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Therapeutic Benefits of Red Garlic: A Narrative Review of Laboratory Studies †

Michele Antonelli [1,*] and Davide Donelli [2]

[1] Private Practice for Evidence-Based Integrative and Preventive Medicine, 42025 Cavriago, Italy
[2] Cardiology Unit, University Hospital of Parma, 43126 Parma, Italy
* Correspondence: michele.antonelli.md@gmail.com
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Abstract: The consumption of garlic (*Allium sativum*), recognized for its historical medicinal significance, is linked to diverse health benefits. In particular, red garlic stands out for its distinct anthocyanin content, contributing to its unique pink-purple clove color, yet despite extensive research on the pharmacological properties of garlic extracts, there remains limited evidence specifically addressing the therapeutic potential of red garlic. A narrative search was conducted in February 2024 on PubMed and Google Scholar to identify relevant studies examining the pharmacological effects of red garlic extracts. Following the search of selected databases, 789 articles were retrieved and 10 laboratory studies were included in this literature review, exploring the impact of red garlic extracts on laboratory models of lung and digestive tract phlogosis, cancer, microbial proliferation, obesity, and responses to inflammation or oxidative stress. The studies analyzed both aged and fresh red garlic extracts, with a specific emphasis on water extracts. The outcomes highlighted significant antioxidant and anti-inflammatory properties of red garlic extracts, also suggesting potential pro-metabolic effects that could be beneficial in addressing excessive weight and dyslipidemia. Moreover, the results point to the inhibitory effect on cancer cell proliferation by red garlic byproducts and the superior anti-inflammatory profile of the hydroalcoholic extract. Comparative analyses between red and black garlic extracts indicate inconclusive evidence regarding antioxidant activity. The findings also suggest a high level of tolerability for the gut microbiota. This literature review aims to provide valuable insights into the therapeutic potential of red garlic extracts and emphasizes the need for further research to fully elucidate their benefits and mechanisms of action.

Keywords: red garlic; health; nutraceuticals; diet; laboratory studies; review

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1. Introduction

Garlic (*Allium sativum*), comprising over 200 chemical compounds, consists of 65% water, 28% carbohydrates, 2.3% organosulfur compounds, 2% proteins, 1.2% free amino acids, and 1.5% fiber, along with fat-soluble vitamins (A, K, E), water-soluble vitamins (C, B1, B2, B3, B6, B8), and minerals (Ca, Fe, Mg, P, K, Na, Zn), with organosulfur compounds contributing to its characteristic taste, odor, and pharmacological properties [1]. Garlic consumption, renowned for its medicinal attributes since ancient times, is associated with various health benefits, including the reduction in blood pressure, antimicrobial activity, inhibition of platelet aggregation, cholesterol-lowering properties, and antiproliferative effects [2].

In particular, red garlic distinguishes itself among various garlic varieties due to its notable anthocyanin content, responsible for its pink-purple clove coloration [3]. Despite extensive research exploring the pharmacological properties of diverse garlic extracts, there is a scarcity of evidence specifically addressing the therapeutic potential of red garlic. Red garlic has a distinctive flavor and composition (see Table 1 for additional details about

the average content of bioactive compounds in different extracts), and it is cultivated in regions such as Italy, Spain, and parts of Asia, though it is increasingly recognized and grown worldwide [4–6]. Traditionally, red garlic has been valued not only as a culinary ingredient but also for its medicinal properties, with applications in folk medicine for its reputed antimicrobial and anti-inflammatory effects [3].

Table 1. Main bioactive compounds found in water and alcoholic extracts of red garlic.

	Water Extract	Alcoholic Extract	Reference
Total polyphenol content	437.63–449.15 mg/100 g	535.40–608.60 mg/100 g	
Alliin	1.18–1.29 mg/g	0.81–0.85 mg/g	[6]
S-allyl-cysteine	2.34–2.60 mg/g	1.52–1.98 mg/g	

The aim of this literature review is to synthesize existing research on the pharmacological effects of red garlic extracts, focusing on their effects in cell or animal models of human diseases.

2. Methods

This narrative review, conducted across PubMed and Google Scholar in February 2024, aimed to synthesize current knowledge on the pharmacological properties of red garlic (*Allium sativum* L.). The search strategy incorporated the keyword "red garlic" and the inclusion criteria encompassed articles written exclusively in English. Relevant experimental studies examining the potential health benefits of garlic extracts were included, while reviews and non-experimental studies were excluded. The results were organized thematically and presented through descriptive tables to provide an integrative overview of the available evidence. This narrative approach allowed for a flexible synthesis of findings across diverse studies, highlighting common themes and emerging insights into red garlic's potential health applications.

3. Results

Following the search of selected databases, 789 articles were retrieved and 10 laboratory studies were included in this literature review, exploring the impact of red garlic extracts on laboratory models of lung and digestive tract phlogosis, cancer, microbial proliferation, obesity, and responses to inflammation or oxidative stress [3,5,7–14]. Both aged and fresh red garlic extracts were utilized, with a prevalence of water extracts (refer to Table 2 for comprehensive details). The outcomes measured in these studies revealed that red garlic extracts exhibit antioxidant and anti-inflammatory properties, suggesting potential pro-metabolic effects that could be beneficial in countering excessive weight and dyslipidemia. No toxicity was observed in normal cells; however, a significant inhibitory effect on cancer cell proliferation was documented with red garlic byproducts [5,10]. Distinctions were observed in the anti-inflammatory profiles, with the hydroalcoholic extract demonstrating superior performance [9]. Comparative studies between red and black garlic extracts did not consistently establish the superiority of one extract over the other in terms of antioxidant activity [7,13]. The findings also suggested a high level of tolerability for the gut microbiota [3].

Table 2. Summary of laboratory studies about red garlic properties.

Experimental Model		Extract/s		Outcomes	Ref.
Respiratory system inflammation	Cigarette smoke-induced cell death in human bronchial smooth muscle cells	Aged red garlic versus aged black and fresh garlic	Water extracts	↑ GSH content ↓ Generation of ROS The effect was more pronounced with red garlic	[7]
	LPS-treated RAW 264.7 macrophages and acute lung inflammatory mice	Aged red garlic	Water extract	↓ LPS-induced NO production	[8]
Digestive system inflammation	LPS-treated mouse colon specimens	Nubia red garlic	Hydroalcoholic and water extracts	↓ LPS-induced COX-2, TNF-α, NF-kB, and IL-6 production ↓ PG-E2 The hydroalcoholic extract showed a better anti-inflammatory profile	[9]
Cancer	Colon cancer cell line HCT116 and myoblast cell line C2C12	Sulmona red garlic	Hydroalcoholic extract	↓ Cancer cell proliferation ↓ TNF-α, HIF 1-α, VEGF, and TRPM8 No toxicity for myoblasts	[5]
	Human transitional cell carcinoma and normal cells (L929)	Fresh red garlic	Water extract	↓ Cancer cell proliferation No toxicity for normal cells	[10]
Inflammation and microbial proliferation	LPS-treated RAW 264.7 macrophages	Aged red garlic	Water extract	↓ NF-κB and HO-1 activation	[11]
	Human monocytes and macrophages exposed to H_2O_2 *S. aureus*, *L. rhamnosus*, and *P. aeruginosa*	Sulmona red garlic	Hydroalcoholic extract	↓ H_2O_2-induced COX-2, NF-kB, and peroxynitrite intracellular amounts No antibacterial activity on the microbial species sampled	[3]
Obesity and oxidative stress	3T3-L1 preadipocytes Pancreatic lipase activity	Red garlic	Hexane, chloroform, ethyl acetate, butanol, and water extracts	↓ Lipase activity = Preadipocyte proliferation ↓ Oxidative stress markers The hexane extract had the highest phenolic and flavonoid content	[14]
	Obese rats fed with a high-fat diet	Red garlic	?	↓ 5–7% of total lipid levels in the liver (↑ 5% of lipid excretion in the stool) ↓ 5–7% of lipid peroxidase activity ↑ 7% of antioxidant activity	[12]
	Cell model of oxidative stress	Aged red garlic versus aged black and fresh garlic	Water extracts	Red garlic had a higher antioxidant activity than fresh garlic, but lower than that of the black variety	[13]

Legends: COX-2 = cyclooxygenase-2; GSH = glutathione; HIF1-α = hypoxia-inducible factor; HO-1 = heme oxygenase-1; IL-6 = interleukin-6; *L. rhamnosus* = *Lactobacillus rhamnosus*; NF-kB = nuclear factor-kB; *P. aeruginosa* = *Pseudomonas aeruginosa*; PG-E2 = prostaglandin E2; Ref. = reference; ROS = reactive oxygen species; *S. aureus* = *Staphylococcus aureus*; TNF-α = tumor necrosis factor alpha; TRPM8 = transient receptor potential M8; VEGF = vascular endothelial growth factor. *Symbols*: ↑: significant increase; ↓: significant decrease; =: no significant changes; ?: not specified.

4. Discussion

Research on red garlic extracts has demonstrated their potential therapeutic effects across various systems, particularly in respiratory and digestive inflammation, cancer, and metabolic disorders (see Table 2). In studies involving respiratory system inflammation, red garlic extracts demonstrated superior protective effects against cigarette smoke-induced cell death in human bronchial smooth muscle cells, significantly increasing glutathione levels and reducing reactive oxygen species generation compared to both aged black and fresh garlic [7]. Additionally, in macrophages treated with lipopolysaccharide (LPS), red garlic extracts were found to effectively decrease nitric oxide production, highlighting their potential in managing acute lung inflammation [11]. In the context of digestive system inflammation, red garlic exhibited a strong anti-inflammatory profile, significantly reducing COX-2, TNF-α, NF-kB, and IL-6 production in LPS-treated mouse colon specimens; in particular, the hydroalcoholic extract showed more pronounced effects compared to its water counterpart [9]. Furthermore, investigations into cancer treatment have demonstrated that red garlic hydroalcoholic extracts inhibited the proliferation of colon cancer cell lines (HCT116) and human transitional cell carcinoma without exhibiting toxicity to normal cells, indicating its potential utility for oncologic research [5,10]. Moreover, red garlic extracts have also been explored for their impact on obesity and oxidative stress [12–14]. In preadipocytes, various solvent extracts of red garlic significantly reduced pancreatic lipase activity, diminished oxidative stress markers, and decreased cell proliferation, with the hexane extract showing the highest phenolic and flavonoid content [14]. Similarly, studies on obese rats indicated that red garlic supplementation resulted in reduced lipid levels in the liver and enhanced antioxidant activity, further supporting its role in mitigating metabolic disorders [12]. In general, the health-promoting potential of red garlic may be partly attributed to anthocyanins, water-soluble flavonoids known for their antioxidative and anti-inflammatory properties: recent evidence also suggests that anthocyanins play a role in modulating the gut microbiota, which could enhance the therapeutic synergy of bioactive organosulfur compounds common to all garlic varieties [15,16].

It is demonstrated that the bioactive content and profile in garlic extracts are influenced by the plant part, extraction method, and mixture, with high-pressure extraction yielding higher recoveries of hydrophilic compounds and macerates containing the highest amounts of lipophilic compounds [17]. Additionally, it has been observed that the anti-inflammatory effects of garlic extracts are diminished through short-term heating [18], the physicochemical characteristics of red garlic undergo alterations during processing [19], and diverse garlic varieties exhibit different concentrations of organosulfur bioactive compounds [20]. In brief, the diverse influences on bioactive content and profiles in garlic extracts necessitates consideration in harnessing its therapeutic potential.

Garlic supplementation is renowned for its potential health benefits, but one common side effect is the occurrence of bad odor and breath [21]. In fact, sulfur compounds present in garlic can be absorbed into the bloodstream and released through the breath and skin. Although the intensity of the odor may vary among individuals, the characteristic garlic smell can persist for several hours or even days after supplementation. While the odor may be a temporary inconvenience, it is essential to consider this aspect when incorporating garlic supplements into daily routines, particularly in social or professional settings where the lingering smell may be undesirable [22]. To minimize garlic-induced bad breath associated with garlic extract supplements, consumers might consider opting for enteric-coated formulations, timing their intake with meals, or using chewable supplements containing chlorophyll or parsley/mint. Staying hydrated, practicing oil pulling, maintaining good oral hygiene, and limiting garlic consumption before social gatherings can also be beneficial strategies. While these approaches aim to mitigate the effects of garlic, it is important to remember that red garlic is utilized for its therapeutic benefits, and therefore, these suggestions are intended to enhance comfort without compromising its health advantages.

5. Conclusions

In summary, this literature review suggests the therapeutic potential of red garlic extracts, primarily water-based, in diverse experimental models. The observed antioxidant, anti-inflammatory, and potential pro-metabolic effects warrant further research to comprehensively understand the mechanisms of action and therapeutic applications of red garlic extracts.

Future studies should focus on several key areas to further elucidate the therapeutic potential of red garlic extracts. First, more in-depth investigations into the mechanisms underlying its antioxidant and anti-inflammatory effects, particularly in different organ systems, are needed. Research should explore how specific bioactive compounds, such as anthocyanins and organosulfur compounds, interact at the molecular level, especially in relation to gut microbiota modulation. Additionally, clinical trials assessing the long-term safety and efficacy of red garlic extracts, including optimal dosing and potential side effects, would be valuable. Given the variability in bioactive content based on extraction methods and garlic variety, future studies should standardize these variables to better assess the therapeutic consistency of red garlic.

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