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## The Magical Spice Kalonji (*Nigella sativa*) Redefined: A Review of Advances in Its Nutritional, Industrial, and Therapeutic Benefits

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### Abstract

*Nigella Sativa*, also called black cumin or kalonji, is a highly valued and flexible plant that has been used in food, medicine, and industry for a long time. Because of their unique taste and smell, the seeds are very popular. They are used in everything from lamb meals to bread and chutneys. *Nigella sativa* is used in food, but it has also been looked at to see if it could be used as a drug. It's been used to treat health problems like hyperhomocysteinemia, heart disease, and high blood pressure because it kills bacteria and fights free radicals. This "magical spice" is also used in many different businesses. As a preservative, it keeps cheeses and pickles free of harmful germs throughout production. Constant new research into its potential health advantages further strengthens the case that it is a multipurpose plant of considerable scientific interest. More and more research is being done on *Nigella sativa*, and each new discovery highlights its potential benefits. Oxidative stress, high cholesterol, and cardiovascular health are just few of the concerns that have been demonstrated to benefit from it.

**Key words:** kalonji, nutrition, value addition, therapeutic effects

### Introduction

In the year 2015, the United Nations took a historic step by reintroducing the Sustainable Development Goals, a visionary initiative designed to guide global efforts towards a more sustainable future. Among these goals, the third objective emerged as a beacon of hope, dedicated to "Good Health and Well-Being." This goal was not merely a statement of intent but a comprehensive strategy that sought to promote a state of flourishing health through the judicious use of medicinal plants and eco-friendly practices. Traditional medicine, steeped in ancient wisdom, has long tapped into the healing potential of plant extracts to address a myriad of human ailments. Recognizing the immense value of this age-old practice, the

World Health Organization (WHO) has been at the forefront of emphasizing the pivotal role of research into medicinal plants. Their commitment extends to scrutinizing scientific findings, ensuring quality assurance, assessing safety, evaluating effectiveness, and understanding potential medication interactions. This rigorous approach underscores the seriousness with which medicinal plants are considered agents of healing in the treatment of human illnesses. Importantly, the utilization of medicinal plants goes beyond the realm of healthcare; it also becomes a guardian of biodiversity and a pillar of support for local communities that have historically relied on traditional healing practices. This dual benefit underscores the interconnectedness of our well-being with the natural world and the preservation of indigenous knowledge. Incorporating traditional medicine into modern healthcare systems carries immense promise, particularly in light of the growing challenge posed by antibiotic resistance.

As we stand at the crossroads of an escalating health crisis, medicinal plants offer a ray of hope by providing alternative treatment options for a spectrum of diseases. This approach not only diversifies our healthcare arsenal but also helps mitigate the overuse of antibiotics, a practice that has contributed significantly to the rise of antibiotic-resistant pathogens. Medicinal plants, particularly those with a wide variety of useful biological properties, have a powerful attraction. The black cumin seed is a rare treasure among the many untapped natural resources. Its potential to improve our health and help us overcome a number of health problems makes it an intriguing area to study. In this chapter, we examine the role that medicinal plants play in the complex web of sustainable healthcare. We delve into the significant effect that this ancient knowledge has on our quest for health and happiness, and we highlight the extraordinary black cumin seed as a representation of the latent potential in our natural environment.

#### **Need & Scope of *Nigella Sativa* (Kalonji)**

*Nigella sativa* L., more popularly known as "black cumin," is from the highly regarded Ranunculaceae family of plants. Historical records show that it has been used as a medicine and a culinary ingredient for ages upon centuries (Srinivasan, 2018). All around the

world, including in Asia, Africa, Europe, and the Americas, this unique crop grows well. Black cumin, however, reaches its highest levels of production and significance in just a handful of nations. These nations include India, Pakistan, Iran, Iraq, and Turkey. Within the vast expanse of India, a kaleidoscope of states contributes to the cultivation of black cumin. Gujarat, Rajasthan, West Bengal, Madhya Pradesh, Assam, Bihar, Uttar Pradesh, Punjab, Jammu & Kashmir, Himachal Pradesh, and Tamil Nadu stand as the key protagonists in this agricultural narrative (Sultana *et al.*, 2017). However, it is essential to note that comprehensive statistical data on the precise acreage under black cumin cultivation, its output, and productivity remains relatively scarce. Though elusive, some insights into the production landscape emerge. Predictive estimates suggest a cultivation area encompassing approximately 9,000 hectares, with India standing as a stalwart producer, yielding an impressive 7,000 to 8,000 metric tons of black cumin seeds annually (Huchchannanavar *et al.*, 2019). These figures, while indicative of the crop's significance, highlight the need for more robust data collection and reporting mechanisms to fully appreciate the extent of black cumin's contribution to agriculture and medicine alike.

Black cumin stands as a veritable treasure trove of nutritional riches. Its profile boasts an array of essential components, making it a coveted addition to both dietary and medicinal realms. Let's unravel the nutritional marvel that is black cumin.

#### ***Cultivation and Harvesting of Nigella Sativa (Kalonji)***

The well-known plant *Nigella sativa* has a yearly growth cycle and normally grows to a height of 20-30 cm. The flowers, which come in a range of hues from yellow to white to pink to light blue to pale purple, have a fragile appearance and resemble threads. The fruit is a large capsule with three to seven follicles, each of which contains several seeds (Al-Ali *et al.*, 2008). Kalonji seeds are collected in the early stages of their maturation when they still have a hint of green before they drop their seed coat. This period is critical because it coincides with the highest concentrations of aromatic oils and consequently increases the value of these oils on the market.

Good harvesting practices protect seed viability and prevent fruits from spoiling. Sun drying is a traditional method of preserving crops post-harvest, although threshing is often done with wooden sticks (Datta *et al.*, 2012). *Nigella sativa*, has been used for both culinary and medical applications for an extensive period of time. The extensive study that covers this subject across several centuries, including both historical and modern contexts, makes it an engaging subject for scientific research.

#### **Nutritional Riches: Unveiling the Secrets of a Healthy Diet**

Delving into the nutritional aspects, *Nigella sativa* seeds reveal a tapestry of fatty acids, encompassing high levels of unsaturated fatty acids (such as eicosadienoic acid, dihomolinoleic acid, oleic acid, and linoleic acid) alongside saturated fatty acids like palmitic and stearic acids (Nickavar *et al.*, 2003). The presence of non-essential amino acids such as arginine, glycine, alanine, cystine, glutamate, aspartate, proline, serine, and tyrosine further enhances its nutritional profile (El Naggar *et al.*, 2017).

#### **Nigella sativa: A Treasure Trove of Vitamins and Minerals**

*N. sativa* also shines with its substantial vitamin and mineral content, encompassing tocopherol, thiamine, pyridoxine, niacin, folic acid, riboflavin, calcium, phosphorus, magnesium, potassium, sodium, zinc, copper, iron, manganese, and selenium (Mukhtar *et al.*, 2019). Black cumin dazzles with its diverse nutritional content. Within its tiny seeds, protein content varies from a substantial 20 to an astounding 85 per cent, providing a valuable source of this essential macronutrient. Furthermore, its dietary fiber content registers at a commendable 7.94 per cent, making it a significant contributor to digestive health. Vitamins such as folic acid, thiamine, niacin, selenium, and pyridoxine grace its nutritional makeup. In the realm of minerals, black cumin seeds are rich in zinc, magnesium, potassium, sodium, and chlorine.

**Essential Amino Acids:** Black cumin doesn't just stop at protein; it also offers a spectrum of essential amino acids vital for overall well-being. Cysteine, methionine, glutamate, arginine, and aspartate are among the amino acids present, enhancing its nutritional appeal (Gullu and Gulcan, 2013).

**Bioactive Components:** Beyond its fundamental nutrients, black cumin harbors bioactive treasures. Thymoquinone, the star player among these bioactive compounds, resides predominantly in its oil. This compound boasts an impressive repertoire of therapeutic benefits, including gastrointestinal protection. The seed oil itself comprises a palette of fatty acids, with palmitic acid (20.4%) and linoleic acid (64.6%) as notable constituents. (Kiralan *et al.*, 2017).

**Sterols and Essential Oils:** Black cumin doesn't hold back when it comes to beneficial compounds. Sterols such as stigmasterol, sitosterol, campesterol, and 5-avenasterol make their presence felt, contributing to the reduction of cholesterol levels. Additionally, essential oils ranging from 0.4 to 2.5 percent are a noteworthy component of black cumin seeds (Aydin and Kart, 2021).

**Versatile Applications:** The multifaceted black cumin finds its way into a multitude of applications worldwide. In the culinary realm, it serves as a preservative, spice, and flavoring agent, elevating dishes with its aromatic presence. Its applications extend to pain management for headaches and back pain, treatment of various ailments, and pharmacological interventions, where it showcases properties like antihypertensive, antioxidant, analgesic, antidiabetic, neuroprotective, antiparasitic, and more. Its utility spans across sectors, including cuisine, pickling, baking, confectionery, pharmaceuticals, perfumes, and as a preservative for fermented vegetables and pickled commodities (Kiralan *et al.*, 2017).

As we explore the nutritional and bioactive wealth of black cumin, we begin to appreciate the depth of its contributions to both health and culinary arts. Its multifaceted nature continues to captivate researchers, chefs, and health enthusiasts alike, offering a tantalizing glimpse into the potential of nature's bounty.

#### **Industrial Applications of Nigella Sativa (Kalonji)**

Kalonji oil, derived from the remarkable *Nigella sativa* seeds, has found its place in various industrial applications, unveiling its multifaceted utility. The oxidative stability of vegetable oils is greatly improved because to their use in the food sector. The health advantages of kalonji oil, which are introduced during the blending process, are preserved with the oils' extended shelf life. Adding nutritional content while

maintaining quality is a huge plus in the kitchen (Hassanien *et al.*, 2014). Additionally, kalonji oil acts as a protector of cheese, especially when the cheese is kept in the refrigerator. Because of its inherent qualities, it protects cheese against spoilage and contamination during storage (Sultan *et al.*, 2011). Scientists have shown that adding kalonji oil to cookies may boost both their nutritional value and their appeal to customers (Sultan *et al.*, 2011). Natural seafood preservation solutions, such as those using kalonji oil, are a potential new direction in the field of food science (Baptista *et al.*, 2020), as shown by studies of the sensory qualities and shelf life of fresh fish fillets.

#### ***Use of Nigella sativa (Kalonji) in Modern Cuisine***

Beyond its industrial significance, the versatility and unique flavor of kalonji make it an enticing ingredient for contemporary fusion recipes. Its distinct taste adds depth and complexity to dishes, propelling them to culinary excellence. From kalonji-infused pasta to delectable kalonji-spiced desserts, the creative potential knows no bounds. As we delve into the fusion of this ancient spice with modern culinary artistry, we embark on a journey to unlock its functional food potential while paying homage to its rich historical legacy in traditional medicine. The earthy and subtly nutty aroma of kalonji lends depth and dimension to dishes, presenting an innovative culinary palette. By incorporating kalonji into our modern recipes, we savor not only its distinctive and exotic flavor but also harness a myriad of potential health benefits. From a sprinkle of kalonji atop a refreshing salad to its infusion into a velvety soup, the adaptability of this spice opens the doors to a spectrum of culinary creations. Through careful experimentation and a harmonious blend with complementary ingredients, we can craft dishes that showcase the intricacies of kalonji without overwhelming the overall dining experience. Kalonji oil has transcended its traditional roots to become a versatile player in both industry and modern cuisine. Its journey continues as researchers explore its long-term benefits, ensuring that this ancient treasure remains relevant in our evolving culinary landscape. With kalonji, the possibilities are as boundless as our culinary imagination, and the flavor journey promises to be nothing short of extraordinary.

#### ***Innovations in Oil Extraction Techniques***

- ***Traditional Methods and Their Limitations***

In the realm of oil extraction, conventional techniques like mechanical pressing and solvent extraction have long held sway (Tiwari, 2015). However, the imperfections inherent in these established methods, such as heightened resource consumption, prolonged processing times, diminished yields, and environmental sustainability concerns, have spurred the quest for innovative alternatives (Sharma *et al.*, 2019). Research by Puertolas *et al.* (2016) underscores that approximately 80% of the oil content within oleaginous seeds can be effectively extracted through physical means, leaving the remaining 20% to necessitate alternative technologies. Solvent extraction, favored for its simplicity and cost-effectiveness, as noted by Tan *et al.* (2016), commonly employs N-hexane due to its advantageous properties, including swift recovery, low latent vaporization heat ( $330 \text{ kJ kg}^{-1}$ ), a narrow boiling point range (63 to 69°C), excellent solubility, and nonpolar characteristics (Konopka *et al.*, 2016; Kumar *et al.*, 2017).

- ***Emergence of Non-conventional Techniques***

The limitations posed by traditional extraction methods have catalyzed the exploration of nonconventional approaches for recovering essential components from plant and seed materials. These novel techniques offer advantages over conventional methods in terms of efficiency and reduced solvent consumption. Furthermore, their eco-friendliness and sustainability align with contemporary environmental concerns. These innovative methods, noted for their cost-effectiveness, have gained traction among consumers and industries alike, delivering tall-standing benefits for various applications (Chemat *et al.*, 2012).

#### ***Novel Extraction Techniques for processing of Nigella Sativa (Kalonji) Oil***

In the current landscape of oil extraction, several pioneering methods have emerged as viable alternatives to traditional approaches. These techniques include:

##### ***1. Supercritical Fluid Extraction:***

Supercritical fluid extraction is a method that utilizes a supercritical fluid, often carbon dioxide ( $\text{CO}_2$ ), which is brought to a state that combines the properties of a gas and a liquid under specific temperature and pressure

conditions. In this state, the supercritical fluid can penetrate solid materials like plant matter and dissolve compounds of interest. The extracted components are left behind when the supercritical fluid transforms back into a gas once the pressure and temperature are brought back to normal. SFE is renowned for producing high-quality extracts with little to no solvent residue (Mandal *et al.*, 2007).

### **2. Ultrasound-Assisted Extraction (UAE):**

High-frequency sound waves (ultrasound) are used in ultrasound-assisted extraction to cause disruption to plant cells. Ultrasound's cavitation (bubble-forming and -bursting) mechanical actions aid in the lysis of cell membranes and the release of bioactive substances. Shorter extraction times, higher yields, and lower energy usage are all reasons why UAE is so well-liked (Chemat *et al.*, 2017).

### **3. Microwave-Assisted Extraction (MAE):**

In microwave-assisted extraction, both the solvent and the plant material are heated using microwaves. Microwaves cause thermal expansion inside the sample, which stimulates the secretion of chemicals from plant cells. This technique has gained popularity due to its effectiveness and the short amount of time it takes to extract substances from them compared to more conventional approaches. (Vorobiev and Lebovka 2008).

### **4. Ohmic Heating Extraction:**

In ohmic heating extraction, a sample (usually a combination of solvent and plant material) is heated by applying an electric resistance. Rapid heating occurs because the electrical resistance creates heat inside the sample itself. Ohmic heating is often employed in conjunction with other extraction methods because of how well it stimulates the release of chemicals (Maskan 2001).

### **5. Pulsed Electric Field Extraction (PEF):**

Short, high-voltage electrical pulses are applied to a sample in pulsed electric field extraction. These pulses puncture the membranes of cells momentarily, allowing for the diffusion of substances. PEF is used to extract intracellular chemicals from bacteria, and it is a gentle approach that maintains the purity of delicate compounds. (Vorobiev and Lebovka 2008).

These innovative extraction methods have several benefits, including expedited processing times, higher extraction yields, and less solvent residue in the final

product. Sustainable and efficient extraction procedures are in high demand in many industries, including the food, pharmaceutical, and natural product sectors, thus researchers and businesses are turning to these strategies.

### ***Nigella Sativa: A Potentially Medicinal Herb***

#### **• Antimicrobial Potential**

The antimicrobial qualities of essential oils derived from spices and aromatic plants have often been praised, with their phenolic components being principally responsible for these effects. *Nigella sativa* essential oil, in particular, stands out due to its rich content of phenolic compounds like p-cymene, thymol, and carvacrol. It's the synergy between these components that lends *Nigella sativa* essential oil its remarkable antimicrobial prowess. In fact, studies have shown that this oil can exert significant inhibitory effects against various bacteria, including *Bacillus cereus*, *Bacillus subtilis*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa*, even at concentrations of 2000 and 3000 ppm, resulting in complete zone inhibition. Impressively, its antibacterial prowess rivals that of common antibiotics like ampicillin and cloxacillin (Singh *et al.*, 2005).

#### **• Antioxidant Potential**

In the realm of food quality, preventing the oxidation of lipids and proteins is paramount. Synthetic antioxidants, however, have raised concerns in the food and medical industries due to potential harm and toxicity. Enter *Nigella sativa* seeds, naturally endowed with antioxidant properties. Studies have explored their potential in combating hyperhomocysteinemia (HHcy), a condition associated with oxidative stress and lipid abnormalities. Black cumin oil and thymoquinone, found in *Nigella sativa* seeds, have been administered to mitigate oxidative stress in rats with HHcy. Results indicate elevated antioxidant status, with increased activity of enzymes like glutathione peroxidase and superoxide dismutase. These findings hint at a promising natural approach to alleviate HHcy-related complications, emphasizing the safety profile of kalonji oil and thymoquinone as compared to traditional medications. (El-Saleh *et al.*, 2004)

#### **• Cardioprotective and Blood Pressure-Regulating Properties of *Nigella sativa* Seeds**

*Nigella sativa* seeds have emerged as potential allies in the fight against cardiovascular disease (CVD). Studies on individuals with moderate hypertension demonstrated significant blood pressure reductions after eight weeks of *Nigella sativa* consumption. Similarly, research on rabbits with high cholesterol revealed inhibited plaque formation and diabetic patients experienced improved left ventricular systolic function. Additionally, a combination of *N. sativa* seeds and honey led to reduced triglyceride and total cholesterol levels and an increase in high-density lipoprotein cholesterol (HDL-C) among individuals with hypercholesterolemia. Both healthy individuals and those with hypercholesterolemia experienced weight loss and lower blood pressure. While promising, further research is needed to fine-tune dosages and seed varieties and explore potential interactions with conventional CVD medications (references needed). Hyperhomocysteinemia is an important topic of research since it has showed promise as an antioxidant and may help reduce cholesterol levels. With these findings, it may be included in treatment programs, offering physicians a safer, more effective alternative to synthetic pharmaceuticals. It needs to be tested in more clinical studies to find out the best doses and ways to use it to treat different health problems. This includes looking into how it could help treat heart disease, diabetes, and other long-term conditions.

#### ***Nigella sativa's Potential Applications in the Food Industry Sector***

For centuries, *Nigella sativa* seeds have graced culinary creations, enhancing flavor and acting as a natural preservative. These seeds have found their place in a wide array of dishes, from yoghurt, pickles, sauces, and salads to baked goods and cheese. They're also valued as carminatives, adding zest to bread and culinary preparations. In various regions, *Nigella sativa* seeds are an essential part of spice blends like "panch phoram" in India, Bangladesh, and Nepal. Beyond the kitchen, these seeds have been employed as insect repellents for grain protection. As their popularity grows, *Nigella sativa* seed oil has found applications in functional foods, cosmetics, industry, and pharmaceuticals. This versatile oil has even exhibited protective properties against UV radiation, making it a valuable asset in various domains

#### ***Preservation Powers***

Kalonji seed oil has proven its mettle in food preservation, extending the shelf life of date pastes by enhancing their storage stability. Various concentrations of kalonji seed oil were tested, with 400 ppm emerging as the optimal concentration for preserving color, texture, flavor, and taste characteristics. Impressively, this concentration rivaled the effectiveness of sodium benzoate as a preservative (Bahtiti, 2015).

#### ***Enhancing Dairy Delights***

Butter, a beloved dairy product, faces challenges from spoilage bacteria and rancidity due to its high nutrient content. Kalonji oil, when added to butter at different concentrations (0.05%, 0.1%, and 0.2%), emerges as a natural solution to prevent microbiological deterioration and rancidity without resorting to synthetic preservatives. The bioactive components in kalonji, particularly p-cymene and thymoquinone, exhibit radical scavenging and antibacterial properties, making them effective preservatives (Cakmakçi *et al.*, 2014). Tulum, a sheep's milk cheese, benefits from the addition of kalonji, which helps in reducing spoilage by coliform bacteria, yeast, and molds. The microbial count decreases with an increase in kalonji concentration, contributing to the preservation of cheese quality (Mahgoub *et al.*, 2013).

Incorporating *Nigella sativa* and kalonji oil into food applications showcases their potential not only as flavor enhancers but also as natural preservatives, safeguarding the quality and safety of various food products. Further exploration and fine-tuning of their use hold promise for both culinary and food preservation endeavors.

#### ***Utilization of Nigella sativa Seeds in Indian Cuisine***

The incorporation of *Nigella sativa* seeds is a common practice in Indian culinary traditions, where they play a significant role in enhancing the flavors of various dishes. Particularly, these seeds are widely utilized in the preparation of gently simmered lamb dishes like korma, infusing them with their distinctive aroma and taste (Abdallah, 2017; Sharma, 2005). In Indian cuisine, *Nigella sativa* seeds find their way into a variety of dishes, including vegetable and dhal (lentil) preparations. They are also a key ingredient in the creation of flavorful chutneys, adding depth and complexity to these condiments. While *Nigella sativa* oil is often associated with medicinal uses, the seeds

themselves possess a mildly pungent taste that complements a range of culinary applications. In dishes such as curries, pastries, and Mediterranean cheeses, the whole seeds are frequently employed, contributing their distinctive flavor profile. Despite the relatively low aromatic profile of *Nigella sativa* seeds, they are renowned for their carminative attributes, which contribute to improved digestive function and the mitigation of gastrointestinal distress. In addition to being a staple in Indian cuisine, these seeds have garnered widespread international recognition as a versatile spice and condiment. The seeds are offered in two forms: whole and crushed, providing versatility in their use in culinary contexts (Goreja, 2003).

In some European locales, the use of *Nigella sativa* seeds as a replacement for conventional pepper is sporadically seen, imparting a distinctive flavor profile to a variety of culinary preparations. It is worth mentioning that in Middle Eastern cuisine, these seeds are often used in bread dough, hence playing a significant role in imparting the particular taste found in the region's preferred rolls (Sharma, 2005). In addition to their culinary uses, dried *Nigella* seeds have been used in several industries. They have many applications beyond the food industry, including pickling, baking, confectionery, pharmaceuticals, and aromatherapy. The antimicrobial characteristics of these substances render them very desirable for their preservation capabilities, especially in the context of maintaining the quality and microbiological safety of dairy products, such as cheeses (Abdallah, 2017).

#### **Major Highlights and Findings**

The future seems promising for *Nigella sativa* (kalonji) in traditional cuisines, novel food developments and even for therapeutic uses as well. *Nigella sativa* also has useful substances that could be used to make new medicines. Extraction and packaging of these substances for drug delivery methods is an interesting area that could be studied in the future. *Nigella sativa* is a plant that can help make useful foods and nutraceuticals. This is because there is a growing desire for natural and healthy foods. Putting its benefits into everyday meals is a place where new ideas can be tried. As more people want natural and environmentally friendly goods, *Nigella sativa* is likely to be used in more businesses as a natural preservation and antibacterial agent. It is a good choice because it is stable in different

situations. But there may not be a lot of scientific proof to back up *Nigella sativa*'s specific health benefits, and more study is needed to prove that it works as a functional food or nutrition ingredient. In the end, *Nigella sativa*, also known as the "magical spice," shows how well custom and science work together. It has been used in cooking, medicine, and industry for hundreds of years, and researchers are still finding new ways to use it. As we look to the future, the seeds of this amazing plant give us hope for a better and tastier world. Scientists are learning that *Nigella sativa* could be a powerful antioxidant and anti-inflammatory drug as they learn more about its chemical ingredients. Because of these qualities, it could be a good choice for making new medicines and useful foods. *Nigella sativa* also has a long past and is important to different cultures, so it will continue to be valued and used by people all over the world. This helps bridge the gap between traditional knowledge and current science.

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