Pharmacogn. Res., 2026; 18(4):1195-1205.
https://www.phcogres.com

Review Article

# Bioactive Secondary Metabolites of *Allium fistulosum* L.: Nutraceutical and Pharmacological Implications

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## ABSTRACT

**Background and Objectives:** *Allium fistulosum L.* (spring onion), a member of the *Amaryllidaceae* family, is valued for its nutritional and therapeutic properties. This review aims to summarize its phytochemical composition, pharmacological activities, and potential applications in nutraceuticals, pharmaceuticals, and functional foods. **Materials and Methods:** A comprehensive literature search was conducted using Google Scholar, PubMed, Scopus, and ScienceDirect. Botanical identification was verified through The Plant List, and chemical structures were confirmed using PubChem and peer-reviewed sources. Relevant *in vitro, in vivo*, and clinical studies were analyzed. **Results:** *A. fistulosum* contains sulfur-containing compounds, flavonoids, phenolic acids, phytosterols, and saponins. These bioactive constituents exhibit antioxidant, anti-inflammatory, antimicrobial, and anticancer activities. Mechanistically, they modulate oxidative stress, inflammatory mediators, and metabolic pathways, contributing to reduced risk of chronic diseases such as cancer, diabetes, and cardiovascular disorders. **Conclusion:** *Allium fistulosum* is a promising natural source of bioactive secondary metabolites with significant therapeutic potential. However, further molecular studies, standardization strategies, and well-designed clinical trials are necessary to support its translational application in health-promoting products.

**Keywords:** Allicin, *Allium fistulosum*, Antioxidants, Functional Foods, Phenolic Acids, Phytochemicals, Secondary Metabolites, Spring Onions.

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**Received:** 19-01-2026;
**Revised:** 04-03-2026;
**Accepted:** 21-05-2026.

## INTRODUCTION

*Allium fistulosum* L., more commonly known as Welsh onion, is a member of the genus Allium, which is noted for its abundance of bioactive chemicals and its potential efficacy as a food product. Vitamins (particularly vitamin C), minerals, organosulfur compounds (particularly allicin), phenolic acids (ferulic acid, chlorogenic acid, gallic acid), saponins, and a wide variety of flavonoid and kaempferol derivatives are the hallmarks of this species' phytochemical composition (Kim *et al*., 2023).

The remarkable antioxidant, anti-inflammatory, anti-microbe, anti-hypertension, and anti-cancer benefits shown by many plant parts, including bulbs, stems, leaves, and roots, are attributed to these phytochemicals. *Allium fistulosum* is an excellent medicinal and functional food option due to its high levels of sulfur compounds and polyphenols, which provide powerful antioxidant and anti-oxidative-stress capabilities shows in Figure 1. The chemical variety of this species is further shown by phytochemical screening, which also reveals the presence of additional bioactive classes such as terpenoids, sterols, alkaloids, saponins, and tannins (Balkrishna *et al*., 2023; Puvarasan A/L Manoring, 2024).

Due to its potential use in preventative medicine, nutraceutical production, and as a natural substitute for commercial preservatives, spring onion is quickly gaining the attention of the scientific community. Its long history of use in traditional medicine for the treatment of cardiovascular, metabolic, and viral problems is evidence of the medicinal potential of its many secondary metabolites (Kim *et al*., 2023).

OPEN ACCESS
Manuscript TECHNOMEDIA

**DOI:** 10.5530/pres.20260037

## METHODOLOGY

A comprehensive literature search and analysis of peer-reviewed scientific publications were conducted using popular and accessible sources such as Scopus, Google Scholar, ScienceDirect, and PubMed. This allowed for the execution of the present review. *Allium fistulosum* (spring onion) phytochemical content, nutritional value, and pharmacological characteristics were systematically compiled from publications, research papers, and review articles published between 2010 and 2025.

We used The Plant List and other trusted botanical databases to double-check the species' taxonomic profile and make sure we were classifying it correctly. We used the PubChem and PubMed databases to get the chemical structures and identities of all the compounds, and then we double-checked them using other academic sources. After that, we checked the research' data for scientific validity and reliability by tabulating, comparing, and critically reviewing it.

### Botanical of *Allium fistulosum*

Spring onion, Welsh onion, Japanese bunching onion, and *Allium fistulosum* L. are all names for the same perennial herbaceous plant species in the *Amaryllidaceae* family. The ordinary onion (*Allium cepa*) is distinguished by its bulb-forming habit, whereas this species is known for its thick bundles of thin, cylindrical leaves that may grow up to 60 cm in length and are edible and medicinal (Kayat *et al*., 2021).

A single or aggregated cylindrical organism with a persistent, terete, and hollow or fistulose-structured center, accompanied by 28 leaves, may have a diameter ranging from 17 to 26 cm. A compact globular inflorescence (umbel) composed of several tiny, bisexual flowers ranging in color from white to light purple is produced by raising another hollow stalk (scape) above the scape, which may reach a height of 15 to 70 cm (Padula *et al*., 2022) (are shows in Figure 2).

The perennial herbaceous plant species *Allium fistulosum* L. goes by several names in the *Amaryllidaceae* family, including spring onion, Welsh onion, Japanese bunching onion, and many more. In contrast to the bulb-forming habit of the common onion (*Allium cepa*), this species is renowned for its delicious and medicinal thick bundles of thin, cylindrical leaves that may reach a length of 60 cm (Kayat *et al*., 2021).

The diameter of a single or aggregated cylindrical organism may range from 17 to 26 cm, and it can have 28 leaves and a persistent, terete, hollow, or fistulose-structured core. An additional hollow stalk (scape) that may reach a height of 15 to 70 cm is raised above the scape to create a compact globular inflorescence (umbel) of many small bisexual flowers that range in color from white to light purple.

### Nutritional significance

*Allium fistulosum*, also called spring onion or Welsh onion, is a nutritional powerhouse that adds great value to both regular and functional diets. Although they are abundant in most essential nutrients, the new stems are rather low in calories (around 34 per 100 g). They include a wealth of nutrients, including vitamin C (ascorbic acid), minerals (potassium, calcium, magnesium, and iron), and B vitamins (B2, B3, B6, B12, and carotenoids). In addition, the high quantities of dietary fiber (2.4 g per 100 g) that *Allium fistulosum* offers help keep the digestive system healthy and increase satiety (Adamczewska-Sowińska *et al*., 2012).

Bioactive chemicals found in *Allium fistulosum* include macronutrients, phenolic acids (such as ferulic acid and p-coumaric acid), and sulfur-based compounds (allicin included), among many others. Flavonoids (such as quercetin and kaempferol) make up the majority of these substances. Bioactive compounds like these help cells fight oxidative stress and inflammation, which in turn lowers the likelihood of developing chronic diseases. Additionally, the plant's extracts have been demonstrated to modulate serum lipid profiles, regulate blood glucose, lipid metabolism in experimental models, and hypertension; empirical studies have also indicated that the extracts have hypolipidemic, antihypertensive, antidiuretic, cardioprotective, and anti-obesity effects. That is according to (Zhao *et al*., 2021).

The addition of plant sterols (stigmasterol, 2-sitosterol, and campesterol), saponins, and excellent protein enhances its functional dietary properties even more. *Allium fistulosum* is an excellent addition to vegetarian and health-conscious diets since it is low in calories, rich in micronutrients, phytonutrients, and secondary metabolites that promote good health (Hwang *et al*., 2018).

### Vitamins

The spring onion, or *Allium fistulosum*, is a great food source of several vitamins that are essential for human physiological wholeness. Vitamin A, mostly in the form of beta-carotene, is an intriguing carotenoid derivative that plays an important role in the eyes for things like vision, immunological function, cell division, and differentiation. The fact that beta-carotene helps keep cells in check and the eyes healthy further demonstrates the beneficial effects of this vegetable on skin and eyesight (Asensi-Fabado and Munné-Bosch, 2010).

Thiamine (B1), riboflavin (B2), nicotinic acid (B3), pyridoxine (B6), and folate (B9) are all present in *Allium fistulosum* comprehensive B-vitamin profile. Thiamine is essential for proper glucose metabolism and CNS function, whereas riboflavin is critical for healthy cell division and tissue development. In addition to its involvement in skin and neurological function maintenance, nicotinic acid is engaged in metabolic cascades

and energy release. In pregnancy, pyridoxine helps with neurodevelopment and neurotransmitter production, whereas folate is important in fetal morphogenesis, cell proliferation, and deoxyribonucleotide synthesis (Tardy *et al*., 2020).

Vitamin C, or ascorbic acid, is abundant in *Allium fistulosum*, and its quantity varies from plant to plant; typically, the bulb has lower vitamin C concentrations than the leaves. Vitamin C is an effective endogenous antioxidant that protects cellular components from oxidative damage, increases collagen formation, and improves immunological reactivity. *Allium fistulosum* is a great functional food because it has a wide variety of vitamins, phytochemicals, and mineral compounds that work together to promote health, development, and energy metabolism (Sung *et al*., 2015).

## Minerals

Among the many sources of essential minerals, *Allium fistulosum* also called spring onion or Welsh onion is particularly noteworthy for its impact on human health. Potassium, which is abundant in this fruit, is essential for maintaining fluid balance, proper nerve impulse conduction, regular muscular contractions, and blood pressure regulation. Calcium, another abundant element in this species, is essential for healthy bones, blood clotting, and muscle contractions. A high concentration of magnesium and phosphorus aids in energy metabolism, maintains bone density, and facilitates a broad variety of enzyme reactions in the human body (Majkowska-Gadomska *et al*., 2016; Rouphael *et al*., 2012).

The effects of *Allium fistulosum*, also known as spring onion or Welsh onion, on human health stand out among the many mineral sources. Fluid equilibrium, normal conduction of nerve impulses, regular contractions of muscles, and control of blood pressure are all supported by the abundance of potassium in this fruit. Bone health, blood clotting, and muscular contractions all depend on calcium, another mineral found in abundance in this species. Magnesium and phosphorus, when present in high concentrations, help the body with energy metabolism, keep bones dense, and enable a wide range of enzyme processes (Lee *et al*., 2018).

## Calories and Fat

The low calorie and fat content of spring onion (*Allium fistulosum L.*) make it a great food to include in weight loss diets. You may eat a lot of it without worrying about your daily calorie intake since it contains about 31 to 34 kilocalories per 100 -1 fresh weight (the exact number varies somewhat depending on the origin). In terms of lipids, spring onions are rather low in content, averaging just around 0.2-0.4 g of total fat per 100 g. People who are watching their fat consumption for weight loss or maintenance might benefit from these meals because of the low lipid content. In keeping with the guidelines for heart health, the composition is mostly unsaturated lipids with little saturated fatty acid concentration. Because of its high nutritional value which is a result of its low caloric value, low energy density, and abundance of dietary fiber, vitamins, and minerals *Allium fistulosum* is used extensively in culinary farms all over the world. This is due in large part to the fact that it is both delicious and nutritious (Pradhan *et al*., 2018; Wang *et al*., 2023; Xie *et al*., 2023).

## Dietary Fiber

About 2.4 g of spring onion (*Allium fistulosum*) produces 100 g of fresh mass, and it has a lot of nutritional fiber. The health advantages of this fiber percentage are based on its ability to promote digestive health by encouraging regular stool and to function as a prebiotic, which increases the growth of good gut microbes. The stalk, which includes dietary fibers, complex polysaccharides, and a variety of mono- and glycosidic structures, is particularly interesting from this perspective. In addition to improving gastrointestinal health in general, these fibers are linked to a more robust and diverse gut microfiltration (Li *et al*., 2024).

A 100 g of fresh mass may be produced from around 2.4 g of spring onion (*Allium fistulosum*), which is rich in nutritious fiber. Because of its dual role as a prebiotic which promotes the development of beneficial gut microbes-and an aid to digestive health (more frequent bowel movements), this fiber percentage is beneficial to health. From this vantage point, the stalk comes into its own since it contains dietary fibers, complex polysaccharides, and various mono- and glycosidic structures. These fibers are associated with better gut microfiltration, which in turn improves overall gastrointestinal health (Gupta *et al*., 2025).

## Ethnomedicinal significance

Traditional medicine practitioners in East Asia, including the Chinese, Japanese, Korean, and Vietnamese communities, have long recognized the ethnomedicinal value of *Allium fistulosum* L., or spring onion. From respiratory infections (like the common cold and influenza) to gastrointestinal issues, musculoskeletal disorders (like arthritis), cardiovascular disorders (like hypertension and cardiac diseases), and other febrile and parasitic diseases, it has historically been used to treat a broad range of pathology (Ijeomah *et al*., 2020).

The whole plant, including its leaves, stems, roots, and bulbs, is tested for medicinal use. While bulbs have been said to improve vision and immune system function, roots and stems have been utilized as slightly active antipyretics and for the common cold. Parts of the plant are often used in a rice congee recipe according to traditional Chinese medicine, which claims to have anti-inflammatory and antiarthritic properties. The antihypertensive, antifungal, antiviral, and antioxidant bioactivities of the aerial portions have been confirmed by modern pharmacological research, which supports the historic assertions of medicinal effectiveness (Lee *et al*., 2025b).

Ethnomedicinally, *Allium fistulosum* is said to alleviate cold-related symptoms including stuffy nose, aid digestion, and stimulate circulation. The complex phytochemical composition of this plant is thought to be responsible for its medical versatility. It contains flavonoids, sulfur-containing components (like allicin), saponins, and phenolic acids, all of which interact with different biological pathways (Čepulienė *et al.*, 2024).

## Botanical and Taxonomical Overview

The perennial herbaceous plant *Allium fistulosum* L. belongs to the family *Amaryllidaceae* and goes by several names, including scallion, spring onion, Welsh onion, Japanese bunching onion, and spring onion. This is how it is categorized taxonomically are shows in Table 1.

*Allium fistulosum* is a native of Eastern Asia, including Japan and China, and it has been farmed all over the world for its culinary and traditional medical uses. The ordinary onion, *Allium cepa*, produces enormous bulbs, but this species doesn't. Its clumping perennial growth and distinctive hollow-tubular leaves make it a profitable crop that may be harvested throughout the year in certain areas (Kamenetsky and Rabinowitch, 2010).

## Morphology and anatomy

Originating in Japan and China, the *Allium fistulosum* plant has since been cultivated globally for its culinary and traditional medicinal use. This kind of onion does not grow the massive bulbs that the common onion, *Allium cepa*, does. In certain regions, it is possible to harvest this crop at any time of year due to its clumping perennial growth and unique hollow-tubular leaves (Ara *et al.*, 2020).

There is a vast array of traditional medicinal and culinary uses for the green pseudostems of *A. f. fistulosum*. Following the blossoming, upright, hollow stalks that measure 61 to 91 ′ inches in height produce an umbel conflux of 50 to 100 small, star-shaped flowers that range in color from white to light purple and have six tepals. The specific epithet for the tubular construction of the basal leaves reflects its etymological roots, while the leaves themselves are linear with parallel veining and complete edges ("*fistulosum*" means 'hollow').

Differences in stem color (green, white, red, or purple), stem thickness, leaf shape, leaf length, and organoleptic taste intensity are some of the ways in which different cultivars exhibit intraspecific morphological variation. The cross-section of a leaf is anatomically similar to a tube; this shape enhances the plant's ability to withstand drought by storing water. With a comparatively basic architecture compared to bulbous Allium species, the epidermis is glabrous and has very visible vascular bundles. *A. fistsulosum* is exceptionally adapted to the continuous growing and succeeding crop in cold conditions because to its vigorous, non-bulbous growth form and anatomical alterations.

## Distribution and cultivation practices

As a result of its widespread distribution and remarkable ecological flexibility, the spring onion, also known as the Welsh onion, or *Allium fistulosum*, is an integral component of vegetable farming in many regions. Although it is native to East Asia more especially China and Japan this plant has been domesticated extensively in temperate, subtropical, and tropical climates throughout the Americas, Europe, and Asia. China now dominates production, cultivating crops on an area more than 500,000 hectares-far bigger than Japan, Korea, and other nations combined. The United States, Egypt, Morocco, Germany, and a

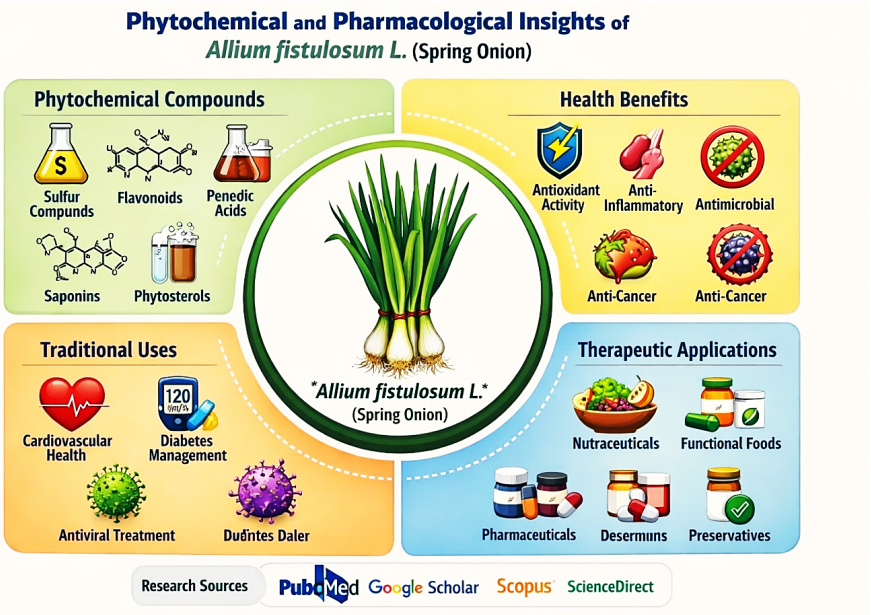


**Figure 1:** Graphical abstract of *Allium fistulosum*.

**Figure 2:** Overview of morphemically Allium *fistulosum*.

number of African countries (such as Sudan, Kenya, and Ghana) depend on it for both internal and export purposes, and there are substantial production records from these countries outside of Asia (Chakravarty and Zhang, 2024).

Fertile, well-drained soils ranging in texture from sandy to loamy are ideal for *Allium fistulosum*, and it's best to plant it in an area that gets moderate rainfall. While the plant does have some drought resistance, it is best irrigated regularly for agronomic reasons, particularly during the long dry seasons. Both direct seeding and transplanting may be used to establish them, although for optimal production, it is recommended to utilize disease-free planting material planted in soils with low pathogen populations. Perennial plantings of *Allium fistulosum* are suitable for regions with moderate winters (temperate climates, for example), whereas annual plantings are required in regions with very cold winters (Nakajima *et al*., 2024).

## Phytochemical Constituents of Spring Onion

The many phytochemical components found in spring onion, *Allium fistulosum*, provide it dual use as a food source and a therapeutic herb. Important components include phenolic acids (ferulic acid and p-coumaric acid), sterols (2-sitosterol, campesterol, and stigmasterol), and flavonoid components (isoquercitrin, kaempferol, quercetol, and quercitrin) shows in Table 2. The plant also contains sulfur-containing compounds, steroidal sapogenins, a series of cinnamic acid amides, fistuloimidates, and onionins A1, A2, and A3, as well as sulfur-containing compounds, diallyl disulfide, and yuccagenin (Waghulde *et al*., 2020).

Particular components found in the bulbs include welsonins A1, coumaran derivatives, and hydroxy phenols; in the foliar tissues, flavonoids, saponins, steroids, and sulfur compounds are present. They include the same substances found in the roots and seeds, including fistulosin, tianshic acid, vanillic acid, and daucasterol shows in Figure 3. This plant's traditional medicinal use is based on its phytochemicals, which have a wide array of pharmacologic activities, such as antioxidant, anti-inflammatory, antimicrobial, anticancer, anti-obesity, antihypertensive, and cardioprotective effects (Alagarsamy *et al*., 2018).

While factors such as location and climate can alter the phytochemical profile of *Allium fistulosum*, the presence of sulfur-containing compounds, flavonoids, phenolic acids, and steroidal saponins makes it a potent bioactive agent source for phytognosy and functional food research. New therapeutic opportunities associated with this extensively cultivated vegetable may emerge from more investigation into these components and their synergy (Okungbowa *et al*., 2017).

## Overview of primary vs. secondary metabolites

Plants and other creatures rely on primary metabolites, which are organic substances, for growth, development, and fundamental metabolic activities. Carbohydrates, proteins, lipids, nucleic acids, vitamins, and starch are all part of this group, and they are all generated during the vegetative stage. Essential functions performed by these include energy production, structural material synthesis (e.g., cellulose), and genetic material transport (DNA, RNA). Essential for cellular repair and reproduction, they are mostly produced in large quantities (Zhou *et al*., 2021).

In turn, secondary metabolites are molecules that play important ecological functions but aren't physically necessary for the plant's existence and growth. The majority of these metabolites alkaloids, terpenoids, phenolics, and flavonoids are formed during the stationary or succeeding stages of development. They serve as a kind of defense, shielding plants from herbivores, diseases, and abiotic challenges; pollinators and seed dispersers may even find them attractive. Because of their low concentrations and high interspecificity, secondary metabolites attract particular attention in pharmacognosy are shows in Table 3. This is because the vast majority of these compounds have potent biological functions and therapeutic effects, making them promising candidates for new pharmaceuticals and nutritional supplements (Olsovska *et al*., 2024).

## Flavonoids

The spring onion's (*Allium fistulosum* L.) phytochemicals are mostly flavonoids, which are abundant in the plant's pseudostem and green leaves. The most prevalent flavonoids in this species are isoquercitrin, kaempferol, quercetin, quercetrin, and myricetin; these flavonoids are well-known for their antioxidant properties. The quantitative data indicates that the total flavonoid concentration in the leaves of *A. fistulosum* ranges from 26 to 31 mg quercetin equivalents per gram of dry leaf. Among the allium species, kaempferol is found at quite high levels (Lee *et al*., 2025a).

Some of the health benefits of the flavonoids in spring onions include quercetin 4-O-glucoside (spiraeoside), which has antioxidant, anti-inflammatory, antidiabetic, antihypertensive,

anticholinergic, and anticancer properties. The cells are protected from oxidative stress by these bioactive components, which scavenge free radicals, reduce lipid peroxidation, and decrease the release of pro-inflammatory enzymes in response to traumatic or infectious signals. The anti-inflammatory actions of *A. fistulosum* fruit extracts have been supported by empirical data that these extracts mediate the generation of nitric-oxides and the creation of the Cyclooxygenase-2 (COX-2) enzyme (Kothari *et al.*, 2020).

Based on comparative studies, it has been shown that whereas onion leaves (*Allium cepa*) have greater absolute quantities of certain flavonols, the kaempferol content and hydroxycinnamic acid derivatives of *A. fistulosum* leaves are even better. The importance of these leaves as dietary sources of flavonoids is emphasized by this. The antioxidant and radical-scavenging characteristics of spring onions are directly linked to their high flavonol content, which lends credence to their culinary and therapeutic uses (Thompson *et al.*, 2005)

## Phenolic acids

*Allium fistulosum* L., also known as spring onion, has an abundance of phenolic acids, a class of secondary metabolites that greatly enhance the plant's health-promoting and antioxidant properties. Under phytochemical conditions, the plant's leaves, bulbs, and seeds were discovered to have very high concentrations of two primary phenolic acids, ferulic acid and p-coumaric acid (Kirov *et al.*, 2017).

Both the non-hydrolyzed and hydrolyzed extracts have high concentrations of ferulic acid, the most prevalent phenolic acid (703.01 and 1000 g, respectively, before and after hydrolysis). This chemical is often found in spring onion tissues and has a role in antioxidant defense by neutralizing free radicals and protecting cell membranes. It is also an anti-carcinogen and anti-inflammatory. The antioxidant p-coumaric acid has several uses, including reducing inflammation and cancer risk, protecting cell membranes from damage, and neutralizing free radicals. Regarding its abundance and biologic importance in host defense and human nutrition and health, its concentrations range from about 11.05 mg 100 g -1 (non-hydrolyzed) to over 302 mg 100 g -1 (hydrolyzed). Sinapic acid, vanillic acid, and 4-hydroxybenzoic acid are additional phenolic acid components that may be present in spring onions (e.g., in the seed and leaf) upon hydrolysis. When these phenolic acids work together, they boost the plant's resistance to oxidative stress and inflammatory pathways, and they may even help ward against chronic illnesses like diabetes, cancer, and cardiovascular problems.

## Steroidal saponins

Upon hydrolysis, spring onions (including their seeds and leaves) may include additional phenolic acid components such as sinapic acid, vanillic acid, and 4-hydroxybenzoic acid. The synergistic effects of these phenolic acids strengthen the plant's defenses against oxidative stress and inflammatory pathways; moreover, they show promise in the fight against diabetes, cancer, and heart disease (Dey and Khaled, 2015).

Steroid sapagenins with one or more sugar residues make them up. This includes spirostanol and furostanol variants. The plant also contains Fistulosaponins (A-F), a group of steroidal saponins that have shown remarkable anti-ischemic effects and reoxygenation anti-hypoxia damage on human endothelial cells; these compounds are targeted by oil and bulbs. The allium yuccagenin and tigogenin found in *A. fistulosum* and other species may have anti-inflammatory, immunomodulatory, and cholesterol-lowering effects (Lanzotti *et al.*, 2012).

The steroidal saponins found in spring onions have cytotoxic effects on tumor cells, an inhibitor of intestinal cholesterol absorption and serum cholesterol, and anticancer and cardiovascular protective applications. Because of their actions on the cell membrane of pathogens, saponins may also increase immunity and have antifungal and antibacterial characteristics (Geng *et al.*, 2021).

## Pharmacological and Therapeutic Potential

### *Antioxidant properties*

The spring onion, or *Allium fistulosum*, is a powerful antioxidant because it contains many bioactive substances, including minerals, sulfur-containing compounds (like allicin), phenolic acids (like ferulic acid), flavonoids (like quercetin and kaempferol), and ascorbic acid. Protecting cells from harm linked to the pathophysiology of chronic diseases, this group of phytochemicals quenches Reactive Oxygen Species (ROS), reduces lipid peroxidation, and more (Kazemzadeh *et al.*, 2023).

Experimental studies have shown that several spring onion vegetative elements, including the pseudostem, leaves, and roots, all have potent antioxidant properties. However, early results indicate that the stem extracts may be the most efficient. Spring onions are a natural powerhouse when it comes to antioxidant capacity, according to quantitative assessments using well-established methodologies of antioxidant capacity (DPPH radical scavenging and ferric reducing antioxidant power, or FRAP) (El-Sayed and Shazly, 2024).

**Table 1: Taxonomical Overview.**

| Taxonomical Overview | |
|---|---|
| Kingdom | Plantae |
| Phylum | *Magnoliophyta* or Tracheophyta (Angiosperms) |
| Class | *Liliopsida* (Monocotyledons) |
| Order | Asparagales |
| Family | Amaryllidaceae |
| Genus | *Allium* |
| Species | *Fistulosum* |

**Table 2: Phytochemical constituents of Spring Onion (*Allium fistulosum*).**

| Phytochemical Class | Specific Compounds | Plant Part | Description |
|---|---|---|---|
| Flavonoids | Isoquercitrin, Quercitrin, Quercetin, Kaempferol, Quercetol | Leaves, Aerial parts | Total flavonoids ~25.75 µg/g (ethanolic extract); Isoquercitrin (280 µg/mL in extract) |
| Phenolic Acids | Ferulic acid, p-Coumaric acid, Sinapic acid, 4-Hydroxybenzoic acid, Vanillic acid | Leaves, Bulbs, Seeds | Ferulic acid 499-1636 µg/100g (leaf, before and after hydrolysis); p-Coumaric acid also abundant |
| Sulfur-Containing Compounds | Allicin, Alliin, Diallyl disulfide | Leaves, Bulbs | Allicin ~20 µg/mL in *A. fistulosum* extracts; Strong antimicrobial and antioxidant agents |
| Steroidal Saponins | Yuccagenin, Fistulosaponins A1-F, Tigogenin, Cynnamic acid amides, Onionins A1-A3 | Seeds, Bulbs, Leaves | Potent bioactive saponins with anti-inflammatory and anticancer properties |
| Phytosterols | β-Sitosterol, Campesterol, Stigmasterol | Leaves, Whole plant | Stigmasterol unique to *A. fistulosum* |
| Alkaloids | Various unidentified alkaloids | Leaves, Bulbs | Total alkaloids ~22.5 µg/g (ethanolic extract) |
| Others | Coumarin derivatives, Hydroxy phenol, Fistuloimidates, Cinnamic acid amides, Typheramide, Alfrutamide | Bulbs, Roots, Seeds | Unique bioactive secondary metabolites contributing to pharmacological effects |

One example of a flavonoid-based profile is quercetin 4′ O sugar (spiraeoside), which has several functions: it neutralizes free radicals, inhibits inflammatory pathways via inhibition of Cyclooxygenase-2 (COX-2), and so on. Therefore, the anti-inflammatory and antioxidant properties of spring onion function in tandem. The decrease of blood pressure and the diminution of NADH/NADPH oxidase activity are two ways in which the cardioprotective effects of antioxidants manifest, highlighting their importance in reducing oxidative stress-induced hypertension (Aquino *et al.*, 2023).

## Anti-inflammatory activity

The extensive list of health advantages associated with spring onion (*Allium fistulosum*) is supported by several research, which may be attributed to the presence of bioactive chemicals inside it. It has every vitamin, mineral, and phytochemical that the body needs to support healthy immune function, bones, blood sugar regulation, and heart health. Flavonoids, such as quercetin, have powerful anti-inflammatory and antioxidant properties, and vitamin C's abundance may be used to modulate immunity by neutralizing reactive oxygen species and lowering inflammation (Kim *et al.*, 2022).

Researchers found that green onion extracts had an anti-inflammatory impact by reducing levels of pro-inflammatory cytokines and blocking Cyclooxygenase-2 (COX-2), an enzyme critical to the inflammatory cascade's pathogenesis. Because of its unique pharmacological profile, spring onion is useful in the treatment of a variety of medical disorders, including arthritis and heart disease. In addition, the plant's therapeutic value is enhanced by the anti-inflammatory and anti-microbial properties of sulfur compounds like allicin (Kang *et al.*, 2015).

As a result of its ability to regulate hunger, heat production, and fat deposition, spring onion is also useful in the treatment of metabolic diseases and obesity. Its antioxidant properties protect cell structures from oxidative stress, which is associated with long-term health problems like diabetes, cardiovascular disease, and cancer. Some potential anti-cancer action may be achieved via increasing apoptosis and decreasing tumor cell proliferation, according to recent research (Fomina and Kukushkina, 2021; Nazir *et al.*, 2022).

## Antimicrobial and antifungal effects

The spring onion, *Allium fistulosum*, contains bioactive saponins like fistulosides and sulfur-based compounds, especially allicin, which have potent antibacterial and antifungal effects. Root, leaf, and stem extracts, among others, have demonstrated potent antifungal activity against a variety of pathogenic fungi, including *Aspergillus brasiliensis, Candida albicans, Bacillus subtilis*, and a large number of *Trichophyton* species; the MICs for these compounds range from 0.2 to 6.2 mg/mL, depending on the individual compound and the target fungus (Zohri *et al.*, 1995).

There is a strong correlation between the amount of allicin and the antifungal activity. Allicin inhibits fungal growth and disrupts fungal cell membranes. The potential for employing *Allium fistulosum* and its separated fistulosides as natural medicines is highlighted by their outstanding antibacterial capabilities, which help to prevent fungal diseases. Additionally, spring onion extracts have been shown to impede viral replication and exhibit antibacterial properties against Gram positive bacteria, particularly *Bacillus subtilis*, in addition to their antifungal activities. Total antibacterial activity is conditional on extraction methods and plant components; typically, stem extracts have the highest activity (Albandary, 2023).

## Anticancer potential

The potent natural compounds found in fresh green onions suggest they may be useful in the battle against cancer. These chemicals, such as sulfur-based ones that are related to allicin, do more than sit idle; they activate self-destruct mechanisms inside

aberrant cells. Quercetin and other flavonoids join in by reducing the rate of tumor growth. Proteins associated with edema and unregulated cell proliferation, such as COX-2 and iNOS, are likewise targeted by saponins and plant acids. In experimental studies using colon cancer rat models, onion extract inhibited the formation of new blood vessels that supplied tumors with blood. Not only that, but it also decreased the depth to which such aggregates invaded adjacent tissues. When exposed, cells designated for destruction reacted more strongly. This synergy of effects implies that a common vegetable might have a subtle but significant impact in the background.

Researchers have shown that some components extracted from *A. fistulosum* bulbs, such as welsonins and onionin A1, change the behavior of tumor-friendly macrophages. This changes the environment that allow tumors to develop, which slows down the spread of cancer in lab-based settings. From a different perspective, their capacity to combat oxidation and soothe inflammation inside tissues alleviates strain on systems that are often taken over during the progression of cancer. These changes occur covertly, but they coincide with critical events that have been associated with cells becoming rogue for a long time (Bozinou *et al*., 2023).

Just below the surface, when extracted with methanol, leaf portions are more effective on MCF-7 cells. Looking at it another way, the substance that emerges from the bulb really combats several types of cancer. When taken as a whole, the compounds found in *A. fistulosum* work in a variety of ways, including blocking cellular signals, slowing growth or triggering cell death, and reducing inflammation and tumor-related blood vessel creation. These multi-faceted effects make it stand out as a potential foundation for future cancer therapies in addition to being a practical daily diet (Fragis *et al*., 2018; Arshad *et al*., 2017).

## Comparative Phytochemistry of Spring Onion with Other Allium Species

Isoquercitrin and quercitrin, two flavonoids, are abundant in *Allium fistulosum* but absent in related cousins like *Allium ursinum*. However, not all compounds are unique; for example, p-coumaric acid and ferulic acid are present in both. Hydrolysis of *A. fistulosum*, however, results in a much higher concentration of ferulic acid. I find it strange that once breakdown occurs, only that species exposes sinapic acid. Sterols provide a different perspective: β-sitosterol is present in both kinds, campesterol is between them, while stigmasterol is exclusive to *A. fistulosum* (Vlase *et al*., 2012).

While both *Allium cepa* and *A. fistulosum* include phytochemicals such as sulfur compounds, flavonoids, and saponins, a comparison of the two plants' chemical profiles reveals striking differences. The distinctive scent and medicinal capabilities of *A. fistulosum* are characterized by D-limonene and unique sulfur glycosides, whereas *A. cepa* displays a different mix of volatile and non-volatile bioactive chemicals with different primary components. According to quantitative data, *A. cepa* bulbs typically have a higher total flavonoid content, but *A. fistulosum* leaves have a higher kaempferol content and a higher concentration of some phenolic acids, including ferulic acid (Inala *et al*., 2019).

## Potential in pharmacognosy and drug discovery

Spring onion, *Allium fistulosum*, is a promising plant for pharmacognosy and drug development due to its wide variety of pharmacological activity and abundance of phytochemicals. The fact that it has a long history of usage in folk medicine for a variety of ailments (such as the common cold, the flu, stomachaches, headaches, arthritis, and parasite infections) demonstrates its ethnomedicinal relevance to many different societies. Extracts from different sections of plants have anti-inflammatory, antibacterial, antiviral, anti-obesity, anti-oxidant, and anti-cancer effects today, thanks to modern pharmacological research that have validated many of these traditional applications (Sung *et al*., 2018).

This effect is due in part to the actions of certain bioactive components, including flavonoids, sulfur-containing compounds (allicin and derivatives), steroidal saponins (fistulosaponins), and cinnamic acid amides, which all regulate immune responses, inhibit tumor growth, and protect against oxidative stress. Aqueous extracts have been shown to alleviate arthritic symptoms in animal models, ethanol extracts have been found to be as effective as aspirin as an analgesic, and so on.

As a prospective legitimate immunomodulator, *Allium fistulosum* boosts innate immunity by increasing cytokine production and phagocytic capacity. The fact that it may modify endocrine

**Table 3: Below show the differences.**

| Feature | Primary Metabolites | Secondary Metabolites |
|---|---|---|
| Role | Essential for growth and development | Not essential for basic survival; ecological roles |
| Production Phase | Growth phase | Stationary or late growth phase |
| Quantity Produced | Large quantities | Small quantities |
| Distribution | Common and similar in all plants | Species-specific and diverse |
| Examples | Carbohydrates, proteins, lipids, nucleic acids | Alkaloids, terpenoids, phenolics, flavonoids |
| Function in Plants | Energy, structure, genetic information | Defense, attraction, competition |
| Application in Medicine | Limited direct use | Major source of drugs and bioactive compounds |

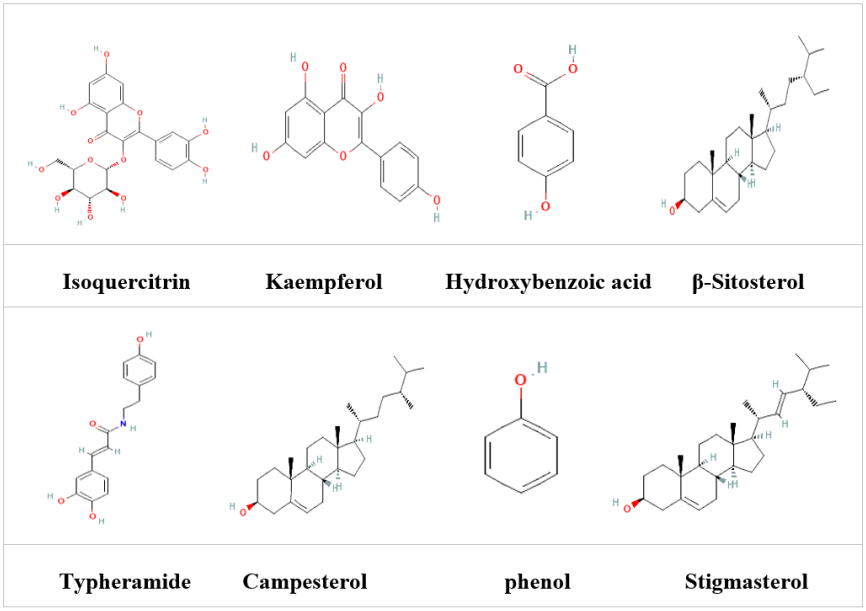


**Figure 3:** Some chemical constituents of Spring Onion (*Allium fistulosum*).

disruption, which is important for diseases like polycystic ovarian syndrome (PCOS), adds to the therapeutic potential. The plant's extracts show promise as a natural antibacterial pharmacotherapy source due to its hepatoprotective properties and antimicrobial pathogen activity (Bnouham *et al.*, 2006).

## CONCLUSION

The Allium genus includes the highly prized spring onion (*Allium fistulosum* L.), which displays a broad variety of pharmacological actions due to its abundance of phytochemicals. Saponins, sulfur-based compounds, phenolic acids, and flavonoids make up the bulk of this species' phytochemicals, and they all work together to combat cancer, inflammation, microbes, and oxidative stress. Together, these bioactive components reduce oxidative stress, strengthen the immune system, and help ward against chronic and degenerative diseases. Additionally, the plant's nutritional profile which includes vital minerals, vitamins, and bioactive sulfurates makes it more suitable for usage with the functional food component. Research on pharmacogenetics has identified *A. fistulosum* as a promising option due to its distinct phytochemical and biological properties that set it apart from other Allium species. Nevertheless, more advanced research is needed to understand its mechanisms of action, pharmacokinetics, and therapeutic efficacy through *in vivo* and clinical trials, despite the extensive documentation of its traditional applications and empirical validation of its biological effects. Second, efforts should be made to standardize extracts, formulate existing chemicals, and find new ones. When it comes to potential applications in drug discovery, nutraceutical creation, and plant-based medicinal agents, *A. fistulosum* has a lot of promise as a natural and sustainable source.

## FUTURE DIRECTIONS

While the traditional applications and biological effects of *Allium fistulosum* are well-documented and empirically validated, significant gaps remain. Future research must focus on advanced investigations to elucidate the specific mechanisms of action and pharmacokinetics of its bioactive compounds. There is a critical need for rigorous *in vivo* studies and clinical trials to confirm therapeutic efficacy in humans. Furthermore, efforts should be directed toward the standardization of extracts and the formulation of existing chemicals to ensure consistency. Exploring *A. fistulosum* for the discovery of new bioactive agents could lead to sustainable advancements in drug discovery and nutraceutical development.

## ACKNOWLEDGEMENT

Shubham Anand and Ankita Sharma conceptualized the review, planned the outline, and structured the manuscript. Shubham Anand, Ankita Sharma, Dr. Pushpendar Bardiya, and Deep Singh Bhadouriya were responsible for writing the manuscript and developing the figures. Shivpal Rewapati contributed to the literature search and data collection. Dr. Naveen Shivavedi assisted in data interpretation and preparation of figures and tables. All authors reviewed, revised, and approved the final manuscript for publication.

## ABBREVIATIONS

***A. fistulosum*:** *Allium fistulosum*; ***A. cepa*:** *Allium cepa*; **ROS:** Reactive Oxygen Species; **DPPH:** 2,2-Diphenyl-1-picrylhydrazyl; **FRAP:** Ferric Reducing Antioxidant Power; **COX-2:** Cyclooxygenase-2; **iNOS:** Inducible Nitric Oxide Synthase; **MIC:** Minimum Inhibitory Concentration; **NADH:** Nicotinamide Adenine Dinucleotide (Reduced Form); **NADPH:** Nicotinamide

Adenine Dinucleotide Phosphate (Reduced Form); **CNS:** Central Nervous System; **PCOS:** Polycystic Ovarian Syndrome; **MCF-7:** Michigan Cancer Foundation-7 Breast Cancer Cell Line; **DNA:** Deoxyribonucleic Acid; **RNA:** Ribonucleic Acid; **ABA:** Abscisic Acid.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

## AUTHOR CONTRIBUTIONS

Richa Kothari, Amrita Goyal, and Shubham Anand conceptualized the review, planned the outline, and structured the manuscript, with primary contribution and coordination led by Shubham Anand. Shubham Anand, Dr. Kavita Shukla, Ankita Sharma, Harsha Raikwar, Pushpendar Bardiya, and Deep Singh Bhadouriya were responsible for writing the manuscript and developing the figures. Shivpal Rewapati contributed to the literature search and data collection. Naveen Shivavedi assisted in data interpretation and preparation of figures and tables. All authors reviewed, revised, and approved the final manuscript for publication.

## SUMMARY

This review comprehensively highlights the nutritional, phytochemical, ethnomedicinal, and pharmacological significance of *Allium fistulosum* L. (spring onion), a member of the *Amaryllidaceae* family widely cultivated in East Asia and other parts of the world. The plant is recognized not only as a culinary vegetable but also as a valuable functional food and medicinal resource.

Phytochemical investigations reveal that *A. fistulosum* is rich in sulfur-containing compounds (such as allicin and diallyl disulfide), flavonoids (quercetin, kaempferol, isoquercitrin), phenolic acids (ferulic acid, p-coumaric acid), steroidal saponins, and phytosterols. These bioactive constituents contribute to significant antioxidant, anti-inflammatory, antimicrobial, antihypertensive, anti-obesity, and anticancer activities. Experimental studies demonstrate that extracts from different plant parts modulate oxidative stress, inflammatory mediators, lipid metabolism, and apoptotic pathways.

Nutritionally, the plant provides essential vitamins (A, C, and B-complex), minerals (potassium, calcium, magnesium), dietary fiber, and low caloric content, enhancing its value in preventive healthcare and metabolic regulation. Comparative phytochemical analyses further indicate unique constituents that differentiate *A. fistulosum* from other Allium species.

Although preclinical evidence strongly supports its therapeutic potential, further molecular investigations, extract standardization, pharmacokinetic profiling, toxicity evaluation, and well-designed clinical trials are required to translate its bioactive potential into validated nutraceutical and pharmaceutical applications.

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**Cite this article:** Kothari R, goyal A, Anand S, Shukla K, Sharma A, Raikwar H, *et al*. Bioactive Secondary Metabolites of *Allium fistulosum* L.: Nutraceutical and Pharmacological Implications. Pharmacog Res. 2026;18(4):1195-205.