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Efficacy of Ginger (Zingiber officinale) in Combating Aging and Enhancing Metabolic Health: A Review of Recent Advances

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Abstract

Aging is a complex process associated with oxidative stress, chronic inflammation, and metabolic disorders such as obesity and diabetes, leading to a decline in overall health. Natural compounds, particularly ginger (Zingiber officinale), have gained attention for their potential in mitigating these effects due to their antioxidant, anti-inflammatory, and metabolic regulatory properties. However, despite extensive research on ginger's bioactive compounds, the precise molecular mechanisms underlying its role in aging and metabolic health remain unclear. This review aims to bridge this gap by systematically analyzing recent studies on ginger's impact on oxidative stress, inflammation, and metabolic dysfunction. A literature search was conducted across PubMed, NIH, and Google Scholar, focusing on peer-reviewed studies from 2015 to 2024. Findings indicate that ginger's bioactive compounds, especially 6-gingerol and 6-shogaol, significantly reduce oxidative damage, modulate inflammatory pathways, and enhance metabolic processes, thereby improving glucose metabolism, lipid profiles, and neuroprotection. Additionally, studies suggest that ginger influences key molecular pathways such as Nrf2 activation, NF-κB modulation, and AMPK regulation, contributing to its therapeutic potential. However, limitations include the reliance on in vitro and animal studies, inconsistent methodologies, and a lack of large-scale human trials. Future research should focus on clinical validation, dosage standardization, and personalized nutrition applications. Overall, this review underscores ginger's potential as a functional food for promoting healthy aging and metabolic well-being while emphasizing the need for further research to establish its clinical efficacy.

Keywords: Aging, Zingiber officinale, Antioxidant, Anti-inflammatory Agents, Oxidative stress, Functional food, Neuroprotection, Glucose metabolism Disorders.

1. Introduction

Aging is a multilateral process whereby physiological functions slow down gradually with age, there is an increase in susceptibility to diseases, and the quality of life declines. This decline usually comes with problems of metabolic health, including obesity, diabetes, and cardiovascular diseases (1). This is important because it interacts with aging; the effects of age can sometimes enhance the metabolic disorder, creating this cycle of declining health outcomes.

Some of the interesting natural compounds that interest individuals are their potentials to fight against aging and metabolic health. Among these compounds, ginger (Zingiber officinale) is of specific interest, owing to the fact that it has a long history both as a culinary spice and traditional medicine. For so long, ginger has been used by different cultures for therapeutic purposes, including its anti-inflammatory, antioxidant, and antimicrobial effects (2). This is important because it interacts with aging; the effects of age can sometimes enhance the metabolic disorder, creating this cycle of declining health outcomes.

Some of the interesting natural compounds that interest individuals are their potentials to fight against aging and metabolic health. Among these compounds, ginger (Zingiber officinale) is of specific interest, owing to the fact that it has a long history both as a culinary spice and traditional medicine. For so long, ginger has been used by different cultures for therapeutic purposes, including its anti-inflammatory, antioxidant, and antimicrobial effects (3). Oxidative stress is a condition that occurs when free radicals and antioxidants are not in balance, causing damage to cells and inflammation. This damage has been associated with several age-related diseases, such as neurodegenerative disorders and metabolic syndromes.

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The scientific evidence shows that ginger increases the antioxidant defenses of the body by upregulating the expression of antioxidant enzymes, thus reducing oxidative damage and improving cellular health (4)

Moreover, its anti-inflammatory effects are what give ginger its potential to be used in the treatment of age-related conditions. Inflammation is the term given to chronic inflammation, which is low-grade and associated with aging. There are several studies showing that ginger can reduce inflammatory markers, indicating it may be able to reduce chronic inflammation associated with age-related diseases (5). By modulating inflammatory pathways, ginger may contribute to improved metabolic health outcomes, such as better insulin sensitivity and lipid profiles.

The importance of natural compounds like ginger in health promotion cannot be underestimated. With a shift in focus towards preventive healthcare strategies, incorporation of functional foods into the diets of individuals will be an avenue for betterment of overall health. Due to its versatility, ginger can be easily adapted for use in multiple culinary applications and is therefore available to most who wish to upgrade their dieting habits. Such products being consumed nourish the health of individuals and resonate well with conventional diets as they create a holistic sense towards wellness.

Recent advances in research have further illuminated the potential of ginger as an effective intervention for combating aging and enhancing metabolic health. For instance, studies have indicated that ginger supplementation can positively influence metabolic pathways related to fat metabolism and glucose homeostasis (6). Additionally, animal models have shown that ginger can extend lifespan by counteracting key hallmarks of aging such as mitochondrial dysfunction and genomic instability (4). These findings underscore the need for continued exploration into the therapeutic applications of ginger and its bioactive constituents.

Despite the growing interest in natural compounds for health promotion, there remains a significant gap in understanding the precise molecular mechanisms through which ginger (Zingiber officinale) combats aging and enhances metabolic health. Aging is closely linked to oxidative stress, chronic inflammation, and metabolic disorders such as obesity and diabetes, yet conventional therapeutic approaches often fail to address these interconnected processes holistically. While ginger has been traditionally recognized for its antioxidant and anti-inflammatory properties, existing research lacks a comprehensive synthesis of its role in mitigating age-related metabolic dysfunction and modulating key molecular pathways. This review aims to bridge this gap by systematically analyzing recent advances in ginger research, focusing on its bioactive compounds, their impact on aging-related oxidative stress and inflammation, and their potential in regulating metabolic pathways such as Nrf2 activation, NF-κB modulation, and AMPK regulation. Through this synthesis, the review seeks to establish ginger as a functional food with promising applications in promoting healthy aging and preventing metabolic disorders.

2. Methodology

2.1 Search Strategy

In this review, the author utilized previous 10-year researches that were published in peer-reviewed journals. Data was searched on widely used databases such as PubMed, NIH, and Google Scholar. Time frame filters were then applied to improve the review. In order to conduct this review, data was collected with a specific focus on publications released between 2015 and 2024 investigating the efficacy of ginger in combating aging and enhancing metabolic health. As indicated in Table 1 below, the author chose particular search approaches in order to obtain the data.

Table 1 Search Strategies (Source: Author)

S. No.	Search Strategy
1.	(“Ginger (Zingiber officinale)”) AND (“Aging”) OR (“Metabolic health”) AND (“Functional foods)” OR (“Natural compounds”) OR (“Dietary interventions”) AND (“Oxidative stress”) OR (“Inflammation”) OR (“Metabolic dysfunction”) AND (“6-Gingerol”) AND (“6-Shogaol”) AND (“Paradols”)
2.	(“Ginger extracts”) AND (“Antioxidant enzymes”) OR (“Superoxide dismutase (SOD))” OR (“Catalase (CAT)”) AND (“Nrf2 pathway”) AND (“6-Shogaol”) AND (“NF-κB pathway”) AND (“Cytokines”) AND (“TNF-α”) OR (“IL-6”)

3.	(“Neurodegeneration”) OR (“Cognitive decline”) AND (“Alzheimer's disease)” AND (“Synaptic plasticity”) OR (“Acetylcholine”) OR (“Insulin sensitivity”) AND (“Glucose metabolism”) AND (“Lipid profiles”) AND (“AMPK regulation”)
4.	(“α-glucosidase inhibition”) OR (“Type 2 Diabetes (T2DM)”) OR (“Glycemic control”) AND (“HbA1c”) OR (“Cardiovascular diseases)” OR (“Lipid metabolism”)

2.2 Selection Criteria

Table 2 represents the inclusion and exclusion criteria of the studies that were utilized to review the efficacy of ginger in combating aging and enhancing metabolic health.

Table 2. Inclusion and Exclusion Criteria (Source: Author)

Inclusion Criteria	Exclusion Criteria
Studies that were published in journals with peer-reviewing policies provided by the publishers were included.	Studies that were published in journals with peer-reviewing policies not provided by the publishers were excluded.
The studies included in the review were selected based on having the keyword "ginger", "aging" and "metabolic health".	The studies not having the specific keyword “ginger”, “aging” and “metabolic health” were excluded from the review.
The studies published in the last 10 years from 2015 to 2024 were included in this review.	The studies performed or papers published prior to 2015 were excluded.
Only studies that were accessible in full-text format for the public view were included.	Studies not accessible in open access format in any authorized database were excluded.

2.3 Data Analysis

10 studies were selected based on their titles, publishers, and main objective of the review aligned with the current study’s rationale. The analysis of the obtained data from the 10 articles was conducted using critical analysis as presented in the discussion. The data was obtained by utilizing recurrent keywords in the paper such as “ginger”, “aging” and “metabolic health”.

2.4 Quality Assessment

The review addresses the study quality based on the efficacy of ginger in combating aging and enhancing metabolic health. It includes the criteria on which the chosen publications were most relevant to the review aim and were published between 2015-2024. Availability of full-text studies was another important requirement that was given priority. These criteria contribute to the quality and reliability of the synthesized data by developing discussions and conclusions on the efficacy of the studies included in this review. The review’s main objective is to provide a thorough understanding on the efficacy of ginger in combating aging and enhancing metabolic health.

3. Results

Table 3 outlines the included researches and provides insights into the efficacy of ginger in combating aging and enhancing metabolic health.

Table 3 Included Studies

S.No	Author	Journal	Title	Objective	Results
1.	Mao et al. 2019	Foods	Bioactive Compounds and Bioactivities of Ginger	To analyze the bioactive compounds in ginger and their effects on aging and metabolic health.	Found that gingerols, shogaols, and paradols possess significant antioxidant and anti-inflammatory properties, reducing oxidative stress and improving insulin sensitivity.

2.	Offei-Oknye et al. 2015	Food and Nutrition Sciences, 6(5), 445-451.	Processing effects on phytochemical content and antioxidative potential of ginger Zingiber officale.	Investigated the impact of ginger extract on metabolic parameters in diabetic rats.	Demonstrated reduced blood glucose levels and improved lipid profiles due to increased antioxidant enzyme activity.
3.	Zhang et al. 2022	Molecules	Red Ginger's Medicinal Uses	Evaluated the antioxidant capacity of processed vs. fresh ginger.	Found that processing methods enhance total phenolic and flavonoid content, improving antioxidant activity.
4.	Van et al. 2024	Current Medicinal Chemistry	Ginger and Its Bioactive Compounds in Diabetes	Reviewed ginger's anti-diabetic properties and mechanisms of action.	Found that ginger inhibits α-glucosidase activity, reducing postprandial blood sugar spikes.
5.	Ozkur et al. 2022	Oxidative Medicine and Cellular Longevity	Ginger for Healthy Aging: Systematic Review	Examined the antioxidant and anti-inflammatory properties of ginger.	Showed that ginger significantly reduces oxidative stress markers and inflammation, mitigating age-related diseases.
6.	Ayustaningwarno et al. 2024	Frontiers in Nutrition	Ginger's Antioxidant, Anti-inflammatory, and Immunomodulatory Activities	Investigated the effect of ginger on inflammatory pathways.	Found that ginger decreases pro-inflammatory cytokines (TNF-α, IL-6) by modulating NF-κB signaling.
7.	Matin et al. 2024	Biomolecules	Effects of Ginger on the Hallmarks of Aging	Studied the neuroprotective effects of ginger in Alzheimer's disease	Found that ginger improves memory and learning by enhancing neurotransmitter levels like acetylcholine.
8.	Carvalho et al. 2020	Revista Latino-Americana de Enfermagem	Effectiveness of Ginger in Reducing Metabolic Levels in Diabetes	Investigated the impact of ginger supplementation in T2DM patients.	Demonstrated significant reductions in fasting blood glucose and total cholesterol levels.
9.	Peng et al. 2015	Food & Function	Activation of Nrf2 Target Enzymes by Ginger	Explored the effect of 6-shogaol on the Nrf2 pathway.	Found that ginger increases Nrf2 translocation, leading to upregulation of antioxidant genes.

10.	Zhu et al. 2018	Evidence-Based Complementary and Alternative Medicine	Effects of Ginger on Type 2 Diabetes and Metabolic Syndrome	Conducted a meta-analysis of 10 RCTs on ginger's effect on diabetes.	Found that ginger supplementation improves glycemic control, significantly reducing HbA1c and fasting blood glucose levels.

4. Discussion

4.1. Phytochemical Composition of Ginger: Bioactive Compounds & Mechanisms in Aging and Metabolism

A paper published by Mao et al. in 2019 aimed to investigate the phytochemical composition of the spice and its biological activities. The authors applied a systematic review methodology with the intention of analyzing a variety of studies concerning the bioactive compounds, in which gingerols, shogaols, and paradols are key compounds. The result shows that these compounds possess remarkable antioxidant and anti-inflammatory activities crucial for the elimination of oxidative stress due to aging. Specifically, the study highlighted that 6-gingerol, a primary component of fresh ginger, effectively reduces oxidative stress markers in cellular models, thus suggesting its potential role in delaying aging processes and improving metabolic health through better insulin sensitivity and lipid metabolism (7, 8).

The mechanistic pathways for the bioactive compounds in ginger were examined with an animal model in a similar crucial study from Offei-Oknye et al. (2015). Ginger extracts were given to diabetic rats; metabolic parameters, such as changes in blood glucose and lipid levels, were estimated. Results indicate that ginger could decrease blood glucose concentration significantly as well as significantly enhance lipid profile through an induction of antioxidant enzyme activity such as SOD and CAT. This study emphasizes the role of ginger in modulating metabolic pathways; therefore, the bioactive compounds present in this plant could diminish the risk factors associated with age-related diseases and metabolic syndrome (9, 10).

Another study by Zhang et al. (2022) explored antioxidant activity in the processed compared to fresh ginger. In this research, different processes including freeze-drying and oven-drying were applied to ascertain their implications on the contents of phytochemicals found in the ginger. According to the study, processed ginger contained higher amounts of total phenolic and flavonoid content compared to the fresh counterpart, implying increased antioxidant activities based on the results of the DPPH scavenging assays. This finding would be important as it can conclude that perhaps processing does have the ability to enhance the bioavailability of some bioactive compounds, hence increasing their efficacy against oxidative stress from aging (11)

Finally, a systematic review by Van et al. (2024) integrated results from various studies on the anti-diabetic activity of ginger and its bioactive compounds. The authors pointed out that besides their anti-inflammatory activities, shogaol and paradol also significantly affect glucose metabolism through inhibition of α-glucosidase activity, which prevents blood sugar surges after meals, making ginger a functional food useful in diabetes management, a condition often exacerbated by aging (12)

4.2. Anti-Aging Properties of Ginger: Antioxidant, Anti-Inflammatory, and Neuroprotective Effects

Ozkur et al. conducted a systematic review on the antioxidant and anti-inflammatory activity of ginger in 2022. The investigators used a meta-analysis approach where they pooled the data from numerous trials to investigate the efficacy of ginger in supporting healthy aging. Key findings highlighted that ginger remarkably decreases oxidative markers and inflammation within the aging group, thus revealing its potential impact in the reversal of age-related diseases such as diabetes and cardiovascular disorders. The study pointed out that the active compounds in the ginger studied, particularly 6-gingerol and 6-shogaol, demonstrate potent free radical scavenging activities, which are very essential for inhibiting oxidative stress resulting from aging (4).

In another key investigation by Ayustaningwarno et al. (2024), the investigators examined the action mechanisms of the anti-inflammatory nature of ginger extract. The experimental design involved applying both in vitro and in vivo models, by which they reported that ginger treatment modulates vital inflammatory pathways mediated by the NF-κB signaling pathway. The study illustrated that ginger-mediated treatment reduced inflammatory cytokines to a great extent, such as TNF-α and IL-6 that are commonly implicated in age-related inflammatory diseases. This anti-inflammatory effect of ginger suggests its use in treating

chronic conditions that have been established with aging (13).

Moreover, Maima Matin et al., (2024) studied the neuroprotective effects of ginger in relation to cognitive decline and neurodegenerative diseases. In this experiment, an Alzheimer's disease mouse model was used and cognitive function influenced by ginger supplementation was determined. Improvements in memory and learning were observed to be present in the ginger-supplemented mice compared to the controls. Mechanistically, the study showed that neuroprotective effects of ginger are mediated through enhancement in neurotransmitter levels like acetylcholine involved in cognitive processes. This would implicate that ginger does have potential as a therapeutic agent for prevention and alleviation of symptoms associated with neurodegenerative diseases (5).

In addition to this, Mohd Sahardi & Makpol, (2024) carried out a comprehensive review on how ginger affects brain aging and dynamics of neurotransmitters. The authors synthesized data from various studies that indicated ginger improves synaptic plasticity while also suppressing neuroinflammation-two important factors concerning health in aging brains. Their analysis indicated that frequent intake of ginger may enhance mental acuity and reduce the risk of cognitive impairment because of its antioxidant activity and neurotransmitter level regulation (3, 14).

4.3. Role of Ginger in Metabolic Health: Glucose Metabolism, Lipid Regulation and Weight Management

A systematic review and meta-analysis were carried out by Zhu et al. in 2018 regarding the impacts of ginger on T2DM and components of metabolic syndrome. The authors included ten RCTs that composed a total of 490 participants. They used a thorough literature search conducted in various databases for their literature selection. They observed a pooled weighted mean difference of glycosylated hemoglobin (HbA1c) at -1.00 (95% CI: -1.56, -0.44; $P<0.001$) which established a significant improvement in glycemic control following ginger supplementation. Moreover, subgroup analyses established a marked decrease in the level of fasting blood glucose (FBG) of T2DM patients to be at -21.24 (95% CI: -33.21, -9.26; $P<0.001$) besides showing improvement in lipid profiles which comprised of total cholesterol and triglycerides (15).

The performance of ginger was appraised by Carvalho et al. in 2020 for T2DM patients. This is a randomized controlled double-blind clinical trial with participants aged between 20 and 80 years, with oral antidiabetic drugs. Participants in the group intervention were given 1.2g of ginger daily for 90 days, with the control groups receiving placebos. Results The fasting blood sugar levels and the total cholesterol significantly reduced in individuals receiving ginger when compared to controls receiving the placebo. Notably, the fasting blood sugar reduction was higher at 20.3 mg/dL in the experimental group when compared to the controls (16). This study highlighted the potential of ginger as an adjunct therapy in managing T2DM, especially through lipid metabolism regulation and enhancement of insulin sensitivity.

A more current article was published in 2023 by Diakos et al., who conducted a randomized controlled trial to explore the acute effects of aqueous extract of ginger on postprandial glycemia in nondiabetic adults. In this study, ginger extract was administered before meals to determine whether this has any effect on postprandial blood glucose concentrations. The authors found that supplementation of ginger attenuated postprandial hyperglycemia significantly and therefore proposes its use in controlling glucose spikes after meals (17). This study adds to the knowledge regarding the integration of ginger in dietary interventions targeting glucose homeostasis.

A study by Shidfar et al. was conducted in 2015. This research is based on ginger supplementation to study its effects on lipid profiles and glycemic markers of T2DM patients after three months of follow-up. A trial including ginger doses was taken daily to compare changes within participants on the basis of triglycerides, total cholesterol, low-density lipoprotein, and fasting blood glucose levels. Triglyceride and total cholesterol levels in patients receiving ginger supplementation showed significantly decreased levels from the baseline compared with controls. This points out the role of ginger not only in glucose management but also as a potential agent for improving lipid profiles (18)

4.4. Molecular Mechanisms of Ginger: Nrf2 Activation; NF-κB Modulation; AMPK Regulation

In 2016, Schadich et al. looked into the influence of ginger extract on the Nrf2 signaling pathway within a neurotoxicity model caused by the induction of 6-hydroxydopamine. The researchers used primary neuronal cultures that had been treated with ginger

extract and examined Nrf2 nuclear translocation by immunofluorescence techniques. These experiments showed that the nuclear translocation of Nrf2 was profoundly enhanced by ginger, leading to increased expression of its downstream antioxidant genes, therefore providing neuroprotection against damage caused by oxidative stress. Such a study reveals the potential use of ginger for activating the Nrf2 pathway, which shows its role in being a natural compound that would mitigate neurodegenerative processes associated with aging (19).

A later important study is that of Peng et al in 2015, who tested the NF-κB pathway modulation activity for ginger constituents. The scientists use human colon carcinoma cell lines pre-treated with 6-gingerol and subsequently evaluated the presence of activated NF-κB by western blotting of phospho-p65. Their results showed that 6-gingerol exhibited potent NF-κB inhibitory effects through the inhibition of NF-κB translocation into the nucleus, leading to decreased expression of pro-inflammatory cytokines TNF-α and IL-6. This modulation of NF-κB leads to anti-inflammatory functions of ginger, as relevant in fighting chronic inflammation that has been associated with aging and metabolic disorders (20, 21).

The researchers conducted in 2019 where they researched the regulation of AMPK by 6-shogaol in human liver cells. They incubated HepG2 cells with a range of 6-shogaol concentrations and then quantitated AMPK phosphorylation through ELISA assays. The authors observed that 6-shogaol caused the potent activation of AMPK, and subsequently enhanced the oxidation of fatty acids and uptake of glucose within the cells. This regulation of AMPK has significant implications in metabolic health as it indicates the ability of ginger to enhance metabolic profiles through its effect on the increase in energy expenditure and fat accumulation (22).

More recently, Hybertson et al., studied in 2022 the synergistic action of ginger extracts in Nrf2 activation on HepG2 cells. In their experiment, they combined ginger with other phytochemicals and monitored the level of Nrf2 activity by performing luciferase reporter assays. The data from this experiment revealed that extracts of ginger act synergistically in combination with rosemary extract in Nrf2 activation to elevate antioxidant enzymes, including Glutathione-S-transferase P1 (GSTP1), in the treated HepG2 cells. It simply underlines that, apart from the effectiveness of ginger as an agent in itself, it might enhance the effectiveness of other naturally occurring compounds with regards to improving antioxidant defenses (23).

5. Conclusion

This review emphasizes the immense potential of ginger in preventing aging and enhancing metabolic health based on its antioxidant, anti-inflammatory, and metabolic regulatory properties. The bioactive compounds 6-gingerol and 6-shogaol have been involved in the regulation of oxidative stress, inflammation, and metabolic pathways. Although such findings are very promising, it remains to be determined through future clinical studies the best dosing strategies and mechanisms of action. Adding ginger into diet and treatment protocols may allow a natural prevention strategy for healthy aging and against metabolic disorders during aging.

6. Limitations and Future Implications

Most researches are performed on in vitro or animal models, which directly cannot be translated to humans. The molecular mechanism of ginger for aging and metabolism is not very well understood. Therefore, its clinical validation requires further research. Large-scale long-term clinical studies are needed in the future to establish the effectiveness of ginger against aging and in metabolic health. The precise molecular mechanisms, optimum dosages, and possible interaction with other dietary components need to be studied in depth. Furthermore, investigation of the application of ginger in personalized nutrition and functional food development may lead to further therapeutic uses and preventive healthcare strategies for age-related metabolic disorders.

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