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Review Article

EFFECT OF GINGER AGAINST ARSENIC INDUCED TOXICITY ON HEPATIC ORGAN

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ABSTRACT

Arsenic-induced hepatotoxicity poses a significant public health concern due to its detrimental effects on liver function, including oxidative stress, inflammation, and apoptosis. This review explores the protective role of ginger (*Zingiber officinale*) in mitigating arsenic-induced hepatic damage, highlighting its potent antioxidant, anti-inflammatory, and anti-apoptotic properties. The bioactive compounds of ginger, such as gingerols, shogaols, and flavonoids, have been shown to neutralize reactive oxygen species (ROS), restore antioxidant enzyme activity, and suppress pro-inflammatory cytokines like TNF-α and IL-6. These mechanisms collectively contribute to improved liver function, reduced oxidative damage, and enhanced hepatocyte regeneration. Hepatoprotective potential of ginger is further supported by its ability to modulate apoptotic pathways, reduce lipid peroxidation, and enhance cellular detoxification processes. Comparative studies indicate that the efficacy of ginger is on par with or superior to synthetic antioxidants and standard hepatoprotective agents like silymarin, with the added advantage of minimal toxicity. However, limitations in current research, such as the lack of standardized formulations, insufficient human trials, and incomplete understanding of molecular pathways, present challenges to its clinical application. Future research should prioritize large-scale clinical trials, pharmacokinetic studies, and investigations into synergistic effects with other therapeutic agents. Addressing these knowledge gaps will pave the way for the development of ginger-based interventions for liver diseases.

INTRODUCTION

Arsenic, historically termed the “Poison of Kings and the King of Poisons,” has been recognized for its toxicity since ancient times. [1] A metalloid with the atomic number 33, relative atomic mass 74.92, and the symbol "As," arsenic exhibits both metallic and non-metallic properties. It exists in group VA of the periodic table, with its predominant oxidation states being arsenite (AsIII) and arsenate (AsV) in reducing and oxygenated conditions, respectively. [2] Among these, arsenite (AsIII) is known to be more toxic than arsenate (AsV). [3]

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Arsenic contamination is a significant global concern, primarily affecting drinking water through sources such as mining, smelting, and agricultural practices like pesticide or fertilizer use. [4] Additionally, arsenic is found in soil, air, food, and water, [5] making exposure inevitable in many regions. Chronic exposure to arsenic has severe health implications, including metabolic disorders, sterility, dermatosis, hyperkeratosis, gangrene, and skin cancer. [6-8] The primary targets of arsenic toxicity are the skin, red blood cells, nervous system, and metabolic organs. [6,9,10] Long-term arsenic exposure has been linked to diabetes, [6] hepatic, alveolar, and adrenal tumors, [9,10] and disruptions in the reproductive system. Studies in humans and animal models highlight its detrimental effects on testicular tissue, steroidogenesis, and spermatogenesis in males, as well as reproductive disturbances in females. [11-13]

Given its widespread toxicity, there is growing interest in natural remedies that can mitigate harmful effects of arsenic. One such remedy is *Zingiber officinale*, commonly known as ginger. Widely used in food and traditional medicine, ginger has been employed to treat conditions such as vomiting, pain, indigestion, and colds. [14-16] Its therapeutic potential is attributed to its antioxidant, anti-inflammatory, and anti-cancer properties. [17] Antioxidative capabilities of ginger allow it to scavenge reactive oxygen species (ROS), such as superoxide anions and hydroxyl radicals, thereby reducing oxidative stress. [18,19] The bioactive compounds in ginger, including gingerols, shogaols, zingerone, and gingiberols, play a significant role in these protective effects. [20,21]

This review aims to provide a comprehensive understanding of arsenic-induced hepatic toxicity and to highlight the mitigating effects of ginger in combating such toxicity. By exploring the mechanisms of hepatotoxic effects of arsenic and hepatoprotective properties of ginger, this review seeks to establish the potential role of ginger as a natural intervention for arsenic-induced liver damage.

Arsenic-Induced Hepatotoxicity

Arsenic-induced hepatotoxicity is a well-documented phenomenon with complex mechanisms of action that lead to significant liver damage. The liver, as a primary site for arsenic metabolism and detoxification, is highly susceptible to arsenic-induced toxicity. Arsenic predominantly enters hepatocytes and undergoes biotransformation to generate methylated metabolites such as monomethylarsonic acid (MMA) and dimethylarsinic acid (DMA), which are highly reactive and toxic.[22] This metabolic process is accompanied by the production of excessive reactive oxygen species (ROS), leading to oxidative stress, lipid peroxidation, and subsequent damage to cellular membranes.[23]

At the morphological level, arsenic exposure disrupts the architecture of hepatic tissue. Histopathological studies reveal significant changes, including hepatocellular necrosis, sinusoidal dilation, vacuolar degeneration, and inflammatory infiltrates in arsenic-exposed liver tissues.[24] The toxic effects of arsenic on liver function manifest as elevated levels of serum enzymes such as alanine transaminase (ALT), aspartate transaminase (AST), and alkaline phosphatase (ALP), reflecting hepatic injury and impaired liver function.[25]

Oxidative stress plays a pivotal role in arsenic-induced hepatotoxicity. The excessive ROS generated during arsenic metabolism overwhelms antioxidant defenses of the liver, including enzymes such as superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx). This imbalance leads to oxidative damage to DNA, proteins, and lipids, resulting in cellular dysfunction and apoptosis.[26] Additionally, arsenic exposure triggers a pro-inflammatory response by activating nuclear factor-kappa B (NF-κB) and increasing the expression of inflammatory cytokines such as tumor necrosis factor-alpha (TNF-α), interleukin-1 beta (IL-1β), and interleukin-6 (IL-6).[27] These inflammatory processes further exacerbate hepatic injury and fibrosis.

Chronic arsenic exposure has profound long-term implications for liver health. Persistent oxidative stress and inflammation can lead to hepatic fibrosis, cirrhosis, and increased risk of hepatocellular carcinoma.[28] Epidemiological studies have also linked chronic arsenic exposure to non-alcoholic fatty liver disease (NAFLD) and insulin resistance, highlighting its role in metabolic liver diseases.[29] Furthermore, arsenic-induced DNA damage and epigenetic modifications contribute to the activation of oncogenic pathways, enhancing the potential for liver carcinogenesis.[30]

PHARMACOLOGICAL PROPERTIES OF GINGER

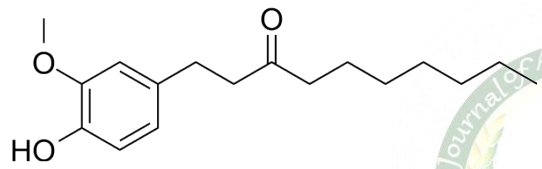
Ginger, a widely used spice and medicinal herb, possesses numerous pharmacological properties attributed to its bioactive compounds. The major active constituents of ginger include gingerol (**1**), shogaol (**2**), paradol (**3**), zingerone (**4**), and volatile oils such as sesquiterpenes and monoterpenes.[31] Among these, 6-gingerol is the most abundant in fresh ginger and is known for its potent antioxidant, anti-inflammatory, and anticancer properties.[32] Shogaols, formed during the drying process or thermal decomposition of gingerols, exhibit even stronger antioxidant and anti-inflammatory activities.[33] Paradols and zingerone also contribute to the therapeutic potential of ginger, particularly through their antioxidative and anti-apoptotic effects.[34]

Ginger exerts hepatoprotective effects through multiple mechanisms. Its antioxidant properties play a crucial role in neutralizing ROS and reducing oxidative stress, which is a key factor in arsenic-induced liver damage. Gingerols and shogaols enhance the activity of endogenous antioxidant enzymes such as SOD, CAT, and GPx, thereby preventing lipid peroxidation and protecting cellular membranes.[26] Additionally, anti-inflammatory effects of ginger are mediated through inhibition of NF-κB signaling and suppression of pro-inflammatory cytokines, including TNF-α, IL-1β, and IL-6. This reduces inflammation and limits liver damage caused by chronic arsenic exposure.[27] Ginger also exhibits anti-apoptotic effects by modulating the expression of apoptosis-regulating proteins such as Bcl-2 and Bax, thereby protecting hepatocytes from arsenic-induced programmed cell death.[35]

Evidence supporting the efficacy of ginger in reducing toxicity is substantial. Experimental studies have demonstrated that ginger supplementation

mitigates arsenic-induced hepatotoxicity by reducing oxidative stress and inflammation. For instance, rats treated with ginger extract showed significant improvements in liver enzyme levels (ALT, AST), reduced histopathological damage, and enhanced antioxidant enzyme activity compared to arsenic-exposed controls.[36] Another study reported that ginger supplementation alleviated DNA damage and lipid peroxidation in arsenic-exposed animals, highlighting its protective role at the cellular level.[37] Furthermore, clinical studies have shown that ginger effectively reduces markers of inflammation and oxidative stress in individuals with various liver conditions, further validating its hepatoprotective potential.[38,39]

Gingerol (**1**) Shogaols (**2**)



Paradols **(3)** Zingerone (**4**)

Figure 1: Major bioactive constituents of ginger

Role of Ginger Against Arsenic-Induced Hepatotoxicity

Arsenic exposure leads to significant hepatotoxicity primarily through oxidative stress, inflammation, and hepatocellular necrosis. Once arsenic enters the human body, it is metabolized in the liver, where methylation occurs, requiring S-adenosylmethionine and glutathione (GSH) as cofactors. This metabolic process generates ROS and lipid peroxides, leading to oxidative damage, apoptosis, and the release of inflammatory cytokines that exacerbate liver injury.[40] The hepatotoxic effects of arsenic are also associated with increased MDA and conjugated diene levels, reduced enzymatic activities of SOD and CAT, and elevated serum levels of liver enzymes such as SGPT and SGOT, indicative of hepatocellular damage and inflammation. [40,41]

Antioxidant Properties of Ginger

Ginger has shown significant potential in mitigating arsenic-induced hepatotoxicity due to its robust antioxidant properties. Bioactive compounds in ginger, such as gingerols, shogaols, and flavonoids, act as potent free radical scavengers, neutralizing ROS and restoring oxidative balance. These compounds enhance the activities of endogenous antioxidant enzymes, including SOD, GPx, and catalase, while also increasing GSH levels, which are often depleted in arsenic toxicity. [42,43] This dual action of reducing oxidative stress and replenishing antioxidant defenses makes ginger an effective protector against arsenic-induced hepatic damage.

Anti-Inflammatory Effects of Ginger

In addition to its antioxidant capabilities, ginger exhibits potent anti-inflammatory properties. It suppresses the NF-κB signalling pathway and reduces the production of pro-inflammatory cytokines such as TNF-α, IL-1β, and IL-6, which are commonly elevated in arsenic-induced hepatic inflammation.[27] The ability of ginger to modulate the inflammatory response alleviates chronic liver inflammation and reduces damage caused by prolonged arsenic exposure. Moreover, studies have demonstrated that 6-gingerol, a major bioactive compound in ginger, significantly decreases the expression of inflammatory markers in arsenicated liver tissues, further underscoring its hepatoprotective role. [36,44]

Prevention of Hepatocyte Apoptosis

Ginger also prevents hepatocyte apoptosis, a hallmark of arsenic-induced liver damage. By regulating the expression of apoptotic proteins, ginger increases the levels of anti-apoptotic Bcl-2 while reducing pro-apoptotic Bax and caspase-3 activity. This modulation effectively inhibits programmed cell death in liver cells and supports cellular regeneration.[35]

Comparative Efficacy of Ginger

Compared to synthetic and natural hepatoprotective agents, ginger demonstrates comparable or superior efficacy.[45] While synthetic antioxidants focus primarily on reducing oxidative stress, they often lack anti-inflammatory or regenerative properties and may carry toxicity risks.[46] Ginger provides a holistic approach by addressing oxidative stress, inflammation, and cellular repair. [47] For instance, studies comparing ginger with silymarin, a well-known hepatoprotective agent, found that both were effective in reducing oxidative stress and inflammation. However, ginger provided additional benefits by inhibiting apoptosis and promoting hepatocyte regeneration, making it a more comprehensive solution. [48,49]

Pre-clinical Studies

In animal models, ginger supplementation has shown remarkable effects in alleviating arsenic-induced liver damage. Studies have reported significant reductions in liver enzyme markers such as SGPT and SGOT, improvements in antioxidant enzyme activity, and decreases in lipid peroxidation levels. Histopathological analyses further confirm that ginger prevents hepatocellular necrosis and inflammation, highlighting its protective role against arsenic toxicity. [40,41] Additionally, in vitro studies have demonstrated that the bioactive compounds of ginger scavenge ROS and protect hepatocytes from oxidative damage, validating its therapeutic potential. [50]

Mechanisms of Ginger in Hepatoprotection

Ginger exerts hepatoprotective effects through a combination of antioxidant, anti-inflammatory, anti-apoptotic, and cellular regenerative mechanisms. Its bioactive constituents, including gingerols, shogaols, paradols, and flavonoids, play a central role in neutralizing oxidative stress by scavenging ROS and enhancing the activity of endogenous antioxidant enzymes such as SOD, CAT, and GPx. [42,43] These compounds also prevent lipid peroxidation, a process that generates MDA, a marker of oxidative damage, by maintaining membrane integrity and restoring GSH levels, which are often depleted in liver injury caused by toxins or oxidative stress. [34] Furthermore, ginger inhibits pro-inflammatory pathways by downregulating the NF-κB signaling pathway and reducing the expression of pro-inflammatory cytokines, including TNF-α, IL-1β, and IL-6. [27] These actions help to mitigate chronic inflammation associated with hepatotoxicity.

In addition to its anti-inflammatory effects, ginger modulates apoptotic pathways, reducing hepatocyte apoptosis by balancing the expression of apoptotic and anti-apoptotic proteins. For example, ginger upregulates anti-apoptotic Bcl-2 expression while downregulating pro-apoptotic Bax and caspase-3 activities, effectively preventing programmed cell death in liver cells. [35] Additionally, ginger extract and its active constituents (6-gingerol and 6-shogaol) have been shown to improve mitochondrial function, a critical component of cellular energy metabolism, further supporting hepatocyte viability and repair processes during liver injury. [51,52]

When compared to synthetic hepatoprotective agents, ginger provides a more comprehensive approach by addressing oxidative stress, inflammation, and cellular repair simultaneously, without the associated risks of toxicity. [32] The ability of 6-shogaol to modulate gene expression related to detoxification enzymes, such as γ-glutamyl-cysteine ligase (GCL), further highlights its role in enhancing the resilience of liver against hepatotoxic insults. [53] These multi-targeted mechanisms make ginger a promising natural intervention for protecting liver health and treating hepatotoxic conditions.

Limitations and Knowledge Gaps

Despite extensive research on the hepatoprotective effects of ginger, several limitations and knowledge gaps persist, warranting further investigation. Firstly, the majority of studies exploring the hepatoprotective mechanisms of ginger have been conducted in preclinical settings, primarily using animal models or *in vitro* systems. While these studies provide valuable insights, they often lack direct translational relevance to humans due to differences in metabolism, dosing, and physiological responses. The limited availability of well-designed, large-scale clinical trials in humans creates uncertainty regarding the optimal dosage, long-term safety, and efficacy of ginger in hepatoprotection. Additionally, while the bioactive compounds of ginger, such as gingerols and shogaols, have been widely studied, their pharmacokinetics, bioavailability, and potential interactions with other therapeutic agents are not fully understood, particularly in populations with existing liver diseases or comorbid conditions.

Moreover, much of the research focuses on the antioxidant, anti-inflammatory, and anti-apoptotic properties of ginger without addressing the complex interplay between these mechanisms in specific pathological conditions. For instance, the potential synergistic effects of ginger with other hepatoprotective agents, dietary factors, or traditional

medicines remain largely unexplored. Additionally, the role of ginger in addressing chronic liver diseases, such as NAFLD or liver fibrosis, requires more comprehensive studies to determine its therapeutic potential beyond acute toxicological models.

Another significant gap is the variability in ginger extract preparation and standardization. Studies often utilize different extraction methods, concentrations, and formulations, making it challenging to compare results or establish standardized treatment protocols. The lack of data on the impact of genetic, dietary, and environmental factors on the efficacy of ginger further complicates its clinical application. Lastly, the safety profile of ginger is generally favourable; however, its long-term effects on liver health and potential adverse reactions, especially at high doses or in vulnerable populations such as pregnant women or individuals with compromised hepatic function, remain inadequately explored.

Addressing these limitations will require a multidisciplinary approach, including randomized controlled trials, standardized extract formulations, and mechanistic studies that integrate systems biology and omics technologies. Such efforts will provide a clearer understanding of potential of ginger as a hepatoprotective agent and its applicability in clinical practice.

Future Directions

Future research on the hepatoprotective effects of ginger should focus on bridging the existing gaps in knowledge and addressing current limitations. A key priority is the initiation of well-designed, large-scale, randomized controlled trials (RCTs) in human populations to validate findings from preclinical studies and establish the efficacy, safety, and optimal dosing of ginger in managing various liver disorders, including arsenic-induced hepatotoxicity, NAFLD, and liver fibrosis. Additionally, advanced pharmacokinetic studies are needed to explore the bioavailability, metabolism, and tissue distribution of bioactive compounds of ginger, such as gingerols and shogaols, in humans, particularly in individuals with compromised liver function. The development of standardized ginger formulations and extraction methods would also facilitate consistency in future studies and enable cross-study comparisons.

Furthermore, future studies should explore the molecular mechanisms underlying the hepatoprotective effects of ginger in greater detail. Investigations using systems biology approaches, such as genomics, transcriptomics, proteomics, and metabolomics, can provide a comprehensive understanding of how ginger modulates oxidative stress, inflammation, and apoptosis at the cellular and systemic levels. Research should also focus on evaluating the synergistic potential of ginger with other natural or synthetic hepatoprotective agents, as well as its role in multi-modal therapeutic approaches for liver diseases.

Exploring the effects of ginger on chronic liver conditions, such as alcoholic liver disease, cirrhosis, and hepatocellular carcinoma, could open new avenues for therapeutic applications. Additionally, the role of ginger in modulating gut-liver axis interactions, microbiota composition, and bile acid metabolism represents an emerging area of interest in liver health research. Finally, long-term studies assessing the safety and tolerability of ginger in diverse populations, including those with pre-existing liver conditions, pregnant women, and elderly individuals, will be crucial for its clinical translation as a hepatoprotective agent. These future directions will help establish ginger as a reliable and evidence-based therapy for liver health.

In summary, ginger emerges as a promising natural hepatoprotective agent with compelling evidence supporting its efficacy against arsenic-induced hepatotoxicity and other liver disorders. Through its potent antioxidant, anti-inflammatory, and anti-apoptotic activities, ginger effectively mitigates oxidative stress, modulates inflammatory responses, and promotes hepatocyte regeneration, thereby offering a multi-faceted approach to liver protection. Its bioactive compounds, such as gingerols, shogaols, and flavonoids, play a central role in neutralizing ROS, restoring antioxidant enzyme activities, and suppressing pro-inflammatory cytokines, contributing to improved hepatic function and structural integrity.

Despite these promising findings, limitations in existing research, including the lack of standardized formulations, insufficient human studies, and gaps in understanding its molecular mechanisms, highlight the need for further investigations. Future research should focus on large-scale clinical trials, pharmacokinetic profiling, and exploring the synergistic potential of ginger with other therapeutic agents. Moreover, studies addressing long-term safety, tolerability, and its role in the gut-liver axis and other chronic liver conditions will expand its therapeutic applications.

CONCLUSION

In conclusion, ginger holds significant potential as a safe, effective, and affordable hepatoprotective agent. With continued research and clinical validation, ginger could become an integral part of therapeutic strategies aimed at mitigating liver damage caused by toxic exposures, oxidative stress, and chronic liver diseases, contributing to improved liver health and overall well-being.

REFERENCES

1. Vahidnia A, Van der Voet GB, De Wolff FA. Arsenic neurotoxicity-a review. Human and Experimental Toxicology. 2007, 26(10): 823-832.
2. WHO. Arsenic and arsenic compounds (Environmental Health Criteria 224), 2nd ed. Geneva: World Health Organization, International Programme on Chemical Safety 2001.
3. Yousef MI, El-Demerdash FM, Radwan FME. Sodium arsenite induced biochemical perturbations in rats: Ameliorating effect of curcumin. Food and Chemical Toxicology. 2008; 46(11): 3506-3511.
4. Matschullat J. Arsenic in the geosphere-a review. Science of the Total Environment 2000; 249(1-3): 297-312.
5. Nuntharatanapong N, Chen K, Sinhaseni P, Keaney JF. EGF receptor-dependent JNK activation is involved in arsenite-induced p21Cip1/Waf1 upregulation and endothelial apoptosis. American Journal of Physiology-Heart and Circulatory Physiology. 2005; 289(1): H99-H107.
6. Longnecker MP, Daniels JL. Environmental contaminants as etiologic factors for diabetes. Environ Health Perspect. 2001; 6(Suppl.): 871-876.
7. Zadorozhnaja TD, Little RE, Miller RK, Mendel NA, Taylor RJ, Presley BJ, et al. Concentrations of arsenic, cadmium, copper, lead, mercury, and zinc in human placentas from two cities in Ukraine. Journal of Toxicology and Environmental Health. 2000; 61: 255-263.
8. Saha AK. Pollution in ground water in West Bengal, Final report, Steering Com- mittee, Arsenic Investigation Project. India: PHE Dept., Government of West Bengal, 1991; pp. 1-56.
9. Waalkes MP, Ward JM, Liu J, Diwan BA. Transplacental carcinogenicity of inorganic arsenic in the drinking water, induction of hepatic, ovarian, pulmonary, and adrenal tumors in mice. Toxicology and Applied Pharmacology. 2003; 186: 7-17.
10. Waalkes MP, Liu J, Ward JM, Diwan BA. Mechanisms underlying arsenic carcino- genesis, hypersensitivity of mice exposed to inorganic arsenic during gestation. Toxicology. 2004; 198: 31-38.
11. Sukla JP, Pandey K. Impaired spermatogenesis in arsenic-treated freshwater fish Colisafasciatus (BlandSch). Toxicology Letters. 1984; 21: 191-195.
12. Sarkar M, Chaudhuri GR, Chattopadhyay A, Biswas NM. Effect of sodium arsenite on spermatogenesis, plasma gonadotrophins and testosterone in rats. Asian Journal of Andrology. 2003; 5: 27-31.
13. Yang CY, Chang CC, Tsai SS, Chuang HY, Ho CK, Wu TN. Arsenic in drinking water and adverse pregnancy outcome in an arseniasis-endemic area in northeastern Taiwan. Environmental Research. 2003; 91: 29-34.
14. Joshi D, Srivastav SK, Belemkar S, Dixit VA. *Zingiber officinale* and 6- gingerol alleviate liver and kidney dysfunctions and oxidative stress induced by mercuric chloride in male rats: A protective approach. Biomedicine & Pharmacotherapy. 2017; 91: 645-655.
15. Wang WH, Wang ZM. Studies of commonly used traditional medicine ginger. Zhongguo Zhong Yao Za Zhi. 2005; 20: 1569-1573.
16. White B. Ginger: An overview. American Family Physician. 2007; 75: 1689-1691.
17. Shukla Y, Madhulika S. Cancer preventive properties of ginger: A brief review. Food and Chemical Toxicology. 2007; 45: 683-690.
18. Shimada T. Xenobiotic-metabolizing enzymes involved in activation and detoxification of carcinogenic polycyclic aromatic hydrocarbons. Drug Metabolism and Pharmacokinetics. 2006; 21: 257-276.
19. Sajwicz W. Toxicity of pyrimidine derivatives under oxidative stress conditions: Chemiluminescence based assays in systems containing erythrocytes, mitochondria or blood plasma. Pharmacological Reports. 2007; 59: 206-215.
20. Surh YJ. Molecular mechanisms of chemo preventive effects of selected dietary and medical phenolic substances. Mutation Research. 1999; 428: 305-327.
21. Altman RD, Marcussen KC. Effects of a ginger extract on knee pain in patients with osteoarthritis. Arthritis & Rheumatology. 2001; 44: 2531-2538.
22. Khairul I, Wang QQ, Jiang YH, Wang C, Naranmandura H. Metabolism, toxicity and anticancer activities of arsenic compounds. Oncotarget. 2017; 8(14): 23905-23926.
23. Sharma P, Jha AB, Dubey RS, Pessarakli M. Reactive Oxygen Species, Oxidative Damage, and Antioxidative Defense Mechanism in Plants under Stressful Conditions. Journal of Botany. 2012; 2012: 217037.
24. Shangloo P, Gupte B, Syed M. Histopathological Effect of Arsenic in Drinking Water on Liver and Kidney of Albino Rat: A Light Microscopic Study. International Journal of Scientific Research in Dental and Medical Sciences. 2021; 3: 166–170.
25. Islam K, Haque A, Karim R, Fajol A, Hossain E, Salam KA, Ali N, Saud ZA, Rahman M, Rahman M, Karim R, Sultana P, Hossain M, Akhand AA, Mandal A, Miyataka H, Himeno S, Hossain K. Dose-response relationship between arsenic exposure and the serum enzymes for liver function tests in the individuals exposed to arsenic: a cross-sectional study in Bangladesh. Environmental Health. 2011; 10: 64.

26. Hu Y, Li J, Lou B, Wu R, Wang G, Lu C, Wang H, Pi J, Xu Y. The Role of Reactive Oxygen Species in Arsenic Toxicity. Biomolecules. 2020; 10(2): 240.
27. Zhang Z, Pi R, Luo J, Liu J, Zhang A, Sun B. Association between arsenic exposure and inflammatory cytokines and C-reaction protein: A systematic review and meta-analysis. Medicine (Baltimore). 2022; 101(50): e32352.
28. Banerjee P, Gaddam N, Chandler V, Chakraborty S. Oxidative Stress-Induced Liver Damage and Remodeling of the Liver Vasculature. American Journal of Pathology. 2023; 193(10): 1400-1414.
29. Frediani JK, Naioti EA, Vos MB, Figueroa J, Marsit CJ, Welsh JA. Arsenic exposure and risk of nonalcoholic fatty liver disease (NAFLD) among U.S. adolescents and adults: an association modified by race/ethnicity, NHANES 2005-2014. Environmental Health. 2018; 17(1): 6.
30. Islam R, Zhao L, Wang Y, Lu-Yao G, Liu LZ. Epigenetic Dysregulations in Arsenic-Induced Carcinogenesis. Cancers. 2022; 14: 4502.
31. Rahmani AH, Shabrmi FM, Aly SM. Active ingredients of ginger as potential candidates in the prevention and treatment of diseases via modulation of biological activities. International Journal of Physiology, Pathophysiology and Pharmacology. 2014; 6(2): 125-136.
32. Promdam N, Panichayupakaranant P. [6]-Gingerol: A narrative review of its beneficial effect on human health. Food Chemistry Advances. 2022, 1: 100043
33. Bischoff-Kont I, Primke T, Niebergall LS, Zech T, Fürst R. Ginger Constituent 6-Shogaol Inhibits Inflammation- and Angiogenesis-Related Cell Functions in Primary Human Endothelial Cells. Frontiers in Pharmacology. 2022; 13: 844767.
34. Ayustaningwarno F, Anjani G, Ayu AM, Fogliano V. A critical review of Ginger's (*Zingiber officinale*) antioxidant, anti-inflammatory, and immuno-modulatory activities. Frontiers in Nutrition. 2024; 11: 1364836.
35. Choi NR, Choi WG, Kwon MJ, Woo JH, Kim BJ. [6]-Gingerol induces Caspase-Dependent Apoptosis in Bladder Cancer cells via MAPK and ROS Signaling. International Journal of Medical Sciences. 2022; 19(7): 1093-1102.
36. Adetutu A, Aborisade AB, Ogunsina FA, Adegbola PI, Olaniyi TD. Ginger mitigated the health risks associated with arsenic-contamination of rats feed via inflammatory and apoptosis regulation. Ecotoxicology and Environmental Safety. 2024; 269: 115768.
37. Makpol S, Abdul Sani NF, Hakimi NH, Rani NA, Zakaria SNA, Rasid AFA, Gunasekaran G, Mohd Sahardi NFN, Tan JK, Ghafar NA, Mad Nordin MF. Zingiber officinale Roscoe Prevents DNA Damage and Improves Muscle Performance and Bone Integrity in Old Sprague Dawley Rats. Evidence-Based Complementary and Alternative Medicine. 2020; 2020: 3823780.
38. Rahimlou M, Yari Z, Hekmatdoost A, Alavian SM, Keshavarz SA. Ginger Supplementation in Nonalcoholic Fatty Liver Disease: A Randomized, Double-Blind, Placebo-Controlled Pilot Study. Hepatitis Monthly. 2016; 16(1): e34897.
39. Sheikhhossein F, Borazjani M, Jafari A, Askari M, Vataniyan E, Gholami F, Amini MR. Effects of ginger supplementation on biomarkers of oxidative stress: A systematic review and meta-analysis of randomized controlled trials. Clinical Nutrition ESPEN. 2021; 45: 111-119.
40. Rao CV, Pal S, Mohammed A, Farooqui M, Doescher MP, Asch AS, Yamada HY. Biological effects and epidemiological consequences of arsenic exposure, and reagents that can ameliorate arsenic damage in vivo. Oncotarget. 2017; 8: 57605-57621.
41. Li S, Tan HY, Wang N, Zhang ZJ, Lao L, Wong CW, Feng Y. The Role of Oxidative Stress and Antioxidants in Liver Diseases. International Journal of Molecular Sciences. 2015; 16(11): 26087-26124.
42. Mairuae N, Noisa P, Palachai N. Phytosome-Encapsulated 6-Gingerol- and 6-Shogaol-Enriched Extracts from *Zingiber officinale* Roscoe Protect Against Oxidative Stress-Induced Neurotoxicity. Molecules. 2024; 29(24): 6046.
43. Alsahli MA, Almatroodi SA, Almatroudi A, Khan AA, Anwar S, Almutary AG, Alrumaihi F, Rahmani AH. 6-Gingerol, a Major Ingredient of Ginger Attenuates Diethylnitrosamine-Induced Liver Injury in Rats through the Modulation of Oxidative Stress and Anti-Inflammatory Activity. Mediators of Inflammation. 2021; 2021: 6661937.
44. Wu Y, Sun X, Li H, Chu X, Xue Y, Qi J, Jia Q, Han X, Chu L, Guan S, Wang X. 6-Gingerol attenuates arsenic trioxide-induced liver injury by inhibiting pyroptosis and ROS-NLRP3 inflammatory signaling pathway: Based on network pharmacology analysis and experiment verification. Journal of Functional Foods. 2023; 105: 105551.
45. Mahmoud RH, Elnour WA. Comparative evaluation of the efficacy of ginger and orlistat on obesity management, pancreatic lipase and liver peroxisomal catalase enzyme in male albino rats. European Review for Medical and Pharmacological Sciences. 2013; 17(1): 75-83.
46. Tumilaar SG, Hardianto A, Dohi H, Kurnia D. A Comprehensive Review of Free Radicals, Oxidative Stress, and Antioxidants: Overview, Clinical Applications, Global Perspectives, Future Directions, and Mechanisms of Antioxidant Activity of

Flavonoid Compounds. Journal of Chemistry. 2024; 2024: 5594386.

47. Pázmándi K, Szöllősi AG, Fekete T. The "root" causes behind the anti-inflammatory actions of ginger compounds in immune cells. Frontiers in Immunology. 2024; 15: 1400956.
48. Oke GO, Abiodun AA, Imafidon CE, Monsi BF. Zingiber officinale (Roscoe) mitigates CCl4-induced liver histopathology and biochemical derangements through antioxidant, membrane-stabilizing and tissue-regenerating potentials. Toxicology Reports. 2019; 6: 416-425.
49. Hamza AA, Heeba GH, Hamza S, Abdalla A, Amin A. Standardized extract of ginger ameliorates liver cancer by reducing proliferation and inducing apoptosis through inhibition oxidative stress/ inflammation pathway. Biomedicine & Pharmacotherapy. 2021; 134: 111102.
50. Yang K, Lu Y, Yue Z, Jin S, Wang P, Liu C, Wang L, Yin Q, Dang X, Guo H, Chang J. 6-Gingerol activates the Nrf2 signaling pathway to alleviate hydrogen peroxide induced oxidative stress on primary chicken embryo hepatocytes. Journal of Functional Foods. 2024; 122: 106535.
51. Oh S, Lee MS, Jung S, Kim S, Park H, Park S, Kim SY, Kim CT, Jo YH, Kim IH, Kim Y. Ginger extract increases muscle mitochondrial biogenesis and serum HDL-cholesterol level in high-fat diet-fed rats. Journal of Functional Foods. 2017; 29:193-200.
52. Deng X, Zhang S, Wu J, Sun X, Shen Z, Dong J, Huang J. Promotion of Mitochondrial Biogenesis via Activation of AMPK-PGC1α Signaling Pathway by Ginger (*Zingiber officinale* Roscoe) Extract, and Its Major Active Component 6-Gingerol. Journal of Food Science. 2019; 84(8): 2101-2111.
53. Mao QQ, Xu XY, Cao SY, Gan RY, Corke H, Beta T, Li HB. Bioactive Compounds and Bioactivities of Ginger (*Zingiber officinale* Roscoe). Foods. 2019; 8(6): 185.

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