POPŁAWSKA, Natalia Aleksandra, ŚLIZ, Justyna, SKORUPSKA, Marta, CZECZOTKA, Magdalena Joanna and WOŹNIAK, Krzysztof. Ginger (Zingiber officinale) - A Beneficial Effect on Health and Physical Activity. Quality in Sport. 2024;16:52218. eISSN 2450-3118.
https://dx.doi.org/10.12775/QS.2024.16.52218
https://apcz.umk.pl/QS/article/view/52218

The journal has had 20 points in Ministry of Higher Education and Science of Poland parametric evaluation. Annex to the announcement of the Minister of Higher Education and Science of 05.01.2024. No. 32553.
Has a Journal's Unique Identifier: 201398. Scientific disciplines assigned: Economics and finance (Field of social sciences); Management and Quality Sciences (Field of social sciences).
Punkty Ministerialne z 2019 - aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 r. Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398.
Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych).

The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 06.06.2024. Revised: 25.05.2024. Accepted: 03.07.2024. Published: 07.07.2024.

Ginger (Zingiber officinale) - A Beneficial Effect on Health and Physical Activity

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ABSTRACT

Introduction:

Ginger (Zingiber officinale) is a member of the Zingiberaceae plant family and is indigenous to Southeast Asia. It has been widely utilized as an herbal remedy in numerous nations and is known for its beneficial properties, such as anti-inflammatory, antioxidant, and anti-apoptotic

effects. Ginger is commonly consumed for its various health benefits, including alleviating coughs, reducing pain, addressing nausea, aiding digestion, and exhibiting analgesic and anti-inflammatory effects. Recently, research has begun to uncover the potential benefits of ginger on physical activity and athletic performance.

Materials and methods:

A comprehensive examination of scientific and medical literature was performed using the PubMed and Google Scholar databases. The search terms employed were: "ginger," "ginger anticancer," "ginger anti-inflammatory," and "ginger antiemetic."

Conclusion:

Ginger, scientifically known as Zingiber officinale, is a widely utilized herb with various biological effects including anti-inflammatory, antioxidant, anticancer, and antibacterial properties primarily attributed to four phenolic compounds: gingerols, shogaols, paradols, and zingerone. Notably, 6-shogaol, an active ingredient in ginger, shows promise as a natural anticancer product with potential therapeutic benefits. Also, several scientific studies have indicated that ginger supplementation may lead to reduced muscle soreness, improved endurance performance, and decreased inflammation in response to intense physical activity.

Key words: ginger; anticancer; anti-inflammatory; Zingiber officinale; antioxidant; gingerols

INTRODUCTION

Ginger (Zingiber officinale) is a member of the Zingiberaceae plant family and is indigenous to Southeast Asia [1]. Throughout history, ginger has been a staple in the diets of Asia's native populations, particularly in China and India, where it is utilized as both a spice and a sweetener in local cuisine and as an herbal remedy for various ailments. Numerous studies have established that ginger is widely utilized as an herbal remedy in numerous nations [2]. It is commonly employed to alleviate coughs by virtue of its expectorant qualities, aiding in the loosening and expulsion of phlegm. Additionally, ginger is utilized to mitigate pain, address nausea and vomiting, counteract poisoning, and facilitate digestion. The rhizome, or underground stem, is the part of the plant that is commonly consumed [3]. Ginger's tuberous rhizomes are widely recognized for their advantageous properties, such as anti-inflammatory, antioxidant, anti-apoptotic, antiviral, and antibacterial effects [4,5]. Ginger bioactive compounds display analgesic and anti-inflammatory properties by inhibiting the COX2 and LOX pathways, thereby impeding the metabolism of arachidonic acid. The effects of ginger are akin to those of the NSAIDs family; however, they do not adversely affect the stomach mucosa [6]. Numerous research

studies have demonstrated the efficacy of ginger in both the prophylaxis and treatment of gastrointestinal, cardiovascular, respiratory, and neurological diseases [7,8].

AIM OF THE STUDY

The purpose of this study is to conduct a comprehensive investigation into the diverse health effects of ginger and its constituent compounds on human health, taking into account both biochemical and physiological factors. The review encompasses an analysis of the compounds found in ginger, their positive effects on various human body systems, and the mechanisms of their action. Additionally, this work aims to highlight the antioxidant, anti-inflammatory, antibacterial, antiemetic, and anti-cancer properties of ginger, emphasizing the benefits of its regular consumption.

STATE OF KNOWLEDGE

Bioactive compounds in ginger

Ginger comprises approximately 400 distinct components, including carbohydrates, lipids, terpenes, and phenolics. These compounds are categorized as pungent and aromatic. Pungent compounds encompass gingerols (GNs), shogaols (SGs), zingerones, gingerdione, paradols, zerumbone, and capsaicin, while aromatic compounds include pinene, borneol, cumene, camphene, zingiberol, and bisabolen [9]. The biological effects of ginger are primarily attributed to four phenolic compounds: gingerols, shogaols, paradols, and zingerone. Both in vitro and in vivo studies have consistently demonstrated the potent anti-inflammatory and antioxidant properties of these compounds [10,11]. Major polyphenols in fresh ginger are 6-gingerol, 8-gingerol, and 10-gingerol [12]. Gingerols are sensitive to high temperatures and can easily undergo dehydration to form shogaol. It has been observed that the transformation of gingerols to shogaol due to temperature exposure can be influenced by the method of heating (dry or wet) as well as the form of ginger used (fresh or dried) [13]. Zingerone, a compound derived from the degradation of gingerols, is identified as 4-(4-hydroxy-3-methoxyphenyl)-butan-2-one. This substance is formed through the cooking or drying of the rhizome and shares chemical similarities with aromatic compounds like vanillin and eugenol. The biologically active compounds of ginger are typically present in its essential oils [14]. Paradols, another set of pungent compounds, are recognized for their antioxidant and anti-inflammatory properties, particularly in their ability to act against Cyclooxygenase 1 (COX-1) [15]. Although the degradation of ginger root can result in the production of mycotoxins such as mycophenolic acid, there is currently no evidence of human disease onset due to this cause [16]. Recent research indicates that 6-SG exhibits greater biological efficacy compared to 6-GN [17,18], without any discernible side effects. Consequently, dry ginger powder is

recognized as having superior medicinal potency in contrast to raw ginger [10,19]. Currently, it is feasible to acquire pure 6-gingerol, the primary constituent in ginger rhizomes, through total synthesis methods [20].

Antioxidant activity

Free radicals are highly reactive atoms or molecules characterized by one or more unpaired electrons in their outer shells. Reactive oxygen species (ROS) are generated through the interaction of oxygen with specific molecules within all aerobic cells. ROS have the potential to induce oxidative alterations in key cellular macromolecules, including carbohydrates, lipids, proteins, and DNA [21]. In the human body, oxidative stress arises when the natural antioxidation processes fail to maintain equilibrium between the generation and removal of reactive oxygen species (ROS). Some of described effects are attributed to the activation of the Nrf2 signaling pathway, leading to the accumulation of reactive oxygen species (ROS) and subsequent cellular damage via lipid peroxidation [22,23]. This process can trigger chronic inflammation, contributing to tissue destruction. However, ginger facilitates a protective mechanism by enhancing the activity of the enzyme paraoxonase-1, thus preventing lipid oxidation in low-density lipoproteins (LDL) [24]. Additionally, ginger's antioxidant properties inhibit lipid peroxidation. In a particular investigation, pre-treatment with ginger extract was found to inhibit the IL-1β-induced increase of reactive oxygen species (ROS) and lipid peroxidation in C28/I2 human chondrocytes. This inhibition was accompanied by a significant decrease in the gene expression of corresponding antioxidant enzymes [25]. Furthermore, 6-gingerol upregulates Beclin1 expression, promoting autophagy in endothelial cells, while also inhibiting the PI3K/AKT/mTOR pathway signaling, all without impacting the cell cycle [20]. Numerous phytochemical extracts derived from ginger have been shown to exhibit various antioxidant properties, including the ability to scavenge superoxide, hydroxyl, and nitric oxide radicals in vitro in a manner that is dependent on the dosage [26].

The antioxidant content and composition of plant extracts can vary based on several factors, such as the extraction solvent, extraction temperature and duration, and storage conditions [27]. The antioxidant activity in ginger extracts was found to be higher when prepared using ethanol, methanol, and acetone solvents compared to extracts prepared using water [28,29]. Several bioactive compounds found in ginger, including 6-gingerol, 8-gingerol, 10-gingerol, and 6-shogaol, have been identified as exhibiting antioxidant properties. In vitro studies have shown that 6-gingerol demonstrates the highest level of antioxidant activity, followed by 6-shogaol [30].

Anti-inflammatory activity

Inflammation is the body's defensive response that occurs following invasion by microorganisms, exposure to antigens, or damage to cells and tissues. This process encompasses intricate interactions among various cell types, mediators, receptors, and signaling pathways. Numerous studies have demonstrated the anti-inflammatory properties of ginger and its active compounds. Initially, it was proposed that ginger's anti-inflammatory effects are primarily linked to its ability to inhibit the synthesis of prostaglandins and leukotrienes [19]. Both fresh ginger, primarily composed of gingerols, and dried ginger extracts, a major source of shogaols, have been shown to suppress the production of lipopolysaccharide- (LPS-) induced prostaglandin E2 (PGE2) [31,32]. Several studies have indicated that the administration of ginger at the conclusion of a treatment regimen resulted in decreased TNF-α levels [33]. This suggests that ginger may serve as an adjunct anti-inflammatory therapy for certain conditions. Moreover, compounds found in ginger, such as 6-gingerol and 6-shogaol, demonstrate anti-inflammatory properties by inhibiting the production of inflammatory mediators including prostaglandin E2, NO, inflammatory cytokines (TNF-α), interleukin-1β (IL-1β), and the pro-inflammatory transcription factor NF-κB. Additionally, they exhibit inhibitory effects on COX-1 and COX-2 [34]. 6-Gingerol has demonstrated the ability to inhibit xanthine oxidase, an enzyme responsible for the oxidation of hypoxanthine to xanthine and xanthine to uric acid in the final stage of purine metabolic degradation, leading to the production of reactive oxygen species [35]. Furthermore, research has confirmed its capacity to enhance the activity of two antioxidant enzymes, superoxide dismutase, and catalase [36]. In animal studies, 6-gingerol has shown regulatory effects on lipogenesis, fatty acid oxidation, mitochondrial function, and oxidative stress in rats. Additionally, it has been observed to concentration-dependently increase the activity of the antioxidant enzyme superoxide dismutase (SOD) and decrease levels of malondialdehyde (MDA), a marker of lipid peroxidation [37].

A study revealed that 6-SG suppressed the release of TNF-α, IL-1β, and NO in LPS-stimulated RAW264.7 macrophages. This suggests a potential therapeutic effect in chronic inflammatory conditions primarily involving macrophages [38].

According to two recently published meta-analyses, the impact of ginger supplementation on inflammatory markers in humans was evaluated. The analyses revealed significantly reduced levels of serum CRP, TNF-alpha, IL-6, and PGE2 over a 2-3 month period compared to control groups [39,40].

Antibacterial activity

Recent research has demonstrated that ginger and its bioactive components exhibit antibacterial, antifungal, and antiviral properties. Notably, ginger and its active constituents have shown efficacy against drug-resistant bacteria such as Escherichia coli, Salmonella typhi, Staphylococcus aureus, Pseudomonas aeruginosa, Mycobacterium tuberculosis, and Enterococcus faecalis, as well as fungi such as Candida albicans [41,42]. The cytokine interferon-γ (IFN-γ), which is secreted by natural killer cells and activated by T lymphocytes, plays a crucial role in the body's defense against viral and bacterial infections. In human T lymphocyte cells, 6-SG was observed to increase IFN-γ transcription and expression in a manner that is dependent on the dosage [43]. Ginger essential oil (GEO) is the volatile oil extracted from the root of ginger. Nanocapsules formulated with GEO exhibited significant antibacterial efficacy against E. coli, Bacillus subtilis, and S. aureus [44]. In a study conducted by Wang et al., it was demonstrated that the antibacterial mechanism of GEOs entails damage to the bacterial cell membrane. This damage leads to the leakage of macromolecular substances, such as bacterial proteins and nucleic acids, culminating in a reduction of bacterial metabolic activity and, ultimately, bacterial cell death. The GEO treatment may impact the physiological activity of test organisms by influencing the expression of genes responsible for key enzymes involved in cell lysis. This sheds light on the antibacterial mechanism at the molecular level [45].

Antiemetic activity

Nausea and vomiting represent the most prevalent and troublesome adverse effects encountered by cancer patients undergoing chemotherapy. Despite the recent advancements in effective pharmacological and antineoplastic combination treatments, the success rate of these interventions remains suboptimal [46]. Numerous animal and human studies have indicated that ginger extract may effectively manage chemotherapy-induced nausea and vomiting (CINV). Ginger is recognized for its ability to alleviate nausea and vomiting by way of the inhibitory effects of gingerols or shogaols on 5-Hydroxytryptamine type 3 (5-HT3) receptors and by reducing 5-HT. It is presumed that gingerols and shogaols exhibit antiemetic effects by attaching to the serotonin binding site and acting on the 5-HT3 receptor ion-channel complex [47,48]. Additionally, many preclinical studies have indicated that ginger's efficacy in managing CINV stems from its ability to inhibit neurokinin-1 and dopamine receptors. This effect is complemented by the herb's antioxidant and anti-inflammatory properties [49]. Chemotherapy can have an impact on gastrointestinal motility and neurotransmitters. Research has indicated that delayed gastric emptying, a result of chemotherapy, may play a

significant role in explaining CINV [50,51]. Studies have shown that the gingerols present in ginger significantly improved delayed gastric emptying caused by cisplatin in a manner that was dependent on the dosage [52]. In recent meta-analyses, it was demonstrated that ginger, administered in the form of oral extracts or capsules, exhibited greater efficacy in the prevention of acute nausea and vomiting in patients undergoing chemotherapy treatment [53,54].

Anticancer activity

Ginger has demonstrated efficacy in cancer treatment. In Singapore, cooked ginger rhizomes are utilized for cancer prevention while Palestinians use an infusion of the rhizome to combat breast cancer [55,56]. A soup made from ginger root, turmeric, and honey is commonly employed as a general cancer treatment [57]. The nutritional, health, and medicinal benefits of ginger primarily arise from its bioactive components, particularly the pungent gingerols and their dehydrated form, shogaols. Studies have indicated that shogaols, particularly 6-shogaol, exhibit stronger biological activity than gingerols [58]. 6-Shogaol has demonstrated efficacy in combating various diseases, including cancer. Its anticancer properties have been substantiated and acknowledged in numerous cancer models, encompassing breast, cervical, colon, and prostate cancer [59,60,61,62]. Numerous in vitro and in vivo studies have demonstrated that 6-shogaol displays minimal to no cytotoxic effects on normal cells and tissues, while exerting a significant cytotoxic effect on cancer cells. In the context of breast cancer, 6-shogaol has been shown to effectively eliminate breast cancer stem cells, including monolayers and spheroids, at a concentration that does not adversely affect non-cancerous cells [59]. The differential impact of 6-shogaol on normal and tumor cell lines is believed to be associated with its ability to stimulate increased production of reactive oxygen species (ROS). However, the precise mechanism underlying this selectivity remains to be elucidated [63]. In the model of colorectal cancer, 6-shogaol demonstrated significant toxicity to human colon cancer cells at a concentration of 80 μM, resulting in 95% and 90% reduction in viability for SW480 and SW620, respectively. In contrast, the viability of normal fibroblasts WI38 was only reduced by 17% [61]. The study conducted by Saha et al. demonstrates that 6-Shogaol exhibits significant anticancer activity against human and mouse prostate cancer cells. This activity is attributed to its ability to inhibit cell survival and induce apoptosis by reducing STAT3 and NF-κB activity. These findings collectively suggest that 6-Shogaol may serve as a potential chemopreventive and/or therapeutic agent for prostate cancer [64].

Scientific studies on ginger and physical activity

Several studies have investigated the effects of ginger supplementation on physical performance and recovery, with promising results:

Study on Muscle Soreness:

A randomized controlled trial conducted by Black et al. evaluated the effect of ginger on muscle soreness induced by eccentric exercise. Participants consuming ginger experienced significantly reduced muscle pain compared to the placebo group, suggesting that ginger may aid in faster recovery and less perceived pain post-exercise [65].

Endurance and Performance:

A study by Mashhadi et al. explored the impact of ginger on endurance performance in male athletes. The results indicated that ginger supplementation improved endurance performance, likely due to its anti-inflammatory and antioxidant effects, which enhance muscle recovery and reduce fatigue [66].

Anti-inflammatory Response:

Another study by Wilson et al. assessed the effects of ginger on inflammatory markers in response to intense physical activity. The findings showed a significant decrease in pro-inflammatory cytokines in the ginger group, supporting its role in reducing exercise-induced inflammation [67].

CONCLUSION

Ginger, scientifically known as Zingiber officinale, is a widely utilized herb composed of approximately 400 distinct components. The biological effects of ginger are primarily attributed to four phenolic compounds: gingerols, shogaols, paradols, and zingerone. Research indicates that these components demonstrate various activities, including anti-inflammatory, antioxidant, anticancer, and antibacterial properties. Notably, ginger supplementation shows potential in offering protection against cancer, particularly in its early stages, and may alleviate symptoms associated with aggressive treatments such as chemotherapy. Of particular interest is 6-shogaol, an active ingredient in ginger, which exhibits promise as a natural anticancer product with therapeutic prospects in various types of cancer. Furthermore, 6-shogaol demonstrates varying sensitivity to cancer and non-cancer cells, with minimal to no toxicity observed in normal cells at lethal doses for cancer cells. Additionally, ginger and its bioactive components display antibacterial, antifungal, and antiviral properties. Although these findings are noteworthy, further investigation into the diverse anti-inflammatory actions

of ginger is warranted to comprehensively understand their effects and potential synergies with commercially available drugs.

DISCLOSURE

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Receiving funding – no specific funding.

All authors have read and agreed with the published version of the manuscript.

Financial statement

This research received no external funding.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availibity Statement

Not applicable.

Conflict of interest

The authors deny any conflict of interest.

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