HUNGARIAN UNIVERSITY OF AGRICULTURE AND LIFE SCIENCES

IN VITRO EVALUATION OF A TOXIC HERBICIDE FORMULATION AND ITS INGREDIENTS

THESES OF DOCTORAL (PhD) DISSERTATION

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1. INTRODUCTION AND OBJECTIVES

Over the past decades, with the advancement of industry and agriculture, the production of chemical substances with various toxic effects has increased significantly. In recent years the application of pesticide formulations and the potential for human exposure arising from their use have, , been associated with a range of toxic effects, including carcinogenicity. The task of risk assessment is to estimate the likelihood of health- and environment-damaging effects resulting from exposure to hazardous substances, and to periodically re-evaluate these risks as scientific knowledge advances. Therefore, identifying potential hazards and estimating exposures has become of increasingly importance in the risk assessment of pesticide formulations.

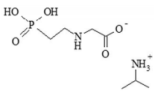
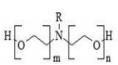
The globally dominant herbicide active substance, *GLY*, has a considerable impact on the environment and may affect various non-target organisms. The presence of *GLY* and its residues in different environmental matrices can lead to unintended human exposure as well. Numerous studies over the past decades have demonstrated the side effects of *GLY* and its formulated products (e.g., cytotoxicity, genotoxicity, apoptotic effects). As a result of mounting scientific evidence and strong criticism, the scheduled European Union re-evaluation of *GLY* (and its formulated product ROUNDUP CLASSIC [R]) has been repeatedly postponed.

There is currently no consensus on the health effects of *GLY* in humans. While the United States Environmental Protection Agency (EPA) and the European Food Safety Authority (EFSA) have classified *GLY* as "not likely to be carcinogenic to humans," the International Agency for Research on Cancer (IARC) has categorized it as "probably carcinogenic to humans" (Group 2A). Currently, *GLY* is approved for use in the European Union until 15 December 2033.

During my research, I assessed the effects of *GLY*, a commercial *glyphosate*-based herbicide (*GBH*) formulation, and a surfactant present in the formulation (Table 1) on several cellular endpoints—including viability, DNA damage, apoptosis, and cell cycle progression—across different mammalian cell lines.

Throughout the experimental phase of my research, I employed test methods that are widely accepted and scientifically validated on a global scale. Cell viability was assessed using flow cytometry and the 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) assay. Genotoxicity was evaluated by flow cytometry and the comet assay, and the results obtained from the two methods were compared. The effects on apoptosis and cell cycle progression were analyzed using flow cytometric techniques.

Table 1. Composition and characteristics of the tested GLY active ingredient, GLY-containing pesticide formulation, and formulant

Active ingredient name	**CAS number**	**Active ingredient concentration**	**Structural formula**	**Adjuvant concentration**	**Physical appearance**
glyphosate isopropylammonium salt (*GLY*-IPA-salt)	38641-94-0	62% (486 g/L *GLY* acid equivalent)		–	water-soluble emulsion
Pesticide product name	**Active ingredient**	**Active ingredient concentration**	**Adjuvants**	**Adjuvant concentration**	**Formulation type**
Roundup Classic	*GLY-IPA salt*	41.5% (360 g/l *GLY* acid equivalent)	polyethoxylated tallow amine mixture (POE-15)	15.5%	soluble liquid concentrate
Formulant Name	**CAS number**	**Formulant concentration**	**Structural formula of the formulant**	**Adjuvant concentration**	**Formulation type**
Emulson AG GPE 3SS	*POE-15 (CAS 61791-26-2)*	100%		–	water-soluble emulsion

2. MATERIALS AND METHODS

Literature data have confirmed that *GLY* exerts biological effects on various mammalian cell lines. Therefore, we aimed to assess the effects of *GLY***,** Roundup Classic (*R*), and its formulating agent *POE-15* on cell lines of mammalian origin that have been rarely mentioned or not previously addressed in the scientific literature. For this purpose, we selected two distinct cell lines of mammalian origin.

The neuroectodermal NE-4C neural stem cell line was chosen due to its pronounced sensitivity. This cell line is uniquely characterized by the lack of a functional p53 tumor suppressor protein and by its strong responsiveness to retinoic acid–induced neural differentiation. As a second model, we employed the MC3T3-E1 cell line, which exhibits somewhat lower sensitivity. The rationale behind this choice was twofold: firstly, this pre-osteoblastic cell line is also related to retinoic acid signaling mechanisms; secondly, based on our preliminary observations, *GLY* markedly inhibited the adhesion of these spontaneously transformed bone-forming precursor cells to the culture surface, ultimately leading to the identification of a *GLY*-specific integrin-inhibitory effect.

The concentrations of *GLY* and *POE-15* used in our experiments can be expressed in several ways: mass concentration (e.g., g/L), percentage concentration (e.g., g/100 mL), molar concentration (e.g., mol/L, M), or as the dilution/concentration of the R formulation in which the respective component is present at the given concentration. This latter is referred to as the Roundup Classic–equivalent concentration, or simply Roundup-equivalent concentration.

With the exception of the MTT assay, cells were seeded into 6-well culture plates at a density of 1.5×10^5 cells per well. Following a 24-hour

incubation, treatments with varying concentrations of *GLY-IPA***,** R, or *POE-15* were applied in MEM or α-MEM culture medium. For the MTT assay, NE-4C and MC3T3-E1 cells were seeded into 96-well plates at a density of 5×10^4 cells/mL, with a final volume of 200 μL per well. The treatment duration in all experiments was 24 hours. The experimental results allowed for a comparative assessment of the sensitivity of the selected cell lines and the analytical techniques applied.

3. RESULTS AND DISCUSSION

Based on the results of the MTT assays, the tested compounds exerted inhibitory effects on cell viability, particularly in the case of NE-4C cells. The IC_{50} values calculated during the experiments are presented in detail in Table 2. For NE-4C cells, the cytotoxicity of *POE-15* proved to be 200 times higher compared to that of the active substance. Flow cytometry results also indicated a higher level of cytotoxicity for both *POE-15* and the formulation compared to the active ingredient alone. According to viability measurements, NE-4C cells were found to be 1.1–2 times more sensitive than the MC3T3-E1 cell line.

In the genotoxicity studies, we used the lowest genotoxic dose (LGD) to define the genotoxic threshold, given that IC_{50} values cannot be determined in genotoxicity assays. The LGD refers to the lowest dose at which the tested compound induces a positive response in a genotoxicity test. In the evaluation of DNA damage, results from the comet assay revealed 2910-fold and 2247-fold higher DNA migration in the case of *POE-15* compared to *GLY-IPA* and the formulation, respectively. MC3T3-E1 cells proved to be less sensitive to DNA-damaging effects compared to NE-4C cells. In the case of MC3T3-E1 cells, the LGD values determined following treatment with *POE-15*, *R*, and *GLY-IPA* were 271-fold, 120-fold, and 3.2-fold higher, respectively, than the corresponding values observed in NE-4C cells. DNA damage was also detected in the negative control in our experiments, which can be attributed to the lack of the p53 tumor suppressor protein in the NE-4C cell line. The comet assay proved to be more sensitive in the NE-4C cell line. The pattern of LGD values observed in the MC3T3-E1 cells corresponded to the trend seen in NE-4C cells. Compared to the effects of *GLY-IPA* and the formulation, *POE-15*

induced 401-fold and 8.4-fold higher levels of DNA damage in NE-4C and MC3T3-E1 cells, respectively.

During the assessment of apoptosis, the effects of the treatments were confirmed based on both annexin levels and caspase 3/7 activity measurements. In NE-4C cells, *POE-15* treatment resulted in a 2.6-fold and 273-fold higher proportion of apoptotic cells compared to *GLY-IPA* and R treatments, respectively. In the MC3T3-E1 cell line, the highest proportion of apoptotic cells was observed following *POE-15* exposure. After 24 hours of treatment, the proportion of dead cells increased, while the number of viable cells decreased in a dose-dependent manner. Based on our findings, *POE-15* induced apoptosis at lower concentrations than R. Notably, differences were observed between the analytical methods applied for the evaluation of apoptotic responses.

Based on cell cycle analysis, it was observed that the majority (~46%) of NE-4C cells in the negative control group were in the growth phase (G_0/G_1) following 24 hours of exposure. In contrast, treatment with the tested compounds resulted in a significantly lower proportion of cells in this phase compared to the control, with a clear dose-dependent decrease. The early stage of DNA replication (S phase) was not affected by *GLY-IPA* treatment; however, a reduction in the proportion of cells in the S phase was observed following exposure to the formulation and *POE-15*. In the mitotic G_2/M phase, an increase in the proportion of cells was detected after treatments, with the most pronounced elevation observed at the lowest tested concentration of *GLY-IPA*. As the concentration increased, the proportion of cells in the G_2/M phase gradually declined. Although *GLY-IPA* increased the proportion of NE-4C cells, cellular proliferation was arrested in the G_0/G_1 phase due to suboptimal conditions, and only a small fraction of the cells progressed through the checkpoint to enter the S and G_2/M phases. As a result, the

proportions of cells in these latter phases were lower than in the control group. In the MC3T3-E1 cell line, a higher proportion of cells (~80%) were detected in the G_0/G_1 phase in the negative control compared to NE-4C cells. A high relative abundance of cells in the quiescent (G_0) and initial growth (G_1) phases is characteristic of MC3T3-E1 cells. However, in the R- and *POE-15*-treated groups, the proportion of cells in the G_0/G_1 phase was reduced. Similar to NE-4C cells, the tested compounds did not influence the proportion of cells in the S phase in MC3T3-E1 cells. An increase in the proportion of cells in the G_2/M phase was observed following treatments.

Our results showed the following toxicity trend for both cell lines applied: *GLY-IPA* << R < *POE-15*.

Table 2.Half-maximal inhibitory concentration (IC_{50}) for cytotoxicity and apoptosis and lowest genotoxic dose (LGD) values for genotoxicity disruption determined for glyphosate, polyethoxylated tallowamine (POE-15) and Roundup Classic.*

IC_{50} and **LGD** value (expressed as % Roundup Classic equivalent concentration and µg/ml) [a]							
	GLY-IPA		***POE-15***		**R [c]**		
	(%)	(µg/ml)	(%)	(µg/ml)	(%)	*GLY-IPA* (µg/ml)	*POE-15* (µg/ml)
Cell line				**NE-4C [b]**			
Cell viability							
MTT (biotest)	0.652±0.006	3168.72	0.00315±0.00007	5.72	0.00995±0.00010	48.36	18.06
Cell Analyzer kit (Muse)	0.595±0.009	2891.70	0.00115±0.00007	2.09	0.00469±0.00008	22.79	8.51
DNA damage							
Comet (biotest)	0.0259	125.87	0.0000089	0.043	0.00002	0.09	0.03
DNA Damage kit (Muse)	0.0376	182.55	0.000295	0.54	0.00117	5.68	2.12
Programmed cell death							
Annexin V Dead Cell kit (Muse)	0.246±0.134	1195.56	0.00092±0.00005	1.67	0.00238±0.00003	11.57	4.32
Caspase 3/7 kit (Muse)	0.568±0.043	2760.48	0.00099±0.00002	1.80	0.00748±0.00012	36.35	13.58

	GLY-IPA		***POE-15***		**Ro** [c]		
	(%)	(µg/ml)	(%)	(µg/ml)	(%)	*GLY-IPA* (µg/ml)	*POE-15* (µg/ml)
Cell line				**MC3T3-E1** [b]			
Cell viability							
MTT (biotest)	0.7256±0.0068	3526.42	0.00639±0.00003	11.60	0.0101±0.0004	49.09	18.33
Cell Analyzer kit (Muse)	1.2495±0.0024	6072.57	0.00936±0.00085	16.99	0.0187±0.0007	90.88	33.94
DNA damage							
Comet (biotest)	0.0835	405.97	0.0024125	4.38	0.00224	10.89	4.07
DNA Damage kit (Muse)	0.0375	182.15	0.0000935	0.17	0.000786	3.82	1.43
Programmed cell death							
Annexin V Dead Cell kit (Muse)	0.2731±0.0045	1327.27	0.01169±0.00048	21.22	0.0167±0.0013	81.16	30.31
Caspase 3/7 kit (Muse)	0.6412±0.0339	3116.23	0.00649±0.00012	11.78	0.0073±0.0001	35.48	13.25

* The LGD value is the first time a genotoxic effect is observed after control treatment

[a] Mass-per-volume percent concentrations of diluted Roundup Classic containing the corresponding concentrations of these substances.

[b] Cell lines – NE-4C: established from the cerebral vesicles of 9-day-old mouse embryos lacking the functional p53 genes; MC3T3-E1: osteoblast precursor cell line derived from Mus musculus (mouse) calvaria.

[c] Percentage concentrations of the formulated herbicide and actual concentrations of the active ingredient and the formulant in Roundup Classic at the given mass-per-volume concentration are indicated.

The relationship between *GLY* and commonly used food additives and known food contaminants introduces a novel perspective on the accumulation of chemical residue particularly in the context of food safety and public health. *GLY* is used extensively as the active ingredient in herbicidal formulations, raising growing concerns about its presence in agricultural products and foodstuffs due to its potential to enter the food chain as a residue. Both *GLY* and various food additives or contaminants—such as acrylamide, benzoic acid, and citric acid—have demonstrated genotoxic effects, including DNA damage and chromosomal aberrations. DNA damage induced by genotoxic agents can contribute to malignant cellular transformation, indicating a possible carcinogenic potential. *GLY* typically enters food products via residues on treated crops, while additives like benzoic acid and citric acid are intentionally introduced during food processing. The level of human exposure plays a critical role in determining the associated risk. Although *GLY* may be present at low concentrations in food, concerns remain regarding its potential long-term health effects. In contrast, food additives and contaminants are governed by comprehensive regulatory standards aimed at minimizing potential health risks. The intersection of *GLY* residues and food additives draws attention to potential health risks associated with cumulative dietary exposure to agricultural and food-processing chemicals The genotoxic effects of such substances may cumulatively contribute to an increased risk of cancer over time. Accordingly, rigorous regulation and ongoing research are essential to better understand and mitigate these risks. To minimize human exposure, both agricultural practices and food processing techniques must be optimized to ensure consumer health and safety.

Ecotoxicological research has traditionally focused on the active ingredients of pesticides, although under environmentally relevant conditions, living organisms are exposed to complex pesticide formulations. The wide

range of effects observed in non-target organisms challenges the assumption that herbicides act selectively on target plant species. Both *GLY* and GBHs have been shown to exert unintended adverse effects on a broad array of terrestrial and aquatic organisms, including non-target plants, microorganisms, insects, arachnids, earthworms, various aquatic invertebrates, and vertebrates. These adverse outcomes are primarily associated with oxidative stress and disturbances in vital physiological and homeostatic processes, with documented evidence of genotoxic and cytotoxic effects. Due to its intensive use, *GLY* is widely present in the environment and – as I have emphasized before – it sometimes exerts harmful effects on non-target organisms. In addition, it can enter drinking water and the food chain. In humans, it has been associated with various health issues, such as cancer and hormonal disruptions, although the extent of these effects remains controversial. Research is ongoing, while an increasing number of professional recommendations advocate for the reduction of *GLY* use and for stricter, safer regulations regarding its application. The evidence presented in this dissertation indicates that *GLY* and GBHs may exert substantial effects on non-target organisms in both soil-dwelling and aquatic ecosystems. Owing to its physicochemical properties, *GLY* can readily reach aquatic environments. Similarly, the adverse effects of *GLY* and GBHs on terrestrial ecosystems are increasingly supported by experimental data. Investigations involving aquatic plant and animal species suggest that one of the primary toxic mechanisms of GBHs is oxidative stress, which is closely associated with the apoptotic processes, DNA damage, and cytotoxicity observed in our study. As these effects occur at the cellular level, *in vitro* studies are essential for elucidating the underlying mechanisms.

4. NEW SCIENTIFIC RESULTS

1. Among the three substances tested , both viability assays yielded results of comparable magnitude; however, higher values were measured in the MC3T3-E1 cell line compared to the NE-4C cell line. Notably, the NE-4C cell line appeared more sensitive in the flow cytometry assay, as MTT assay results were 91%, 36%, and 47% higher (mean ± SD: 58% ± 29%) than those obtained by flow cytometry. In contrast, an inverse pattern was observed for the MC3T3-E1 cell line, where MTT assay values exceeded the flow cytometric results by 58%, 68%, and 54% (mean ± SD: 60% ± 7%), indicating greater sensitivity in the MTT assay.

2. Based on the lowest genotoxic dose (LGD) values obtained from our genotoxicity assays, the NE-4C cell line proved to be, on average, two orders of magnitude more sensitive in the comet assay than the MC3T3-E1 cell line. This pronounced difference is clearly attributable to the absence of the p53 tumor suppressor protein—and consequently, to the lack of efficient DNA damage repair mechanisms—in the NE-4C cells. In contrast, for the MC3T3-E1 cell line, the flow cytometry-based DNA damage detection kit yielded a more sensitive response, with LGD values being lower by 44%, 3%, and 35% (on average 27% ± 22%) compared to those obtained with the comet assay.

3. The NE-4C cell line exhibited, on average, 55% greater sensitivity in the apoptosis assay detecting all apoptotic cells compared to the caspase-3/7 assay, which detects both apoptotic and dead cells. Findings from this study indicate that, in response to *POE-15*, the NE-4C cell line demonstrated approximately ninefold higher sensitivity in both apoptosis assays relative to the MC3T3-E1 cell line.

4. Cell cycle analysis of NE-4C cells demonstrated that *GLY-IPA* treatment results in cell cycle arrest in the G_0/G_1 phase, as the cells do not sense optimal conditions for growth and fail to pass the first restriction point. Notably, the highest proportion of cells in the G_0/G_1 phase was observed at the lowest concentration tested, where a statistically significant difference was detected compared to the control treatment ($p < 0.05$). Treatment with R and *POE-15* induced a monotonic, dose-dependent decrease in the percentage of cells in the G_0/G_1 phase, ranging from 0.0007% to 0.0026% (expressed as Roundup Classic-equivalent concentrations). Except for the lowest concentration of R, significant increases ($p < 0.001$) in the proportions of cells in the S and G_2/M phases were observed compared to controls following both R and *POE-15* treatments. In MC3T3-E1 cells, the proportion of cells in the G_0/G_1 phase under control conditions was on average 57% higher than that observed in NE-4C cells, but this proportion decreased following treatment. The percentage of cells in the S phase was unaffected by treatment, whereas an increase in the G_2/M-phase cell population was noted after 24 hours of exposure.

5. CONCLUSIONS AND RECOMMENDATIONS

The data obtained from the experiments clearly demonstrated that the various analytical methods differ in both sensitivity and informational value. The MTT assay is suitable for assessing overall cellular viability, while flow cytometry allows for the evaluation of more detailed cell physiological parameters. The comet assay provides the advantage of visual information, whereas the flow cytometry-based DNA damage assay offers quantitative and objective data acquisition. The combined application of these assays also revealed that different cell lines respond with varying sensitivity to the same compounds. This was particularly relevant in the assessment of *POE-15* toxicity, as the results indicated that this compound alone is several orders of magnitude more toxic than *GLY-IPA* alone.

In general, the test substances used in this dissertation (*GLY-IPA*, R, and *POE-15*) exhibited inhibitory effects in all assays compared to the control treatments, although the extent of these effects varied, as detailed in the Results section. Among the substances tested, *POE-15* induced the most pronounced inhibitory effects. This outcome is not unexpected, given that, in 2016, the European Union banned GLY-based formulations containing *POE-15* as a surfactant—an important step toward improving the safety of pesticide products.

The potential association between *GLY* exposure and non-Hodgkin lymphoma (NHL) remains one of the most contentious issues regarding the safety of *GLY*. Over the years, numerous studies have investigated this possible link: while some suggest that *GLY* exposure may increase the risk of developing NHL, others have found no convincing evidence to support this claim. Non-Hodgkin lymphoma encompasses a group of malignancies affecting cells of the lymphatic system. The International Agency for

Research on Cancer (IARC) has specifically emphasized an elevated risk among agricultural workers, who are typically exposed to the chemical in higher amounts and over extended periods. In light of these considerations, several conclusions can be drawn from the present experimental findings: both *R* and *POE-15* exert greater toxic effects than *GLY-IPA* on the two tested murine cell lines—the neuroectodermal, stem cell-like NE-4C cells and the MC3T3-E1 preosteoblast cells.

In all of our experiments, the two cell lines exhibited characteristic differences, with NE-4C cells consistently demonstrating at least 2.5-fold greater sensitivity to the tested substances. The link between *GLY* and food additives highlights the potential health risks posed by the presence of agricultural chemicals and additive residues in food products. The genotoxic properties of these substances may contribute to an increased risk of carcinogenesis, underscoring the need for stringent regulation and ongoing scientific investigation. In order to reduce exposure, not only should agricultural practices be re-evaluated and improved, but food processing protocols must also be optimized to ensure adequate protection of consumer health.

A Research has also highlighted that various food additives may exert synergistic effects with *GLY*, potentially exacerbating health risks. Technologies applied in modern food production can further contribute to the presence of such substances, indicating that a reassessment of manufacturing processes may also be necessary. Experts in the field of food safety agree that regulatory frameworks must keep pace with scientific advancements in order to protect long-term consumer health. It is equally important to consider alternative approaches—such as the promotion of organic farming—which may reduce the reliance on chemical inputs. Overall, the issue of *GLY* and food additives represents a global concern that warrants thorough

investigation and effective regulatory action. More conscious consumer choices, the wider adoption of sustainable agricultural practices, and the integration of emerging scientific findings can help minimize associated risks. Through the studies conducted and the results presented in this dissertation, I aim to contribute to this ongoing effort.

6. LIST OF PUBLICATIONS

1. SCIENTIFIC JOURNAL ARTICLE:

a) Articles in journals with impact factors (IF)

Klátyik, S., Simon, G., Takács, E., **Oláh, M.**, Zaller, J. G., Antoniou, M. N., Benbrook, C., Mesnage, R., Székács, A. (2025). Toxicological concerns regarding *glyphosate*, its formulations, and co-formulants as environmental pollutants: a review of published studies from 2010 to 2025. *Archives of Toxicology*. doi:10.1007/s00204-025-04076-2, D1, IF: 4,8

Najam, M., Javaid, S., Iram, S., Pasertsakoun, K., **Oláh, M.,** Székács, A., Aleksza, L. (2025). Microbial biodegradation of synthetic polyethylene and polyurethane polymers by pedospheric microbes: towards sustainable environmental management. *Polymers*, 17(2), 169. doi:10.3390/polym17020169, Q1, IF: 4,1

Klátyik, Sz., Simon, G., **Oláh, M.**, Mesnage, R., Antoniou, M. N., Zaller, J. G., Székács, A. (2024) Aquatic ecotoxicity of *glyphosate*, its formulations, and co-formulants: evidence from 2010-2023. *Environmental Sciences Europe*, 36: 22. doi:10.1186/s12302-024-00849-1, Q1, IF: 5,481

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Farkas, E., Szekacs, A., Kovacs, B., **Olah**, **M.,** Horvath, R., Szekacs, I. (2018) Label-free optical biosensor for real-time monitoring the cytotoxicity of xenobiotics: a proof of principle study on *glyphosate*. *Journal of Hazardous Materials*, 351: 80-89. doi:10.1016/j.jhazmat.2018.02.045, D1, IF:6,7

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b) Articles in journals without impact factors (IF) Külföldi kiadású

Oláh, M., Farkas, E., Székács, I., Horvath, R., Székács, A. (2022) Cytotoxic effects of Roundup Classic and its components on NE-4C and MC3T3-E1 cell lines determined by biochemical and flow cytometric assays. *Toxicology Reports*, 9: 914-926. doi:10.1016/j.toxrep.2022.04.014, Q2

Kónya, É., Szabó, E., Bata-Vidács, I., Deák, T., **Ottucsák, M.**, Adányi, N., Székács, A. (2016) Quality management in spice paprika production as a synergy of internal and external quality measures. *Intl. J. Biol. Biomol. Agric. Food Biotech. Engineer.*, 10(3), 160-166.

Klátyik, Sz., Darvas, B., Mörtl, M., **Ottucsák, M**., Takács, E., Bánáti, H., Simon, L., Gyurcsó, G., Székács, A. (2016) Food safety aspects of pesticide residues in

spice paprika. *International Journal of Biological, Biomolecular, Agricultural, Food and Biotechnological Engineering*, **10**(3), 156-159.

c) In a Hungarian-language, non-impact-factor domestic journal

Oláh, M., Farkas, E., Székács, I., Horvath, R., Klátyik, Sz., Székács, A. (2022) A Roundup Classic gyomirtó szer és összetevői citotoxikus hatásainak vizsgálata *Ökotoxikológia* 4(3-4.), 54-60.

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Oláh, M., Farkas, E., Székács, I., Horvath, R., Székács, A. (2021) A Roundup Classic és összetevőinek citotoxikus és genotoxikus hatásai NE-4C és MC3T3-E1 sejtvonalakon *Ökotoxikológia* 3(2) 18-19.

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Ottucsák, M., Kocsis, Zs., Tarnóczai, T., Marcsek, Z., Major, J. (2015) Ösztrogénreceptorra ható vegyületek vizsgálata in vitro rendszerben, *Egészségtudomány*, LIX. (2)92.

Ottucsák, M., Kocsis, Zs., Tarnóczai, T., Kelemen, K., Marcsek, Z., Major, J. (2014) Ösztrogén receptor transzkripció aktivációs vizsgálat a HeLa9903 sejtvonalon, az OECD TG 455 alapján, GLP rendszerben *bioKontroll* 5. évfolyam 2. Szám 75-76.

2. CONFERENCE PUBLICATIONS

a) In foreign language:

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