Nigella sativa: Unveiling the Morphology, Anatomy, Economic Value, and Therapeutic Spectrum of Black Cumin

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Introduction

Nigella sativa L., commonly known as black cumin, or kalonji, is an annual flowering plant belonging to the Ranunculaceae, family. This plant has garnered significant attention due to its widespread traditional uses and scientific evidence supporting its diverse properties.

Botanical Classification and Nomenclature

The scientific classification of *Nigella sativa* places in the plant kingdom, as detailed in Table 1. The genus name *Nigella* is derived from the Latin word '*niger*,' meaning 'black,' a direct reference to the distinctive color of its seeds.

Geographical Distribution and Cultivation

Nigella sativa is indigenous to specific regions of Eastern Europe, notably Bulgaria and Romania, and Western Asia, encompassing Cyprus, Turkey, Iran, and Iraq (Dabeer et al., 2022). From these native origins, the plant has naturalized and spread extensively across a much wider geographical area, including various parts of Europe, northern Africa, and eastward into Myanmar. Its adaptability has

led to its widespread cultivation in Mediterranean countries, Central Europe, and Southwest Asia. In India, its cultivation is prominent in states such as Bengal, Assam, and Maharashtra.

Table 1: Classification for Nigella sativa: (J. Bentham and J.D. Hooker)

Rank	**Classification**
Kingdom	Plantae
Class	Dicoteledons
Sub-Class	Polypetalae
Series	Thalamiflorae
Order	Ranales
Family	Ranunculaceae
Genus	*Nigella*
Species	*N. sativa*

Historical Significance and Traditional Uses

The history of *Nigella sativa* uses dates back millennia, with archaeological evidence pointing to its earliest cultivation approximately three thousand years ago (Salih et al., 2009). Seeds have been unearthed in ancient Egyptian sites, including the tomb of Tutankhamun, and in a Hittite flask in Turkey from the second millennium BC (Salih et al., 2009). Historically, it was a valued condiment in the Old World, used to flavor food.

Beyond its culinary role, *N. sativa* holds deep-rooted significance in numerous folk medicinal practices and traditional wisdom systems across the globe. Its use is well-documented in Islamic, Arabic, Unani, Ayurvedic, Chinese, Malay, Greek-Roman, Jewish, and Tibb-e-Nabawi (Prophetic Medicine) traditions (Khan & Rehman, 2021). *N. sativa* has been revered, often hailed as a "universal healer," a "miraculous plant," or "the herb from heaven." In Arabic, it is affectionately known as "Habbatul barakah," meaning 'the seed of blessing,' a testament to its perceived wide-ranging benefits (Kruk, 2024).

The consistent and broad application of *N. sativa* in traditional medicine for a vast array of ailments, including dyspnea, cough, asthma, headache, dysmenorrhea, obesity, diabetes, hypertension, gastrointestinal issues, skin disorders, inflammation, fever, and rheumatism, is notable. This extensive historical empirical observation of its efficacy is now increasingly supported by modern scientific validation, which demonstrates a wide spectrum of pharmacological activities such as antioxidant, anti-inflammatory, antimicrobial, antidiabetic, anticancer, immunomodulatory, hepatoprotective, and renal protective properties (Alberts, 2024). This convergence of ancient wisdom and contemporary research highlights the significant potential for traditional medicine systems to serve as valuable guides for modern drug discovery.

Morphology

The morphology of *Nigella sativa* encompasses its visible structural characteristics, from its overall growth habit to the intricate details of its flowers, fruits, and seeds (Plate- 1).

General Plant Characteristics

Nigella sativa is characterized as an annual herbaceous flowering plant, completing its life cycle within a single year. It typically attains a height of 20–30 cm, though some reports indicate it can grow taller, reaching up to 45 cm or even 60 cm. The plant exhibits a rather stiff, erect, and branching stem, which can be slightly hairy and possess a shiny green appearance. Observations suggest variations in branching patterns, with some accessions showing dense branching at the base, while others branch predominantly in the upper regions. The stem is herbaceous, cylindrical, and covered with fine hairs, including glandular ones.

The leaves of *N. sativa* are finely divided and linear, though not thread-like. They are arranged alternately along the stem. Leaf blade length typically ranges from 25–50 mm and is described as linear to lanceolate in shape. The plant anchors itself with a well-developed taproot system, characterized by stout, elongated, cylindrical, and branched roots.

Flower Morphology

The flowers of *Nigella sativa* are noted for their delicate appearance. They are typically colored pale blue and white, although variations in color, including yellow, pink, or pale purple, have been reported. Each flower usually bears five to ten petals, with some descriptions specifically mentioning five petals. The flowers are borne solitarily on long peduncles. Within the flower, numerous stamens are present, along with five or six elongated, fused carpels.

Fruit and Seed Morphology

The fruit of *Nigella sativa* is a prominent feature, described as a large and inflated capsule. This capsule is typically composed of three to seven united follicles, with some sources specifying five or six segments. Each of these follicles contains numerous seeds. The mature capsule is black-colored and may present an "odd, toothed" appearance.

The seeds, which are the most economically important part of the plant, are small and somewhat compressed. They are typically three-cornered, or trigonous, with two sides appearing flat and one convex. Externally, the seeds are black or dark brown, while internally they are white and oleaginous (oily). Their shape is often described as angular or funnel-shaped. The dimensions of the seeds are generally around 2-3.5 mm in length and 1-2 mm in width. A distinguishing characteristic of *N. sativa* seeds is their strong, agreeable aromatic odor, often likened to

nutmeg. Their taste is spicy, pungent, and notably bitter, with some individuals detecting a faint hint of strawberries.

Fig. A. *Nigella sativa* plant B. Flower & Fruit C. Seeds

Anatomy

The internal structure, or anatomy, of *Nigella sativa* reveals intricate cellular and tissue arrangements that underpin its macroscopic features and biological functions.

Nigella sativa (black cumin) primarily exhibits the fundamental anatomical features characteristic of a dicotyledonous plant in its root, stem, and seed structures. For instance, its stem has vascular bundles arranged in a ring and an angular outline, while the root shows a central vascular cylinder for water and nutrient transport. However, it also possesses prominent oil droplets within the root xylem, suggesting a role in storing or transporting valuable lipid compounds. Additionally, its seeds are particularly distinctive, featuring a protective epidermis with papillose outgrowths, a clear hypodermis, and a notable reddish-brown pigmented layer rich in thick-walled, rectangular cells (Pandey, 2024). The endosperm of the seed is densely packed with oil globules, serving as a primary reservoir for the plant's bioactive oils, with the tiny embryo nestled at its core (Plate-2).

Economic Importance

The economic significance of *Nigella sativa* is multifaceted, stemming from its widespread use in culinary traditions, its valuable oil production, and its emerging roles in agriculture and as an ornamental plant.

Culinary and Food Applications

The seeds of *Nigella sativa* are extensively utilized as a spice in numerous cuisines globally, with a particular prominence in Arab and Halal culinary traditions. These versatile seeds are ground to create bitter qizha paste in Palestine and are a key ingredient in dry-roasted form to flavor curries, various vegetables, and pulses. They serve as a popular seasoning in recipes incorporating pod fruits, salads, and poultry. They are also an essential component of the traditional Bengali spice mixture known as panch phoron (Sarkar, 2019), which translates to a 'mixture of five spices'.

A significant factor contributing to the economic importance and widespread acceptance of *N. sativa* in the food industry is its classification by the Food and Drug Administration (FDA) in the United States. The FDA designates *Nigella sativa* L. as Generally Recognized as Safe (GRAS) for use as a spice, natural seasoning, or flavoring.

Oil Production and Industrial Uses

Nigella sativa seeds are a rich source of valuable oils, containing approximately 36–38% fixed oil and 0.4–2.5% essential oil. Other reports indicate fixed oil content ranging from 30-44.2% and essential oil from 0.4-1.49% (Liao, 2020). The essential oil is particularly rich in bioactive compounds, with gas chromatography (GC) and gas chromatography-mass spectrometry (GC-MS) analyses identifying p-cymene, thymoquinone, α-thujene, longifolene, β-pinene, α-pinene, and carvacrol as its main components, collectively accounting for approximately 85% of the total content (Aksu, 2020). The fixed oil is also

nutritionally dense, comprising 26% protein, 25% carbohydrates, 8.4% crude fiber, 4.8% ash, carotene, and essential minerals such as copper, phosphorus, zinc, and iron. Overall, the seeds contain 13.5-22% protein, 38-40% fat, 3.7% moisture, 3.7% ash, and 17-32% carbohydrates.

The oil derived from *N. sativa* is utilized in folk medicine, as a flavoring agent for bread and cheese, and as a spice in various meals. Beyond culinary applications, the essential oils find use in the perfume and pharmaceutical industries.

Medicinal Properties and Pharmacological Activities

Nigella sativa has been extensively studied for its medicinal properties, with a vast array of pharmacological activities attributed to its rich phytochemical profile.

Key Bioactive Compounds

The therapeutic efficacy of *Nigella sativa* is primarily linked to its diverse array of bioactive compounds (Table. 2), which are predominantly concentrated in the essential oil extracted from its seeds. Oils are 32% to 40% of the total composition. *N. sativa* oil contains linoleic acid, oleic acid, palmitic acid, and trans-anethole, and other minor constituents, such as nigellicine, nigellidine, nigellimine, and nigellimine N-oxide. Aromatics include thymoquinone, dihydrothymoquinone, p-cymene, carvacrol, α-thujene, thymol, α-pinene, β-pinene and trans-anethole (Aksu, 2020). Protein and various alkaloids are present in the seeds (Hannan, 2021).

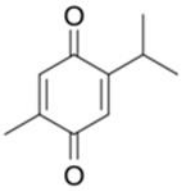
Furthermore, *N. sativa* contains tocols, which are important natural antioxidants like tocopherols (alpha, beta, gamma, and delta isomers), with γ-tocopherol typically being the most abundant (Suri & Sareen, 2022).

The presence of multiple compounds, each with its own biological activity (e.g., antioxidants, antimicrobials, anti-inflammatories), may lead to enhanced or complementary therapeutic effects (universal healer) that are greater than those of any single isolated compound. This suggests that isolating individual compounds may not fully capture the plant's comprehensive therapeutic potential, advocating for continued research into the efficacy of whole extracts or combinations of compounds.

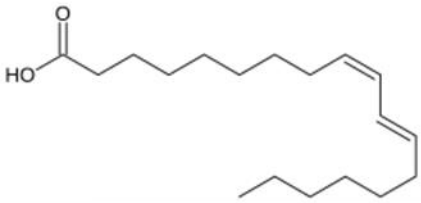
Traditional Medicinal Applications across Cultures

Nigella sativa holds profound historical and religious significance, having been utilized in various ancient and traditional medicinal systems, including those of ancient Egypt, Greece, Rome, as well as Islamic, Arabic, Unani, Ayurvedic, Chinese, Malay, Jewish, and Tibb-e-Nabawi traditions (Table. 3).

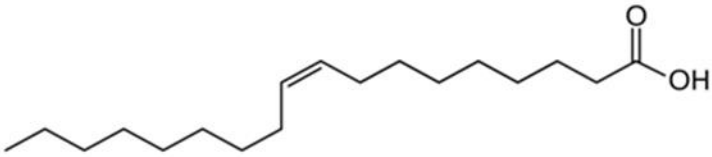
Plate. 2



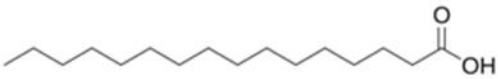
Thymoquinone



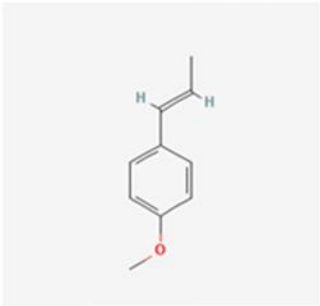
Rumenic acid, an example of conjugated linoleic acid



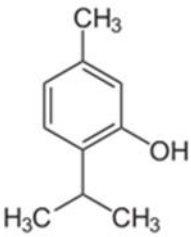
Oleic acid



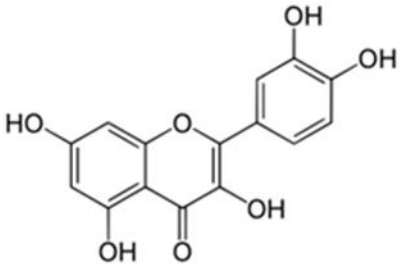
Palmitic acid



Anethole



Thymol



Quercetin

Table 2: Major Bioactive Compounds of Nigella sativa and Their Pharmacological Activities

Compound Class	**Specific Compounds**	**Primary Pharmacological Activities**
Terpenes/Terpenoids	Thymoquinone (TQ), p-cymene, α-thujene, longifolene, β-pinene, α-pinene, carvacrol, t-anethole	Antioxidant, Anti-inflammatory, Antimicrobial, Antidiabetic, Anticancer, Immunomodulatory

Alkaloids	Nigellicine, Nigellimine, Nigellidine, Nigelamines A1–A5	Lipid metabolism-promoting, various others
Polyphenols	Phenolic acids (e.g., caftaric, caffeic, ferulic), Flavonoids (e.g., quercetin, kaempferol, rutin)	Antioxidant, Anti-inflammatory, Anti-aging
Fatty Acids	Unsaturated fatty acids, Oleic acid, Glycerolipids, Phospholipids	Nutritional, various others
Phytosterols	β-sitosterol, Stigmasterol, Δ7-stigmasterol, Δ7-avenasterol, Campesterol, Cholesterol	Cholesterol-lowering
Miscellaneous	Proteins, Carbohydrates, Crude fiber, Ash, Minerals, Saponins, Tannins	Nutritional, various others

Table 3: Traditional Medicinal Uses of Nigella sativa

Cultural/Traditional System	**Ailment/Condition**	**Specific Application (Examples)**
Unani, Ayurvedic, Chinese, Islamic	Respiratory Issues	Seeds/oil for bronchodilator, expectorant effects
Islamic, Arabic, Unani, Ayurvedic	Metabolic & Endocrine Disorders (Diabetes, Obesity, Dyslipidemia)	Seeds/oil for blood sugar & lipid management
Islamic, Arabic, Unani, Ayurvedic	Cardiovascular Health (Hypertension)	Seeds/oil as hypotensive agent
Islamic, Arabic, Unani, Ayurvedic, Folk Medicine	Gastrointestinal Disorders	Seeds as digestive, carminative, anthelmintic, appetite stimulant
Islamic, Arabic, Unani, Ayurvedic, Folk Medicine	Inflammation & Pain	Seeds/oil for analgesic, anti-inflammatory effects

Islamic, Arabic, Unani, Ayurvedic, Folk Medicine	Infections (Bacterial, Fungal, Viral, Parasitic)	Seeds/oil for antimicrobial, anti-parasitic properties
Islamic, Arabic, Unani, Ayurvedic, Folk Medicine	Skin Disorders (Eczema, Boils, Nasal Ulcers, General Skin Diseases)	External application of seeds/oil
Islamic, Arabic, Unani, Ayurvedic	Women's Health (Dysmenorrhea, Menstrual Regulation, Lactation)	Seeds as emmenagogue, lactagogue
Various	Other (Fever, Jaundice, Paralysis, Kidney Stones, Diuretic, Liver Tonic, Regaining Sense of Smell)	Seeds/oil for febrifuge, diuretic, hepatoprotective, renal protective effects

Scientifically Validated Pharmacological Actions

Extensive scientific research over recent decades has rigorously investigated and substantiated many of the traditional claims regarding *Nigella sativa*, while also uncovering additional pharmacological properties (Table. 4).

Table 4: Scientifically Validated Pharmacological Activities of Nigella sativa

Activity Class	**Specific Actions**	**Key Bioactive Compounds**
Antioxidant	Scavenges free radicals, inhibits ROS production	Thymoquinone, Polyphenols (flavonoids, phenolic acids), Tocols
Anti-inflammatory	Inhibits NO radical excretion, blocks cyclooxygenase enzymes	Thymoquinone, Polyphenols
Antimicrobial	Antibacterial, Antifungal, Antiviral, Anti-parasitic	Thymoquinone, Carvacrol, t-anethole, 4-terpineol, other volatile oils
Metabolic Regulation	Antidiabetic, Antiobesity, Hypolipidemic (lowers cholesterol, triglycerides)	Thymoquinone, Phytosterols
Anticancer	Inhibits cancer cell line growth, tumor suppression	Thymoquinone

Immunomodulatory	Increases immune system activity	Thymoquinone
Organ Protective	Hepatoprotective, Renal Protective, Neuroprotective, Gastroprotective	Thymoquinone, other compounds
Respiratory	Bronchodilator, Spasmolytic	Thymoquinone, other compounds
Cardiovascular	Antihypertensive	Thymoquinone, Phytosterols
Analgesic	Pain relief	Thymoquinone, other compounds

Challenges and Future Directions in Research

Black cumin is an important plant with a long history of use in cooking and medicine. Its seeds are popular spices, and its oils, full of beneficial compounds like thymoquinone, are increasingly valuable. New processing methods, like decortications, are helping to improve the quality of these oils for commercial use. Scientifically, black cumin is recognized for its wide range of health benefits, including antioxidant, anti-inflammatory, antidiabetic, and anticancer effects, which are due to the combined action of its many natural compounds. This makes it a promising natural remedy for various complex diseases.

While black cumin offers significant therapeutic potential, it's crucial to use it responsibly. Its safety depends on the dose and duration of use and special care is needed for sensitive individuals. It can also interact with other medications, potentially altering their effects. Therefore, professional medical advice is essential, especially if you're taking multiple drugs. Future research should focus on its antimicrobial properties, how it interacts with different foods, and rigorous clinical trials to confirm its health claims in humans, ensuring its safe and effective use.

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