Print ISSN: 0375-9237
Online ISSN: 2357-0350

EGYPTIAN JOURNAL OF BOTANY (EJBO)

Therapeutic, cosmetic, and agricultural applications of *Allium sativum* L. (garlic) and *Allium cepa* L. (onion): A review

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PUBLISHED BY
THE EGYPTIAN
BOTANICAL SOCIETY

Therapeutic, cosmetic, and agricultural applications of *Allium sativum* L. (garlic) and *Allium cepa* L. (onion): A review

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MINI REVIEW ARTICLE

Allium sativum L. (garlic) and *Allium cepa* L. (onion) have been significant herbs since ancient times, extensively utilized by various communities globally. Both plants offer a wide array of benefits and applications in medicine, cosmetics, and agriculture. They have proven to be effective in treating or preventing various conditions, including cancer, coronary heart disease, hypercholesterolemia, type 2 diabetes, obesity, and hypertension. Garlic and onion exhibit a range of medicinal properties. For instance, compounds such as allyl sulfide derivatives are known to be the main active components responsible for garlic's anticancer effects by inhibiting tumor cell growth and demonstrating chemopreventive properties. Regarding agricultural applications, *A. sativum* and *A. cepa* are known for their insecticidal, antifungal, and nematicidal properties, making them valuable as natural pesticides. Furthermore, garlic and onion are recognized for their anti-aging and anti-inflammatory characteristics, crucial in skincare treatments. This review aims to provide insights into the therapeutic, cosmetic, and agricultural uses of *Allium sativum* L. (garlic) and *Allium cepa* L. (onion), contributing to the advancement of knowledge to further optimize the beneficial utilization of both species through experiments, clinical studies, and industrial applications.

Keywords: *Allium sativum* L., *Allium cepa* L., Medicine, Beautifying, Agronomy

ARTICLE HISTORY

Submitted: June 28, 2024
Accepted: November 01, 2024

CORRESPONDENCE TO

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DOI: 10.21608/ejbo.2024.300022.2901

EDITED BY: W. Amer

INTRODUCTION

Plants have long served as the most important bioresource for human survival, with humans heavily relying on them for nutrition and medicine. In addition, plants have been utilized in the production of timber, fuel, pesticides, and cosmetic products. According to the World Health Organization (WHO), approximately 65% of people worldwide use plants as their primary means of treating health issues (Deka et al., 2022). Historically, the use of plants in treating various illnesses dates to around 2600 BCE. It has been noted that in Mesopotamia, approximately 1000 compounds derived from plants were employed, including oils from *Cupressus sempervirens*, *Cammiphora* spp., *Cedrus* spp., *Glycyrrhiza glabra*, and *Papaver somniferum* (Deka et al., 2022). The consumption of garlic and onion as both food and medicine in ancient civilizations like Sumeria, Mesopotamia, and ancient Egypt is well-documented. The Yale Babylonian Tablets (1600–1700 BCE) recorded the use of these plants in Mesopotamia's diet (Bottéro, 1987). Garlic was rigorously used by the Sumerians as a healing agent (Petrovska and Cekovska, 2010). There are 22 documented garlic-based medicine recipes in the Codex Elbers (1500 BCE) to treat ailments such as headaches, throat issues, and asthenia (Sharifi-Rad et al., 2016).

The total number of plant species in the ecosystem is estimated to be around 374,000. Among these, the majority are angiosperms, with 295,383 species, followed by pteridophytes (10,560), lycopods (1,290), and gymnosperms (1,079), while the rest consist of bryophytes and algae (Christenhusz & Byng, 2016). The diversity of plants has led to the discovery of numerous secondary metabolites with various biological effects, such as antibacterial, antifungal, and antiviral properties (Soliman et al., 2022; Nessma et al., 2022; Metwally et al., 2022). These findings serve as the scientific foundation for the use of herbs in traditional medicine by different communities since ancient times (Hussein & El-Anssary, 2018).

Allium is one of the largest monocotyledon genera in the Amaryllidaceae family, encompassing over 900 species (Herden et al., 2016). Despite being a biennial plant, *Allium cepa* is often cultivated as an annual, reaching a height of up to 100 cm (Wiczkowski, 2018). *A. cepa* is also known by various common or alternative names, including Egyptian onion, common onion, shallot, among others. Numerous ancient texts mention this valuable spice, establishing it as one of the oldest vegetables (Teshika et al., 2019). *Allium sativum* is a perennial herb grown as a biennial or an annual, reaching a height of 60 cm (Wiczkowski, 2011). It is the most economically significant species in the *Allium* genus, a globally important vegetable crop, and the second

most consumed bulb after the onion (Brewster, 2008; Petropoulus et al., 2018). This highly aromatic herbaceous spice is one of the oldest known herbs, traditionally used since ancient times and mentioned in writings from ancient Egypt, Greece, India, and China (Kuete, 2017; El-Saber Batiha et al., 2020).

The investigation of herbs for their potential and biological properties has garnered significant attention from researchers worldwide. Interestingly, *Allium sativum* L. (garlic) and *Allium cepa* L. (onion) have gained a reputation as potent preventive and therapeutic medicinal agents in many cultures over the centuries (Suleria et al., 2015). Moreover, their good storage and transport endurance significantly impact vegetable production, leading to wider trade compared to other vegetables (Wiczkowski, 2011). This review aims to provide insights into the therapeutic, cosmetic, and agricultural applications of *Allium sativum* L. (garlic) and *Allium cepa* L. (onion). Literature from various databases such as Web of Science, Scopus, PubMed, and Google Scholar have been selected, illustrating the utilization of *A. sativum* and *A. cepa* in medicine, cosmetics, and agriculture from 1987 to 2024. This compilation is essential for advancing knowledge to optimize the beneficial use of both species through experiments, clinical studies, and industrial applications.

Therapeutic application

Garlic and onions are widely considered essential foods due to cultural beliefs regarding their health-boosting properties (Othman et al., 2011). *Allium* spp. contain a variety of phytonutrients and have been effectively utilized to treat and prevent various disorders, including obesity, hypertension, hypercholesterolemia, coronary heart disease, type 2 diabetes, cataracts, and gastrointestinal tract disruptions (Lanzotti, 2006). Garlic and onions possess numerous medicinal properties renowned for their efficacy in treating various diseases. In this context, most plant parts and preparations are beneficial. Chronic and acute inflammatory diseases, such as arteriosclerosis, have shown a decline concomitant with the increase in semi-vegetarian diets, as indicated by epidemiological studies. These findings have led to a significant surge in research on garlic and onions.

Cancer prevention and treatment

The National Cancer Institute (NCI), the American Institute of Cancer Research (AICR), and the World Health Organization (WHO) have all endorsed the inclusion of garlic and onion in our diets due to their established ability to reduce the risk of cancer (Surh, 2003; Zhang et al., 2020). The primary constituents naturally found in garlic are allyl sulfide derivatives, although numerous chemical compounds with anticancer properties have been isolated from this plant. A study carried out by the United States National Cancer Institute revealed that garlic and onion are among the most effective foods with various anticancer properties. These properties include inhibiting the growth of tumor cells and imparting chemopreventive effects (Dahanukar & Thatte, 1997; Bayan et al., 2014).

Breast cancer

Globally, breast cancer is the leading cause of death for women (Ghoncheh et al., 2016; Desai et al., 2019). According to the International Agency for Research on Cancer, WHO, breast cancer is recorded as the most prevalent case in Malaysia with 8,418 (17.3%) patients in 2020. Research on the anticancer properties of garlic and onion has shown that exposing diallyl disulfide (DAS) and S-allylmercaptocysteine, which are compounds found in garlic and onion respectively, will inhibit *in vitro* cell proliferation via the induction of a G2/M phase arrest (Sigounas et al., 1997; Desai et al., 2019). Additionally, quercetin, a constituent of onions, can downregulate the expression of mutant p53 protein involved in breast cancer cell lines. On the other hand, allicin from garlic has the potential to inhibit the proliferation of Michigan Cancer Foundation-7 cell lines (defined as this cell line later) in response to quercetin (Ranganathan et al., 2015; Desai et al., 2019). Furthermore, studies have proven that DAS stimulates the production of glutathione S-transferase and boosts glutathione peroxidase activity *in vitro*, disrupting the regulation of the cell cycle. Both plants exhibit radical scavenging activities, as well as immune modulation stimulated by the aqueous and ethanolic extracts of garlic powder (Tapiero, 2004). Therefore, the increase in consumption of garlic and onion could benefit a person by reducing the risk of breast cancer.

Colorectal Cancer

Globally, colorectal cancer (CRC) ranks third in terms of morbidity rate, following lung cancer and breast cancer (Zhou et al., 2020). According to Ferlay et al. (2024), Malaysia documented a total of 7,150 cases of colorectal cancer in 2022, accounting for 13.8% of all reported cases. This ranks colorectal cancer as the

second most prevalent type of cancer in Malaysia after breast cancer. Adults who consumed a substantial quantity of garlic and onion had a 79% lower risk of developing colorectal cancer compared to those who consumed a minimal amount (Wu et al., 2019). Additionally, some speculate that consuming a specific amount of these plants as food is preferable to supplementation. Concurrent consumption of other foods may easily disturb the absorption of nutrients from garlic and onion in the form of purified or concentrated supplements (Jacobs et al., 2009; Lee et al., 2021).

Cardiovascular disease (CVD) prevention and treatment

In 2019, 32% of global deaths were due to cardiovascular diseases (CVDs), affecting approximately 17.9 million people (World Health Organization, 2021). Both garlic and onion preparations have been used to treat many disorders, including lowering plasma cholesterol and blood pressure, reducing platelet aggregation, and protecting low-density lipoprotein cholesterol (LDL) from oxidation. Garlic has been shown to significantly reduce total cholesterol (TC) and low-density lipoprotein cholesterol (LDL) levels (Sun et al., 2018). The consumption of various garlic preparations, such as oil or extract, effectively reduces blood pressure and oxidative stress in individuals with hypertension. The total cholesterol levels decreased by 1.2-17.3 mg/dL and 12.4-25.4 mg/dL after 1 and 3 months of consuming garlic preparations, respectively, compared to whole garlic (Ackermann et al., 2001). The impact of garlic and onion on lipid profiles demonstrated a significant decrease in triglyceride levels and total cholesterol.

Using sterol 4-alpha-methyl oxidase, garlic aqueous extracts can reduce cholesterol production by up to 75% without harming cells. It is also effective in slowing coronary calcium progression (Yeh & Liu, 2001). Researchers have reported that S-allyl cysteine sulfoxide significantly increased the activity of lecithin acyl transferase in isoproterenol-induced myocardial ischemia and decreased the activity of the 3-hydroxy-3-methylglutaryl-CoA reductase enzyme. Sebastian et al. (1979) discovered that administering onion extract to rabbits fed with sugar resulted in a significant reduction in triglycerides in the blood, liver, and aorta, as well as proteins in the blood and liver.

Diabetic prevention and treatment

It has been estimated that 463 million people (9.3%) suffer from diabetes worldwide (Saeedi et al., 2019). In Malaysia, based on the National Health and Morbidity Survey (NHMS) 2019, the number of cases increased significantly, with 3.9 million recorded in 2019 and expected to rise to 7 million people by 2025 (MalaysiaGazette, 2024). The nutritional and therapeutic benefits of garlic and onion have been shown to play a role in reducing the risk of diabetes (Kumari & Augusti, 2002; Zhai et al., 2018). Studies have reported that garlic and onion extracts possess anti-diabetic effects (Corzo-Martínez et al., 2007). A study by Mathew & Augusti (1975) suggested that oral treatment with the hypoglycemic fraction of onion juice in alloxan-diabetic rabbits improved their glucose tolerance, with the juice being approximately half as effective as phenformin in reducing fasting blood sugar levels. When diabetic patients consumed onion juice-expressed residue with their meals, their hyperglycemia was effectively managed (Lim, 2015). The diabetic condition of alloxan-diabetic rats showed improvement after receiving oral administration of onion and garlic sulfoxide amino acids, specifically S-methylcysteine sulfoxide (SMCS) and S-allylcysteine sulfoxide (SACS) for 30 days (Sheela et al., 1995). Lim (2015) identified several indicators used to assess a person's diabetic condition, including glucose intolerance, weight loss, and a reduction in liver glycogen levels. A study conducted by Afarid et al. (2022) revealed that garlic supplements have a significant healing effect on diabetic macular edema. The clinical investigation showed an improvement in visual acuity, as well as a decrease in central macular thickness and intraocular pressure.

Cosmetic application

The formulation of cosmetic products requires the utilization of plant components with various properties, such as antioxidant, anti-inflammatory, antiseptic, emollient, antiseborrheic, antikeratolytic activities, and antibacterial effects (Aswal et al., 2013). Garlic and onion have been found to have antifungal, anti-aging, anti-inflammatory, and skin-smoothing benefits.

Skin care, which involves using various skin care products based on natural materials, is considered a key product. Concerning garlic and onion, Bito et al. (2018) investigated the potential use of a chemical compound called cycloalliin as an ingredient in cosmetic products. The inhibitory effects of

cycloalliin on the catalytic activity of tyrosinase and cAMP-dependent pathways involved in melanogenesis in B16 mouse melanoma cells were assessed. The results demonstrated that exposure to a high concentration of the compound inhibited the catalytic activity of tyrosinase. This compound acts as a potent inhibitor of adenylate cyclase (AC), which is part of the cAMP signaling pathway of melanogenesis. This suggests that this compound could serve as a skin-lightening ingredient in cosmetic products.

Skin care

Arung et al. (2011) discovered that quercetin, specifically 4'-O-B-D-Glucopyranoside isolated from dried onion skin, exhibited anti-tyrosinase activity, indicating its potential as a skin-whitening agent in cosmetics. Interestingly, the methanol extracts of dried onion skin also demonstrated significant inhibitory activity on melanin biosynthesis in B16 melanoma cells. Moreover, quercetin-3'-O-βD-glucoside, isolated from the methanol extract, showed antioxidant properties, making it an effective substance for treating hyperpigmentation, skin whitening, and protection against oxidative stress (Arung et al., 2011).

Additionally, research has shown that a concentrated gel made from garlic juice extracted from the bulb could enhance the treatment of skin conditions by reducing acne. The anti-acne activity of garlic juice was tested against *Propionibacterium acnes.* Exposure to a 7.5% garlic juice formulation showed anti-acne potential against *P. acnes* (Saptarini & Herawati, 2017). Studies have identified various properties in garlic juice, such as alkaloids, saponins, tannins, monoterpenes, and sesquiterpenes. Garlic contains a range of chemical constituents with diverse activities, including antimicrobial, anti-inflammatory, and antioxidant properties, indicating its potential benefits for acne treatment. Suva & Dubal (2014) conducted a study where they developed a formulation using garlic extract isolated from the scales. The developed formulation exhibited an inhibitory effect on *Staphylococcus aureus* due to its antimicrobial activity, as reported in the study (Suva & Dubal, 2014).

Hair care

The hair care product is ranked number two and three in terms of natural ingredients and value, respectively. Shampoo is the most basic cosmetic used for hair care. However, there have been few studies conducted on the use of these plants for this type of personal care. One such study was conducted by Patel et al. (2018), who formulated an herbal shampoo with a mixture of onion extract and eucalyptus oil. The presence of onion in the formulation is intended to act as a hair growth promoter with its scalp-reducing agent and suggests that the formulated shampoo is optimized to have good hair nourishing properties. Another study performed by Kim (2016) suggested that garlic extract fortifies keratinocytes from ultraviolet (UV) damage and is suitable as an anti-aging material based on an *in vitro* cellular model. Keratinocytes are in the external layer of the skin, as well as in the scalp skin and hair follicles, which produce keratin. Additionally, studies have explored the potential use of garlic as a treatment for hair loss. The presence of organosulfur compounds in garlic, mainly DADS (diallyl disulfide), may promote the regrowth of hair through the application of garlic gel to the bald parts of the scalp.

Agricultural application

Garlic and onion have demonstrated various activities related to protein and sulfur-containing compounds, exhibiting a wide range of potentials such as insecticidal, antifungal, and nematicidal effects. This discovery and understanding have paved the way for utilizing these plants as natural pesticides, offering significant benefits in agricultural practices, as well as for the environment and human health (Anwar et al., 2017; Rinaldi et al., 2019).

Currently, the agricultural sector is emphasizing the need to address environmental issues linked to the extensive use of chemical pesticides (Anwar et al., 2017). A key objective is to promote biological approaches grounded in sustainable pesticide usage to mitigate the environmental hazards associated with chemical applications. The progressive substitution of traditional chemicals with organic products like garlic and onion extracts efficiently controls pests and diseases affecting crops without inducing any toxic effects (Koul et al., 2008; Koul & Walia, 2009; Rinaldi et al., 2019). Consequently, research involving plants, including garlic and onion, as sources for pest management has been gaining momentum over the past two decades.

Insect management

Garlic and onion can be employed to control insect attacks on plants. According to Al-Shuraym et al.

(2020), the mixture of garlic and onion extracted from bulbs affected the growth and mortality of *Rhynchophorus ferrugineus*, a pest that causes significant damage to fruit gardens and palm trees in both its larval and pupal stages. The toxicity is attributed to their bioactive sulfur compounds in various compositions released after being cut, such as alliin, allicin, diallyl sulfide (DAS), diallyl disulfide (DADS), diallyl trisulfide (DAT), S-allyl cysteine (SAC), organosulfur concentrations, and allyl sulfur concentrations (Carson, 1987; Kovarovič et al., 2019; Al-Shuraym et al., 2020). Furthermore, Mamduh et al. (2017) also identified that garlic derived from cloves exhibits insecticidal activity against *Podisus maculiventris* by decreasing the pest's survival rate. Garlic leaves and bulbs contain lectin, which possesses the capability to disrupt the normal physiological and biological functions of insects (Anwar et al., 2017). Lectins are highly esteemed as a promising group of proteins for developing transgenic plants resistant to insects since they are toxic to various insect pests (Upadhyay & Singh, 2012).

Moreover, due to their insect-repelling properties, garlic and onion have been utilized in intercropping systems (McCallum, 2007; Debra & Misheck, 2014). Insects find their host plants by detecting specific volatiles emitted by the plants. Nevertheless, as plant diversity increases, the simultaneous release of volatiles from more than two plants may hinder the host plant's location. In this regard, intercropping is deemed the most efficient biological technique for decreasing crop losses due to insect infestations (Khashi u Rahman et al., 2021). The study by Debra & Misheck (2014) suggests that intercropping garlic and onion with cabbages effectively deterred insect pests and minimized pest infestation in the crop because of their allicin compound, which possesses insecticidal properties. The researchers also revealed that intercropping garlic and onion between rows provides more benefits than intercropping within rows. Moreover, Zhou et al. (2013) reported that intercropping garlic with wheat resulted in a decrease in the population of *Sitobion avenae*, a common pest that threatens wheat crops.

Fungal management

Global crop losses due to fungi range from 10% to 23% annually (Stukenbrock & Gurr, 2023). Filamentous fungi have the capability to infect significant crops such as bananas, sweet potatoes, and tomatoes (Phay et al., 1999; Irkin & Korukluoglu, 2009). In a study by Irkin & Korukluoglu (2009), it was found that the ethyl alcohol and acetone extracts of dehydrated garlic and onion showed antifungal activities *in vitro* against fungi like *Aspergillus niger* and *Fusarium oxysporum,* attributed to their high content of phenolic and sulphur compounds. Amienyo & Afifah (2017) conducted research comparing the effect of garlic extract with chemical fungicides Ridomil and Z-Force on potato late blight disease caused by *Phytophthora infestans.* Garlic extract showed a significant decrease in the disease compared to conventional fungicides, indicating its potential as an effective spray for controlling late blight in potatoes. This effect may be attributed to the suppressive properties of bioactive compounds such as allicin (Rahman & Motoyama, 2000; Amienyo & Afifah, 2017). Additionally, in intercropping systems, garlic and onion can provide disease resistance against fungi. According to El-Anany et al. (2021), intercropping potatoes with garlic and onion resulted in higher yields due to a notable reduction in the development of potato late blight disease.

CONCLUSION

There is no doubt that *A. sativum* and *A. cepa* possess a wide range of applications that could benefit mankind and nature due to their remarkable chemical compounds and biological properties. Their significance extends to medicine, cosmetics, and agriculture. Hence, ongoing research into the potential utilization of these valuable and notable herbs is imperative to unveil their novel properties and biological effects.

CONFLICT OF INTERESTS

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTIONS

Raihan Ismil conceptualised the idea, wrote, reviewed and revised the manuscript, and provided funding. Nurfatihah Ali Besar wrote the first draft.

ETHICS APPROVAL

Not applicable

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