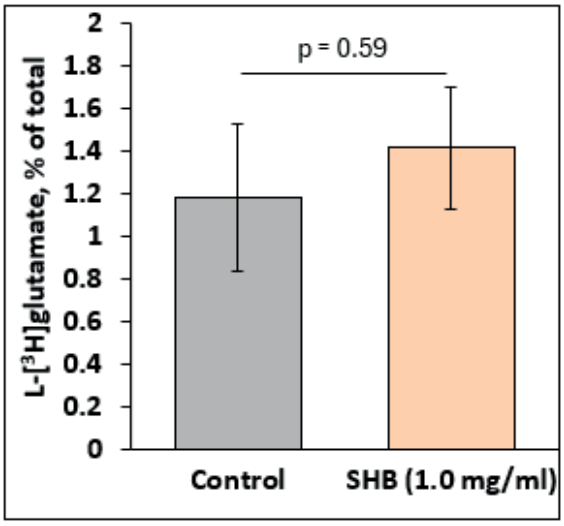


Fig. 2. **Effect of the biochar (SHB, 1.0 mg/ml) on the unstimulated tonic release of L-[^{3}H] glutamate from synaptosomes in Ca^{2+}-free medium.**

Note. Data are the mean ± SEM; $n = 12$.

synaptosomes in the nominally Ca^{2+}-free medium (without EGTA). This increase was eliminated in Ca^{2+}-free, EGTA-containing medium. Therefore, different effects of the biochar on the membrane depolarisation-induced L-[^{3}H] glutamate release from synaptosomes were revealed in the nominally Ca^{2+}-free medium (without EGTA) and the medium in the presence of EGTA (Fig. 3). In particular, this release was higher in the nominally Ca^{2+}-free medium (without EGTA) as compared to that in the presence of EGTA in the synaptosomal incubation medium. It can be suggested that a small amount of internal Ca^{2+} can be released from the biochar into the incubation medium, thereby stimulating weak exocytotic release under EGTA-free conditions. Whereas, in EGTA-containing medium, the released internal biochar Ca^{2+} was bound to EGTA through chelation in the synaptosomal incubation medium, and so could not stimulate exocytosis during membrane depolarisation.

In the next series of experiments, we analyzed the effect of biochar on L-[^{3}H] glutamate release from synaptosomes in Ca^{2+}-containing medium. As shown in Figure 4, the biochar did not influence the high KCl- induced L-[^{3}H]glutamate release in Ca^{2+}-containing medium in nerve terminals as compared to the control (without biochar).

The extrasynaptosomal level of L-[^{3}H] glutamate is a parameter that is tightly associated with Na^+/K^+ electrochemical gradient across the membrane of nerve terminals. The extrasynaptosomal level of L-[^{3}H]glutamate is established by a balance of release and uptake of L-[^{3}H]glutamate, where the latter is driven by this gradient. Sufficient changes in the Na^+/K^+ electrochemical gradient decrease L-[^{3}H]glutamate uptake and increase the extrasynaptosomal level of the neurotransmitter. Since the biochar did not alter the extrasynaptosomal level of L-[^{3}H]-glutamate, it was suggested that biochar did not affect the electrochemical gradient of Na^+ and K^+ across the nerve terminal membrane significantly [13].

The absence of a significant difference in L-[^{3}H]glutamate release between biochar-treated and control synaptosomes in Ca^{2+}-containing medium indicated that the biochar did not substantially interfere with the presynaptic mechanisms responsible for Ca^{2+}-dependent vesicular neurotransmitter release. This finding is particularly relevant for assessing the neurobiocompatibility of the material, because preservation of regulated glutamate exocytosis suggested that the biochar did not disrupt the basic coupling between membrane depolarization, Ca^{2+} entry, and synaptic vesicle fusion.

In contrast, in the nominally Ca^{2+}-free medium, glutamate release in the presence of biochar was significantly higher in the absence of EGTA than in its presence. This difference

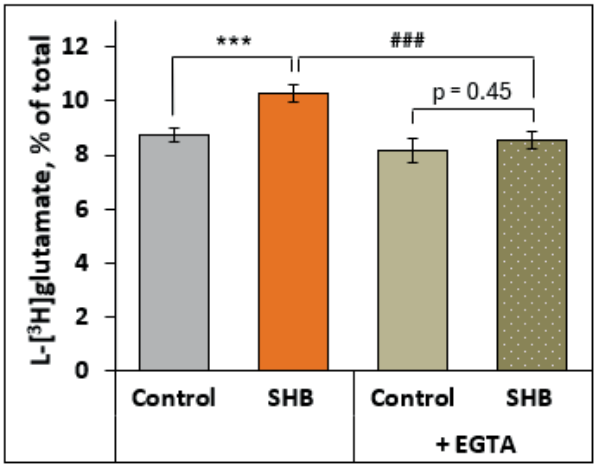


Fig. 3. **Effect of the biochar (SHB, 1.0 mg/ml) on the high KCl-induced L-[^{3}H] glutamate release from synaptosomes in the Ca^{2+}-free medium without and in the presence of EGTA**

Note. Data are the mean ± SEM. ***, $P < 0.001$; as compared to the control in the Ca^{2+}-free medium without EGTA. ###, $P < 0.001$; comparison of the SHB effects in the Ca^{2+}-free medium without and in the presence of EGTA, $n = 12$.

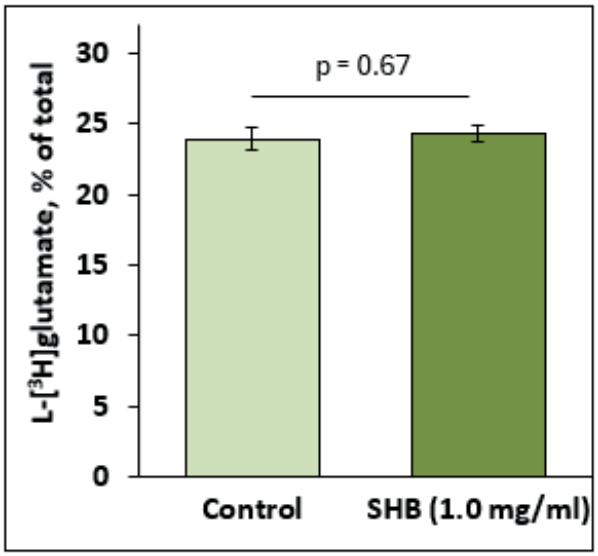


Fig. 4. **Effect of the biochar (SHB, 1.0 mg/ml) on the high KCl- induced L-[^{3}H] glutamate release from synaptosomes in the Ca^{2+}-containing medium.**

Note. Data are the mean ± SEM, $n = 12$.

indicates that residual or contaminating Ca^{2+} may contribute to the release observed under nominally Ca^{2+}-free conditions. EGTA chelated extracellular Ca^{2+} and therefore reduced the availability of free Ca^{2+} for Ca^{2+}-dependent exocytosis. The higher release observed in the absence of EGTA may thus reflect a weak Ca^{2+}-dependent component that becomes detectable when biochar is present. Importantly, this effect should not necessarily be interpreted as direct stimulation of exocytosis by biochar. Biochar may alter the local availability or distribution of Ca^{2+} through surface adsorption/desorption or interactions with the extracellular microenvironment, thereby modifying the effective free Ca^{2+} concentration. Alternatively, the difference may indicate that a fraction of glutamate release under nominally Ca^{2+}-free conditions was mediated by Ca^{2+}-sensitive, non-vesicular mechanisms, such as transporter reversal, which can also be influenced by subtle changes in ionic homeostasis.

Overall, the results are consistent with the conclusion that the biochar largely preserved Ca^{2+}-dependent neurotransmitter exocytosis. At the same time, the difference between EGTA-free and EGTA-containing conditions revealed a possible interaction between the biochar and extracellular Ca^{2+}availability. Further experiments measuring free Ca^{2+}, membrane potential, and glutamate transporter activity would be useful to distinguish between an effect on extracellular Ca^{2+} availability and modulation of non-vesicular glutamate release.

Conclusions

The present findings demonstrated that the biochar did not substantially interfere with depolarization-induced release of L-[^{3}H] glutamate from rat cortical nerve terminals under physiological extracellular Ca^{2+} conditions. Internal Ca^{2+} contained in the biochar can be released to the synaptosomal incubation medium. In contrast, this content was not significant and did not affect the high KCl- induced release of L-[^{3}H] glutamate from nerve terminals in Ca^{2+}-containing medium. The absence of a significant change in glutamate release relative to the untreated control indicated that the biochar preserved the fundamental presynaptic mechanisms underlying regulated neurotransmitter exocytosis and did not induce detectable disruption of synaptic function, thereby confirming biochar biocompatibility and the prospect for medical applications.

Under nominally Ca^{2+}-free conditions, the higher L-[^{3}H]glutamate release observed in the absence of EGTA compared with EGTA-containing medium suggested that residual extracellular Ca^{2+} contributed to glutamate release in the presence of biochar. This effect may reflect an interaction of the biochar with extracellular Ca^{2+} availability or a contribution of Ca^{2+}-sensitive non-vesicular mechanisms. Importantly, these changes were not accompanied by enhanced glutamate release under physiological Ca^{2+} conditions. Overall, the data support the neurobiocompatibility of the biochar with respect to presynaptic glutamate release, while suggesting that its interaction with extracellular Ca^{2+} homeostasis warrants further investigation, including *in vivo* animal modeli.

Funding

This work was supported by the National Research Foundation of Ukraine: NRFU grant # 2023.03/0036 “Functionalized carbon-based nanomaterials obtained by “green methods” from Ukrainian agricultural waste to combat multilevel neurotoxicity induced by xenobiotic/essential transition metals and arsenic”; PI is Dr. N. Krisanova.

Conflict of interest

The authors declare no financial and non-financial competing interests exist.

Author Contributions

N. V. Krisanova, N. G. Pozdnyakova — Conceptualization, Methodology, Investigation, Resources, Visualization, Formal analysis, Supervision, Writing — review & editing, Writing — original draft, Project administration; A. O. Pastukhov, A. V. Terebilenko, M. O. Ivanytsya, Methodology, Investigation; T. A. Borisova, S. V. Kolotilov — Conceptualization, Supervision, Formal analysis, Writing — review & editing, Writing — original draft.

Declaration of Generative AI

During the preparation of this manuscript, the authors utilized ChatGPT-Go to assist in the visualisation of the “Experimental workflow diagram” (Fig. 1) based on specific technical prompts provided by the authors. The actual experimental setup, parameters, and scientific sequence were fully conceived and verified by the authors, who accept full responsibility for the integrity of the visualized methodology.

REFERENCES

1. Mei, Y., Zhuang, S., Wang, J. (2025). Adsorption of heavy metals by biochar in aqueous solution: A review. *Science of the Total Environment*, 968, 178898. https://doi.org/10.1016/j.scitotenv.2025.178898
2. Wu, Y., Yan, Y., Wang, Z., Tan, Z., Zhou, T. (2024). Biochar application for the remediation of soil contaminated with potentially toxic elements: Current situation and challenges. *Journal of Environmental Management*, 351, 119775. https://doi.org/10.1016/J.JENVMAN.2023.119775
3. Pathy, A., Pokharel, P., Chen, X., Balasubramanian, P., Chang, S. X. (2023). Activation methods increase biochar's potential for heavy-metal adsorption and environmental remediation: A global meta-analysis. *Science of The Total Environment*, 865, 161252. https://doi.org/10.1016/J.SCITOTENV.2022.161252
4. Hama Aziz, K. H., Kareem, R. (2023). Recent advances in water remediation from toxic heavy metals using biochar as a green and efficient adsorbent: A review. *Case Studies in Chemical and Environmental Engineering*, 8, 100495. https://doi.org/10.1016/J.CSCEE.2023.100495
5. Guo, W., Yao, X., Chen, Z., Liu, T., Wang, W., Zhang, S., Xian, J., Wang, Y. (2024). Recent advance on application of biochar in remediation of heavy metal contaminated soil: Emphasis on reaction factor, immobilization mechanism and functional modification. *Journal of Environmental Management*, 371, 123212. https://doi.org/10.1016/J.JENVMAN.2024.123212
6. Sivaranjanee, R., Senthil Kumar, P., Chitra, B., Rangasamy, G. (2024). A critical review on biochar for the removal of toxic pollutants from water environment. *Chemosphere*, 360, 142382. https://doi.org/10.1016/J.CHEMOSPHERE.2024.142382
7. Yang, X., Hou, R., Fu, Q., Li, T., Li, M., Cui, S., Li, Q., Liu, M. (2024). A critical review of biochar as an environmental functional material in soil ecosystems for migration and transformation mechanisms and ecological risk assessment. *Journal of Environmental Management*, 360, 121196. https://doi.org/10.1016/J.JENVMAN.2024.121196
8. Long, X. X., Yu, Z. N., Liu, S. wen, Gao, T., Qiu, R. L. (2024). A systematic review of biochar aging and the potential eco-environmental risk in heavy metal contaminated soil. *Journal of Hazardous Materials*, 472, 134345. https://doi.org/10.1016/J.JHAZMAT.2024.134345
9. Li, J., Sun, W., Lichtfouse, E., Maurer, C., Liu, H. (2024). Life cycle assessment of biochar for sustainable agricultural application: A review. *The Science of the Total Environment*, 951, 175448. https://doi.org/10.1016/J.SCITOTENV.2024.175448
10. Nguyen, T. K. T., Nguyen, T. B., Chen, W. H., Chen, C. W., Kumar Patel, A., Bui, X. T., Chen, L., Singhania, R. R., Dong, C. Di. (2023). Phosphoric acid-activated biochar derived from sunflower seed husk: Selective antibiotic adsorption behavior and mechanism. *Bioresource Technology*, 371, 128593. https://doi.org/10.1016/J.BIORTECH.2023.128593
11. Ramirez, L. A., Alvarez, M., Gutierrez, V. S. (2025). From agro-alimentary residue to catalyst: Transforming sunflower seed husk waste into modified biochar for efficient ibuprofen degradation in water. *Journal of Water Process Engineering*, 72, 107458. https://doi.org/10.1016/J.JWPE.2025.107458
12. Zgureva-Filipova, D., Gosheva, L., Petrova, R., Filipov, K. (2023). Utilizing of sunflower seed husk through production of biochar and its application in systems for purification of water contaminated with cadmium. *IOP Conference Series: Earth and Environmental Science*, 1128(1), 012025. https://doi.org/10.1088/1755-1315/1128/1/012025
13. Terebilenko, A. V., Krisanova, N. V., Pozdnyakova, N. G., Mazur, D. O., Dudarenko, M. V., Pastukhov, A. O., Sivko, R. V., ..., Kolotilov, S. V. (2025). Sunflower seed husk biochar: synthesis and toxicity risk assessment. *Biotechnologia Acta*, 18(4), 28–35. https://doi.org/10.15407/biotech18.04.028
14. McGrath, J. C., Drummond, G. B., McLachlan, E. M., Kilkenny, C., Wainwright, C. L. (2010). Guidelines for reporting experiments involving animals: the ARRIVE guidelines. *British Journal of Pharmacology*, 160(7), 1573–1576. https://doi.org/10.1111/j.1476-5381.2010.00873.x
15. Kilkenny, C., Browne, W., Cuthill, I. C., Emerson, M., Altman, D. G., & NC3Rs Reporting Guidelines Working Group. (2010). Animal research: reporting in vivo experiments: the ARRIVE guidelines. *British Journal of Pharmacology*, 160(7), 1577–1579. https://doi.org/10.1111/j.1476-5381.2010.00872.x
16. Cotman, C. W. (1974). Isolation of synaptosomal and synaptic plasma membrane fractions. *Methods in Enzymology*, 31, 445–452. https://doi.org/10.1016/0076-6879(74)31050-6
17. Krisanova, N., Pastukhov, A., Dekaliuk, M., Dudarenko, M., Pozdnyakova, N., Driuk, M., Borisova, T. (2024). Mercury-induced excitotoxicity in presynaptic brain nerve terminals: modulatory effects of carbonaceous airborne particulate simulants.

Environmental Science and Pollution Research International, 31(3), 3512–3525. https://doi.org/10.1007/S11356-023-31359-X/METRICS
18. Larson, E., Howlett, B., Jagendorf, A. (1986). Artificial reductant enhancement of the Lowry method for protein determination. *Analytical Biochemistry*, 155(2), 243–248. https://doi.org/10.1016/0003-2697(86)90432-x
19. Borisova, T., Borysov, A. (2016). Putative duality of presynaptic events. *Reviews in the Neurosciences*, 27(4), 377–383. https://doi.org/10.1515/revneuro-2015-0044
20. Borisova, T. (2016). Permanent dynamic transporter-mediated turnover of glutamate across the plasma membrane of presynaptic nerve terminals: arguments in favor and against. *Reviews in the Neurosciences*, 27(1), 71–81. https://doi.org/10.1515/revneuro-2015-0023

ВПЛИВ БІОВУГІЛЛЯ З ЛУШПИННЯ НАСІННЯ СОНЯШНИКУ НА СТИМУЛЬОВАНЕ КАЛІЄВОЮ ДЕПОЛЯРИЗАЦІЄЮ ВИВІЛЬНЕННЯ L-[^{3}H]ГЛУТАМАТУ З НЕРВОВИХ ЗАКІНЧЕНЬ МОЗКУ

Н. Г. ПОЗДНЯКОВА[1] *(https://orcid.org/0000-0001-9922-5389)*
А. О. ПАСТУХОВ[1] *(https://orcid.org/0000-0001-5837-6412)*
А. В. ТЕРЕБІЛЕНКО[2] *(https://orcid.org/0000-0002-8956-8713)*
М. О. ІВАНИЦЯ[2] *(https://orcid.org/0009-0003-0590-8720)*
С. В. КОЛОТІЛОВ[2] *(https://orcid.org/0000-0002-4780-4378)*
Т. О. БОРИСОВА[1] *(https://orcid.org/0000-0002-6533-1420)*
Н. В. КРИСАНОВА[1] *(https://orcid.org/0000-0001-5208-2982)*

[1]Інститут біохімії ім. О. В. Палладіна НАН України, Київ
[2]Інститут фізичної хімії імені Писаржевського НАН України, Київ

E-mail: nataly.pozdniakova@gmail.com

Мета. Актуальним завданням сучасної біотехнології є пошук ефективних адсорбентів, які мають здатність: 1) детоксикувати важкі метали, 2) є біосумісними та 3) не впливають на гомеостаз фізіологічних металів у нервових клітинах. Раніше ми продемонстрували, що біовугілля, отримане методом піролізу з лушпиння насіння соняшнику з немодифікованою поверхнею, є біосумісним та містить вуглець (89,5%) і кальцій (0,4%). Метою було проаналізувати, чи впливає кальцій, який міститься у біовугіллі (0,4%), на вивільнення L-[^{3}H] глутамату з нервових закінчень.

Методи. Ключові параметри синаптичної передачі були проаналізовані за допомогою пресинаптичних нервових закінчень (синаптосом) кори головного мозку щурів та радіоактивно міченого збуджувального нейромедіатора L-[^{3}H] глутамату.

Результати. Продемонстровано, що біовугілля не впливає на нестимульоване тонічне вивільнення L-[^{3}H]глутамату з синаптосом у середовищі без Ca^{2+}. Вивільнення L-[^{3}H]глутамату з синаптосом, стимульоване калієвою деполяризацією плазматичної мембрани, виміряне у присутності біовугілля в середовищі без Ca^{2+}, було вищим у середовищі без ЕГТА, ніж у присутності ЕГТА. Тоді як вивільнення, індуковане мембранною деполяризацією з нервових закінчень, виміряне у середовищі, що містить Ca^{2+}, не змінювалося у присутності біовугілля порівняно з контролем (без біовугілля).

Висновок. Ca^{2+}, що міститься у біовугіллі, може вивільнятися у середовище інкубації синаптосом. Однак, вміст Ca^{2+} у біовугіллі не був досить вагомим, щоб вплинути на Ca^{2+}-залежне вивільнення L-[^{3}H]глутамату з нервових закінчень, що підтверджує біосумісність біовугілля та перспективу його медичного застосування.

Ключові слова: сільськогосподарські відходи, лушпиння насіння соняшнику, пролізне біовугілля, глутамат, пресинаптичні нервові закінчення, кора головного мозку.

Received 2026/09/19
Revised 2026/10/01
Accepted 2026/10/31