Allium sativum: botanical, chemical, and therapeutic aspects

ABSTRACT

Aims: The presence of *Allium sativum* in human societies dates back thousands of years. Its medicinal and aphrodisiac properties, combined with its distinctive flavor, have found it a valuable ingredient in both cuisine and traditional medicinal practices in various cultures. Not surprisingly, it is one of the most researched and marketed herbal products today. Active substances present in garlic, such as allicin and other sulfur compounds, have been the subject of extensive research, with promising results in several areas of health.
Objective: The main objective of this article is to gather relevant information on the botanical, chemical and therapeutic aspects of garlic in order to provide a comprehensive overview of this important vegetable.
Methodology: The search was undertaken in the following electronic databases: Latin American and Caribbean Literature in Health Sciences (LILACS), United States National Library of Medicine (PubMed) and Scientific Electronic Library Online (SciELO). The terms (in English) used for the bibliographic search were identified in the Health Sciences Descriptors (DeCS): "Garlic", "Botany", "Chemistry" and "Therapeutic Uses". Thirty-one academic texts were selected to construct this work.
Results & conclusion: From the data obtained, it was possible to list several health benefits of garlic, the main ones being: anti-inflammatory, antioxidant, antibacterial and antifungal, anticancer and other protective effects. In this way, *A. sativum* demonstrates a variety of pharmacological effects, which makes it a viable option for the treatment of various diseases, even though its mechanisms of action are poorly understood and require further scientific studies.

Keywords: Allium sativum; Therapeutic aspects; Chemical aspects; Botanical aspects

1. INTRODUCTION

Garlic – scientifically known as *Allium sativum L*. – is a herbaceous, bulbous, perennial plant belonging to the Aliaceae family. It is a diploid, viviparous and asexual species [1]. Its roots are bundled together and are between 40 and 82 cm deep [2]. Its leaves are long and narrow, and the stems develop into bulbils (teeth), which are complex structures rich in starch and aromatic substances. These parts form a rounded bulb with approximately 5 to 20 bulbils, which are long, ovoid and arched in shape. Each garlic clove is wrapped in a thin husk, and the bulb has been widely used in cooking, medicine and religious rituals since ancient times [1].

The origin of its name is unknown, but there are indications that it descends from the Latin word "olere", which means smell. Efficient land preparation is essential for its harvest, during the spring and summer seasons. The soil needs to be well fertilized, sandy and clayey, so that the vegetable reaches a height of around 30 to 90 cm [3,4].

Its presence in human civilizations dates back thousands of years, with its medicinal, aphrodisiac and culinary properties standing out. These have made garlic a valuable component in food and traditional medicinal practices in different cultures, and it is one of the most researched and commercialized herbal products on the market. Traditionally, it has been used to treat a variety of health conditions since ancient times. It is worth noting that the therapeutic actions of garlic are related to the presence of numerous biologically active substances which, taken together, are useful for the therapy of various ailments [4, 5, 6, 7]

Scientific research on *Allium sativum* has listed and validated numerous traditional uses attributed to this plant. In fact, studies have demonstrated its antimicrobial potential, through its bactericidal or bacteriostatic effects, including action on strains of multi-resistant microorganisms [8]; antioxidant, due to the presence of phenolic compounds – such as quercetin, apigenin and myricitin – and organosulphur compounds, such as allicin [9]; immunomodulatory and anti-inflammatory, by promoting the homeostasis of the immune system and modulating certain cytokines [10]; antineoplastic, by inhibiting the growth of metastatic cells [11]; and cardioprotective, considering its benefits for the myocardium – reducing the risk of ischemia and possible heart damage – and its role in reducing blood pressure, cholesterol and triglycerides [12]. It has antiviral activity in cases of colds and flu, and antifungal properties, especially against Candida tropicalis [13]. In fact, active substances present in the plant – such as allicin and other sulphur components – have been the subject of extensive research, with promising results in various areas of health.

Based on these preliminary findings, the main aim of this article is to review relevant information on the botanical, chemical and therapeutic aspects of garlic. It is hoped that the systematization of the data obtained will contribute to scientific knowledge and future research into garlic and its potential benefits for human health.

2. METHODOLOGY

2.1 Bibliographic research strategy

This study consists of an integrative literature review. This type of review makes it possible to synthesize previous research and draw solid conclusions on a given subject, through a thorough analysis of the methodological planning and results found in research related to the subject under analysis [14]. To this end, publications dealing with information of interest on garlic were analyzed.

The search was carried out in the following electronic databases: Latin American and Caribbean Health Sciences Literature (LILACS), the US National Library of Medicine (PubMed) and the Scientific Electronic Library Online (SciELO). The English language terms used for the bibliographic search – "Garlic", "Botany", "Chemistry" and "Therapeutic Uses" – were identified on the Health Sciences Descriptors (DeCS) website. The uniterms chosen were organized into search strategies, which are shown in Table 1.

Table 1. Search strategy used in the literature review and the results found in the databases.

Search strategy (English)	LILACS	PubMed	SciELO
Garlic AND Botany AND Chemistry	1	35	8
Garlic AND Therapeutic Uses	33	134	6

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TOTAL	34	169	14

Search end date: 31/12/2023
Source: Prepared by the authors

The descriptors, when used together ("Garlic AND Botany AND Chemistry AND Therapeutic Uses") or alone ("Garlic AND Botany" and "Garlic AND Chemistry") did not return satisfactory results. Considering the descriptors combined according to Table 1 and the following inclusion criteria – full texts freely available in the aforementioned databases, in the form of articles, monographs, dissertations and theses, without language restriction, published until December 31, 2023, and which addressed the botanical and chemical aspects of garlic, as well as its therapeutic uses – a total of 217 citations were found.

2.2 Selection of articles and exclusion criteria

Based on a preliminary analysis of the citations obtained, 21 duplicate papers were excluded. Of the remaining 196, after reading the titles of the manuscripts, 102 were discarded due to incompatibility with the objectives of this study. The abstracts of the 94 selected studies were then read and 54 articles were excluded as they did not cover the proposed theme. The remaining 40 articles were analyzed in full, 31 of which were selected for this study.

The selection of articles, carried out according to the steps described, is presented in the form of a flowchart (Fig. 1).

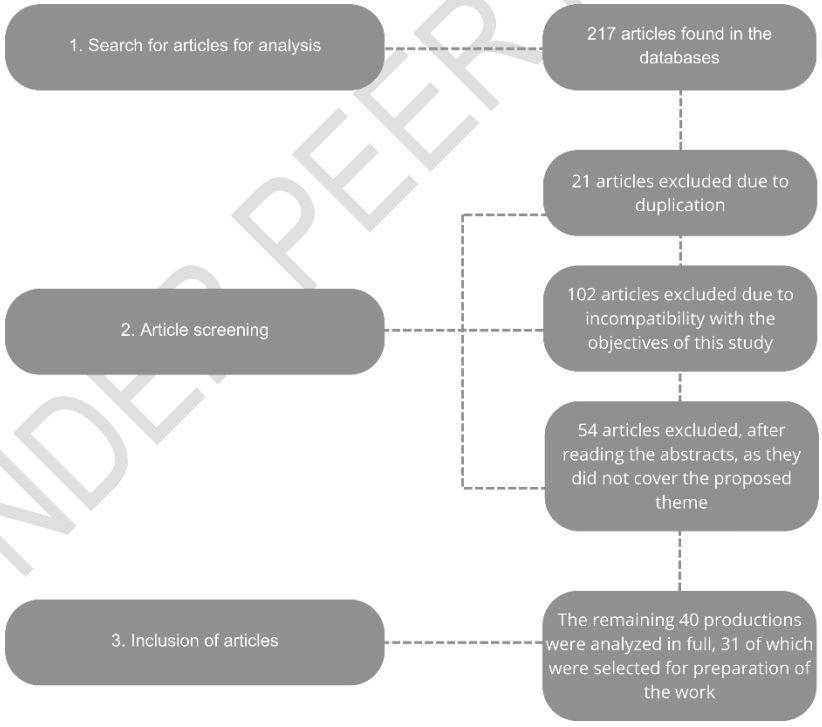

Fig. 1. Flow diagram of the selection and exclusion of articles in the literature review, according to the established criteria.

The chosen texts were read and categorized to present the main concepts related to the topic, as explained in the next section.

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3. RESULTS AND DISCUSSION

From the 31 texts selected, data extraction and descriptive analysis were carried out – these are shown in Table 2.

Table 2. Data on the studies included in this review

Author/year	Title	Objective	Methods	Main results and conclusion
Alkreathy *et al*., 2010	*Aged garlic extract protects against doxorubicin-induced cardiotoxicity in rats*	To investigate the protective effect of AGE against free radical production and DOX-induced cardiotoxicity from a histopathological point of view.	Experimental study *in vivo*	A single dose of DOX caused an increase in the activity of the enzymes LDH and CPK and a significant increase in MDA in the plasma. Pretreatment of rats with AGE for 27 days prior to DOX therapy reduced the activity of both enzymes and significantly decreased the production of MDA in plasma. The results suggest that AGE is potentially protective against doxorubicin-induced cardiotoxicity.
Argüello-García *et al*., 2018	*Activity of thioallyl compounds from garlic against Giardia duodenalis trophozoites and in experimental giardiasis*	Evaluate the *anti-Giardia* activity of fresh aqueous extracts and various garlic TACs	*In vitro* susceptibility test	Garlic extracts affect the integrity of trophozoites, concomitant with the loss of oxidoreductase activities. The activities of several cysteine proteases in lysed trophozoites were inhibited by TACs, as was the effect of the virulence factor. Data

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				suggest a potential use of garlic TACs against *Giardia duodenalis* and in the treatment of giardiasis, along with their additional benefits on host health.
Bachrach *et al*., 2011	*Garlic allicin as a potential agent for controlling oral pathogens*	Testing the antimicrobial activity of allicin present in garlic against oral pathogens associated with dental caries and periodontitis	Experimental study *in vitro*	Allicin was found to be effective against all the bacteria tested. The results support the traditional medicinal use of garlic and suggest the use of allicin in the treatment of dental diseases.
Conceição, 2013	Health effects of ginger, garlic and fennel	Identify the main components of ginger, garlic and fennel and their effect on human health	Literature review	Ginger, garlic and fennel have the ability to act positively on the human body, helping to prevent and treat a variety of diseases and health conditions. Ginger is aimed more at gastrointestinal diseases, garlic at cancer due to its powerful antioxidant properties, and fennel at treating problems associated with the respiratory tract.
Hamad, 2023	*Rutin, a flavonoid compound derived from garlic, as a potential immunomodulatory and anti-inflammatory agent against murine Schistosomiasis mansoni*	Comparing the possible anti-inflammatory, immunomodulatory and parasitological efficacy of rutin, a garlic compound, to PZQ in preventing	Experimental study *in vivo*	Rutin therapy showed anti-schistosomal action. There was a reduction in parasite load and protection against hepatosplenomegaly in mice with *S. mansoni-induced* disease. The data

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		pathological changes caused by *S. mansoni*		raises the possibility of rutin being further investigated as a therapy for infections caused by *S. mansoni*.
Jafari *et al*., 2023	*Therapeutic effects of garlic (Allium sativum) on female reproductive system: A systematic review*	Focus on the effects of garlic on the female reproductive system	Literature review	Garlic may have positive effects on women's reproductive health, such as improving hormonal balance, relieving PMS symptoms and potentially supporting fertility outcomes. This review determined that more research is needed to elucidate the molecular pathways and direct effects of garlic on the female reproductive system. Although garlic has many potential health benefits, it should not be used as a substitute for medication.
Jeremic *et al*., 2020	*Garlic derived diallyl trisulfide in experimental metabolic syndrome: metabolic effects and cardioprotective role*	Examining the effects of DATS, the most potent polysulphide derived from garlic, on metabolic syndrome and myocardial function in rats with metabolic syndrome	Experimental study *in vivo*	DATS can effectively mitigate metabolic syndrome and have protective effects against myocardial injury. In addition, this polysulphide improved cardiac function, cardiodynamic parameters and prevented oxidative and histoarchitectural variation in the

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				heart. DATS, a phytochemical derived from garlic, has the potential to be used, as a herbal supplement, in the treatment of metabolic syndrome and its related manifestations.
Jiang *et al*., 2023	*Garlic consumption and colorectal cancer risk in US adults: a large prospective cohort study*	To clarify the inconsistent results of epidemiological studies on the association between dietary garlic consumption and the incidence of RCC, prospectively evaluating the association in a large US population.	Cohort study	During an average follow-up of 12.05 years, 782 cases of RCC were documented, including 456 cases of proximal colon cancer, 322 cases of distal RCC and 4 cases of RCC of unknown location. The protective association was more pronounced in men, Caucasians and those with lower alcohol consumption. Moderate consumption of garlic in the diet is associated with a decreased risk of RCC in the US population, with variations based on the anatomical subsites of RCC. Further prospective studies are needed to validate these findings in different populations and to explore subsite-specific associations.
Leonese, 2008	Garlic: food and health	Present the characteristics and possible	Literature review	Regular consumption of garlic reduces the

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		benefits of using garlic in human health		risk of heart attacks, promotes the proper functioning of the immune system, lowers blood glucose levels and acts against bacteria and viruses, among other effects. Evidence proves the therapeutic efficacy of garlic in preventing a wide range of illnesses.
Magryś; Olender; Tchórzewska, 2021	*Antibacterial properties of Allium sativum L. against the most emerging multidrug-resistant bacteria and its synergy with antibiotics*	To evaluate the antibacterial activity of *Allium sativum* and its interactions with selected antibiotics against sensitive or resistant bacterial pathogens frequently found in healthcare environments.	Experimental test *in vitro*	Whole *Allium sativum* extract inhibited the growth of a wide range of bacteria, including multi-resistant strains, showing bactericidal or bacteriostatic effects. Depending on the organism, susceptibility to fresh garlic extract was comparable to conventional antibiotics. The results of the study indicate the possibility of using garlic as a supplement during antibiotic therapy in order to increase the effectiveness of gentamicin and ciprofloxacin.
Martins; Petropoulos; Ferreira, 2016	*Chemical composition and bioactive compounds of garlic (Allium sativum L.) as affected by pre- and post-harvest*	Examine all aspects related to the chemical composition and quality of garlic, with a focus on its bioactive properties	Literature review	The quality of garlic, expressed by its chemical composition and the content of bioactive compounds, is highly dependent

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	conditions: A review			on pre- and post-harvest conditions.
Mikaili *et al*., 2013	*Therapeutic uses and pharmacological properties of garlic, shallot, and their biologically active compounds*	To review the pharmacological effects and traditional uses of *Allium sativum, Allium hirtifolium, as* well as their active constituents, to show whether or not they can be used as potential natural sources for the development of new drugs.	Literature review	Garlic and shallots are safe and rich sources of biologically active compounds with low toxicity. More studies are needed to confirm the safety and quality of plants to be used by doctors as therapeutic agents.
Naji *et al*., 2017	*Hepatoprotective and antioxidant effects of single clove garlic against CCl4-induced hepatic damage in rabbits*	To evaluate the antioxidant and preventive effects of SCG and MCG on acute hepatotoxicity induced by CCl_4 in male rabbits.	Experimental study *in vivo*	The SCG extract exhibited greater antioxidant capacity than the MCG extract. The ethanolic extract of SCG was associated with a greater reduction in oxidative toxicity and could be an alternative therapy against acute oxidative liver toxicity.
Nasr, 2017	*The impact of aged garlic extract on adriamycin-induced testicular changes in adult male Wistar rats*	To study the possible protective effects and the underlying mechanism of AGE in testicular damage induced by adriamycin	Experimental study *in vivo*	Remarkable histological, biochemical and ultrastructural improvements were observed in the groups treated with AGE associated with adriamycin. AGE can be used as an adjuvant therapy to treat male infertility and low spermatogenesis induced by cytotoxic drugs or other environmental

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				toxins, through its cytoprotective and antioxidant properties.
Neves, 2013	Chemical and pharmacological aspects of *Allium sativum* Linnaeus (garlic): a brief review	Discuss the chemical and pharmacological characteristics of *Allium sativum* L.	Literature review	*Allium sativum* L. has a number of pharmacological effects, making it a viable alternative for the treatment of a number of illnesses that have hitherto been treated with drugs of synthetic origin.
Pârvu *et al*., 2019	*Allium sativum extract chemical composition, antioxidant activity and antifungal effect against Meyerozyma guilliermondii and Rhodotorula mucilaginosa causing onychomycosis*	To evaluate the antifungal effect of *A. sativum* extract against *Meyerozyma guilliermondii* and *Rhodotorula mucilaginosa*, etiological agents of onychomycosis.	Experimental test *in vitro*	At MIC (120 mg/mL) the micrographs showed structural changes with cell death. *Allium sativum* reduced the oxidative stress index, the production of malondialdehyde and nitric oxide and increased the amount of total thiols in the blood. The effects were comparable to those of allicin and diclofenac. The garlic extract showed antifungal properties against *M. guilliermondii* and *R. mucilaginosa*. Together, the antifungal and antioxidant activities support the idea of using *A. sativum* as a potential alternative treatment for onychomycosis.
Perez-Ortiz *et al*., 2020	*Cost effective use of a thiosulfinate-enriched Allium*	Investigate the effects of a thiosulfinate-	Experimental test *in vitro*	Thiosulfinate-enriched garlic

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	sativum extract in combination with chemotherapy in colon cancer	enriched garlic extract co-administered with 5-FU or oxaliplatin chemotherapy on the viability of colon cancer cells and evaluate the costs of this combined treatment.		extract not only increased the impact of 5-FU and oxaliplatin (500 µM) in decreasing the viability of Caco-2 and HT-29, but also showed a greater effect than standard chemotherapy with 5-FU and oxaliplatin. These results provided evidence for the combination of freeze-dried garlic extract and 5-FU or oxaliplatin as a new chemotherapy protocol for colon cancer. In this way, the combined use of garlic extract with known chemotherapeutic drugs can reduce the costs of clinical therapy.
Rana *et al*., 2011	*Garlic in health and disease*	To review the historical and popular uses of garlic, its antioxidant, hematological, antimicrobial and hepatoprotective effects and its antineoplastic properties and potential toxicity.	Literature review	Garlic's antioxidant, antilipemic, hepatoprotective, hematological, antimicrobial and antineoplastic actions have been demonstrated. Although evidence supports the benefits of garlic, more research is needed to determine the amount required to minimize cancer, cardiovascular risks and hematological diseases, and to provide hepatoprotective

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				and antimicrobial effects.
Rivlin, 2001	*Historical perspective on the use of garlic*	Briefly examine the medical uses of garlic throughout the ages and its role in the prevention and treatment of disease	Literature review	Modern science tends to confirm many of the beliefs of ancient cultures regarding garlic, defining mechanisms of action and exploring the potential effects of garlic for the prevention and treatment of diseases.
Saleh *et al*., 2018	*Protective effect of garlic extract against maternal and foetal cerebellar damage induced by lead administration during pregnancy in rats*	To investigate the beneficial role of garlic extract in protecting maternal and fetal cerebellar damage produced by the administration of different doses of lead (Pb) during pregnancy.	Experimental study *in vivo*	The co-treatment of garlic extract with Pb resulted in a significant decrease in Pb levels compared to those treated with Pb alone. It was also possible to see an improvement in histopathological changes. The coadministration of garlic with Pb has beneficial effects in improving the neurotoxicity induced by this metal, reversing the histopathological alterations in the cerebellum of mother rats and fetuses.
Sánchez-Gloria *et al*., 2021	*Anti-inflammatory effect of allicin associated with fibrosis in pulmonary arterial hypertension*	Evaluating the effects of allicin on inflammation and fibrosis in PAH	Experimental study *in vivo*	Allicin prevented an increase in the thickness of the pulmonary artery wall. In addition, less fibrosis was seen in the groups treated with allicin combined with monocrotaline compared to the

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				groups treated with monocrotaline alone. By modulating pro-inflammatory and pro-fibrotic markers in the lung and heart, allicin delays the progression of PAH.
Schier *et al*., 2023	*Combating Black Fungus: Using Allicin as a Potent Antifungal Agent against Mucorales*	To show whether zygomycetes, significant contributors to mycoses, are sensitive to the natural product allicin	Experimental test *in vitro*	Inhibition of Mucorales fungi by allicin in solution and by allicin vapor has been demonstrated. Fungal sensitivity to allicin depends on the concentration of spores, as demonstrated in a drop test. This study shows the potential of allicin, a sulfur-containing defense compound in garlic, to combat zygomycete fungi. The findings highlight the promise of allicin for applications in nasopharyngeal inhalation infections, suggesting a new therapeutic avenue against challenging fungal infections.
Sendl, 1995	*Allium sativum and Allium ursinum: Chemistry, analysis, history, botany*	To analyze the chemical and botanical aspects of two species of garlic, as well as the history of their use	Literature review	The use of garlic has been well documented by the Egyptians, Greeks and Romans. Garlic extract is known to induce effects such as: lowering serum cholesterol levels, reducing blood

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				pressure, the occurrence of vascular disorders, the incidence of tumors, as well as increasing blood clotting time.
Souza, 2019	Therapeutic effect of *Allium sativum* (garlic) on human health	Conduct a survey of scientific studies on the therapeutic properties of garlic	Integrative review	Several clinical studies and systematic reviews point to the use of garlic in diseases such as: hypercholesterolemia (total cholesterol and fractions), hypertriglyceridemia, neoplasms and type 2 diabetes.
Tesfaye, 2021	Revealing the therapeutic uses of garlic (*Allium sativum*) and its potential for drug discovery	Examining the therapeutic uses and potential role in the development of garlic-based medicines for various human diseases	Literature review	Garlic has anti-inflammatory, rheumatologic, ulcer-inhibiting, anticholinergic, analgesic, antimicrobial, anti-stress, anti-diabetes, anticancer, liver-protecting, anthelmintic, antioxidant, antifungal and wound-healing properties. The plant's nutritional content is significant and it has outstanding therapeutic potential.
Torres *et al*., 2021	*Garlic: an alternative treatment for group B Streptococcus*	Isolate and identify the active compounds in garlic that have antimicrobial activity against *Streptococcus agalactiae*	Experimental test *in vitro*	The active compounds that showed antimicrobial activity were g-glutamyl-S-allyl-cysteine, g-glutamyl-phenylalanine, and the two stereoisomers. All

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				the compounds inhibited the growth of the clinical isolates tested. The antimicrobial compounds in garlic could be a promising source in the search for new drugs to treat *S. agalactiae* infections.
Tudu *et al*., 2022	*Traditional uses, phytochemistry, pharmacology and toxicology of garlic (Allium sativum), a storehouse of diverse phytochemicals: A review of research from the last decade focusing on health and nutritional implications*	Investigate the phytotherapeutic properties of garlic to provide an up-to-date overview of one of the world's most widely used (and best-selling) medicinal and food plants, with notes on ethnobotanical information validated by pre-clinical tests.	Literature review	Garlic has great pharmacological potential due to its potent antioxidant, anti-inflammatory and immunomodulatory properties. Based on pre-clinical studies, compounds from *A. sativum*, especially sulphur-containing compounds, some flavonoids and polyphenols have been shown to be useful in the treatment of certain human conditions, particularly those related to cancer and cardiovascular diseases.
Yi *et al*., 2019	*Anti-cancer activities of S-allylmercaptocysteine from aged garlic*	Analyze the mechanisms associated with the antiproliferative, antimetastatic and pro-apoptotic effects of SAMC in various cancer models.	Literature review	Current research provides convincing evidence that SAMC has anti-tumor, anti-oxidative and anti-inflammatory properties. SAMC can also inhibit tumor cell proliferation by inducing histone acetylation and

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				inhibiting microtubule polymerization. It has also been discovered that SAMC increases the chemosensitivity of cancer cells. In this way, the development of new drugs based on SAMC or AGE can be used to prevent or treat cancer.
Zhang *et al*., 2020	*Phytochemicals of garlic: Promising candidates for cancer therapy*	Discuss the promises and pitfalls of garlic for cancer treatment	Literature review	Garlic has been shown to exhibit antineoplastic activities at various stages of carcinogenesis. However, the nutritional or chemopreventive role of garlic goes far beyond the notion that garlic has therapeutic effects against cancer.
Zhu *et al*., 2022	*Garlic-derived organosulfur compounds regulate metabolic and immune pathways in macrophages and attenuate intestinal inflammation in mice*	Evaluate the mechanisms underlying the bioactivity of garlic compounds and their ability to regulate responses to enteric infections	Experimental test *in vitro*	Garlic-derived organosulfur compounds exert anti-inflammatory activity on macrophages and IEC, and regulate gene expression during intestinal infection. These compounds may therefore have potential as functional food components to improve intestinal health in humans and animals.
Zhu; Zeng, 2020	*Garlic extract in prosthesis-related infections: a literature review*	To explore the antibacterial effect and antibiofilm	Literature review	The antibacterial and antibiofilm activities of garlic extract suggest

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	activities of garlic extract and its potential for use in the treatment of ARI	broad clinical applications in the future. The evidence to date suggests that garlic extract is a promising candidate for the treatment of ARI, although more research is needed

AGE = aged garlic extract; CCR = colorectal cancer; DOX = doxorubicin; LDH = lactate dehydrogenase; CPK = phosphokinase; MDA = malonyldialdehyde; TAC: thioallyl compounds; PZQ = praziquantel; DATS = diallyl trisulfide; SCG = single clove garlic; MCG = multi clove garlic; MIC = minimum inhibitory concentration; 5-FU = 5-fluorouracil; PAH = pulmonary arterial hypertension; SAMC = S-allylmercaptocysteine; IEC = intestinal epithelial cells; IAP = periprosthetic joint lesions.

The selected articles were read and the data obtained was organized into sections – (i) "Botanical aspects", (ii) "Chemical aspects" and (iii) "Therapeutic aspects" – which will be presented below.

3.1 Botanical aspects

“Garlic (*Allium sativum*) is believed to have originated in Central Asia and belongs to the Aliaceae family” [15]. “It is a hardy, asexual herbaceous plant whose flat, robust leaves can reach up to 70 cm in height. The leaf sheaths form a pseudostem. The real stem is long, reddish in color and is the starting point for the roots” [6, 16, 17]. “It also has pink or white pseudoumbellate flowers. The plant's fruit consists of trichotomous capsules containing black seeds” [18].

“Garlic develops a series of bulbils, popularly known as "cloves", forming the bulb, which originates in the lower part of the pseudostem. In general, the bulbils are long and oval in shape, surrounded by leaves of varying colors: white, violet, red, purple and brown. Each bulb is a complex structure, rich in starch and aromatic compounds, capable of generating a new plant” [18, 19].

“Botany categorizes all varieties of garlic as derived from the species *Allium sativum*. Within this species, there are two subspecies, Ophioscorodon and Sativum, giving rise to distinct varieties. Of those belonging to the Ophioscorodon type, the following stand out: Asian, Criollo, Purple Stripe, Marbled Purple Stripe, Porcelain and Rocambole. Two are classified as Sativum: Artichoke and Silver” [19].

“It is estimated that there are more than 600 garlic sub-varieties worldwide. This is due to the way in which the individual characteristics of garlic are altered according to growing conditions, including soil type, temperature, rainfall, altitude and other climatic characteristics specific to each region” [17, 19].

3.2 Chemical aspects

“Garlic's properties are associated with its extremely rich composition” [9]. Garlic contains at least 33 sulphur compounds, around 1% to 2% of its dry weight [18, 20], various enzymes and 17 amino acids. In addition, whole garlic contains steroid glycosides and lectins [21].

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“Whether consumed as a raw vegetable or after processing into oil, extract or even powder, there are pronounced differences in the chemical composition and, consequently, in the content of bioactive compounds between the various garlic formulations available” [18, 22].

“The intact bulb contains alliin, an odorless, crystalline amino acid that is insoluble in water. The characteristic taste and aroma of *Allium sativum* is attributed to the presence of sulphur compounds – i.e. those containing sulphur atoms – which are soluble in water and lipids” [23].

“When garlic cloves are "damaged" (attacked by microbes, crushed, cut, chewed, dehydrated, pulverized or exposed to water), allicin (diallyl disulfide S-oxide) is produced from its biologically inactive precursor, alliin” [21]. “Allicin, along with other volatile sulphur compounds (Fig. 2), is responsible for garlic's biological activity” [23]. “Allicin is very unstable and decomposes rapidly into a variety of products, including ajoenes and allyl sulfides (allyl methyl trisulfide, diallyl sulfide, diallyl disulfide and diallyl trisulfide)” [20].

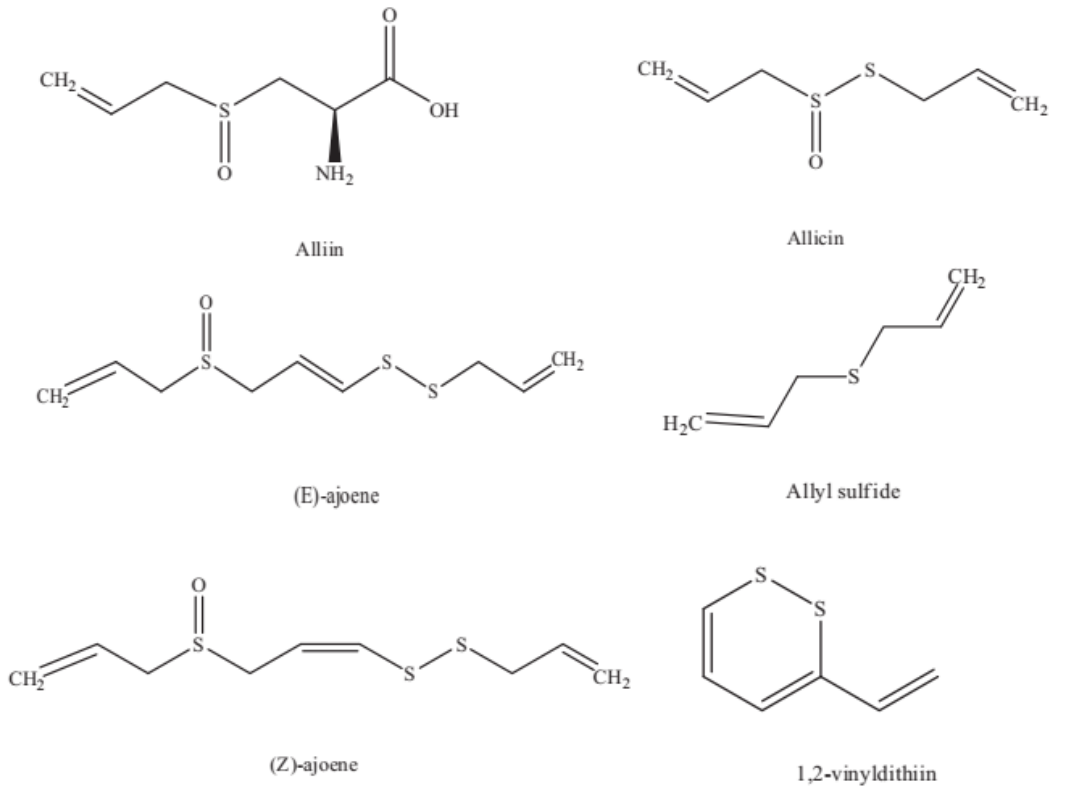

Fig. 2 Stereochemical structure of the most representative bioactive constituents of *Allium sativum* L
Source: Martins; Petropoulos; Ferreira, 2016

“The volatile nature of these bioactive compounds is highly involved in the defense mechanisms of garlic plants against pests and various pathogens, since their release is combined with cell damage and injury to plant tissues” [22].

“In addition to volatile compounds, garlic is also rich in vitamins (mainly B vitamins and vitamin C), antioxidants, flavonoids, trace elements and minerals (especially P, K and Se) and other

phytonutrients, of which saponins and sapogenins, phenolic compounds, nitrous oxides, amides and proteins such as glutamyl peptides are particularly noteworthy" [18, 22, 23].

"The two main active components of garlic are allicin and ajoene, with allicin being the most important. However, allicin is rapidly oxidized, very volatile and unstable, so it breaks down quickly as soon as the garlic is damaged, which is why it is difficult to use. Ajoene, on the other hand, is biologically active and more stable than allicin, so it has been the subject of more research" [24].

"Garlic oil, aged garlic extract and steam-distilled garlic do not contain significant amounts of alliin or allicin, but they do contain various allicin transformation products, among which none seem to have as much physiological activity as fresh garlic or garlic powder" [21]. "On the other hand, garlic extract and garlic oil are more stable compared to other preparations, due to the hydrogen bond between water and the reactive oxygen atom, which increases the stability of allicin" [24].

"Garlic is a source of bioactive phytonutrients that may have anti-inflammatory, immunomodulatory and other properties. However, the mechanism(s) underlying the bioactivity of these compounds and their ability to regulate responses to infections and other diseases remain unclear" [25].

3.3 Therapeutic aspects

"Garlic – a common component of the human diet – has been used since ancient times in the folk medicine of different cultures [26]. Interest in the potential benefits of garlic was noted in records found in Egyptian pyramids and ancient Greek temples, as well as in ancient texts – including medical literature – from China, Egypt, Greece, India, Israel and Rome, in which its use was prescribed" [27]. It is even mentioned in the Bible:

> "According to the Bible, the Jewish slaves in Egypt were fed garlic and other allium vegetables, apparently to give them strength and increase their productivity, as it was believed to do for the indigenous Egyptian citizens. The Jewish people must have developed some fondness for garlic, because when they left from Egypt with Moses, it is written that they missed "the fish. the cucumbers, and the melons, and the leeks, and the onions and the garlic" (Num. 11:5)" [27, p. 951].

"Garlic exhibits a wide range of properties, including anti-inflammatory, rheumatologic, ulcer-inhibiting, anticholinergic, analgesic, antimicrobial, anti-stress, anti-diabetes, anticancer, liver-protective, anthelmintic, antioxidant, antifungal and wound-healing, as well as asthma-relieving properties, arthritis, chronic fever, tuberculosis, runny nose, malaria, leprosy, skin discoloration and itching, indigestion, colic, enlarged spleen, hemorrhoids, fistula, bone fracture, gout, urinary tract disease, diabetes, kidney stones, anemia, jaundice, epilepsy, cataracts and night blindness" [6, 26, 28, 29, 30].

"Although the mechanisms of action are unclear and require further research, it is hypothesized that the beneficial effects on health come from the volatile sulfur compounds in garlic, especially allicin [31]. In fact, it is well known that the abundant organosulphur compounds found in garlic interact with thiol groups or thiol-containing compounds in biological systems and increase the bioavailability of hydrogen sulphide (H_2S), playing an important role in reducing inflammation" [32].

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“As a result, garlic is used in a variety of ways as a therapeutic agent in modern society. As a result, scientists from various fields are focusing their efforts on determining the medicinal potential of garlic for human health” [30]. In this regard, Alkreathy et al. (2010), in their study, “investigated the protective effects of AGE (aged garlic extract) against doxorubicin (DOX)-induced free radical production and cardiotoxicity in male rats. The results indicate that total antioxidant activity increased after AGE administration, although vascular dilation, mild congestion and interstitial edema were observed”. “Thus, for the authors, AGE contains a wide range of antioxidants that protect against the harmful cardiac effects of DOX” [28].

The effects of garlic were also observed by Naji et al. (2017), “who evaluated the antioxidant effect and preventive effects of SCG and MCG on acute hepatotoxicity induced by CCl4 in male rabbits”. “The study indicates that SCG has greater protective capacity (regulates the action of free radicals, improves hepatic, cholestatic and hepatic biomarkers, reduces the severity of fibrosis and normalizes hepatocyte architecture) than MCG against liver damage, and may be an effective alternative against acute oxidative liver toxicity” [33].

“Of the numerous health benefits of garlic, the anti-cancer effect is probably the most notable. Observations in recent years have shown that consuming garlic in the diet provides strong protection against cancer risk” [20]. For example, Perez-Ortiz et al. (2020) “investigated the effects of garlic extract enriched with thiosulfinate, co-administered with 5-FU (5-fluoruracil) or oxaliplatin chemotherapy, on the viability of colon cancer cells. The authors concluded that garlic extract enriched with thiosulfinate not only increased the impact of 5-FU and oxaliplatin (500 µM) in decreasing the viability of Caco-2 and HT-29, but also showed a greater effect than standard chemotherapy with 5-FU and oxaliplatin”. “These results provided evidence for the combination of freeze-dried garlic extract and 5-FU or oxaliplatin as a new chemotherapy protocol for colon cancer” [34].

Jiang et al. (2023) also studied “the effects of dietary garlic consumption on protection against colorectal cancer (CRC) in the North American population. In the cohort study, data from 58,508 participants (aged 55-74) in the Prostate, Lung, Colorectal and Ovarian Cancer Screening Trial (PLCO) were analyzed, with dietary data collected using a validated questionnaire. During a median follow-up of 12.05 years, 782 cases of RCC were documented, including 456 cases of proximal colon cancer, 322 cases of distal RCC and 4 cases of RCC with unknown location. Moderate consumption of garlic in the diet was significantly associated with a lower risk of overall RCC”. “The protective association was more pronounced in men, Caucasians and those with lower alcohol consumption. Thus, it was possible to conclude that moderate consumption of garlic in the diet is associated with a lower risk of RCC in the US population” [35].

Yi et al. (2019), who analyzed “the antiproliferative, antimetastatic and pro-apoptotic effects of S-allylmercaptocysteine (SAMC) in various cancer models, concluded that current research has indicated that SAMC has antitumor, antioxidative and anti-inflammatory properties. SAMC can also inhibit tumor cell proliferation by inducing histone acetylation and inhibiting microtubule polymerization. They also found that SAMC increases the chemosensitivity of cancer cells”. “In this way, the development of new drugs based on SAMC or AGE can be used to prevent or treat cancer, since they have the capacity to remove reactive oxygen species, which alter the cells' natural antioxidant defense system” [36].

Several compounds in garlic have important antimicrobial activity. Bachrach et al. (2011) tested “the antimicrobial activity of allicin on oral pathogens associated with dental caries and periodontitis. The substance was found to be effective against all the bacteria tested (Actinomyces oris, Aggregatibacter actinomycetemcomitans, Fusobacterium nucleatum, Porphyromonas gingivalis, Streptococcus mutans and Streptococcus sobrinus)”. “The results

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support the traditional medicinal use of garlic and suggest the use of allicin to alleviate dental problems" [15].

Argüello-García et al. (2018) analyzed "the anti-Giardia activity of AGEs and various garlic TACs. The trials showed that allicin had the greatest anti-parasitic effect" [26]. "Intragastric administration of AGE or allicin promoted a reduction in the number of protozoa and the elimination of trophozoites in infected animals, respectively. These data suggest the potential use of garlic in the treatment of Giardia duodenalis infections, the etiological agent of giardiasis" [37].

When comparing the anti-inflammatory, immunomodulatory and parasitological efficacy of rutin, a garlic compound, to praziquantel (PZQ) in preventing pathological alterations caused by Schistosoma mansoni, Hamad (2023) concluded that rutin therapy showed significant anti-schistosomal action. There was a reduction in parasite load and protection against hepatosplenomegaly in mice with S. mansoni-induced disease; allowing us to hypothesize that rutin should be investigated further as a therapy for infections caused by this helminth [38].

Torres et al. (2021) "sought to isolate and identify the active compounds in garlic that have antimicrobial activity against *Streptoccoccus agalactiae*, a common cause of infections in pregnant women. The active compounds that showed antimicrobial activity were g-glutamyl-S-allyl-cysteine, g-glutamyl-phenylalanine and the two stereoisomers of ajoene, which could be a promising source in the search for new drugs against *S. agalactiae"* [39].

Pârvu et al. (2019) "evaluated the antifungal effect of *A. sativum* extract against *Meyerozyma guilliermondii* and *Rhodotorula mucilaginosa*, etiological agents of onychomycosis. At the minimum concentration of 120mg/mL of extract, micrographs showed structural changes and cell death. In addition, *A. sativum* reduced total serum oxidation, the production of malondialdehyde and nitric oxide and increased total thiols. The effects were comparable to those of allicin and diclofenac. The antifungal and antioxidant properties support the potential of garlic to be used as an alternative treatment for onychomycosis" [40].

Schier et al. (2023) "sought to show the sensitivity of mycoses to the natural product allicin. The study demonstrated the inhibition of Mucorales fungi by allicin in solution and by allicin vapor. Mathematical modeling showed that the efficacy of allicin vapor is comparable to direct contact with the commercially available antifungal agent, amphotericin B (ampB). In solution, the average effective concentration of allicin was found to be 25 to 72 times higher in cell lines compared to fungal spores. The results therefore highlight the promise of allicin for applications in nasopharyngeal infections via inhalation, suggesting a new therapeutic route against challenging fungal infections" [41].

Another interesting study, conducted by Nasr (2017), "analyzed the protective effects and mechanisms of AGE on testicular damage induced by adriamycin, a cytotoxic drug with many adverse effects on different organs of the body. Optimal histological, biochemical and ultrastructural improvements were observed in the groups treated with AGE associated with adriamycin, indicating that AGE can be used as an adjuvant therapy to treat male infertility and drug-induced low spermatogenesis" [42].

Regarding the female reproductive system, Jafari et al. (2023) "sought to understand, through a systematic review, the potential effect of *A. sativum* for preventive and therapeutic purposes. The study reported that garlic can have positive effects on women's reproductive health, such as improving hormonal balance, relieving symptoms of premenstrual tension and potentially supporting fertility outcomes. The data reveals that compounds in garlic, such as allicin and

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ajoene, can modulate various aspects of the female reproductive system, including the regulation of the menstrual cycle, hormonal balance, fertility and reproductive disorders. Still, although garlic has many potential health benefits, it should not be used as a substitute for medication" [43].

The effect of AGE was analyzed by Saleh et al. (2018), who investigated the role of the compound in protecting maternal and fetal cerebellar damage induced by the administration of different doses of lead (Pb) during pregnancy. "The results showed that the administration of Pb to pregnant rats resulted in toxicity to mothers and fetuses. Histopathological examination of the cerebellum of treated mothers and fetuses showed marked alterations mainly in the form of degeneration of Purkinje cells and lack of development of the fetal cerebellum. Co-treatment of garlic extract with Pb resulted in a significant decrease in Pb levels compared to those treated with Pb alone, with an improvement in histopathological alterations" [44].

Sánchez-Gloria et al. (2021) used garlic, specifically allicin, to evaluate its protective effects on inflammation and fibrosis in pulmonary arterial hypertension. The results showed that allicin prevented an increase in the thickness of the pulmonary artery wall. In addition, less fibrosis was seen in the groups treated with allicin combined with monocrotaline compared to the groups treated with monocrotaline alone. By modulating pro-inflammatory and pro-fibrotic markers in the lung and heart, it was concluded that allicin delays the progression of pulmonary arterial hypertension [45].

In view of the above, it is possible to state that garlic is a safe and rich source of biologically active compounds with low toxicity, so that its therapeutic potential can be explored [30], especially in relation to antimicrobial properties and cardiovascular health. Even so, more studies are needed to confirm the safety and quality of plants to be used by doctors as therapeutic agents [31, 46], since the particularities of garlic's chemical composition and the instability of some of its compounds make it difficult to interpret the results and apply them in practice, where the evidence regarding applications is mixed, and there is a need for more robust and well-controlled research.

4. CONCLUSION

The *Allium sativum* is a highly resistant herbaceous plant with a stem and pseudostem, whose robust and flat leaves can reach up to 70 cm in height. Its bulbs – popularly known as "cloves" – are used frequently in the human diet as a seasoning. Furthermore, garlic has also been used since ancient times in folk medicine in various cultures – such as the Chinese, Egyptian, Greek, Hebrew, Hindu and Roman.

Its properties are directly linked to its extremely rich chemical composition: garlic contains at least 33 sulfur compounds, 17 amino acids and several enzymes, as well as steroid glycosides and lectins. Although the mechanisms of action of the different compounds in A. sativum are not fully understood and require further study, there is a hypothesis that the beneficial effects of garlic on health are derived from the volatile sulfur compounds present in its composition, especially allicin. Because it is very unstable, this last substance decomposes quickly into several other bioactive compounds, such as ajoenes and allyl sulfides.

Due to the aforementioned findings discussed throughout this article, garlic has been used in various ways as a therapeutic agent in contemporary society. In fact, the numerous health benefits of garlic include anti-inflammatory, antioxidant, anti-infectious (bacterial and fungal) and antineoplastic actions. In addition, garlic can influence cardiovascular health, helping to

reduce blood pressure and cholesterol levels. Thus, A. sativum demonstrates a variety of pharmacological effects, which makes it a viable option for the treatment of several diseases.

Despite the advances, it is necessary to emphasize the importance of continuing scientific studies in this area, mainly in order to understand the mechanisms of action of the volatile sulfur compounds of garlic in the human body, especially allicin, which, because it is very unstable, makes it difficult to study its effects in a more consistent way, so research focuses more on more stable compounds. Garlic continues to be a food of significant scientific interest and a popular ingredient in many recipes around the world.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

REFERENCES

1. Fante L. Study of the blanching and hot air drying and freeze-drying kinetics of garlic (Allium sativum L.). 2011. 112 f. Dissertation (Master's in Food Science and Technology) – Federal University of Rio Grande do Sul – Porto Alegre, 2011. Portuguese.

2. Galante RM. Extraction of inulin from garlic (Allium sativum L. var. Chonan) and simulation of batch and fixed bed processes. 2008. 195 f. Dissertation (Masters in Chemical Engineering) – Federal University of Santa Catarina, Technological Center – CTC, Florianópolis, 2008. Portuguese.

3. Oomah BD, Mazza G. Linaza products for disease prevention. In: Mazza G, editor. Functional foods: biochemical and processed aspects. Zaragoza: Acribia, 2000. Spanish.

4. Majewski M. Allium sativum: facts and myths regarding human health. Rocz Panstw Zakl Hig. 2014;65(1):1-8.

5. Amagase H, Petesch BL, Matsuura H, Kasuga S, Itakura Y. Intake of garlic and its bioactive components. J Nutr. 2001 Mar;131(3s):955S-62S. DOIi: 10.1093/jn/131.3.955S.

6. Corrêa AD, Siqueira-Batista R, Menezes FS, Oliveira-Júnior WB. Allium sativum. Clinical-therapeutic aspects. Arq Bras Med. 1996;70:613-614. Portuguese.

7. Hasler CM. Functional Foods: Their Role in Disease Prevention and Health Promotion. Institute of Food Technologists. 2001;52(2):57-62.

8. Fifths KD. Garlic, nutrition and health. NutriWeb Magazine. 2001:3(2). Portuguese. Available: http://www.nutriweb.org.br/n0302/alho.htm.

9. Magryś A, Olender A, Tchórzewska D. Antibacterial properties of Allium sativum L. against the most emerging multidrug-resistant bacteria and its synergy with antibiotics. ArchMicrobiol. 2021 Jul;203(5):2257-2268. DOI: 10.1007/s00203-021-02248-z.

UNDER PEER REVIEW

10. Arreola R, Quintero-Fabián S, López-Roa RI, Flores-Gutiérrez EO, Reyes-Grajeda JP, Carrera-Quintanar L et al. Immunomodulation and anti-inflammatory effects of garlic compounds. J Immunol Res. 2015;2015:401630. DOI: 10.1155/2015/401630.

11. Gam D-H, Park J-H, Kim J-H, Beak D-H, Kim J-W. Effects of Allium sativum Stem Extract on Growth and Migration in Melanoma Cells through Inhibition of VEGF, MMP-2, and MMP-9 Genes Expression. Molecules. 2022; 27(1):21.

12. Bhatti R, Singh K, Ishar MP, Singh J. The effect of Allium sativum on ischemic preconditioning and ischemia reperfusion induced cardiac injury. Indian J Pharmacol. 2008 Nov;40(6):261-5. DOI: 10.4103/0253-7613.45152.

13. Diba A, Alizadeh F. In vitro and in vivo antifungal activity of Allium hirtifolium and Alliumsativum. Avicenna J Phytomed. 2018 Sep-Oct;8(5):465-474.

14. Ercole FF, Melo LS, Alcoforado CLGC. Integrative Review versus Systematic Review. Rev. Min. Enferm. 2014;18(1):9-11.

15. Bachrach G, Jamil A, Naor R, Tal G, Ludmer Z, Steinberg D. Garlic Allicin as a Potential Agent for Controlling Oral Pathogens. J Med Food. 2011;14(11):1338–1343.

16. Conceição SFSM. Effects of Ginger, Garlic and Fennel on Health. 2013. 79 f. Research Project (Master's in Pharmaceutical Sciences) – Fernando Pessoa University, Porto, 2013. Portuguese.

17. Tudu CK, Dutta T, Ghorai M, Biswas P, Samanta D, Oleksak P et al. Traditional uses, phytochemistry, pharmacology and toxicology of garlic (Allium sativum), a storehouse of diverse phytochemicals: A review of research from the last decade focusing on health and nutritional implications. Front. Nutr. 2022;9(1):1-19.

18. Sendl A. Allium sativum and Allium ursinum: Chemistry, analysis, history, botany. Phytomedicine. 1995;4(1):323-339.

19. Leonês AC. Garlic: Food and Health. 2008. 41 f. Monograph (Specialization in Gastronomy and Health) – University of Brasília, Brasília, 2008. Portuguese.

20. Zhang Y, Liu X, Ruan J, Zhuang X, Zhang X, Li Z. Phytochemicals of garlic: Promising candidates for cancer therapy. Biomed Pharmacother. 2020;123(1):e109730.

21. Rana SV, Pal R, Vaiphei K, Sharma SK, Ola RP. Garlic in health and disease. Nutr Res Rev. 2011 Jun;24(1):60-71. DOI: 10.1017/S0954422410000338.

22. Martins N, Petropoulos S, Ferreira ICFR. Chemical composition and bioactive compounds of garlic (Allium sativum L.) as affected by pre- and post-harvest conditions: A review. Food Chemistry. 2016;211(1):41–50.

23. Neves KSP. Chemical and pharmacological aspects of Allium sativum Linnaeus (garlic): a brief review. 2013. 30 f. Monograph (Graduation in Pharmacy) – Faculty of Education and Environment, Ariquemes, 2013. Portuguese.

24. Zhu XY, Zeng YR. Garlic extract in prosthesis-related infections: a literature review. J Int Med Res. 2020 Apr;48(4):300060520913778. DOI: 10.1177/0300060520913778.

UNDER PEER REVIEW

25. Zhu L, Myhill LJ, Andersen-Civil AIS, Thamsborg SM, Blanchard A, Williams AR. Garlic-Derived Organosulfur Compounds Regulate Metabolic and Immune Pathways in Macrophages and Attenuate Intestinal Inflammation in Mice. Mol. Nutri. Food Res. 2022;66(7):e2101004.

26. Argüello-García R, Vega-Arnaud M, Loredo-Rodríguez IJ, Mejía-Corona AM, Melgarejo-Trejo E, Espinoza-Contreras EA. Activity of Thioallyl Compounds From Garlic Against Giardia duodenalis Trophozoites and in Experimental Giardiasis. Front. Cell. Infect. Microbiol. 2018;(1):1-18.

27. Rivlin RS. Historical Perspective on the Use of Garlic. The Journal of Nutrition. 2001;131(3):951-954.

28. Alkreathy H, Damanhouri ZA, Ahmed N, Slevin M, Ali SS, Osman A-MM. Aged garlic extract protects against doxorubicin-induced cardiotoxicity in rats. Food Chem. Toxicol. 2010;48(1):951-956.

29. Corrêa AD, Siqueira-Batista R, Quintas LEM. Medicinal plants. From cultivation to therapy. 8ª ed. Petrópolis: Vozes, 2011. Portuguese.

30. Tesfaye A. Revealing the Therapeutic Uses of Garlic (Allium sativum) and Its Potential for Drug Discovery. The Scientific World Journal. 202; 2021(1):1-7.

31. Mikaili P, Maadirad S, Moloudizargari M, Aghajanshakeri S, Sarahroodi S. Therapeutic uses and pharmacological properties of garlic, shallot, and their biologically active compounds. Iran J Basic Med Sci. 2013 Oct;16(10):1031-48.

32. Jeremic JN, Jakovljevic VL, Zivkovic VI, Srejovic IM, Bradic JV, Milosavljevic IM et al. Garlic Derived Diallyl Trisulfide in Experimental Metabolic Syndrome: Metabolic Effects and Cardioprotective Role. Int. J. Mol. Sci. 2020;21(23):9100.

33. Naji KM, Al-Shaibani ES, Alhadi FA, Al-Soudi SA, D'souza MR. Hepatoprotective and antioxidant effects of single clove garlic against CCl4-induced hepatic damage in rabbits. Complementary and Alternative Medicine. 2020;17(411):1-12.

34. Perez-Ortiz JM, Galan-Moya EM, de la Cruz-Morcillo MA, Rodriguez JF, Gracia I, Garcia MT et al. Cost Effective Use of a Thiosulfinate-Enriched Allium sativum Extract in Combination with Chemotherapy in Colon Cancer. Int. J. Mol. Sci. 2020;21(8):2766.

35. Jiang Z, Chen H, Li M, Wang W, Long F, Fan C. Garlic consumption and colorectal cancer risk in US adults: a large prospective cohort study. Front. Nutr. 2023;10(1):1-12.

36. Yi LV, Kwok-Fai SO, Nai-Kei WONG, Jia XIAO. Anti-cancer activities of S-allylmercaptocysteine from aged garlic. Chinese Journal of Natural Medicines. 2019;17(1):43-49.

37. Moreira TR, Bueno ML. Giardíase. In: Siqueira-Batista R, Gomes AP, Silva-Santos S, Santana LA. Parasitology: fundamentals and clinical practice. Rio de Janeiro: Guanabara Koogan, 2020. Portuguese.

38. Hamad RS. Rutin, a Flavonoid Compound Derived from Garlic, as a Potential Immunomodulatory and Anti-Inflammatory Agent against Murine Schistosomiasis mansoni. Nutrients. 2023;15(5):1206.

UNDER PEER REVIEW

39. Torres KAM, Lima SMRR, Torres LMB, Gamberini MT, Silva Junior PI. Garlic: analternative treatment for group B Streptococcus. Microbiol Spectr. 2021;9(3):e00170-21.

40. Pârvu M, Moţ CA, Pârvu AE, Mircea C, Stoeber L, Roşca-Casian O, Ţigu AB. Allium sativum Extract Chemical Composition, Antioxidant Activity and Antifungal Effect against Meyerozyma guilliermondii and Rhodotorula mucilaginosa Causing Onychomycosis. Molecules. 2019;24(21):3958.

41. Schier C, Gruhlke MCH, Reucher G, Slusarenko AJ, Rink L. Combating Black Fungus: Using Allicin as a Potent Antifungal Agent against Mucorales. Int. J. Mol. Sci. 2023; 24(24):17519.

42. Nasr AY. The impact of aged garlic extract on adriamycin-induced testicular changes in adult male Wistar rats. Acta Histochemica. 2017;26(6):648-662.

43. Jafari F, Khalilzadeh S, Nejatbakhsh F. Therapeutic effects of garlic (Allium sativum) on female reproductive system: A systematic review. Heliyon. 2023;12(9):e22555.

44. Saleh HA, Abdel El-Aziz GS, Mustafa HN, Saleh AHA, Mal AO, Deifalla AHS, Aburas M. Protective effect of garlic extract against maternal and foetal cerebellar damage induced by lead administration during pregnancy in rats. Folia Morphol (Warsz). 2018;77(1):1-15. DOI: 10.5603/FM.a2017.0063.

45. Sánchez-Gloria JL, Martínez-Olivares CE, Rojas-Morales P, Hernández-Pando R, Carbó R, Rubio-Gayosso I et al. Anti-Inflammatory Effect of Allicin Associated with Fibrosis in Pulmonary Arterial Hypertension. Int. J. Mol. Sci. 2021;22(16):8600.

46. Souza RG. Therapeutic effect of Allium sativum (garlic) on human health. 2019. 24 f. Monograph (Bachelor of Pharmacy) – Apparecido dos Santos Central Plateau University Center, Gama, Federal District, 2019. Portuguese.

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