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A comprehensive review on radioprotective potency and multifaceted biological activities of gallic acid

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ABSTRACT

This review really digs into all the cool ways gallic acid (GA) can help with health, especially its strong powers in fighting off damage from oxygen radicals and stopping cancer from growing. We dive deep into how GA messes with different cancer cells, making them die off in a controlled way. The presentation also discusses how gallium enhances the efficacy of chemotherapeutic drugs, serving as a robust protective barrier against the adverse effects of chemotherapy. Moving on, we look at how GA helps protect the body from harm caused by radiation or other toxic substances, especially in important parts like the liver, kidneys, and brain. But GA's not just about cancer; it's also great at protecting the nerves, keeping blood vessels healthy, and even stopping diseases before they start. By the end, we get a full picture of how GA moves around the body, how it gets broken down, and all the ways it can protect the body, making it a really interesting natural substance for medical use. As no thorough study has yet explored this topic, this review seeks to comprehensively evaluate the most prominent research on the diverse biological activities of GA, including its radioprotective effects.

Implication for health policy/practice/research/medical education:
Gallic acid (GA) possesses well-established properties as an antioxidant, anti-inflammatory, anti-cancer agent, chemoprotective, and radioprotective agent. Proper use of GA can reduce the side effects of radiation and improve treatment output.

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Introduction

Cancer is a big killer worldwide, caused by lots of different things, such as radiation, which can mess up the DNA in the cells where it hits them (1). Ionizing radiation (IR) is pretty nasty because it can directly damage DNA or make free radicals that break DNA strands, mess up sugar and base parts, leading to cell death, chromosome problems, and mutations. Even though IR helps in finding and treating cancer, there are limits to how safely it can be used for treating tumors. IR is used in things like radiotherapy, making things sterile, and medical check-ups (2), with X-rays being a big part of medicine. Every year, about 10.9 million people get cancer around the world (3), and half of them get some kind of radiation treatment for it (4). This shows why we need things that can protect us from radiation damage. These protectors need to be easy to give, not too toxic, easy to absorb, cheap, and work at different radiation levels (5). Finding these protectors is super important for doctors who treat cancer with radiation (5). The best radioprotectors we have are things like amino thiols and their friends, including stuff like amifostine (WR-2721). Some of these have helped prevent

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issues in cancer patients getting radiation (6). Research is always going on to find new radioprotective drugs that don't have bad long-term effects, last a long time, and are stable, which are the key things we want in these drugs (5,6). Herbal stuff, which people often use for cancer treatment, has also shown some promise in protecting against radiation's bad effects (5,6). Recent studies have shown that some natural plant chemicals can protect cells in lab tests, looking at things like how much they prevent fat from going bad, DNA damage, free radical cleanup, antioxidant levels, cell survival, and changes in cell structure (7). Gallic acid (GA) is a type of phenolic acid commonly found in various plant-based foods consumed by humans, including blueberries, strawberries (8), mangos (9), grape seeds (10), and carob (11). It is also present in beverages like red wine (12), different types of teas (13-15), and coffee (16). Additionally, GA is believed to contribute to the therapeutic effects of several herbal medicines (17,18) traditionally used for healing purposes. In vitro studies have demonstrated that GA promotes the activity of antioxidant enzymes (19), shields the liver from toxic damage, and inhibits lipid peroxidation caused by radiation exposure. Research has attributed numerous pharmacological properties to GA, such as antioxidant, anti-inflammatory, antineoplastic, antimicrobial, chemoprotective, and radioprotective effects (20-22). This review seeks to provide a comprehensive overview of the studies exploring the diverse biological functions of GA, with a focus on its antioxidant, anti-inflammatory, chemoprotective, and radioprotective roles (22).

Phenolic acids

The word "phytochemical" covers a whole bunch of natural stuff that's good for us, with lots of health and nutrition benefits. Among all these, phenolic compounds are a big deal, having at least one ring of benzene with oxygen stuck to it. This huge group of chemicals is sorted by how many carbon atoms they have, like simple phenolics, phenolic acids, and a bunch of others like acetophenones, cinnamic acid stuff, coumarins, and so on (8).

Phenolic acids are a group of compounds defined by the presence of a benzene ring, a carboxylic acid group, and one or more hydroxyl and/or methoxyl groups (Figure 1). They are among the most widespread non-flavonoid phenolic compounds found in plants and can exist in free form, as soluble conjugates, or bound to plant cell walls in an insoluble form. Structurally, phenolic acids are derived from either benzoic acid or cinnamic acid, both of which feature a carboxyl group attached to a benzene ring. Examples of hydroxybenzoic acids include GA, protocatechuic acid, vanillic acid, and syringic acid, while hydroxycinnamic acids include caffeic, ferulic, sinapic, and coumaric acids (8-22).

Phenolic acids are pretty important and common, with a simple structure of a ring with either a short (C6-C1) or a bit longer (C6-C3) chain attached. They are made up of a ring with a carboxyl group hanging off. Some common ones are caffeic acid, ferulic acid, p-hydroxybenzoic acid, protocatechuic acid, vanillic acid, salicylic acid, and GA (23). Right now, people are really into foods that have these phenolic compounds because they are good for us (23). Polyphenols are probably the most common type of these compounds in nature (24). A lot of research has shown they do all sorts of cool things for our health (25). GA, or 3,4,5-trihydroxybenzoic acid (CAS No 149-91-7), is super common in plants (23).

Gallic acid

GA, or gallate, is a big deal because it is a type of benzoic acid that helps make up galatotanins, which are a kind of tannin you can break down that has sugar and different phenol acids in it. This stuff, known as 3,4,5-trihydroxybenzoic acid (Figure 2), has both a phenol and a carboxylic acid vibe, with just one benzene ring. Its formula is C7H6O5, which means it weighs about 170.12 grams. GA looks like a white or light yellow powder that melts at 235 to 240 °C, but then it breaks down. If you heat it up to 100-120 °C, it loses its water and gets unstable (26). It is made by breaking down tannic acid with sulfuric acid at 110 to 120 °C (26). You can find it in lots of foods like strawberries, blueberries, tea, blackberries, grapes, mangoes, walnuts, cashews, hazelnuts, wine, plums, and more (26). It is also in plants like bearberry leaves, pomegranate bark, sumac, witch hazel, oak bark, and tea leaves, either by itself or as part of tannins (27). Red wine has a lot of it, but green tea has even more, and cocoa has the most of all (27). GA can fight inflammation and oxidation (27) in lab tests and in living things (28). It has three OH groups that help it fight off harmful radicals (27). It is good at stopping fungi, bacteria, viruses, allergies, swelling, skin darkening,

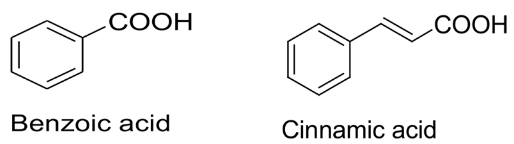
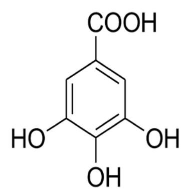


Figure 1. Structures of benzoic acid and cinnamic acid, the backbones of phenolic acids.



Gallic acid (3,4,5-trihydroxy-benzoic acid)

Figure 2. The chemical structure of gallic acid.

tuberculosis, mutations, stomach ulcers, high cholesterol, and weight gain (26-28). It is also protective for the brain, heart, liver, and kidneys (26-29). It fights colds (30-32), high blood pressure (33), and aging (34). Because it is great at cleaning up oxygen radicals. It kills germs like *E. coli*, Staph, Pseudomonas, and Klebsiella. It is tough on cancer cells but leaves normal cells alone, messes with bacterial enzymes, and affects how bacteria cut DNA (35-40). It also stops HIV from doing its thing (35,36), messes with hepatitis C (37,38), and stops herpes from sticking and entering cells. However, it is not perfect; it doesn't get absorbed well, doesn't stick around long in the body, and gets cleared out fast (39,40) (Figure 3).

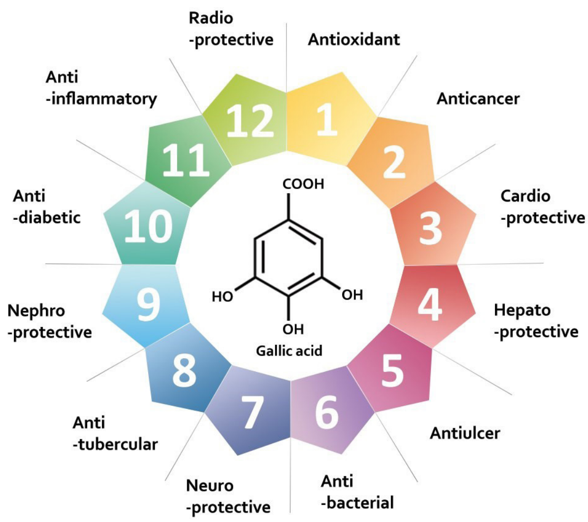


Figure 3. Functions and biological activities of gallic acid.

Antioxidant effects of gallic acid

GA is really good at fighting off damage from oxygen radicals in lab tests (41). Its special parts, the hydroxyl groups, catch these harmful oxygen bits and stop them from causing more trouble. This helps protect fats, DNA, proteins, and enzymes from getting messed up by these radicals (7). Scientists have done all sorts of calculations to see how well it fights different radicals like OH and OOH (42,43). It is great at shielding the cells from damage by stuff like hydroxyl, superoxide, and peroxyl radicals, plus non-radicals like hydrogen peroxide and hypochlorous acid. This makes it super important in stopping cancer and other damage from plant extracts (22). GA tweaks the balance between good and bad oxygen in the body, affecting enzymes like SOD, CAT, GR, and GPx, and it helps cut down on fat damage and controls the production of harmful oxygen (44-47). It also helps protect our liver from poisons by catching free radicals and boosting the body's antioxidant defenses (48-50). One GA can take out up to six DPPH radicals (51). Sometimes, it can make things worse by helping make more harmful radicals when it hooks up with iron, especially when there's not much GA or the pH is low (52). In tests, it is better at catching radicals than stuff like vitamin C, Trolox, caffeic acid, sinapic acid, and vitamin E (53). It has also been shown to help with hardening of the arteries by messing with an enzyme called alkaline phosphatase (54). When mixed with metals like copper, zinc, chromium, or selenium, it is even more effective in lab tests (55). Together with other stuff, it has helped calm down overactive airways in guinea pigs caused by allergies (56). Being overweight makes our body's antioxidant defenses weaker, but in rats, eating too much fat, GA helped boost these defenses, reducing weight gain, and easing problems like fat damage, bad cholesterol levels, and fatty liver (57). With brain cells, GA is a bit of a hero, reducing damage from Alzheimer's-like protein in rat brain cells, stopping calcium from leaking out, and cutting down on cell death (58). It is also really good at protecting nerves, hearts, and livers (7). In some cases, it can harm rat nerve cells when there is too much hydrogen peroxide around (59). It has also protected mouse livers from damage by paracetamol by stopping fat damage, reducing inflammation, and bringing back the body's antioxidant balance (60). GA from Daylily flowers made rats' blood and liver better at fighting radicals (61). It has even helped mice remember better by fighting off brain damage and messing with an enzyme that breaks down a memory-related chemical (62). A recent study showed it could help with stomach ulcers in rats by being an antioxidant (63). GA fights off the bad protein clumps in diseases like Alzheimer's and Parkinson's disease (64). It is good at saving kidneys from damage when blood flow is cut off and then restored (65). It works through some body signals to stop fat damage and harmful stuff like malondialdehyde (66,67). It has also prevented heart damage from a drug in rats (68) and helped clean up damage from aluminum in rats' hearts (69). It was effective against long-term liver damage from a drug in rats (70) and saved kidneys from another drug's harm by boosting antioxidant enzymes (71). In a human study, drinking water with GA reduced damage from oxygen radicals and improved some antioxidant levels without changing the overall antioxidant power (22).

Anti-inflammatory effects of gallic acid

When the body gets hurt or attacked by something from outside, it fights back with inflammation, which involves sending out signals like IL-1β, TNF-α, NO, and PGE2 (72). GA is pretty good at calming this down in different ways. It turns down the volume on a bunch of these signals, like bradykinin, COX-2, substance P, NF-κB, a whole bunch of interleukins, IFN-γ, and TNF-α. It also stops our immune cells from going overboard by cleaning up harmful oxygen bits, reducing MPO activity, and keeping certain cells from rushing into our gut. GA messes with the control centers of our cells, too, like STAT3

(56,66,67,73,74). It helps by lowering the production of things that make inflammation worse, like i-NOS, and by boosting stuff that helps heal, like vWF, HGF, and VEGF, encouraging new blood vessel growth and stopping cell death (74). It has been shown to protect brain cells from damage by reducing inflammation (75). GA also interacts with the body's pathways to control allergies and inflammation, stopping histamine from coming out and reducing reactions (76). It is even involved in turning off a protein that messes with healing, helping with eye issues by calming inflammation (77). It stops certain pathways in cells that would otherwise make inflammation worse, helping with fat-related inflammation and obesity (78). It is good at stopping new blood vessels from forming where they shouldn't, which is important for healing and preventing scars (79).

Anticancer effects of gallic acid

Cancer cells are weird; they grow, move, and react to treatments differently from normal cells. Each cancer type needs its own special treatment, often involving cutting it out, poisoning it with chemo, or zapping it with radiation (80). Polyphenols, which are natural antioxidants, are great at fighting cancer in lots of ways. They can be the main fighters or help make other treatments work better and reduce their side effects (81). GA is especially good at making cancer cells die in a bunch of different cancers, like leukemia, prostate, lung, stomach, colon, breast, cervical, and liver cancers (82). It can make cancer cells produce more harmful oxygen, which helps kill them off, but this depends on stuff like how much oxygen is around, the pH, and metal levels in the cells (83,84). It messes with cancer cell survival by blocking certain pathways (85). Researchers have seen GA make prostate cancer cells die by cutting up important proteins (22,86). It has been shown to stop cancer cells from growing, moving, and dying in a controlled way, while leaving normal cells alone (87). GA can make cancer cells commit suicide through different pathways, including messing with their energy factories, the mitochondria (88). It can also stop cancer cells from fixing their DNA or growing new blood vessels, which they need to survive (88). It has been shown to reduce cancer cell movement and growth in different cancers by messing with their signal pathways (89,90). In some studies, GA has made cancer cells less able to spread or hide, showing promise for treatments for brain cancer (91-94). It has also been used with other drugs to make them work better against cancer, like in breast cancer (85,95-97). GA makes cancer cells grow less and die more, even in cancers that are hard to treat. It stops cancer from growing new blood vessels or spreading. In some experiments, GA has shrunk tumors and helped animals live longer. Even extracts from plants rich in GA have shown that they can slow down cancer growth. In leukemia, GA has shown that it can really mess with the cancer cells' ability to survive (98,99).

Chemoprotective effects of gallic acid

Chemo is a go-to for treating cancer, but it sucks that 90% of folks hit a wall with it because the cancer fights back, making the treatment fail (100). Scientists have been mixing chemo drugs with natural stuff like GA, tannic acid, quercetin, myrecitin, and serotonin to make them work better together and cut down on the bad side effects. These natural compounds are safe and can fight cancer on their own, so they are great to use with chemo, either alone or with other treatments (101). When GA is mixed with chemotherapy drugs, it has been shown to work better than just using one, especially with lung cancer (102). GA and curcumin together may stop triple-negative breast cancer before it even starts in lab tests (103). Giving GA before doxorubicin chemo can help by tweaking, easing, or even undoing the harm doxorubicin does. Before getting doxorubicin, taking GA has helped with liver damage and stress from the treatment, acting like a shield for the liver during cancer fights (104). GA has also been good at protecting against the bad stuff from cyclophosphamide, which can mess with the brain and liver, and the ability to have kids (49,105,106). In mice, it has helped keep blood pressure down, stop the heart from changing shape, and reduce scarring when they had high blood pressure from a drug (107). GA has been shown to fight back against brain damage, calming down some of the body's stress signals (108).

Radioprotective effects of gallic acid

Radiotherapy (RT) is another big hitter in cancer treatment, often teaming up with surgery and chemotherapy. However, it is a mixed bag; some people get better, while others' cancers get tougher and spread (1,109,110). GA has been mentioned for helping with the damage caused by drugs and radiation, especially in the liver and brain. Its good deeds spread to other parts too, like bones, kidneys, reproductive bits, and lungs (65,111). When GA is put in silver nanoparticles, it has changed the cancer cells' reaction to radiation in lab tests (112). GA has helped protect human blood cells from getting their DNA trashed by radiation, stopping them from dying off, too (113). This makes a strong case for using GA, this safe stuff, as a way to protect against radiation, maybe even in food or drugs (114). In mice zapped with radiation, GA has cut down on damage to their DNA, stopped their bone marrow from freezing in time, and kept their bone marrow cells from dying off, showing it is pretty good at protecting against radiation (115).

Discussion

GA has really caught people's eyes because it is so good at fighting off damage from oxygen radicals and stopping cancer (116). However, getting the most out of phenolic acids like GA can be tricky because they don't always stick around long, they're not always easily absorbed, and they can be hard for the body to use (117). GA is a well-known herbal bioactive compound found in many herbs and foods like tea, wine, cashew nuts, hazelnuts, walnuts, plums, grapes, mangoes, blackberries, blueberries, and strawberries. GA has been reported for several pharmacological activities, such as antioxidant, anti-inflammatory, antineoplastic, antimicrobial, antifungal, antibacterial, antiviral, antiallergic, antimelanogenic, antitubercular, antimutagenic, antiulcer, anticholesterol, antiobesity, and immunomodulatory effects. It also shows protective effects on the nervous system, heart, liver, and kidneys. Beyond its therapeutic properties, GA and its esters are also used in various industrial applications, such as food additives and cosmetic products (118). Despite its impressive health benefits, GA is limited by its low permeability and poor bioavailability, which hinder its therapeutic potential (119). However, innovative drug delivery systems have been developed to address these limitations (120). Among these, GA-loaded nanoparticles have shown promise. Nanocarrier systems enhance the physical and chemical stability of GA by encapsulating it within lipid or polymer-based structures. Several types of nanocarriers have been explored for delivering GA, including liposomes, transfersomes, niosomes, dendrimers, phytosomes, micelles, nanoemulsions, metallic nanoparticles, solid lipid nanoparticles, nanostructured lipid carriers, and polymer conjugates (34,121,122). These systems offer improved reactivity, effectiveness, and bioavailability compared to traditional delivery methods, though their clinical use still faces hurdles (123). While nanoparticles offer advantages such as enhanced efficacy and bioavailability, their integration into clinical practice remains challenging. Major concerns include biocompatibility and the risk of triggering immune responses (123). Regulatory agencies like the USFDA and EMA have set strict guidelines to evaluate the toxicity, safety, quality, and efficacy of nanoparticle-based therapies. One issue is that nanoparticles can activate the immune system's complement pathway, potentially causing hypersensitivity reactions. Another concern is the production of free radicals by nanoparticles, which may lead to oxidative stress and damage to lipids, proteins, DNA, and other cellular components. Additionally, the complex and costly manufacturing processes for nanoparticles can limit their accessibility (124). Therefore, further research is essential to improve their safety, understand their interaction with the human body, and streamline regulatory approval.

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Conflict of interests

Not to declare.

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The English language of the article was improved with ChatGPT. Upon generating draft language, the author reviewed, edited, and revised the language to their own liking and takes ultimate responsibility for the content of this publication.

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References

1. Shaghaghi Z, Alvandi M, Nosrati S, Hadei SK. Potential utility of peptides against damage induced by ionizing radiation. Future Oncol. 2021;17(10):1219-35. doi: 10.2217/fon-2020-0577.
2. Gerić M, Gajski G, Mihaljević B, Miljanić S, Domijan AM, Garaj-Vrhovac V. Radioprotective properties of food colorant sodium copper chlorophyllin on human peripheral blood cells in vitro. Mutat Res Genet Toxicol Environ Mutagen. 2019;845:403027. doi: 10.1016/j.mrgentox.2019.02.008.
3. Kuruba V, Gollapalli P. Natural radioprotectors and their impact on cancer drug discovery. Radiat Oncol J. 2018;36(4):265-75. doi: 10.3857/roj.2018.00381.
4. De Ruysscher D, Niedermann G, Burnet NG, Siva S, Lee AW, Hegi-Johnson F. Radiotherapy toxicity. Nat Rev Dis Primers. 2019;5(1):13. doi: 10.1038/s41572-019-0064-5.
5. Dowlath MJ, Karuppannan SK, Sinha P, Dowlath NS, Arunachalam KD, Ravindran B, et al. Effects of radiation and role of plants in radioprotection: a critical review. Sci Total Environ. 2021;779:146431. doi: 10.1016/j.scitotenv.2021.146431.

6. Pooja S, Shetty P, Kumari NS, Shetty KJ. Radioprotective and antioxidant potential of *Tanacetum parthenium* extract and synthetic parthenolide in Swiss albino mice exposed to electron beam irradiation. Int J Radiat Res. 2021;19(1):145-54. doi: 10.18869/acadpub.ijrr.19.1.145.
7. Kahkeshani N, Farzaei F, Fotouhi M, Alavi SS, Bahramsoltani R, Naseri R, et al. Pharmacological effects of gallic acid in health and diseases: a mechanistic review. Iran J Basic Med Sci. 2019;22(3):225-37. doi: 10.22038/ijbms.2019.32806.7897.
8. Heinonen IM, Meyer AS, Frankel EN. Antioxidant activity of berry phenolics on human low-density lipoprotein and liposome oxidation. J Agric Food Chem. 1998;46(10):4107-12. doi: 10.1021/jf980181c.
9. Barreto JC, Trevisan MT, Hull WE, Erben G, de Brito ES, Pfundstein B, et al. Characterization and quantitation of polyphenolic compounds in bark, kernel, leaves, and peel of mango (*Mangifera indica* L.). J Agric Food Chem. 2008;56(14):5599-610. doi: 10.1021/jf800738r.
10. Shi J, Yu J, Pohorly JE, Kakuda Y. Polyphenolics in grape seeds-biochemistry and functionality. J Med Food. 2003;6(4):291-9. doi: 10.1089/109662003772519831.
11. Mardani-Nafchi H, Rahimian G, Amini A, Baratpour I. A systematic review of polyphenols therapeutic and preventive role in cholelithiasis. J Herbmed Pharmacol. 2025;14(2):120-32. doi: 10.34172/jhp.2025.53011.
12. Landrault N, Poucheret P, Ravel P, Gasc F, Cros G, Teissedre PL. Antioxidant capacities and phenolics levels of French wines from different varieties and vintages. J Agric Food Chem. 2001;49(7):3341-8. doi: 10.1021/jf010128f.
13. Lin JK, Lin CL, Liang YC, Lin-Shiau SY, Juan IM. Survey of catechins, gallic acid, and methylxanthines in green, oolong, Pu-erh, and black teas. J Agric Food Chem. 1998;46(9):3635-42. doi: 10.1021/jf980223x.
14. Zuo Y, Chen H, Deng Y. Simultaneous determination of catechins, caffeine and gallic acids in green, oolong, black and Pu-erh teas using HPLC with a photodiode array detector. Talanta. 2002;57(2):307-16. doi: 10.1016/s0039-9140(02)00030-9.
15. Joubert E, Gelderblom WC, Louw A, de Beer D. South African herbal teas: *Aspalathus linearis*, *Cyclopia* spp. and *Athrixia phylicoides*--a review. J Ethnopharmacol. 2008;119(3):376-412. doi: 10.1016/j.jep.2008.06.014.
16. Monteiro M, Farah A, Perrone D, Trugo LC, Donangelo C. Chlorogenic acid compounds from coffee are differentially absorbed and metabolized in humans. J Nutr. 2007;137(10):2196-201. doi: 10.1093/jn/137.10.2196.
17. Shahrzad S, Aoyagi K, Winter A, Koyama A, Bitsch I. Pharmacokinetics of Gallic Acid and Its Relative Bioavailability from Tea in Healthy Humans. J Nutr. 2001;131(4):1207-10. doi: 10.1093/jn/131.4.1207.
18. Yang HL, Chang WH, Chia YC, Huang CJ, Lu FJ, Hsu HK, et al. *Toona sinensis* extracts induces apoptosis via reactive oxygen species in human premyelocytic leukemia cells. Food Chem Toxicol. 2006;44(12):1978-88. doi: 10.1016/j.fct.2006.06.027.
19. Yeh CT, Yen GC. Induction of hepatic antioxidant enzymes by phenolic acids in rats is accompanied by increased levels of multidrug resistance-associated protein 3 mRNA expression. J Nutr. 2006;136(1):11-5. doi: 10.1093/jn/136.1.11.
20. Anand KK, Singh B, Saxena AK, Chandan BK, Gupta VN, Bhardwaj V. 3,4,5-Trihydroxy benzoic acid (gallic acid), the hepatoprotective principle in the fruits of *Terminalia belerica*-bioassay guided activity. Pharmacol Res. 1997;36(4):315-21. doi: 10.1006/phrs.1997.0236.
21. Aglan HA, Ahmed HH, El-Toumy SA, Mahmoud NS. Gallic acid against hepatocellular carcinoma: An integrated scheme of the potential mechanisms of action from in vivo study. Tumour Biol. 2017;39(6):1010428317699127.
22. Badhani B, Sharma N, Kakkar R. Gallic acid: a versatile antioxidant with promising therapeutic and industrial applications. RSC Adv. 2015;5(35):27540-57. doi: 10.1039/c5ra01911g.
23. Siah M, Farzaei MH, Ashrafi-Kooshk MR, Adibi H, Arab SS, Rashidi MR, et al. Inhibition of guinea pig aldehyde oxidase activity by different flavonoid compounds: an in vitro study. Bioorg Chem. 2016;64:74-84. doi: 10.1016/j.bioorg.2015.12.004.
24. Sharma E, Attri DC, Sati P, Dhyani P, Szopa A, Sharifi-Rad J, et al. Recent updates on anticancer mechanisms of polyphenols. Front Cell Dev Biol. 2022;10:1005910. doi: 10.3389/fcell.2022.1005910.
25. Kumar N, Goel N. Phenolic acids: natural versatile molecules with promising therapeutic applications. Biotechnol Rep (Amst). 2019;24:e00370. doi: 10.1016/j.btre.2019.e00370.
26. Fernandes FH, Salgado HR. Gallic acid: review of the methods of determination and quantification. Crit Rev Anal Chem. 2016;46(3):257-65. doi: 10.1080/10408347.2015.1095064.
27. Dhumal JS, Thikekar AK, Kumbhar AB, Jadhav NY, Rasve VR, Patil PJ, et al. Phytochemicals as nutraceuticals: a review. J Neonatal Surg. 2025;14(16S):496-539. doi: 10.63682/jns.v14i16s.4333.
28. Li Y, Xie Z, Gao T, Li L, Chen Y, Xiao D, et al. A holistic view of gallic acid-induced attenuation in colitis based on microbiome-metabolomics analysis. Food Funct. 2019;10(7):4046-61. doi: 10.1039/c9fo00213h.
29. Dutta M, Paul G. Gallic acid protects rat liver mitochondria ex vivo from bisphenol A induced oxidative stress mediated damages. Toxicol Rep. 2019;6:578-89. doi: 10.1016/j.toxrep.2019.06.011.
30. Chang CC, You HL, Su HJ, Hung IL, Kao CW, Huang ST. Anti-influenza A (H1N1) virus effect of gallic acid through inhibition of virulent protein production and association with autophagy. Food Sci Nutr. 2024;12(3):1605-15. doi: 10.1002/fsn3.3852.
31. Govea-Salas M, Rivas-Estilla AM, Rodríguez-Herrera R, Lozano-Sepúlveda SA, Aguilar-Gonzalez CN, Zugasti-Cruz A, et al. Gallic acid decreases hepatitis C virus expression through its antioxidant capacity. Exp Ther Med. 2016;11(2):619-24. doi: 10.3892/etm.2015.2923.
32. Kim H, Chung MS. Antiviral activities of mulberry (*Morus alba*) juice and seed against influenza viruses. Evid Based Complement Alternat Med. 2018;2018:2606583. doi: 10.1155/2018/2606583.
33. Jin L, Piao ZH, Sun S, Liu B, Kim GR, Seok YM, et al. Gallic acid reduces blood pressure and attenuates oxidative stress and cardiac hypertrophy in spontaneously hypertensive rats. Sci Rep. 2017;7(1):15607. doi: 10.1038/s41598-017-15925-1.
34. Chaikul P, Khat-Udomkiri N, Iangthanarat K, Manosroi J,

Manosroi A. Characteristics and in vitro anti-skin aging activity of gallic acid loaded in cationic CTAB niosome. Eur J Pharm Sci. 2019;131:39-49. doi: 10.1016/j.ejps.2019.02.008.
35. Ahn CB, Jung WK, Park SJ, Kim YT, Kim WS, Je JY. Gallic acid-g-Chitosan modulates inflammatory responses in LPS-stimulated RAW264.7 cells via NF-κB, AP-1, and MAPK pathways. Inflammation. 2016;39(1):366-74. doi: 10.1007/s10753-015-0258-2.
36. Singh A, Pal TK. Docking analysis of gallic acid derivatives as HIV-1 protease inhibitors. Int J Bioinform Res Appl. 2015;11(6):540-6. doi: 10.1504/ijbra.2015.073239.
37. Calland N, Albecka A, Belouzard S, Wychowski C, Duverlie G, Descamps V, et al. (-)-Epigallocatechin-3-gallate is a new inhibitor of hepatitis C virus entry. Hepatology. 2012;55:720-9. doi: 10.1002/hep.24803.
38. Hsu WC, Chang SP, Lin LC, Li CL, Richardson CD, Lin CC, et al. Limonium sinense and gallic acid suppress hepatitis C virus infection by blocking early viral entry. Antiviral Res. 2015;118:139-47. doi: 10.1016/j.antiviral.2015.04.003.
39. Faralli A, Shekarforoush E, Mendes AC, Chronakis IS. Enhanced transepithelial permeation of gallic acid and (-)-epigallocatechin gallate across human intestinal Caco-2 cells using electrospun xanthan nanofibers. Pharmaceutics. 2019;11(4):155. doi: 10.3390/pharmaceutics11040155.
40. Zhang G, Zheng C, Huang B, Fei P. Preparation of acylated pectin with gallic acid through enzymatic method and their emulsifying properties, antioxidation activities and antibacterial activities. Int J Biol Macromol. 2020;165(Pt A):198-204. doi: 10.1016/j.ijbiomac.2020.09.195.
41. Hadidi M, Liñán-Atero R, Tarahi M, Christodoulou MC, Aghababaei F. The potential health benefits of gallic acid: therapeutic and food applications. Antioxidants (Basel). 2024;13(8)1001:. doi: 10.3390/antiox13081001.
42. Badhani B, Kakkar R. DFT study of structural and electronic properties of gallic acid and its anions in gas phase and in aqueous solution. Struct Chem. 2017;28(6):1789-802. doi: 10.1007/s11224-017-0958-3.
43. Milenković D, Đorović J, Petrović V, Avdović E, Marković Z. Hydrogen atom transfer versus proton coupled electron transfer mechanism of gallic acid with different peroxy radicals. React Kinet Mech Catal. 2018;123(1):215-30. doi: 10.1007/s11144-017-1286-8.
44. Baptista BJ, Granato A, Canto FB, Montalvão F, Tostes L, de Matos Guedes HL, et al. TLR9 signaling suppresses the canonical plasma cell differentiation program in follicular B cells. Front Immunol. 2018;9:2281. doi: 10.3389/fimmu.2018.02281.
45. Parada E, Casas AI, Palomino-Antolin A, Gómez-Rangel V, Rubio-Navarro A, Farré-Alins V, et al. Early toll-like receptor 4 blockade reduces ROS and inflammation triggered by microglial pro-inflammatory phenotype in rodent and human brain ischaemia models. Br J Pharmacol. 2019;176(15):2764-79. doi: 10.1111/bph.14703.
46. Pereira GA, Arruda HS, de Morais DR, Peixoto Araujo NM, Pastore GM. Mutamba (*Guazuma ulmifolia* Lam.) fruit as a novel source of dietary fibre and phenolic compounds. Food Chem. 2020;310:125857. doi: 10.1016/j.foodchem.2019.125857.
47. Wei L, Zhu P, Chen X, Wang Y, Xu Y. An ultra-high performance liquid chromatography with tandem mass spectrometry method for simultaneous determination of thirteen components extracted from Radix *Puerariae* in rat plasma and tissues: application to pharmacokinetic and tissue distribution study. J Sep Sci. 2020;43(2):418-37. doi: 10.1002/jssc.201900824.
48. Bayramoglu G, Kurt H, Bayramoglu A, Gunes HV, Degirmenci İ, Colak S. Preventive role of gallic acid on hepatic ischemia and reperfusion injury in rats. Cytotechnology. 2015;67(5):845-9. doi: 10.1007/s10616-014-9724-1.
49. Oyagbemi AA, Omobowale OT, Asenuga ER, Akinleye AS, Ogunsanwo RO, Saba AB. Cyclophosphamide-induced hepatotoxicity in Wistar rats: the modulatory role of gallic acid as a hepatoprotective and chemopreventive phytochemical. Int J Prev Med. 2016;7:51. doi: 10.4103/2008-7802.177898.
50. Reckziegel P, Dias VT, Benvegnú DM, Boufleur N, Barcelos RC, Segat HJ, et al. Antioxidant protection of gallic acid against toxicity induced by Pb in blood, liver and kidney of rats. Toxicol Rep. 2016;3:351-6. doi: 10.1016/j.toxrep.2016.02.005.
51. Shojaee MS, Moeenfard M, Farhoosh R. Kinetics and stoichiometry of gallic acid and methyl gallate in scavenging DPPH radical as affected by the reaction solvent. Sci Rep. 2022;12(1):8765. doi: 10.1038/s41598-022-12803-3.
52. Strlic M, Radovic T, Kolar J, Pihlar B. Anti- and prooxidative properties of gallic acid in Fenton-type systems. J Agric Food Chem. 2002;50(22):6313-7. doi: 10.1021/jf025636j.
53. Schlesier K, Harwat M, Böhm V, Bitsch R. Assessment of antioxidant activity by using different in vitro methods. Free Radic Res. 2002;36(2):177-87. doi: 10.1080/10715760290006411.
54. Ghanavati T, Ghatreh-Samani K, Farrokhi E, Heydarian E, Nikookar M. Effect of gallic acid on alkaline phosphatase gene expression in vascular smooth muscle cells. J Mazandaran Univ Med Sci. 2015;25(129):17-25.
55. El-Megharbel SM, Hamza RZ. Synthesis, spectroscopic characterizations, conductometric titration and investigation of potent antioxidant activities of gallic acid complexes with Ca(II), Cu(II), Zn(III), Cr(III) and Se(IV) metal ions. J Mol Liq. 2022;358:119196. doi: 10.1016/j.molliq.2022.119196.
56. Wang X, Zhao H, Ma C, Lv L, Feng J, Han S. Gallic acid attenuates allergic airway inflammation via suppressed interleukin-33 and group 2 innate lymphoid cells in ovalbumin-induced asthma in mice. Int Forum Allergy Rhinol. 2018;8(11):1284-90. doi: 10.1002/alr.22207.
57. Hsu CL, Yen GC. Effect of gallic acid on high fat diet-induced dyslipidaemia, hepatosteatosis and oxidative stress in rats. Br J Nutr. 2007;98(4):727-35. doi: 10.1017/s000711450774686x.
58. Hajipour S, Sarkaki A, Farbood Y, Eidi A, Mortazavi P, Valizadeh Z. Effect of gallic acid on dementia type of Alzheimer disease in rats: electrophysiological and histological studies. Basic Clin Neurosci. 2016;7(2):97-106. doi: 10.15412/j.Bcn.03070203.
59. Smith MA, Herson PS, Lee K, Pinnock RD, Ashford ML. Hydrogen-peroxide-induced toxicity of rat striatal neurones involves activation of a non-selective cation channel. J Physiol. 2003;547(Pt 2):417-25. doi: 10.1113/

jphysiol.2002.034561.
60. Ojeaburu SI, Oriakhi K. Hepatoprotective, antioxidant and, anti-inflammatory potentials of gallic acid in carbon tetrachloride-induced hepatic damage in Wistar rats. Toxicol Rep. 2021;8:177-85. doi: 10.1016/j.toxrep.2021.01.001.
61. Akbari G, Savari F, Mard SA, Rezaie A, Moradi M. Gallic acid protects the liver in rats against injuries induced by transient ischemia-reperfusion through regulating microRNAs expressions. Iran J Basic Med Sci. 2019;22(4):439-44. doi: 10.22038/ijbms.2018.31589.7605.
62. Bavarsad K, Farbood Y, Mard SA, Khoshnam SE, Dianat M, Mirshekari Jahangiri H, et al. Effects of gallic acid on memory deficits and electrophysiological impairments induced by cerebral ischemia/reperfusion in rats following exposure to ambient dust storm. Neurochem Res. 2023;48(9):2911-23. doi: 10.1007/s11064-023-03953-5.
63. Zhou D, Yang Q, Tian T, Chang Y, Li Y, Duan LR, et al. Gastroprotective effect of gallic acid against ethanol-induced gastric ulcer in rats: involvement of the Nrf2/HO-1 signaling and anti-apoptosis role. Biomed Pharmacother. 2020;126:110075. doi: 10.1016/j.biopha.2020.110075.
64. Sakalauskas A, Ziaunys M, Smirnovas V. Gallic acid oxidation products alter the formation pathway of insulin amyloid fibrils. Sci Rep. 2020;10(1):14466. doi: 10.1038/s41598-020-70982-3.
65. Ahmadvand H, Yalameha B, Adibhesami G, Nasri M, Naderi N, Babaeenezhad E, et al. The protective role of gallic acid pretreatment on renal ischemia-reperfusion injury in rats. Rep Biochem Mol Biol. 2019;8(1):42-8.
66. Pandurangan AK, Mohebali N, Mohd Esa N, Looi CY, Ismail S, Saadatdoust Z. Gallic acid suppresses inflammation in dextran sodium sulfate-induced colitis in mice: possible mechanisms. Int Immunopharmacol. 2015;28(2):1034-43. doi: 10.1016/j.intimp.2015.08.019.
67. Pandurangan AK, Mohebali N, Mohd Esa N, Looi CY. Gallic acid attenuates dextran sulfate sodium-induced experimental colitis in BALB/c mice. Drug Des Devel Ther. 2015;9:3923-34. doi: 10.2147/dddt.S86345.
68. Shackebaei D, Hesari M, Ramezani-Aliakbari S, Hoseinkhani Z, Ramezani-Aliakbari F. Gallic acid protects against isoproterenol-induced cardiotoxicity in rats. Hum Exp Toxicol. 2022;41:9603271211064532. doi: 10.1177/09603271211064532.
69. Ogunsanwo OR, Oyagbemi AA, Omobowale TO, Asenuga ER, Saba AB. Biochemical and electrocardiographic studies on the beneficial effects of gallic acid in cyclophosphamide-induced cardiorenal dysfunction. J Complement Integr Med. 2017;14(3):20160161. doi: 10.1515/jcim-2016-0161.
70. Karimi-Khouzani O, Heidarian E, Amini SA. Anti-inflammatory and ameliorative effects of gallic acid on fluoxetine-induced oxidative stress and liver damage in rats. Pharmacol Rep. 2017;69(4):830-5. doi: 10.1016/j.pharep.2017.03.011.
71. Ghaznavi H, Fatemi I, Kalantari H, Hosseini Tabatabaei SM, Mehrabani M, Gholamine B, et al. Ameliorative effects of gallic acid on gentamicin-induced nephrotoxicity in rats. J Asian Nat Prod Res. 2018;20(12):1182-93. doi: 10.1080/10286020.2017.1384819.
72. Pu WL, Zhang MY, Bai RY, Sun LK, Li WH, Yu YL, et al. Anti-inflammatory effects of *Rhodiola rosea* L.: a review. Biomed Pharmacother. 2020;121:109552. doi: 10.1016/j.biopha.2019.109552.
73. Hyun KH, Gil KC, Kim SG, Park SY, Hwang KW. Delphinidin chloride and its hydrolytic metabolite gallic acid promote differentiation of regulatory T cells and have an anti-inflammatory effect on the allograft model. J Food Sci. 2019;84(4):920-30. doi: 10.1111/1750-3841.14490.
74. Radan M, Dianat M, Badavi M, Mard SA, Bayati V, Goudarzi G. In vivo and in vitro evidence for the involvement of Nrf2-antioxidant response element signaling pathway in the inflammation and oxidative stress induced by particulate matter (PM10): the effective role of gallic acid. Free Radic Res. 2019;53(2):210-25. doi: 10.1080/10715762.2018.1563689.
75. Dong X, Luo S, Hu D, Cao R, Wang Q, Meng Z, et al. Gallic acid inhibits neuroinflammation and reduces neonatal hypoxic-ischemic brain damages. Front Pediatr. 2022;10:973256. doi: 10.3389/fped.2022.973256.
76. Domínguez R, Zhang L, Rocchetti G, Lucini L, Pateiro M, Munekata PE, et al. Elderberry (*Sambucus nigra* L.) as potential source of antioxidants. Characterization, optimization of extraction parameters and bioactive properties. Food Chem. 2020;330:127266. doi: 10.1016/j.foodchem.2020.127266.
77. Shanmuganathan S, Angayarkanni N. Chebulagic acid chebulinic acid and gallic acid, the active principles of Triphala, inhibit TNFα induced pro-angiogenic and pro-inflammatory activities in retinal capillary endothelial cells by inhibiting p38, ERK and NFkB phosphorylation. Vascul Pharmacol. 2018;108:23-35. doi: 10.1016/j.vph.2018.04.005.
78. Tanaka M, Sato A, Kishimoto Y, Mabashi-Asazuma H, Kondo K, Iida K. Gallic acid inhibits lipid accumulation via AMPK pathway and suppresses apoptosis and macrophage-mediated inflammation in hepatocytes. Nutrients. 2020;12(5):1479. doi: 10.3390/nu12051479.
79. Li Q, Lyu C, Chen D, Cai W, Kou F, Li Q, et al. Gallic acid treats hypertrophic scar in rabbit ears via the TGF-β/Smad and TRPC3 signaling pathways. Pharmaceuticals (Basel). 2023;16(11):1514. doi: 10.3390/ph16111514.
80. Delfi M, Sartorius R, Ashrafizadeh M, Sharifi E, Zhang Y, De Berardinis P, et al. Self-assembled peptide and protein nanostructures for anti-cancer therapy: targeted delivery, stimuli-responsive devices and immunotherapy. Nano Today. 2021;38. doi: 10.1016/j.nantod.2021.101119.
81. Patra S, Panda PK, Naik PP, Panigrahi DP, Praharaj PP, Bhol CS, et al. *Terminalia bellirica* extract induces anticancer activity through modulation of apoptosis and autophagy in oral squamous cell carcinoma. Food Chem Toxicol. 2020;136:111073. doi: 10.1016/j.fct.2019.111073.
82. Sourani Z, Pourgheysari B, Beshkar P, Shirzad H, Shirzad M. Gallic acid inhibits proliferation and induces apoptosis in lymphoblastic leukemia cell line (C121). Iran J Med Sci. 2016;41(6):525-30.
83. Dorniani D, Saifullah B, Barahuie F, Arulselvan P, Bin Hussein MZ, Fakurazi S, et al. Graphene oxide-gallic acid nanodelivery system for cancer therapy. Nanoscale Res Lett. 2016;11(1):491. doi: 10.1186/s11671-016-1712-2.
84. Eghbaliferiz S, Iranshahi M. Prooxidant activity of polyphenols, flavonoids, anthocyanins and carotenoids: updated review of mechanisms and catalyzing metals. Phytother Res. 2016;30(9):1379-91. doi: 10.1002/ptr.5643.
85. Jabbari N, Feghhi M, Esnaashari O, Soraya H, Rezaie J.

Inhibitory effects of gallic acid on the activity of exosomal secretory pathway in breast cancer cell lines: a possible anticancer impact. Bioimpacts. 2022;12(6):549-59. doi: 10.34172/bi.2022.23489.
86. Kaur M, Velmurugan B, Rajamanickam S, Agarwal R, Agarwal C. Gallic acid, an active constituent of grape seed extract, exhibits anti-proliferative, pro-apoptotic and anti-tumorigenic effects against prostate carcinoma xenograft growth in nude mice. Pharm Res. 2009;26(9):2133-40. doi: 10.1007/s11095-009-9926-y.
87. Singh A, Fatima K, Srivastava A, Khwaja S, Priya D, Singh A, et al. Anticancer activity of gallic acid template-based benzylidene indanone derivative as microtubule destabilizer. Chem Biol Drug Des. 2016;88(5):625-34. doi: 10.1111/cbdd.12805.
88. Heidarian E, Keloushadi M, Ghatreh-Samani K, Jafari-Dehkordi E. Gallic acid inhibits invasion and reduces IL-6 gene expression, PSTAT3, PERK1/2, and pAKT cellular signaling proteins in human prostate cancer DU-145 cells. Int J Cancer Manag. 2017;10(11):e9163. doi: 10.5812/ijcm.9163.
89. Paolini A, Curti V, Pasi F, Mazzini G, Nano R, Capelli E. Gallic acid exerts a protective or an anti-proliferative effect on glioma T98G cells via dose-dependent epigenetic regulation mediated by miRNAs. Int J Oncol. 2015;46(4):1491-7. doi: 10.3892/ijo.2015.2864.
90. Heidarian E, Keloushadi M, Ghatreh-Samani K, Valipour P. The reduction of IL-6 gene expression, pAKT, pERK1/2, pSTAT3 signaling pathways and invasion activity by gallic acid in prostate cancer PC3 cells. Biomed Pharmacother. 2016;84:264-9. doi: 10.1016/j.biopha.2016.09.046.
91. Saffari-Chaleshtori J, Heidari-Sureshjani E, Moradi F, Molavian Jazi H, Heidarian E. The study of apoptosis-inducing effects of three pre-apoptotic factors by gallic acid, using simulation analysis and the comet assay technique on the prostatic cancer cell line PC3. Malays J Med Sci. 2017;24(4):18-29. doi: 10.21315/mjms2017.24.4.3.
92. Santos EM, da Rocha RG, Santos HO, Guimarães TA, de Carvalho Fraga CA, da Silveira LH, et al. Gallic acid modulates phenotypic behavior and gene expression in oral squamous cell carcinoma cells by interfering with leptin pathway. Pathol Res Pract. 2018;214(1):30-7. doi: 10.1016/j.prp.2017.11.022.
93. Rezaei-Seresht H, Cheshomi H, Falanji F, Movahedi-Motlagh F, Hashemian M, Mireskandari E. Cytotoxic activity of caffeic acid and gallic acid against MCF-7 human breast cancer cells: an in silico and in vitro study. Avicenna J Phytomed. 2019;9(6):574-86. doi: 10.22038/ajp.2019.13475.
94. Jing Z, Li M, Wang H, Yang Z, Zhou S, Ma J, et al. Gallic acid-gold nanoparticles enhance radiation-induced cell death of human glioma U251 cells. IUBMB Life. 2021;73(2):398-407. doi: 10.1002/iub.2436.
95. El-Houssiny AS, Kamel NA, Soliman AA, Abd El-Messieh SL, Abd-El-Nour KN. Preparation and characterisation of gallic acid loaded carboxymethyl chitosan nanoparticles as drug delivery system for cancer treatment. Adv Nat Sci Nanosci Nanotechnol. 2022;13(2):025002. doi: 10.1088/2043-6262/ac6c22.
96. Yang JT, Lee IN, Chen CH, Lu FJ, Chung CY, Lee MH, et ak. Gallic acid enhances the anti-cancer effect of temozolomide in human glioma cell line via inhibition of Akt and p38-MAPK pathway. Processes. 2022;10(3):448. doi: 10.3390/pr10030448.
97. Kumar V, Sharma K, Sachan R, Alhayyani S, Al-Abbasi FA, Singh R, et al. Co-drug development of gallic acid and metformin targeting the pro-inflammatory cytokines for the treatment of breast cancer. J Biochem Mol Toxicol. 2023;37(4):e23300. doi: 10.1002/jbt.23300.
98. Gu R, Zhang M, Meng H, Xu D, Xie Y. Gallic acid targets acute myeloid leukemia via Akt/mTOR-dependent mitochondrial respiration inhibition. Biomed Pharmacother. 2018;105:491-7. doi: 10.1016/j.biopha.2018.05.158.
99. Wang D, Guo Y, Liu Y, Sa R, Wang J, Zhang B, et al. Gallic acid enhances the antitumor activity of Icotinib hydrochloride in non-small cell lung cancer via of Hippo-YAP signaling pathway in vitro and in vivo. Res Sq [Preprint]. January 28, 2022. Available from: https://www.researchsquare.com/article/rs-1217354/v1.
100. Moshafi MH, Torabizadeh SA, Mohamadnezhad F, Jomehzadeh A, Khodaei M, Samareh Fekri H. *Ferulago angulata* as a good radioprotector against genotoxicity. Curr Radiopharm. 2022;15(2):110-6. doi: 10.2174/1874471014666210426111806.
101. Ibrahim NA, Wang Z, Chow MS. Chemosensitizing effects of five phytochemical compounds on cancer cells. IIOAB J. 2016;7:428-34.
102. Wang R, Ma L, Weng D, Yao J, Liu X, Jin F. Gallic acid induces apoptosis and enhances the anticancer effects of cisplatin in human small cell lung cancer H446 cell line via the ROS-dependent mitochondrial apoptotic pathway. Oncol Rep. 2016;35(5):3075-83. doi: 10.3892/or.2016.4690.
103. Moghtaderi H, Sepehri H, Delphi L, Attari F. Gallic acid and curcumin induce cytotoxicity and apoptosis in human breast cancer cell MDA-MB-231. Bioimpacts. 2018;8(3):185-94. doi: 10.15171/bi.2018.21.
104. Omobowale TO, Oyagbemi AA, Ajufo UE, Adejumobi OA, Ola-Davies OE, Adedapo AA, et al. Ameliorative effect of gallic acid in doxorubicin-induced hepatotoxicity in Wistar rats through antioxidant defense system. J Diet Suppl. 2018;15(2):183-96. doi: 10.1080/19390211.2017.1335822.
105. Oyagbemi AA, Omobowale TO, Saba AB, Adedara IA, Olowu ER, Akinrinde AS, et al. Gallic acid protects against cyclophosphamide-induced toxicity in testis and epididymis of rats. Andrologia. 2016;48(4):393-401. doi: 10.1111/and.12459.
106. Oyagbemi AA, Omobowale TO, Saba AB, Olowu ER, Dada RO, Akinrinde AS. Gallic acid ameliorates cyclophosphamide-induced neurotoxicity in Wistar rats through free radical scavenging activity and improvement in antioxidant defense system. J Diet Suppl. 2016;13(4):402-19. doi: 10.3109/19390211.2015.1103827.
107. Jin L, Lin MQ, Piao ZH, Cho JY, Kim GR, Choi SY, et al. Gallic acid attenuates hypertension, cardiac remodeling, and fibrosis in mice with NG-nitro-L-arginine methyl ester-induced hypertension via regulation of histone deacetylase 1 or histone deacetylase 2. J Hypertens. 2017;35(7):1502-12. doi: 10.1097/hjh.0000000000001327.
108. Maya S, Prakash T, Goli D. Effect of wedelolactone and gallic acid on quinolinic acid-induced neurotoxicity and impaired motor function: significance to sporadic amyotrophic lateral sclerosis. Neurotoxicology. 2018;68:1-

12. doi: 10.1016/j.neuro.2018.06.015.
109. Yazdi AH, Ghadimi Farah A, Alvandi M, Shaghaghi Z. Survey on ionizing radiation including gamma-ray exposure among the medical staff working in the non-intensive ward of Farshchian cardiovascular hospital in Hamadan, Iran. Avicenna J Clin Med. 2022;29(3):156-60. doi: 10.32592/ajcm.29.3.156.
110. Shaghaghi Z, Narimani Javid R, Alvandi M. Advancements in cardiac catheterization safety: novel radiation protection approaches redefining occupational health. Curr Cardiol Rev. 2025;21(1):e1573403X304828. doi: 10.2174/011573403x304828240819050538.
111. Olusoji MJ, Oyeyemi OM, Asenuga ER, Omobowale TO, Ajayi OL, Oyagbemi AA. Protective effect of gallic acid on doxorubicin-induced testicular and epididymal toxicity. Andrologia. 2017;49(4):e12635. doi: 10.1111/and.12635.
112. Sunil Gowda SN, Rajasowmiya S, Vadivel V, Banu Devi S, Celestin Jerald A, Marimuthu S, et al. Gallic acid-coated sliver nanoparticle alters the expression of radiation-induced epithelial-mesenchymal transition in non-small lung cancer cells. Toxicol In Vitro. 2018;52:170-7. doi: 10.1016/j.tiv.2018.06.015.
113. Chakka R, Vadaguru Dakshinamurthy R, Rawal P, Belladamadagu Appajappa S, Pramanik S. Gallic acid a flavonoid isolated from *Euphorbia hirta* antagonizes gamma radiation induced radiotoxicity in lymphocytes in vitro. J Complement Integr Med. 2023;20(1):146-52. doi: 10.1515/jcim-2022-0196.
114. Harwansh RK, Deshmukh R, Shukla VP, Khunt D, Prajapati BG, Rashid S, et al. Recent advancements in gallic acid-based drug delivery: applications, clinical trials, and future directions. Pharmaceutics. 2024;16(9):1202. doi: 10.3390/pharmaceutics16091202.
115. Xue Q, Chen Q, Wang M, Liu L. [Radioprotective effects of gallic acid on bone marrow cells in mice]. Wei Sheng Yan Jiu. 2022;51(1):91-8. doi: 10.19813/j.cnki.weishengyanjiu.2022.01.016. [Chinese].
116. Ashrafizadeh M, Zarrabi A, Mirzaei S, Hashemi F, Samarghandian S, Zabolian A, et al. Gallic acid for cancer therapy: molecular mechanisms and boosting efficacy by nanoscopical delivery. Food Chem Toxicol. 2021;157:112576. doi: 10.1016/j.fct.2021.112576.
117. Ma FW, Deng QF, Zhou X, Gong XJ, Zhao Y, Chen HG, et al. The tissue distribution and urinary excretion study of gallic acid and protocatechuic acid after oral administration of *Polygonum capitatum* extract in rats. Molecules. 2016;21(4):399. doi: 10.3390/molecules21040399.
118. Braun DE, Bhardwaj RM, Florence AJ, Tocher DA, Price SL. Complex polymorphic system of gallic acid-five monohydrates, three anhydrates, and over 20 solvates. Cryst Growth Des. 2013;13(1):19-23. doi: 10.1021/cg301506x.
119. Bai J, Zhang Y, Tang C, Hou Y, Ai X, Chen X, et al. Gallic acid: Pharmacological activities and molecular mechanisms involved in inflammation-related diseases. Biomed. Pharmacother. 2021;133:110985. doi: 10.1016/j.biopha.2020.110985.
120. Harwansh RK, Yadav M, Deshmukh R, Rahman A. Recent insights into nanoparticulate carrier systems of curcumin and its clinical perspective in the management of various health issues. Curr Pharm Des. 2023;29(18):1421-40. doi: 10.2174/1381612829666230613115447.
121. Kucuk N, Primozic M, Knez Z, Leitgeb M. Incorporation of biologically active ingredient gallic acid into nano-scale lipid vesicles. Chem Eng Trans. 2023;100:517-22. doi: 10.3303/cet23100087.
122. García-Gurrola A, Escobar-Puentes AA, Rincón S, Martínez-Bustos F, Zepeda A. Succinylated starch nanocapsules loaded with the polyphenolic extract from arugula (*Eruca sativa*) leaves: colloidal, chemical, and structural properties. Starke. 2021;73(11-12):2100059. doi: 10.1002/star.202100059.
123. Niazi SK. The United States Food and Drug Administration's platform technology designation to expedite the development of drugs. Pharmaceutics. 2024;16(7):918. doi: 10.3390/pharmaceutics16070918.
124. Kyriakides TR, Raj A, Tseng TH, Xiao H, Nguyen R, Mohammed FS, et al. Biocompatibility of nanomaterials and their immunological properties. Biomed Mater. 2021;16(4):042005. doi: 10.1088/1748-605X/abe5fa.