

Garlic as a medicine throughout the ages (Review)

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Received January 9, 2025; Accepted March 7, 2025

DOI: 10.3892/wasj.2025.337

Abstract. Garlic (*Allium sativum*) has been integral to human culture and medicine for >5,000 years, serving as both a culinary staple and therapeutic agent. The present review discusses the ethnobotanical and medicinal significance of garlic across civilizations, from its origins in Central Asia to its global dissemination through trade and cultural exchange. Ancient cultures, including those of Egypt, Greece, China, Persia, Sumer and India, recognized its antimicrobial, cardiovascular and immune-enhancing properties, integrating garlic into diets, rituals and medicinal practices. Specific preparation methods, such as fermentation and aging, contributed to the therapeutic versatility of garlic, as observed in black garlic traditions. Moreover, the symbolic role of the plant in religious and spiritual practices highlights its multifaceted significance. Contemporary scientific research validates a number of historical claims, emphasizing the relevance of garlic in modern medicine. By discussing its historical applications and cultural interpretations, the present review aimed to provide a comprehensive understanding of garlic as a bridge between ancient knowledge and modern science.

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Key words: garlic, *Allium sativum*, ethnobotany, medicinal uses, ancient traditions, black garlic

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1. Introduction: Historical context

Garlic (*Allium sativum*) is one of the earliest domesticated plants, with evidence of its use dating back >5,000 years (1,2). It originated in Central Asia, particularly in regions such as the Tien Shan and Pamir mountain ranges, before spreading through trade networks such as the Silk Road and the Columbian Exchange (1,3). Its adaptability to diverse climates and its dual role as a food and medicine facilitated its integration into various cultures globally.

By 3000 BCE, garlic had become a dietary and medicinal staple in ancient Egypt, where it was valued for enhancing physical endurance and offered as a sacred gift to deities (4). At ~2000 BCE, it was recorded in Indian Ayurvedic texts and Chinese medicinal treatises, focusing on its therapeutic uses in treating respiratory ailments and digestive disorders (5). Ancient Greece and Rome embraced garlic as well, using it to bolster athletic performance and as a battlefield remedy (6). Roman soldiers introduced garlic to Northern Europe and the British Isles.

Garlic reached Africa around the 1st century CE, where it became integral to local medicinal practices, particularly for respiratory and infectious diseases (7). The Columbian Exchange in the 1500s marked its introduction to the Americas, where indigenous populations integrated it into their pharmacopoeias (3,8).

Through the middle Ages and Renaissance, garlic retained its reputation as a protective agent against epidemics and a symbol of health and resilience (9). Modern research continues to validate the historical uses of garlic, emphasizing its antimicrobial, cardiovascular and immune-supporting properties and its importance to present-time medicine (10,11).

2. Ethnobotanical studies

Ethnobotany explores the dynamic associations between plants and human societies, with the emphasis on their cultural, medicinal, and economic significance. Garlic (*Allium sativum*), is among the earliest domesticated plants, and exemplifies these associations, demonstrating how a

single species has become a cornerstone of human history and tradition (12). The ethnobotanical significance of garlic dates back >5,000 years to Central Asia, where it was first cultivated for its resilience and utility (1). Archaeological findings in Bronze Age Uzbekistan demonstrate its integration into early agricultural and medicinal practices (1).

Ancient Egyptian texts document the dual role of garlic as a food and sacred offering, consumed by pyramid builders to enhance strength and endurance, and used in rituals to symbolize protection and vitality (4). It is of interest to note that cultures who developed without contact with one another came to similar conclusions about the efficacy of garlic. For example, by 2000 BCE, garlic appeared in Indian Ayurvedic treatises as a 'Rasayana' (rejuvenator), prescribed for digestive health and immunity (5). Simultaneously, in China, garlic was utilized to treat stomach ailments and as a natural antibiotic, reflecting its medicinal similarity (13). Trade had contributed to the use of garlic in the old world. The spread of garlic via the Silk Road embedded it into the traditions of Greece and Rome (1,6). Greek athletes consumed it to bolster strength, while Roman soldiers carried it across the empire, planting it in newly conquered territories. In sub-Saharan Africa, garlic became a staple in traditional medicine by the 1st century CE, used for respiratory and infectious diseases (7). During the Columbian Exchange, garlic was introduced to the Americas, where it was adapted into indigenous pharmacopoeias for treating wounds and digestive ailments (3,8).

Contemporary ethnobotanical research highlights the continued relevance of garlic. In Ethiopia, garlic remains central to treating respiratory issues and livestock diseases (14). Urban ethnobotany reveals its adaptability in informal health networks; for example, in Lagos, Nigeria, garlic is an accessible remedy for common illnesses (15). Interdisciplinary methodologies, including phylogenetic and computational analyses, have deepened our understanding of garlic's cultural significance. Genetic studies trace its selective breeding for medicinal traits, while machine learning models link traditional garlic preparations to proven antimicrobial and cardio protective effects (16).

3. An overview of botany

Garlic (*Allium sativum* L.) is a widely recognized plant belonging to the family Amaryllidaceae, notable for its extensive use in both culinary and medicinal contexts across various cultures globally (17). As a species, garlic is distinguished within the genus *Allium*, a group that encompasses other important plants such as onions, leeks and chives, all well-known for their characteristic flavors and health benefits. Garlic (*Allium sativum* L.), is a bulbous plant (18). Its characteristic underground bulb, composed of individual cloves and vegetative propagation distinguish it from numerous other crops. This asexual reproduction has resulted in limited genetic variability, though significant diversity persists in traditional landraces across Central Asia, the Mediterranean and South Asia (1). Of note, two primary ecotypes dominate cultivation: Softneck (*A. sativum* var. *sativum*), adapted to warmer climates, and hardneck (*A. sativum* var. *ophioscorodon*), thriving in cooler regions (19). These differ in clove arrangement, flavor and storage capacity. Ecologically, garlic is resilient, thriving

in poor soils and arid conditions, rendering it a critical crop for food security in regions impacted by climate change. Phytochemically, garlic is rich in sulfur-containing compounds such as allicin, which contributes to its antimicrobial, antioxidant, and cardioprotective properties (17,20).

4. Garlic in ancient cultures

Extensive research in archaeology and ethnobotany emphasizes the dual role of garlic in ancient societies, as both a medicinal agent and a component of ritual and spiritual practices (21). In this section, the historical path of garlic across time, geography and cultures is discussed.

Garlic names in history. The pungent aroma of garlic and its notable medicinal properties have inspired various aliases across cultures. In ancient Egypt, garlic was sometimes termed as the 'plant of immortality', a testament to its sacred status and its use in rituals, mummification and as nourishment for laborers building the pyramids (4). Garlic was known as 'a snake grass' in Greece, due to its effect against snake-bites (6). In Roman culture, garlic earned the name 'stinking rose', highlighting its pungent smell, which was both admired and disliked, yet recognized for its health benefits (22). In traditional Chinese medicine, garlic was referred to as 'the divine herb', stressing its extensive use in treating ailments and promoting longevity (13). In Jewish tradition, garlic was named 'the bride's food' for its supposed aphrodisiac properties and its role in marital customs (23). Similarly, in parts of Africa, garlic was known as 'the protector' for its association with warding off evil spirits and safeguarding health (7).

Archaeological evidence of the use of garlic in antiquity. Archaeological discoveries have provided substantial evidence of the presence and utilization of garlic in ancient civilizations. Clay models of garlic bulbs were found in the tomb of El Mahasna, dating back to ~3700 BCE (4). Additionally, well-preserved garlic cloves were discovered in the tomb of Tutankhamun (c. 1323 BCE), suggesting its use in burial practices. At the Late Bronze Age site of Akrotiri on Thera (modern-day Santorini), archaeologists uncovered garlic remains (24). Residue analysis of 4,000-year-old pottery from Uzbekistan revealed traces of garlic, indicating its use in Central Asian diets during that period (1). Archaeological excavations at Ein Gedi, a site near the Dead Sea, Israel, revealed evidence of garlic cultivation and use in antiquity (25).

Garlic in ancient Egypt. The ancient Egyptians pioneered in the cultivation of garlic, recognizing its value as an important plant. The Ebers Papyrus, one of the oldest and most comprehensive medical texts from ancient Egypt, stresses the significance of garlic in their medicinal repertoire, highlighting its application in treating ailments and its preservative qualities in the mummification process (4,26). Moreover, the presence of garlic in Egyptian pyramids and its mention in ancient Greek temples illustrate its historical and cultural significance. It was buried with the dead to accompany them in the afterlife and used as an offering to the gods, symbolizing protection and vitality. The qualities of garlic according to the ancient Egyptians were as follows: It clears flatulence,

improves digestion, used as a laxative, shrinks hemorrhoids, provides energy and vitality, and is believed to free the body of 'bad spirits' (26).

Garlic in ancient Sumer. The Sumerian culture, dating back to 4000 BC, respected garlic not merely as a food, but as an integral part of their health and spiritual practices (5,27). This ancient society, pioneers in the development of writing, recorded the uses of garlic on clay tablets, revealing a deep understanding of its medicinal properties. The Sumerians recognized the ability of garlic to enhance physical strength and combat diseases, making it a common prescription for maintaining vitality and treating ailments (28). Furthermore, garlic held a sacred place in Sumerian rituals, believed to possess protective qualities against negative forces. It was used in ceremonies to cleanse and safeguard sacred spaces.

Garlic in ancient Persia. In ancient Persia (modern-day Iran), garlic (*Allium sativum*) was highly valued for its culinary, medicinal and cultural significance (29). Its presence in the traditional Nowruz celebration, where cloves of garlic were featured in the *Haft-sin* table to symbolize health and medicine, highlights its deep-rooted cultural importance. Medicinally, garlic was an integral part of Iranian traditional medicine, where it was prescribed for respiratory infections, digestive issues, and as a general health tonic due to its antimicrobial and anti-inflammatory properties (30). Historical accounts also reveal that garlic was used to treat cutaneous leishmaniasis, a prevalent skin disease, through topical application, reflecting its role in dermatological treatments. Moreover, garlic held significant economic value during the Achaemenid Empire; records from the reign of King Cyrus (559-530 BCE) document a royal purchase of 395,000 bunches of garlic, emphasizing its widespread cultivation and importance (29).

Garlic in ancient Greece. In ancient Greek culture, garlic (*Allium sativum*) was not only a staple in the culinary world, but also a key component of medicinal practices and health care (6). The reputation of garlic in ancient Greece is well documented, notably by leaders, such as Hippocrates, who is often called the 'Father of Medicine'. He prescribed garlic for a wide range of conditions, including respiratory issues, poor digestion and general fatigue. Its antimicrobial and anti-inflammatory properties, as understood today, lend credence to its use for treating infections and reducing symptoms associated with respiratory conditions (31,32). The Greeks used garlic as a remedy to cleanse the arteries and to improve heart health. Modern research supports this ancient practice, demonstrating that garlic can indeed have beneficial effects on heart health by lowering blood pressure, reducing cholesterol levels and preventing atherosclerosis (10).

Garlic in ancient China and Japan. Garlic holds a place of honor in Chinese history, dating back to 2700 BC (33). The Chinese admired garlic for its ability to balance the energies of the body, enhance digestive health, and act as a powerful antibiotic for treating various ailments such as respiratory conditions and infections, reflecting an early understanding of its broad-spectrum antimicrobial properties (13,34).

The philosophical base of Taoism and Confucianism also highlighted the role of garlic in promoting longevity and vitality, integrating it into daily life and royal prescriptions alike (35). This holistic approach demonstrates the sophisticated grasp that ancient China had of natural remedies, where garlic was both a symbol of strength and a practical tool for health maintenance. It is assumed that garlic was introduced in Japan 2,000 years later than in China; however, it was part of the daily diet and was used as a medicinal plant in the same manner (36).

Garlic in ancient Korea. Garlic also played a crucial role in ancient Korea as a key medicinal plant (37). Korean folklore tells the story of a bear and a tiger who wished to become human. They were told to consume only garlic and mugwort for 100 days while staying in a cave. The bear succeeded and transformed into a woman, eventually giving birth to Dangun, the legendary founder of Korea (38). This myth highlights the symbolic association of garlic with transformation, vitality and health. In traditional Korean medicine, garlic was used to treat digestive issues, respiratory ailments and fatigue. Its antimicrobial properties rendered it a critical remedy for infections, aligning with the principles of Korean traditional medicine (39). Modern research confirms the probiotic-enhancing properties of garlic in fermented foods, emphasizing its enduring nutritional and therapeutic relevance (40).

Garlic in ancient Africa. Garlic was highly valued in various parts of ancient Africa for its medicinal and culinary uses. In ancient Ethiopia, garlic was often used as a remedy for respiratory issues, infections, and to boost physical strength (14). Traditional Ethiopian healers utilized garlic for its antimicrobial and antifungal properties, which were believed to protect both physical and spiritual well-being (41).

Beyond Ethiopia and Egypt, garlic was integrated into herbal concoctions across the continent, used in the treatment of digestive disorders, skin infections and fever. In African spiritual practices, garlic was often employed to ward off evil spirits and negative forces (42).

Garlic in ancient America. In ancient America, garlic was utilized by several indigenous cultures, although not as extensively as in the Old World (8,43). Some Native American tribes, such as the Cherokee, used wild garlic as part of their traditional medicine to treat respiratory ailments, digestive issues, and for wound care (44). Garlic was also applied as an antiseptic for infections and to help symptoms of coughs and colds.

In addition to its medicinal applications, garlic was valued for its insect-repelling properties, serving as a practical tool in agricultural practices and protecting stored food supplies (45). The aromatic plant also featured in spiritual practices among some tribes, where it was believed to possess protective qualities against harm and malevolent influences (8).

Garlic in ancient India. In ancient India, the tradition of garlic is integrated into Ayurvedic medicine, where it was used as a 'Rasayana' or rejuvenator (5). Its applications were diverse, ranging from enhancing physical strength and immunity to treating infections and digestive disorders (46). Ayurvedic

Table I. Medicinal uses of garlic and ancient countries/regions.

Medicinal uses of garlic	Countries/regions in ancient times
Infection treatments	China, India, Babylon, Persia
Fatigue and endurance enhancement	Egypt, Greece, Babylon, Persia
Stomach and digestive disorders	India, China, Egypt, Persia
Respiratory issues	China, Greece, India, Ethiopia
Cardiovascular health	Greece, Rome, Persia
Parasite elimination	India, Babylon, Egypt, Persia
Wound care and skin conditions	Babylon, Egypt, Persia
Spiritual protection	Jewish traditions, Africa, Persia
Aphrodisiac properties	Jewish traditions
Fermentation and immunity enhancement	Korea
Antimicrobial properties (plague prevention)	Europe (Christian communities, 'Four Thieves Vinegar')

practitioners valued garlic for its five 'tastes' (sweet, sour, salty, bitter and pungent), believing it could harmonize the fundamental elements of the body and promote internal balance (47). Garlic was also part of the spiritual and dietary practices of ancient India, used in rituals and as a culinary ingredient to purify food and prevent disease.

Garlic in the medieval and Renaissance eras. During the medieval and Renaissance eras, the reputation of garlic as a potent protective and healing agent flourished, particularly in the context of plagues and widespread epidemics (9,48). Historical records and medical treatises from these times frequently mention garlic as a preventative measure and a remedy for various ailments (49). For instance, garlic was a common ingredient in the 'Four Thieves Vinegar', a concoction believed to protect against the plague (50). The lore suggests that grave robbers who anointed themselves with this vinegar, which contained garlic among other herbs, managed to evade the Black Death, highlighting the supposed antiseptic and disease-preventing qualities of garlic (51). Its use extended beyond physical healing, serving as a symbolic shield against evil forces and misfortune.

A summary of the medicinal uses of garlic in ancient cultures according to region is presented in Table I. The contribution of each culture is elaborated in Table II.

5. Black garlic and other methods of using garlic in antiquity

Throughout history, garlic has been prepared and utilized in diverse forms, fresh, cooked, crushed and infused in liquids such as wine, with each method enhancing its culinary and many medicinal properties, such as cardiovascular effects (52). In ancient Egypt, garlic was consumed raw by laborers to boost strength and endurance and was cooked to mellow its pungency for inclusion in daily meals (4). The Greeks and Romans often crushed garlic to release its allicin compound, believed to possess significant health benefits, and mixed it with wine to create medicinal tinctures for treating digestive disorders and infections (6,21). In medieval Europe, garlic-infused wine became a common remedy for various illnesses, capitalizing on the renowned antimicrobial properties of garlic (9).

Aged garlic, including what is currently known as black garlic, recognized for its milder aroma and enhanced medicinal properties, also played a role in antiquity, by using traditional preservation methods (53). While the contemporary process of producing black garlic involves fermenting garlic under controlled heat and humidity for several weeks, similar results were likely achieved in ancient times through natural aging practices. For instance, in Korea, fermentation of garlic in traditional practices produced a form of aged garlic with sweet, umami-rich flavors, used in medicinal preparations to boost immunity and vitality (40,54). In ancient Egypt and Greece, garlic stored for extended periods would naturally age, intensifying its medicinal properties. The aging process likely increased the concentration of sulfur compounds, enhancing its antioxidant and anti-inflammatory effects (55). Modern research supports this, demonstrating that aged garlic extract (AGE) and black garlic provided increased health benefits, including cardiovascular protection and immune support (56). A comparison of the traditional processing methods is presented in Table III.

6. Garlic and religions

Garlic has held a unique place in the religious and cultural practices of Islamic, Jewish, Christian and Buddhist communities throughout history (57). While its significance varies among these traditions, the association of garlic with health, spirituality and daily life emphasize its enduring relevance.

Garlic in Islamic tradition. In Islamic tradition, garlic is acknowledged in the Hadith (sayings of the Prophet Muhammad) and is mentioned in relation to etiquette and religious practices (58). The pungent odor of garlic led Prophet Muhammad to discourage its consumption before attending congregational prayers in mosques. In a well-documented Hadith, the Prophet said: 'Whoever has eaten garlic or onion should keep away from us or our mosque, and stay in his house' (59). Despite this restriction, garlic was widely used in Islamic medicinal practices. Influential Islamic scholars and physicians, such as Ibn Sina (Avicenna), noted the therapeutic properties of garlic in their medical treatises (60). Garlic was

Table II. Historical uses of garlic in different cultures

Culture	Historical use of garlic
Ancient Egypt	Strengthening workers, offering to gods, treating ailments, mummification preservative
Ancient Greece	Improving athletic performance, treating respiratory ailments, cardiovascular health
Ancient Sumer	Enhancing physical strength, protection against malevolent forces, spiritual practices
Ancient China	Balancing body energies, digestive health, broad-spectrum antibiotic
Ancient India	Ayurvedic Rasayana, harmonizing body elements, infection treatment
Ancient Korea	Transformation in folklore, treating digestive issues, health-promoting in fermented food
Ancient Africa	Treating respiratory issues, infections, spiritual protection, component of herbal remedies
Ancient America	Treating respiratory ailments, digestive issues, antiseptic for wounds, pest repellent

Table III. Comparison of garlic traditional processing methods.

Garlic type	Processing method	Key bioactive compounds and chemical structures	Health benefits	Bioavailability (scale 1-5) ^a	Author(s), year of publication	(Refs.)
Fresh garlic	Raw cloves, minimal processing	Allicin (C ₆ H ₁₀ OS ₂), sulfur compounds [diallyl disulfide (C ₆ H ₁₀ S ₂)]	Antimicrobial, immune-boosting, cardioprotective	****	Tesfaye, 2021	(31)
Aged garlic extract (AGE)	Aged for 12-20 months in ethanol solution	S-allyl cysteine (C ₆ H ₁₁ NO ₂ S), polyphenols (quercetin-C ₁₅ H ₁₀ O ₇)	Antioxidant, neuroprotective, cardiovascular support	*****	Rivlin, 2001	(2)
Black garlic	Fermented at high humidity and heat for weeks	Amadori compounds (fructosyl-arginine-C ₁₂ H ₂₂ N ₄ O ₆), polyphenols	Anti-inflammatory, gut health, antioxidant	***	Verma <i>et al</i> , 2023	(16)

^aThe asterisks (*) correspond to the scale of 1-5 with a single asterisk corresponding to 1 point and five asterisks corresponding to 5 points, respectively.

prescribed for various ailments, including infections, digestive issues and parasitic infestations (60).

Garlic in Jewish tradition. In Jewish tradition, garlic holds marked historical and cultural significance. The Torah references garlic indirectly in the context of the Israelites longing for the foods they consumed in Egypt, which included garlic, as described in *Numbers 11:5* (61). The Talmud, a central text of Rabbinic Judaism, provides detailed insight into the medicinal and dietary roles of garlic (23). It lists garlic among foods consumed for their health benefits, particularly on Friday evenings to enhance vitality. The sages of the Talmud attributed five key properties to garlic: It satiates, warms the body, brightens the face, increases fertility, and combats intestinal parasites (62). Additionally, garlic was considered to have aphrodisiac properties and was associated with marital harmony. The importance garlic extended beyond physical health. In Jewish folklore, it was believed to ward off the 'evil eye' and protect against evil spirits, signifying its dual role as both a physical remedy and a spiritual safeguard (63).

Garlic in Christian tradition. In Christian tradition, the role of garlic is less explicitly documented in religious texts; however, it is prevalent in the folk practices and medicinal traditions of Christian communities (64). During the Middle Ages, garlic was widely regarded as a protective agent against evil forces and diseases. In some Christian rituals, garlic was used as a symbol of warding off evil spirits (9). Monastic medicine, practiced by Christian monks in the Middle Ages, also featured garlic prominently. Monasteries served as centers of learning and healing, where herbal remedies were prepared. Garlic was a staple in these remedies, used to treat infections, improve digestion and boost immunity (65).

Garlic in Buddhism. In various Buddhist traditions, garlic is among the 'Five Pungent Spices', along with onions, chives, leeks and shallots, that practitioners are advised to avoid (66). This guidance is rooted in ancient texts and observed for several reasons. The *Śūraṅgama Sūtra*, a significant Mahayana Buddhist text, suggests that consuming these pungent vegetables can adversely affect meditation practice (67). In the *Vinaya Pitaka*, the monastic code for Theravada Buddhists,

there are specific rules regarding the consumption of garlic. Monks and nuns are generally advised against eating garlic due to its strong odor, which can be offensive and may hinder social interactions within the monastic community (68). However, exceptions are made when garlic is used for medicinal purposes.

7. Illustrations of garlic in ancient manuscripts

Illustrations of garlic and its cultivation frequently appear in ancient manuscripts, reflecting its significance in early agricultural and medicinal traditions (69). In medieval herbals and botanical treatises, garlic is often depicted with distinctive bulb clusters, elongated leaves, and flowering stems, emphasizing its easily recognizable morphology. Manuscripts such as the *Tacuinum Sanitatis*, a 14th-century medieval health guide, vividly portray garlic being harvested and prepared, highlighting its role in promoting health and vitality (70).

Similarly, ancient Islamic and Greco-Roman texts include detailed drawings of garlic, often accompanied by instructions on its cultivation, medicinal uses, and storage methods (71). For example, an Islamic manuscript by Ibn al-Baitar, a 13th-century Andalusian botanist and physician, contains intricate depictions of garlic, alongside detailed descriptions of its therapeutic applications in treating fevers, infections and digestive disorders (72).

One of the earliest and most influential references to garlic comes from *De Materia Medica*, a seminal work by Dioscorides, a renowned Greek physician and pharmacologist of the 1st century CE (73). This five-volume treatise, a cornerstone of ancient medical knowledge, described garlic (*Allium sativum*) as a versatile remedy for various ailments. Dioscorides highlighted garlic's ability to treat respiratory issues, digestive problems, and parasitic infections. In addition to its internal applications, garlic was prescribed for external use, such as a poultice for skin conditions and wounds (74).

8. Garlic and superstitions

Garlic has been steeped in superstitions and symbolic meanings across numerous ancient cultures (75). In ancient Egypt, garlic held significant spiritual and protective connotations. Cloves of garlic were discovered in the tomb of Tutankhamun (c. 1323 BCE), suggesting its use as a safeguard for the afterlife (4). It was believed that the strong aroma of garlic could repel evil spirits and protect both the living and the dead. Similarly, in Greek and Roman traditions, garlic was considered to ward off evil entities and was commonly used in rituals for protection (6,76).

In Jewish folklore, garlic was revered for its protective properties against the 'evil eye' (63). Talmudic texts describe garlic as gladdening the heart and eliminating jealousy, making it a powerful symbol of harmony and protection in households. In parts of Africa, garlic was hung in doorways or worn as necklaces to repel witches and evil spirits (42). In ancient India and China, garlic was similarly valued for its ability to repel demons and disease, often burned as incense or placed in strategic locations within homes (13,77).

9. Garlic and the effect of smell

The pungent and often overpowering smell of garlic has profoundly influenced its use and perception across cultures and eras (78). While its odor was celebrated for its association with strength and vitality, it also evoked aversion in certain contexts. In ancient Egypt, the strong aroma of garlic was admired, symbolizing its potency as both a food and a sacred offering, particularly for gods and the deceased (4). In Greco-Roman cultures, the smell of garlic was both lauded and criticized; while soldiers consumed it for its perceived ability to achieve bravery and endurance, others regarded its odor as unrefined (6,79).

In Islamic tradition, the smell of garlic was deemed disruptive in communal worship, leading to a recommendation in the Hadith that garlic not be consumed before attending mosque prayers (58). Despite this, the odor of garlic was often linked to its medicinal efficacy, as traditional practitioners believed its pungency reflected its power to expel toxins and purify the body (80).

10. Synopsis of the value of garlic

The journey of garlic through history as a medicinal and cultural plant is very significant. From the Sumerians, who recognized its strength-enhancing properties, to the Egyptians, who integrated it into both daily health practices and sacred rituals, garlic emerged as a cornerstone of ancient medicine. Its role in Greek and Roman traditions further highlights its importance; Hippocrates prescribed garlic for respiratory and digestive disorder, while Roman soldiers utilized it to treat battlefield wounds and enhance physical endurance.

In the East, garlic played a dual role as both a culinary and medicinal staple. In ancient China, it was used for balancing the energies of the body and as a natural antimicrobial agent, aligning with the principles of traditional Chinese medicine. Similarly, Ayurvedic practitioners in India used garlic to harmonize bodily elements and promote vitality.

It is interesting to note that these ancient applications reflect a sophisticated understanding of the health benefits of garlic, many of which are supported by modern scientific discoveries (81). Studies highlight the pharmacological potential of garlic compounds, such as allicin and sulfur containing compounds other than allicin, which possess antioxidant, anti-inflammatory and lipid-lowering effects (82,83).

The latest scientific discovering emphasizes garlic relevance not only as a historical remedy but also as a critical component of modern health strategies: Research has confirmed that allicin, the sulfur-containing compound in garlic, exhibits potent antimicrobial, antiviral, and antifungal properties, aligning with its historical use in preventing infections and treating wounds (20). Furthermore, AGE has been shown to improve cardiovascular health by reducing blood pressure and cholesterol levels, reinforcing its traditional role in Korean, Japanese and Chinese medicine for circulatory support (10). Emerging studies also highlight the neuroprotective potential of garlic, with evidence suggesting that its bioactive compounds may help mitigate cognitive decline and neurodegenerative diseases such as Alzheimer's disease (84). Additionally, research

into garlic's immunomodulatory effects demonstrates its ability to enhance immune function, a property long valued in ancient healing systems (85). These modern findings confirm that garlic remains a potent natural remedy, bridging the gap between historical wisdom and contemporary medical science.

Bridging disciplines: An interdisciplinary approach to garlic research

i) Ethnobotany: Historical and cultural insights. The deep-rooted presence of garlic in ancient Egyptian, Greek, Chinese and Indian medicine highlights its cross-cultural medicinal value, much of which modern pharmacology now validates. Traditional systems, such as Ayurveda and traditional Chinese medicine recognized its benefits for digestion, immunity and infection control, shaping herbal medicine today (31). Research in urban Africa, Latin America and Asia has revealed its continued role in self-care and informal health networks (7). Computational models further illustrate how selective breeding has preserved its medicinal traits over time (16).

ii) Pharmacology: Bioactive compounds and modern validation. The efficacy of garlic is now substantiated by its bioactive compounds, allicin, diallyl disulfide and S-allyl cysteine, which exhibit antimicrobial, antioxidant and anti-inflammatory properties (20). Recent research confirms its potential in managing chronic diseases, including hypertension, diabetes, and neurodegenerative disorders such as Alzheimer's disease (34). Ongoing efforts in nutraceutical development aim to enhance the bioavailability and therapeutic stability of garlic.

iii) Agriculture: Sustainability and climate resilience. The adaptability of garlic to arid conditions and poor soils renders it a critical crop for food security amid climate change (85). Agricultural research focuses on improving yields through organic farming, soil microbiome studies, and genetic conservation. Selective breeding programs also aim to boost disease resistance, ensuring a stable global supply.

By integrating ethnobotany, pharmacology and agriculture, garlic research continues to bridge historical knowledge with modern science, unlocking new applications for health and sustainability.

11. Future research directions: Building on the historical medicinal uses of garlic

Garlic has been respected as a medicinal plant for >5,000 years, with its use documented in Egyptian, Mesopotamian, Indian, Chinese, Greek and Roman texts. Its historical applications for immunity, infection control, digestive health and vitality provide a strong foundation for future research. The continuity of the medicinal role of garlic suggests the need for scientific validation of traditional knowledge, leading to innovative therapeutic applications. Below are key future research directions based on historical evidence:

i) Standardizing garlic in modern medicine based on ancient practices. Ancient Egyptian and Roman sources describe garlic as a natural remedy for strength and endurance. Pyramid workers consumed it to boost stamina, while Roman soldiers

used it to recover from physical exertion and wounds (31). In the future, clinical trials are required to evaluate the role of garlic in improving exercise endurance, muscle recovery and wound healing. Studies on athletic performance, mitochondrial function, and post-exertion inflammation may confirm its traditional role (2).

ii) Investigating the role of garlic in digestive and metabolic health. Ayurveda and traditional Chinese medicine have emphasized the digestive and detoxifying effects of garlic, using it to balance bodily humors and eliminate intestinal parasites (34,46). In future research, the prebiotic and gut microbiome-modulating effects of garlic need to be further investigated. Investigating its effects on the gut flora, digestion and metabolic disorders (e.g., diabetes, obesity) could confirm its relevance in modern medicine (16).

iii) Expanding research on the antimicrobial and immune-boosting properties of garlic. Garlic was widely used in medieval Europe during plagues as a protection against disease, while ancient Indian and Chinese medicine employed it as an antimicrobial agent (20). Antibiotic-resistant bacteria and viral infections pose a significant challenge today. Thus, further studies are required to investigate the role of garlic as a natural antibiotic and to determine its application in pandemic preparedness, antimicrobial therapies and alternative medicine for infectious diseases (34).

iv) Understanding the neuroprotective and cognitive effects of garlic. Ancient Greek and Roman texts, including those of Hippocrates and Dioscorides, mentioned garlic as a remedy for mental clarity and cognitive well-being. Modern research suggests that garlic has neuroprotective properties; however, further research is required on its role in preventing cognitive decline, Alzheimer's disease and age-related neurological disorders (84).

v) Developing personalized garlic-based nutraceuticals. Ancient texts demonstrate that garlic preparations varied by region: Raw garlic in Egyptian and Greek medicine, aged garlic in Chinese medicine, and fermented garlic in Ayurvedic traditions. Personalized nutrition approaches could determine which garlic preparation is most effective for specific populations and conditions. Advances in genomics and metabolomics could guide customized garlic-based supplements.

vi) Sustainable cultivation and climate adaptation research. The resilience of garlic in arid climates and poor soils renders it an essential crop in regions ranging from Central Asia to the Mediterranean. Scientists need to explore genetic improvements for climate-resistant garlic varieties, particularly in the face of climate change and food security concerns (85).

In conclusion, the historical medicinal use of garlic provides a roadmap for future scientific exploration. Ancient ethnobotanical knowledge provides valuable insight that needs to be systematically tested in modern pharmacological and clinical settings. Through interdisciplinary research, garlic could transition from a traditional remedy to an integral part of modern health strategies, bridging the gap between history and science.

Acknowledgements

The author wishes to thank Mr. Roy Amram (The Academic College of Tel-Aviv Yaffo, Tel Aviv, Israel), whose organizational skills and analytical perspective helped structure the documentation process and enhance the accessibility of complex research findings.

Funding

No funding was received.

Availability of data and materials

Not applicable.

Authors' contributions

ZYB conceived and designed the study, performed the literature search, and wrote and edited the manuscript. The author has read and approved the final manuscript. Data authentication is not applicable.

Ethics approval and consent to participate

Not applicable.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests

Use of artificial intelligence tools

During the preparation of this work, AI tools were used to improve the readability and language of the manuscript or to generate images, and subsequently, the authors revised and edited the content produced by the AI tools as necessary, taking full responsibility for the ultimate content of the present manuscript.

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