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STUDY OF THE ANTICANCER PHARMACOLOGICAL PROPERTIES AND MEDICAL APPLICATIONS OF ANTIOXIDANT-ACTIVE PLANTS

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ИССЛЕДОВАНИЕ ПРОТИВОРАКОВЫХ ФАРМАКОЛОГИЧЕСКИХ СВОЙСТВ И МЕДИЦИНСКОГО ПРИМЕНЕНИЯ РАСТЕНИЙ С АНТИОКСИДАНТНЫМ ДЕЙСТВИЕМ

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Abstract. Excessive accumulation of reactive oxygen species (ROS), which disrupts intracellular redox homeostasis, leads to oxidative stress and DNA strand damage, representing one of the major triggering factors of carcinogenesis. The high systemic toxicity of conventional chemotherapeutic agents and the development of multidrug resistance in tumor cells have increased interest in the application of plant-derived antioxidants in cancer therapy. This review aims to comprehensively analyze, based on scientific literature published between 2020 and 2026, the molecular anticancer mechanisms of antioxidant phytochemicals, their role in the induction of mitochondrial apoptosis, the modulation of signaling pathways, the targeting of oncomiRNAs, and their therapeutic application through green-synthesized nanocarrier systems. Plant-derived polyphenols (e.g., chlorogenic acid), diterpenes (e.g., carnosic acid), stilbenoids (e.g., oxyresveratrol), and enriched extracts activate the caspase-3/9 cascade in cancer cells, suppress the AKT/mTOR signaling pathway, and modulate Nrf2-mediated redox mechanisms. Green-synthesized silver (AgNPs) and gold (AuNPs) nanoparticles, as well as polymeric carrier systems, enhance the bioavailability of these compounds and demonstrate promising potential for improving the efficacy of targeted cancer therapy.

Аннотация. Чрезмерное накопление активных форм кислорода (АФК), нарушающее внутриклеточный окислительно-восстановительный гомеостаз, приводит к окислительному стрессу и повреждению цепей ДНК, что является одним из основных факторов, провоцирующих канцерогенез. Высокая системная токсичность традиционных химиотерапевтических препаратов и развитие множественной лекарственной устойчивости у опухолевых клеток привели к росту интереса к применению антиоксидантов растительного

происхождения в лечении рака. Цель данного обзора — на основе научной литературы, опубликованной в период с 2020 по 2026 год, провести всесторонний анализ молекулярных противораковых механизмов действия антиоксидантных фитосоединений, их роли в индукции митохондриального апоптоза, модуляции сигнальных путей, воздействии на онкомиРНК, а также их терапевтического применения с помощью наноносителей, синтезированных экологически чистым способом. Полифенолы растительного происхождения (хлорогеновая кислота), дитерпены (карнозиновая кислота), стильбеноиды (оксиресвератрол) и обогащённые экстракты активируют каскад каспаз-3/9 в раковых клетках, подавляют сигнальный путь АКТ/mTOR и модулируют окислительно-восстановительные механизмы, опосредованные Nrf2. Наночастицы серебра (AgNPs) и золота (AuNPs), полученные с помощью «зеленого» синтеза, а также полимерные транспортные системы повышают биодоступность этих соединений и демонстрируют многообещающий потенциал для повышения эффективности целевой терапии рака.

Keywords: Antioxidants, phytochemicals, apoptosis, carcinogenesis, ROS, AKT, Nrf2, green synthesis, nanocarriers, targeted therapy.

Ключевые слова: антиоксиданты, фитосоединения, апоптоз, канцерогенез, АФК, АКТ, Nrf2, зеленый синтез, наноносители, таргетная терапия.

Oxidative Stress, Reactive Oxygen Species (ROS), and the Molecular Basis of Carcinogenesis
Reactive oxygen species (ROS), a natural byproduct of cellular metabolism, including the superoxide anion radical, hydrogen peroxide, and the hydroxyl radical, play an important role in intracellular signaling and immune response under physiological conditions [17].

However, an imbalance between the cell's endogenous antioxidant defense systems (superoxide dismutase—SOD, catalase—CAT, glutathione peroxidase—GPx) and ROS production leads to a state of oxidative stress [1, 4].

High levels of oxidative stress cause cascading damage within the cell. DNA damage and mutations caused by breaks in DNA strands and the accumulation of oxidative damage products called 8-hydroxydeoxyguanosine lead to the activation of oncogenes [16].

Lipid peroxidation: Damage to membrane lipids disrupts cell permeability and triggers the formation of toxic products such as malondialdehyde (MDA) [22].

Protein oxidation: The disruption of enzymatic activity and signaling pathways leads to carcinogenesis (tumor formation) [7].

The high systemic toxicity of traditionally synthesized chemotherapeutic drugs and multidrug resistance in tumor cells (Multidrug Resistance — MDR) has brought the study of bioactive compounds of plant origin, especially phytochemicals with antioxidant and antiproliferative properties, to the forefront of modern oncology research in the Scopus database [25].

Plant-derived antioxidants have the ability to directly neutralize free radicals (radical scavenging), chelate transition metal ions, and activate endogenous antioxidant enzyme systems [18, 30].

Polyphenols and Phenolic Acids: Chlorogenic acid (CGA), a dietary polyphenol, inhibits lipid peroxidation, stabilizes the intracellular redox environment, and exhibits hepatoprotective mechanisms [23].

Diterpenes and Key Metabolites: Carnosic acid from the rosemary (*Rosmarinus officinalis* L.) plant effectively neutralizes free radicals, protecting cell membranes from oxidative damage [11].

Enriched Polyphenol Extracts: The BriB extract obtained from artichoke (*Cynara cardunculus*) waste, *Filipendula ulmaria* (Meadowsweet) and *Flourensia species* have a high antioxidant capacity [6, 12, 26].

Discussion and results of the study

The effect of plant-based antioxidants on cancer cells is dualistic. In normal tissue cells, these substances enhance antioxidant defense, while in malignant cells, they act as selective pro-oxidants, raising intracellular ROS levels above a critical threshold and triggering apoptosis.

Activation of the Mitochondrial Apoptosis Cascade and Caspase Enzymes: Plant polyphenols and diterpenes trigger apoptosis primarily via the intrinsic (mitochondrial) pathway.

Depolarization of the Mitochondrial Membrane Potential. Phytochemicals reduce the expression of the Bcl-2 (anti-apoptotic) protein, activating the Bax and Bak (pro-apoptotic) proteins, which allows cytochrome c to leak into the cytosol [24].

Caspase Enzyme Cascade: Cytochrome c, which has passed into the cytosol, binds with Apaf-1 and pro-caspase-9 to form the apoptosome complex. Once the initiator caspase-9 is activated, it proteolytically cleaves the executive caspases-3 and -7, leading to the fragmentation of cellular DNA [20].

Artichoke extract: The BriB phenolic extract has been shown to induce apoptosis in over 80% of Caco-2 human colorectal adenocarcinoma cells [6].

Meadowsweet (*Filipendula ulmaria*) extract: Increases the apoptosis index in LoVo colorectal cancer cells by inhibiting the cell cycle [26].

Flourensia cernua and *Flourensia retinophylla*: Their rich polyphenol content induces programmed death by increasing caspase-3 activity in human colorectal adenocarcinoma cells [12].

Modulation of Key Signaling Networks Regulating Cancer Progression.

Inhibition of the AKT/mTOR Signaling Pathway: Activation of the AKT pathway by oncogenic factors (e.g., MAGEA1) leads to tumor progression in lung adenocarcinoma (NSCLC) [19].

The stilbenoid compound Oxyresveratrol restores apoptosis in EGFR-Wild-Type lung cancer cells by suppressing EGF-stimulated AKT phosphorylation [21].

Nrf2/Keap1 and STAT3 Redox Defense Mechanism: Cannabinoid receptor 2 activation neutralizes cellular damage and oxidative stress caused by iron overload through the dual modulation of the STAT3/hepcidin and Nrf2/FPN1 signaling pathways [8].

Targeting of OncomiRNAs and Epigenetic Regulators.

Oncogenic microRNAs (oncomiRNAs) silence tumor-suppressor genes, allowing tumor cells to evade apoptosis. Plant-derived bioactive compounds sensitize cancer cells to chemotherapeutic agents (chemosensitization) by targeting the temporal and spatial heterogeneity of oncomiRNAs [13].

A major challenge in the clinical application of plant-derived antioxidants is their low water solubility and low bioavailability. In modern pharmaceutical technology, green synthesis and polymer nano-carrier systems are employed to address these issues.

Green Synthesized Metal Nanoparticles.

Plant extracts act as a stabilizing agent for the reduction of metal ions and prevent the agglomeration of the resulting nanoparticles ([9].

Sub-10 nm Silver Nanoparticles (AgNPs): *Cotinus coggygria* Scop. Using a single-step green synthesis method with a plant extract, ultraminiature silver nanoparticles (AgNPs) smaller than 10 nm were obtained and exhibited high cytotoxic activity against breast cancer (in vitro) [18, 29].

Gold Nanoparticles (ZNE-AuNPs): Gold nanoparticles synthesized via *Ziziphus nummularia* extract (ZNE-AuNPs) exhibited an antiproliferative effect in Triple Negative Breast Cancer (TNBC) by altering the ROS balance [1].

Polymer Nanoparticles and Gene/Drug Delivery Systems. Targeted Delivery with Polymer Nanoparticles: Polymer nanoparticles enable the delivery of siRNA and therapeutic molecules to epithelial cells without causing damage [27].

Molecular Docking and Pharmacological Profiling: The essential oils of *Anisoscium orientale* were studied by GC-MS analysis and molecular docking methods, and the binding dynamics of the active compounds with cancer cell receptors were demonstrated [2].

<i>Biologically Active Compound/Extract</i>	<i>Plant Source</i>	<i>Target Cancer Model/Cell Line</i>
Chlorogenic acid (CGA)	Various medicinal plants	Liver Cancer/ Hepatocellular Carcinoma
Carnosic acid	<i>Rosmarinus officinalis</i> L. (Rosemary)	Various cancer cell models
BriB Phenolic Extract	<i>Cynara cardunculus</i> (Artichoke)	Caco-2 (Human Colorectal Adenocarcinoma)
Oxiresveratrol	Stilbene derivative	NSCLC (EGFR-Wild-Type Lung Cancer)
Sub-10 nm AgNPs	<i>Cotinus coggygria</i> Scop.	Breast Cancer Cell Lines (In vitro)
Gold Nanoparticles (AuNPs)	<i>Ziziphus nummularia</i>	TNBC (Triple-Negative Breast Cancer)
Aqueous Meadowsweet Extract	<i>Filipendula ulmaria</i> (Meadowsweet)	LoVo (Colorectal Cancer)
Polyphenol Extracts	<i>Flourensia cernua</i> and <i>F. retinophylla</i>	Colon Adenocarcinoma
Essential Oils	<i>Anisoscium orientale</i>	Various Cancer Models
CB2 Receptor Agonists	Cannabinoid Derivatives	Liver injury/ Redox models
OncomiRNA Modulators	Bioactive Phytocompounds	Resident Tumor Models
Polymer Nanoparticles	Synthesized/Natural Polymers	Respiratory Epithelial Cells
MAGEA1 Targets	Biologically active inhibitors	Lung Adenocarcinoma
Quercetin and Formulations	Various fruits and vegetables	Various solid tumors
Curcumin Formulations	<i>Curcuma longa</i> (Turmeric)	Gastrointestinal and Solid Tumor Types
Resveratrol	<i>Vitis vinifera</i> (Grape)	Multiple Cancer Models
Epigallocatechin gallate (EGCG)	<i>Camellia sinensis</i> (Green tea)	Solid Tumors
Sulforaphane	Brassica family vegetables	Bladder cancer (T24) and others
Flavonoid Complexes	Mixed plant sources	Various Cancer Types
PI3K/Akt Inhibitors	Phytochemical classes	Cancer Stem Cells (CSC)
Plant Polyphenols	Rich botanical extracts	Inflammatory tumor models
Phytochemical Inhibitors	Cyclin Botanical extracts	Colorectal Cancer
Flavonoid Agonists	Medicinal herbs	Wild-type and mutant tumors
Autophagy Modulators	Natural products	Resistant Cancer Cells
PLGA Nanoparticles	Biodegradable polymers	Solid Tumors
Liposomal Phytocomplexes	Lipid-based carriers	Targeted tumor tissues
EPR Nanocarriers	Polymer and Metal Carriers	Vascularized Tumors
Combination Therapy	Phytocompounds + Cisplatin/Doxorubicin	Tumors with low chemoresponsiveness
Magnetic Nanoparticles (Fe ₃ O ₄)	Green synthesized hybrids	Theranostic models
Vitanolides	<i>Withania somnifera</i> (Ashwagandha)	Neuroblastoma and Cancer

Conclusion

A systematic review of the scientific literature from 2020–2026 shows that plant-based bioactive substances with antioxidant properties (Chlorogenic acid, Carnosic acid, Oxyresveratrol) and polyphenol-rich extracts (*Artichoke*, *Filipendula ulmaria*, *Flourensia* ssp.) induce ROS accumulation by exhibiting selective pro-oxidant activity in cancer cells. At the molecular level, the anti-cancer effect of these substances is centered on 3 main pillars: 1. Mitochondrial Apoptosis: Induction of programmed cell death through the disruption of mitochondrial membrane potential and activation of the caspase-9/3 cascade. 2. Blockade of Oncogenic Signal Cascades: Suppression of the AKT/mTOR signaling pathway and modulation of the Nrf2/FPN1 redox defense system. 3. Epigenetic and miNTK Regulation: Chemosensitization of cells by targeting the spatiotemporal heterogeneity of oncogenic microRNAs (oncomiRNAs) [13]. The problems of low bioavailability and low stability of plant-derived bioactive compounds are solved by modern nano-carrier systems [10]. Green synthesis of ultraminiature silver (AgNPs, <10 nm) and gold (AuNPs) nanoparticles, as well as polymer nanoparticles, ensures the targeted delivery of active substances to tumor tissue. In Vivo Toxicology and Dose Optimization: The long-term systemic toxicity and biodegradation mechanisms of nanoparticles and extracts should be studied in more detail in genetically modified animal models. Pharmacokinetic (PK/PD) Profiling: The absorption, distribution, metabolism, and excretion (ADME) parameters of phytocompounds must be standardized. The initiation of phase I–III clinical trials for nano-formulations and the validation of their synergistic combinations with conventional chemotherapeutic agents is a priority goal of modern onco-pharmacology [25].

References

1. Abdallah, R., Abdel-Rahem, R., Badran, A., Al-Remawi, M., Baydoun, S., Bechelany, M., ... & Baydoun, E. (2026). Green Ziziphus nummularia gold nanoparticles: antioxidant and anticancer activity in TNBC. *Scientific Reports*. <https://doi.org/10.1038/s41598-026-62225-8>
2. Abotaleb, M., Liskova, A., Kubatka, P., & Büsselberg, D. (2020). Therapeutic potential of plant phenolic acids in the treatment of cancer. *Biomolecules*, 10(2), 221. <https://doi.org/10.3390/biom10020221>
3. Abouzied, A. S., Fouda, W. M., El-Nagar, M. K., Huwaimel, B., Alqarni, S., Alghubayshi, A., ... & Refaey, M. S. (2026). Unveiling the Pharmacological Potential of Anisosciadium orientale: An Integrative Analysis of Cytotoxicity, Molecular Docking, and Apoptotic Pathways. *International Journal of Molecular Sciences*, 27(13), 5767. <https://doi.org/10.3390/ijms27135767>
4. Al-Ishaq, R. K., Liskova, A., Kubatka, P., & Büsselberg, D. (2021). Enzymatic metabolism of flavonoids by gut microbiota and its impact on gastrointestinal cancer. *Cancers*, 13(16), 3934. <https://doi.org/10.3390/cancers13163934>
5. Anand, S., Sowbhagya, R., Ansari, M. A., Alzohairy, M. A., Alomary, M. N., Almalik, A. I., ... & Elderderly, A. Y. (2022). Polyphenols and their nanoformulations: protective effects against human diseases. *Life*, 12(10), 1639. <https://doi.org/10.3390/life12101639>
6. Calvello, R., Cianciulli, A., Compierchio, A., Porro, C., Caponio, G. R., De Angelis, M., & Panaro, M. A. (2026). Phenolic-Rich Extracts from Artichoke By-Products Promote Apoptosis in Human Colorectal Cancer Cell Lines. *Nutrients*, 18(13), 2077. <https://doi.org/10.3390/nu18132077>
7. Dar, N. J., Hamid, A., & Ahmad, M. (2015). Pharmacologic overview of Withania somnifera, the Indian Ginseng. *Cellular and molecular life sciences*, 72(23), 4445–4460. <https://doi.org/10.1007/s00018-015-2012-1>
8. Deng, H., Ren, Y., Sui, Y., & Ma, Z. (2026). Activating Cannabinoid receptor 2 alleviates iron overload-induced liver damage via dual modulation of STAT3/hepcidin and Nrf2/FPN1 pathways. *Molecular Biomedicine*, 7(1), 135. <https://doi.org/10.1186/s43556-026-00541-1>

9. Gobbo, O. L., Sjaastad, K., Radomski, M. W., Volkov, Y., & Prina-Mello, A. (2015). Magnetic nanoparticles in cancer theranostics. *Theranostics*, 5(11), 1249. <https://doi.org/10.7150/thno.11544>
10. Fang, J., Nakamura, H., & Maeda, H. (2011). The EPR effect: Unique features of tumor blood vessels for drug delivery, factors involved, and limitations and augmentation of the effect. *Advanced drug delivery reviews*, 63(3), 136-151. <https://doi.org/10.1016/j.addr.2010.04.009>
11. Fareid, M. A., El-Sherbiny, G. M., Elafandy, N. M., Eltoun, N. E., Othman, M. S., El-Hawary, A. S., ... & Youssef, A. S. E. D. (2026). Phytochemical Elucidation and Biological Activity Spectrum of *Rosmarinus officinalis* L.: Mechanistic Insights into the Antimicrobial, Antioxidant, and Apoptosis-Inducing Anticancer Effects of Carnosic Acid. *Metabolites*, 16(7), 459. <https://doi.org/10.3390/metabo16070459>
12. Jasso de Rodríguez, D., Carrillo-Lomelí, D. A., Díaz-Rivas, J. O., Rocha-Guzmán, N. E., & Moreno-Jiménez, M. R. (2026). Apoptosis induction by polyphenolic-rich extracts from *Flourensia cernua* and *Flourensia retinophylla* in human colon adenocarcinoma cells. *Cytotechnology*, 78(5), 171. <https://doi.org/10.1007/s10616-026-01041-4>
13. Jeethy Ram, T., & Damodaran, M. (2026). Targeting Spatiotemporal Heterogeneity of oncomiRNAs: A New Frontier in Cancer Therapy. *Cancer Reports*, 9(8), e70639. <https://doi.org/10.1002/cnr2.70639>
14. Kaiser, A. E., Baniyadi, M., Giansiracusa, D., Giansiracusa, M., Garcia, M., Fryda, Z., ... & Bishayee, A. (2021). Sulforaphane: A broccoli bioactive phytochemical with cancer preventive potential. *Cancers*, 13(19), 4796. <https://doi.org/10.3390/cancers13194796>
15. Chakraborti, S. (2025). *Therapeutics of Natural and Synthetic Compounds in Protease-Induced Cancer*. Academic Press.
16. Salehi, B., Mishra, A. P., Nigam, M., Sener, B., Kilic, M., Sharifi-Rad, M., ... & Sharifi-Rad, J. (2018). Resveratrol: A double-edged sword in health benefits. *Biomedicine*, 6(3), 91. <https://doi.org/10.3390/biomedicines6030091>
17. Kopustinskiene, D. M., Jakstas, V., Savickas, A., & Bernatoniene, J. (2020). Flavonoids as anticancer agents. *Nutrients*, 12(2), 457. <https://doi.org/10.3390/nu12020457>
18. Wu, Z., Chen, J., Luo, W., & Kuang, T. (2025). Natural products for intervertebral disc degeneration: Mechanistic insights and therapeutic potentials. *Frontiers in pharmacology*, 16, 1605764. <https://doi.org/10.3389/fphar.2025.1605764>
19. Meng, F., Zhu, Q., & Zhang, S. (2026). MAGEA1 drives tumor progression via activation of the AKT pathway and correlates with elevated radiosensitivity in lung adenocarcinoma. *Journal of Molecular Histology*, 57(4), 263. <https://doi.org/10.1007/s10735-026-10931-y>
20. Mizushima, N. (2007). Autophagy: process and function. *Genes & development*, 21(22), 2861-2873. <https://doi.org/10.1101/gad.1599207>
21. Nimlamool, W., Polhiran, J., Phimthong, N., Potikanond, S., & Wikan, N. (2026). Oxyresveratrol Suppresses EGF-Induced AKT Phosphorylation and Reduces Cellular Fitness While Promoting Apoptosis in EGFR–Wild-Type Non-Small Cell Lung Cancer Cells Under EGF Stimulation. *International Journal of Molecular Sciences*, 27(14), 6403. <https://doi.org/10.3390/ijms27146403>
22. Patel, K., & Patel, D. K. (2022). Therapeutic effectiveness of sinensetin against cancer and other human complications: A review of biological potential and pharmacological activities. *Cardiovascular & Haematological Disorders-Drug Targetsrug Targets-Cardiovascular & Hematological Disorders*, 22(3), 144-154. <https://doi.org/10.2174/1871529x23666221207121955>

23. Pérez, A. P., Peña, F. Z., Torres, K., & Simón, L. (2026). Anticancer, hepatoprotective, and mechanistic evidence of chlorogenic acid in liver cancer: A systematic review. *Biomedicine & Pharmacotherapy*, 202, 119775. <https://doi.org/10.1016/j.biopha.2026.119775>
24. Redondo-Blanco, S., Fernández, J., Gutiérrez-del-Río, I., Villar, C. J., & Lombó, F. (2017). New insights toward colorectal cancer chemotherapy using natural bioactive compounds. *Frontiers in pharmacology*, 8, 109. <https://doi.org/10.3389/fphar.2017.00109>
25. Sarkar, F. H., & Li, Y. W. (2007). Targeting multiple signal pathways by chemopreventive agents for cancer prevention and therapy. *Acta Pharmacologica Sinica*, 28(9), 1305-1315. <https://doi.org/10.1111/j.1745-7254.2007.00689.x>
26. Sobczak, Ł., Wszolek, A., Żwieręło, W., Rybak, K., Nowakowska, A., Stępień-Zawal, E., ... & Maruszewska, A. (2026). Preliminary Assessment of Anticancer Activity of Aqueous Meadowsweet (*Filipendula ulmaria* (L.) Maxim.) Extract in LoVo Colorectal Cancer Cells. *Biomedicines*, 14(7), 1551. <https://doi.org/10.3390/biomedicines14071551>
27. Thompson, M. A., Hamrick, S. K., Borkar, N. A., Ravi, P., Cicek, Y. A., Lehot, V., ... & Prakash, Y. S. (2026). Polymeric nanoparticle-mediated siRNA delivery into primary human bronchial airway cells. *American Journal of Physiology-Cell Physiology*, 331(3), C783-C796. <https://doi.org/10.1152/ajpcell.00127.2026>
28. Gaynanova, G., Vasileva, L., Kashapov, R., Kuznetsova, D., Kushnazarova, R., Tyryshkina, A., ... & Sinyashin, O. (2021). Self-assembling drug formulations with tunable permeability and biodegradability. *Molecules*, 26(22), 6786. <https://doi.org/10.3390/molecules26226786>
29. Ünüvar, Ü., Aslan, T. N., Pehlivanoglu, S., & Coşkun, K. E. (2026). Controlling Growth of Ultrasmall Sub-10 nm Silver Nanoparticles From *Cotinus coggygria* Scop. Extract and Evaluation of Its In Vitro Anti-Breast Cancer, Antioxidant and Antimicrobial Activity. *Journal of Applied Toxicology*. <https://doi.org/10.1002/jat.70353>
30. Li, X. R., Qi, L., Zhang, X. W., Wei, C., Yu, B., & Pei, T. L. (2025). Quercetin and Nano-Derivatives: potential and challenges in cancer therapy. *International journal of nanomedicine*, 6701-6720. <https://doi.org/10.2147/IJN.S509877>

Список литературы:

1. Abdallah R., Abdel-Rahem R., Badran A., Al-Remawi M., Baydoun S., Bechelany M., Baydoun E. Green Ziziphus nummularia gold nanoparticles: antioxidant and anticancer activity in TNBC // Scientific Reports. 2026. <https://doi.org/10.1038/s41598-026-62225-8>
2. Abotaleb M., Liskova A., Kubatka P., Büsselberg, D. Therapeutic potential of plant phenolic acids in the treatment of cancer // Biomolecules. 2020. V. 10. №2. P. 221. <https://doi.org/10.3390/biom10020221>
3. Abouzied A. S., Fouda W. M., El-Nagar M. K., Huwaimel B., Alqarni S., Alghubayshi A., Refaey M. S. Unveiling the Pharmacological Potential of *Anisoscium orientale*: An Integrative Analysis of Cytotoxicity, Molecular Docking, and Apoptotic Pathways // International Journal of Molecular Sciences. 2026. V. 27. №13. P. 5767. <https://doi.org/10.3390/ijms27135767>
4. Al-Ishaq R. K., Liskova A., Kubatka P., Büsselberg D. Enzymatic metabolism of flavonoids by gut microbiota and its impact on gastrointestinal cancer // Cancers. 2021. V. 13. №16. P. 3934. <https://doi.org/10.3390/cancers13163934>
5. Anand S., Sowbhagya R., Ansari M. A., Alzohairy M. A., Alomary M. N., Almalik A. I., Elderderly A. Y. Polyphenols and their nanoformulations: protective effects against human diseases // Life. 2022. V. 12. №10. P. 1639. <https://doi.org/10.3390/life12101639>
6. Calvello R., Cianciulli A., Compierchio A., Porro C., Caponio G. R., De Angelis M., Panaro M. A. Phenolic-Rich Extracts from Artichoke By-Products Promote Apoptosis in Human Colorectal Cancer Cell Lines // Nutrients. 2026. V. 18. №13. P. 2077. <https://doi.org/10.3390/nu18132077>

7. Dar N. J., Hamid A., Ahmad M. Pharmacologic overview of *Withania somnifera*, the Indian Ginseng // Cellular and molecular life sciences. 2015. V. 72. №23. P. 4445-4460. <https://doi.org/10.1007/s00018-015-2012-1>
8. Deng H., Ren Y., Sui Y., Ma Z. Activating Cannabinoid receptor 2 alleviates iron overload-induced liver damage via dual modulation of STAT3/hepcidin and Nrf2/FPN1 pathways // Molecular Biomedicine. 2026. V. 7. №1. P. 135. <https://doi.org/10.1186/s43556-026-00541-1>
9. Gobbo O. L., Sjaastad K., Radomski M. W., Volkov Y., Prina-Mello A. Magnetic nanoparticles in cancer theranostics // Theranostics. 2015. V. 5. №11. P. 1249. <https://doi.org/10.7150/thno.11544>
10. Fang J., Nakamura H., Maeda H. The EPR effect: Unique features of tumor blood vessels for drug delivery, factors involved, and limitations and augmentation of the effect // Advanced drug delivery reviews. 2011. V. 63. №3. P. 136-151. <https://doi.org/10.1016/j.addr.2010.04.009>
11. Fareid M. A., El-Sherbiny G. M., Elafandy N. M., Eltoum N. E., Othman M. S., El-Hawary A. S., Youssef A. S. E. D. Phytochemical Elucidation and Biological Activity Spectrum of *Rosmarinus officinalis* L.: Mechanistic Insights into the Antimicrobial, Antioxidant, and Apoptosis-Inducing Anticancer Effects of Carnosic Acid // Metabolites. 2026. V. 16. №7. P. 459. <https://doi.org/10.3390/metabo16070459>
12. Jasso de Rodríguez D., Carrillo-Lomelí D. A., Díaz-Rivas J. O., Rocha-Guzmán N. E., Moreno-Jiménez M. R. Apoptosis induction by polyphenolic-rich extracts from *Flourensia cernua* and *Flourensia retinophylla* in human colon adenocarcinoma cells // Cytotechnology. 2026. V. 78. №5. P. 171. <https://doi.org/10.1007/s10616-026-01041-4>
13. Jeethy Ram T., Damodaran M. Targeting Spatiotemporal Heterogeneity of oncomiRNAs: A New Frontier in Cancer Therapy // Cancer Reports. 2026. V. 9. №8. P. e70639. <https://doi.org/10.1002/cnr2.70639>
14. Kaiser A. E., Baniyadi M., Giansiracusa D., Giansiracusa M., Garcia M., Fryda Z., Bishayee A. Sulforaphane: A broccoli bioactive phytochemical with cancer preventive potential // Cancers. 2021. V. 13. №19. P. 4796. <https://doi.org/10.3390/cancers13194796>
15. Chakraborti S. Therapeutics of Natural and Synthetic Compounds in Protease-Induced Cancer. Academic Press, 2025.
16. Salehi B., Mishra A. P., Nigam M., Sener B., Kilic M., Sharifi-Rad M., Sharifi-Rad J. Resveratrol: A double-edged sword in health benefits // Biomedicines. 2018. V. 6. №3. P. 91. <https://doi.org/10.3390/biomedicines6030091>
17. Kopustinskiene D. M., Jakstas V., Savickas A., Bernatoniene J. Flavonoids as anticancer agents // Nutrients. 2020. V. 12. №2. P. 457. <https://doi.org/10.3390/nu12020457>
18. Wu Z., Chen J., Luo W., Kuang T. Natural products for intervertebral disc degeneration: Mechanistic insights and therapeutic potentials // Frontiers in pharmacology. 2025. V. 16. P. 1605764. <https://doi.org/10.3389/fphar.2025.1605764>
19. Meng F., Zhu Q., Zhang S. MAGEA1 drives tumor progression via activation of the AKT pathway and correlates with elevated radiosensitivity in lung adenocarcinoma // Journal of Molecular Histology. 2026. V. 57. №4. P. 263. <https://doi.org/10.1007/s10735-026-10931-y>
20. Mizushima N. Autophagy: process and function // Genes & development. 2007. V. 21. №22. P. 2861-2873. <https://doi.org/10.1101/gad.1599207>
21. Nimlamool W., Polhira J., Phimthong N., Potikanond S., Wikan N. Oxyresveratrol Suppresses EGF-Induced AKT Phosphorylation and Reduces Cellular Fitness While Promoting Apoptosis in EGFR-Wild-Type Non-Small Cell Lung Cancer Cells Under EGF Stimulation // International Journal of Molecular Sciences. 2026. V. 27. №14. P. 6403. <https://doi.org/10.3390/ijms27146403>

22. Patel K., Patel D. K. Therapeutic effectiveness of sinensetin against cancer and other human complications: A review of biological potential and pharmacological activities // Cardiovascular & Haematological Disorders-Drug Targetsrug Targets-Cardiovascular & Hematological Disorders). 2022. V. 22. №3. P. 144-154. <https://doi.org/10.2174/1871529x23666221207121955>
23. Pérez A. P., Peña F. Z., Torres K., Simón L. Anticancer, hepatoprotective, and mechanistic evidence of chlorogenic acid in liver cancer: A systematic review // Biomedicine & Pharmacotherapy. 2026. V. 202. P. 119775. <https://doi.org/10.1016/j.biopha.2026.119775>
24. Redondo-Blanco S., Fernández J., Gutiérrez-del-Río I., Villar C. J., Lombó F. New insights toward colorectal cancer chemotherapy using natural bioactive compounds // Frontiers in pharmacology. 2017. V. 8. P. 109. <https://doi.org/10.3389/fphar.2017.00109>
25. Sarkar F. H., Li Y. Targeting multiple signal pathways by chemopreventive agents for cancer prevention and therapy // Acta Pharmacologica Sinica. 2007. V. 28. №9. P. 1305-1315. <https://doi.org/10.1111/j.1745-7254.2007.00689.x>
26. Sobczak Ł., Wszolek A., Żwieręto W., Rybak K., Nowakowska A., Stępień-Zawal E., Maruszewska A. Preliminary Assessment of Anticancer Activity of Aqueous Meadowsweet (*Filipendula ulmaria* (L.) Maxim.) Extract in LoVo Colorectal Cancer Cells // Biomedicines. 2026. V. 14. №7. P. 1551. <https://doi.org/10.3390/biomedicines14071551>
27. Thompson M. A., Hamrick S. K., Borkar N. A., Ravi P., Cicek Y. A., Lehot V., Prakash Y. S. Polymeric nanoparticle-mediated siRNA delivery into primary human bronchial airway cells // American Journal of Physiology-Cell Physiology. 2026. V. 331. №3. P. C783-C796. <https://doi.org/10.1152/ajpcell.00127.2026>
28. Gaynanova G., Vasileva L., Kashapov R., Kuznetsova D., Kushnazarova R., Tyryshkina A., Sinyashin O. Self-assembling drug formulations with tunable permeability and biodegradability // Molecules. 2021. V. 26. №22. P. 6786. <https://doi.org/10.3390/molecules26226786>
29. Ünüvar Ü., Aslan T. N., Pehlivanoğlu S., Coşkuner K. E. Controlling Growth of Ultrasmall Sub-10 nm Silver Nanoparticles From *Cotinus coggygria* Scop. Extract and Evaluation of Its In Vitro Anti-Breast Cancer, Antioxidant and Antimicrobial Activity // Journal of Applied Toxicology. 2026. <https://doi.org/10.1002/jat.70353>
30. Li X. R., Qi L., Zhang X. W., Wei C., Yu B., Pei T. L. Quercetin and Nano-Derivatives: potential and challenges in cancer therapy // International journal of nanomedicine. 2025. P. 6701-6720. <https://doi.org/10.2147/IJN.S509877>

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