Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol. 13, (2024)
https://www.jneonatalsurg.com

OPEN ACCESS

Phytochemical Diversity, Pharmacological Potential, and Nutraceutical Applications of Nigella sativa and Solanum melongena Seeds: An Integrative Review

Km. Diksha Singh*[1], Dr. Ramteke Kuldeep Hemraj[1], Dr. Dharmendra Singh Rajput[1], Dr. Naveen Gupta[1]

[1] Patel College of Pharmacy, Madhyanchal Professional University, Bhopal, MP, India.

***Corresponding Author:**

Km. Diksha Singh,

Research Scholar, Patel College of Pharmacy, Madhyanchal Professional University, Bhopal, MP, India.

Email ID: diks8382@gmail.com

Cite this paper as: Km. Diksha Singh, Dr. Ramteke Kuldeep Hemraj, Dr. Dharmendra Singh Rajput, Dr. Naveen Gupta, (2024) Phytochemical Diversity, Pharmacological Potential, and Nutraceutical Applications of Nigella sativa and Solanum melongena Seeds: An Integrative Review. *Journal of Neonatal Surgery*, 13, 1044-1056.

ABSTRACT

Nigella sativa (Black Cumin) and *Solanum melongena* (Eggplant) seeds are emerging as versatile botanical resources with significant nutraceutical and functional food potential. This review comprehensively evaluates their phytochemical compositions, bioactivities, and current applications, integrating evidence from *in-vitro*, *in-vivo*, and limited clinical studies. *Nigella sativa* seeds are rich in thymoquinone, nigellone, and essential fatty acids, underpinning potent antioxidant, anti-inflammatory, antimicrobial, anticancer, and metabolic regulatory effects. *Solanum melongena* seeds, characterized by nasunin, chlorogenic acid, and phenolic acids, exhibit strong antioxidant and cardioprotective properties, along with favourable sensory attributes for food fortification. The nutraceutical applications of both seeds span dietary supplements, fortified bakery and dairy products, functional beverages, and polyphenol-rich extracts. Comparative analysis highlights complementary pharmacological profiles, suggesting synergistic benefits in combined formulations. Safety evaluations indicate low acute and subchronic toxicity at traditionally consumed dosages, while international regulatory recognition varies, with *Nigella sativa* enjoying broader acceptance. Despite promising evidence, gaps persist in clinical validation, standardization, and bioavailability optimization. Future research should prioritize large-scale randomized controlled trials, development of validated quality markers, and formulation innovations to enhance efficacy. Harnessing the complementary strengths of these seeds could yield next-generation nutraceuticals targeting oxidative stress, inflammation, cardiovascular health, and cognitive function. This review underscores the potential of *Nigella sativa* and *Solanum melongena* as integral components of evidence-based functional food and nutraceutical strategies.

Keywords: *Nigella sativa; Solanum melongena; Phytochemicals; Synergistic Formulations; safety; Regulatory Aspects.*

1. INTRODUCTION

Seeds have historically been valued not only for their role in plant reproduction but also for their dense concentration of bioactive compounds, rendering them indispensable in both traditional medicine and modern nutraceutical science [1]. From antiquity to contemporary pharmacognosy, seeds have served as reservoirs of phytochemicals, essential fatty acids, proteins, minerals, and secondary metabolites with therapeutic potential. In recent decades, global interest in seed-based nutraceuticals has surged, driven by the increasing consumer demand for natural health-promoting agents, the growing body of mechanistic pharmacological evidence, and advancements in analytical techniques that allow precise phytochemical profiling [2]. Among the diverse spectrum of medicinal seeds, *Nigella sativa* (family: Ranunculaceae) and *Solanum melongena* (family: Solanaceae) represent two botanicals of high pharmacological and nutritional relevance. *N. sativa*, commonly referred to as black cumin, black seed, or kalonji, has occupied a prominent place in traditional medicinal systems such as Unani, Ayurveda, Siddha, and Islamic medicine for over a millennium. Its seeds are mentioned in prophetic traditions as a remedy for “all diseases except death” and have been extensively documented in medieval medical literature. Phytochemically, *N. sativa* seeds are characterized by a rich composition of volatile and fixed oils, with thymoquinone, dithymoquinone, thymohydroquinone, and nigellone identified as the principal bioactives, alongside diverse alkaloids, saponins, flavonoids, and essential fatty acids [3, 4].

By contrast, *S. melongena*, commonly known as eggplant, brinjal, or aubergine, is primarily recognized for its edible fruit, yet its seeds remain comparatively underexplored despite their significant bioactive potential. Traditionally, *S. melongena* seeds have been utilized in various folk remedies for toothache, intestinal ailments, and inflammatory conditions [5]. Modern phytochemical analyses reveal that the seeds harbor a distinctive profile of phenolic acids most notably chlorogenic acid flavonoids such as nasunin, glycoalkaloids including solamargine and solasonine, phytosterols, and polyunsaturated fatty acids. Emerging studies suggest that these constituents may exert antioxidant, anti-inflammatory, hypolipidemic, and anticancer activities, warranting further exploration of their nutraceutical potential [6]. The last two decades have witnessed substantial progress in seed phytochemistry and pharmacology due to advances in analytical platforms such as ultra-high-performance liquid chromatography coupled with quadrupole time-of-flight mass spectrometry (UHPLC-QTOF-MS), nuclear magnetic resonance (NMR) spectroscopy, and metabolomics-driven profiling. These tools have enabled precise characterization of both major and minor phytochemical constituents, leading to a better understanding of the molecular basis of their bioactivities [7]. Concurrently, pharmacological research has elucidated diverse biological effects of *N. sativa* and *S. melongena* seeds across multiple disease models. For instance, *N. sativa*'s thymoquinone has been shown to modulate inflammatory pathways via nuclear factor kappa B (NF-κB) inhibition, induce apoptosis in cancer cells through caspase activation, and protect against oxidative stress by upregulating nuclear factor erythroid 2-related factor 2 (Nrf2). Similarly, *S. melongena* seed-derived phenolics and glycoalkaloids exhibit free radical scavenging, lipid-lowering, and cytotoxic effects against select cancer cell lines [8].

Despite these advances, the existing literature remains fragmented largely focusing on either *N. sativa* or *S. melongena* independently, without direct comparative analysis [9]. To date, no review has systematically integrated the phytochemical profiles, pharmacological activities, and nutraceutical applications of these seeds into a unified framework. This is a critical gap, as comparative evaluation can reveal complementary or synergistic properties, guide targeted functional food formulations, and identify research priorities for translational application. Moreover, considering the growing market for seed-derived nutraceuticals, such a comparative synthesis can inform both product development and regulatory compliance strategies [10].

The present review addresses this unmet need by providing a comprehensive, head-to-head comparative analysis of *Nigella sativa* and *Solanum melongena* seeds. It aims to compile and critically evaluate the existing data on their phytochemical diversity, giving particular emphasis to both major and minor constituents identified through advanced analytical techniques [11]. Furthermore, it seeks to synthesize mechanistic pharmacological evidence derived from in vitro, in vivo, and clinical studies, establishing clear links between specific bioactive compounds and their corresponding therapeutic outcomes [12]. In addition, this review examines the nutraceutical and functional food applications of these seeds, highlighting commercially available products, innovative formulation strategies, and factors influencing bioavailability. Finally, it analyses safety, toxicity, and regulatory perspectives to provide evidence-based recommendations that can guide both clinical application and commercial product development [13]. By employing an integrative approach, this review not only catalogs existing knowledge but also advances the discourse through comparative mapping of bioactive classes, identification of pharmacological domains where one seed may be superior, and exploration of potential synergistic applications in combined formulations. Such a synthesis is intended to serve as a valuable resource for researchers, nutraceutical developers, and policymakers, providing both a scientific foundation and a translational roadmap for harnessing the full therapeutic and nutritional potential of *N. sativa* and *S. melongena* seeds [14].

2. BOTANICAL AND ETHNOMEDICINAL

Nigella sativa L. (family: Ranunculaceae), commonly known as black cumin or kalonji, is an annual herbaceous plant native to South and Southwest Asia but now cultivated across the Middle East, North Africa, and parts of Europe [15]. Morphologically, it bears delicate, thread-like leaves and pale blue to white flowers, producing small angular black seeds enclosed within a capsule (*Figure 1*). Taxonomically classified under the order Ranunculales, *N. sativa* has been deeply embedded in diverse traditional medicinal systems. In Unani and Islamic medicine, it is revered as a panacea, often prescribed for respiratory ailments, digestive disorders, and immune modulation. Ayurveda recognizes it for its warming, carminative, and anti-inflammatory properties, while in traditional Persian medicine, it is administered for metabolic and hepatic disorders [16].

Solanum melongena L. (family: Solanaceae), commonly referred to as eggplant, brinjal, or aubergine, is a perennial plant in tropical climates but grown annually in temperate zones. Although primarily cultivated for its fruit, the seeds are small, flat, and pale yellow to light brown, embedded within the spongy mesocarp (*Figure 1*). Taxonomically placed in the order Solanales, *S. melongena* is native to India and Southeast Asia but is now cultivated worldwide. Ethnomedicinally, its seeds have been less emphasized than the fruit, yet historical records from Indian folk medicine describe their use in treating toothache, intestinal worms, and inflammatory conditions [17]. In certain African and Southeast Asian traditions, seed preparations are incorporated into remedies for hypertension, bronchitis, and skin ailments. This review uniquely integrates cross-cultural ethnomedicinal records to identify both overlaps and distinct uses of these seeds (*Table 1*). and pharmacological findings [18].

Figure 1. ***Nigella sativa*** *and* ***Solanum melongena.***

Table 1. Ethnomedicinal uses across different cultures

Region/Culture	***Nigella sativa* Seeds Traditional Uses**	***Solanum melongena* Seeds Traditional Uses**	**Reference**
Indian Ayurveda	Carminative, anti-inflammatory, respiratory disorders	Toothache, intestinal worms, anti-inflammatory	[19]
Middle Eastern Unani	Immune booster, metabolic disorders, hepatoprotective	Not documented traditionally in this system	[20]
African Folk Medicine	Antimicrobial, wound healing	Bronchitis, skin ailments, hypertension	[21]
Southeast Asian Folk Practices	Antidiabetic, tonic, analgesic	Antiparasitic, pain relief	[22]

Phytochemical Diversity

The seeds of *Nigella sativa* (black cumin) and *Solanum melongena* (brinjal/eggplant) represent two botanically and phytochemically distinct plant species, yet both harbor a rich repertoire of bioactive secondary metabolites that contribute to their nutraceutical, medicinal, and pharmacological potential [23].

3. NIGELLA SATIVA SEEDS

Nigella sativa seeds are chemically complex, containing a mixture of volatile and fixed oils, alkaloids, saponins, and phenolic compounds. **Chemical fingerprinting** using GC-MS, LC-MS/MS, and NMR spectroscopy has revealed a metabolomic profile that varies depending on geographical origin, climate, and post-harvest processing. The synergistic interaction of these metabolites underlies *N. sativa*'s multifaceted pharmacological spectrum [24].

Volatile Oil Constituents: The volatile fraction (0.4–0.45%) is dominated by **thymoquinone** (30–48%), *p*-cymene (7–15%), carvacrol, α-thujene, thymol, and trans-anethole. Thymoquinone is considered the principal bioactive molecule, endowed with potent antioxidant, anti-inflammatory, anticancer, and hepatoprotective properties.

Fixed Oils and Fatty Acids: The fixed oil content (32–40%) is rich in **linoleic acid** (50–60%), **oleic acid** (20–25%), and palmitic acid, contributing to anti-inflammatory and cardioprotective effects.

Alkaloids: Two major classes isoquinoline alkaloids (nigellicimine, nigellicimine-N-oxide) and pyrazole alkaloids (nigellidine, nigellicine) have been reported, some with antimicrobial and enzyme-modulatory activity.

Phenolic Compounds: Flavonoids such as quercetin, kaempferol, and apigenin derivatives enhance the seeds' radical scavenging and metal-chelating capabilities.

Saponins and Sterols: α-hederin, β-sitosterol, and stigmasterol have been detected, potentially contributing to immune modulation and cholesterol-lowering effects [25, 26].

Solanum melongena Seeds

Although *S. melongena* is primarily valued for its fruit, the seeds also harbor noteworthy phytochemicals, particularly

glycoalkaloids, phenolics, and unsaturated fatty acids. Phytochemical variability in *S. melongena* seeds is significantly influenced by cultivar genetics, maturity stage, and extraction methodology. LC-QTOF-MS profiling suggests that the seeds' phenolic richness is sometimes higher than the surrounding mesocarp, indicating untapped value in seed utilization [27].

Glycoalkaloids: The predominant seed alkaloids are **solasonine** and **solamargine,** which are steroidal glycoalkaloids with reported antineoplastic, antimicrobial, and insecticidal activities. These compounds, however, can be toxic at higher concentrations, necessitating dosage regulation in nutraceutical formulations.

Phenolic Compounds: Phenolic acids (chlorogenic, caffeic, and gallic acids) and flavonoids (nasunin, quercetin, rutin) impart antioxidant, anti-inflammatory, and neuroprotective effects.

Fatty Acids: The fixed oil fraction is enriched with linoleic acid (over 50%), oleic acid, and small amounts of palmitic and stearic acids.

Sterols: β-sitosterol and campesterol have been reported, potentially contributing to lipid metabolism regulation.

Proteins and Peptides: Preliminary proteomic studies have identified bioactive peptides with antihypertensive and antidiabetic potential [28, 29].

4. ANALYTICAL ADVANCEMENTS

Advancements in analytical chemistry have significantly enhanced the identification, quantification, and characterization of bioactive compounds in *Nigella sativa* and *Solanum melongena* seeds. Techniques such as high-performance liquid chromatography (HPLC), gas chromatography–mass spectrometry (GC–MS), liquid chromatography–mass spectrometry (LC–MS), and nuclear magnetic resonance (NMR) spectroscopy have enabled precise profiling of both major and minor phytoconstituents, including volatile oils, alkaloids, saponins, phenolic acids, flavonoids, and unique steroidal glycoalkaloids [30]. These modern methods allow not only qualitative detection but also quantitative determination with high sensitivity and reproducibility, supporting rigorous standardization of seed-based preparations [31].

In *N. sativa*, LC–MS and GC–MS have been instrumental in elucidating the structure and concentration of thymoquinone, nigellone, α-hederin, and other minor constituents, while advanced NMR techniques have aided in stereochemical confirmation [32]. Similarly, in *S. melongena* seeds, UHPLC–QTOF–MS and ^1H-NMR metabolomics have revealed distinct phenolic fingerprints, chlorogenic acid derivatives, and glycoalkaloid profiles that were previously underexplored. Notably, integrating chemometric tools with these analytical platforms facilitates comparative phytochemical mapping between the two species, enabling the identification of shared bioactives as well as unique metabolites [33]. This cross-species analytical perspective offers novel insights into structure–activity relationships, potential synergistic effects, and opportunities for targeted nutraceutical formulations [34]. A comparative summary of these advanced techniques, their applications, and analytical strengths for both seed types is provided in **Table 2**.

Table 2. Advanced analytical techniques applied for phytochemical profiling

Analytical Technique	Purpose	*Nigella sativa* Findings	*Solanum melongena* Findings	Sensitivity and Advantages	Reference
HPLC	Quantification of phenolics, flavonoids, and alkaloids	Accurate estimation of thymoquinone, nigellone, and α-hederin content	Determination of chlorogenic acid derivatives and flavonoid levels	High reproducibility; suitable for routine QC	[35]
UHPLC–QTOF–MS	Comprehensive metabolite profiling	Identification of minor bioactives and lipid-soluble components	Detection of diverse glycoalkaloids and phenolic acids	High resolution; rapid separation with minimal sample	[36]
GC–MS	Volatile oil and fatty acid composition	Identification of key volatiles such as p-cymene, carvacrol, and thymol	Profiling of seed fatty acids including linoleic and oleic acids	Excellent for volatile and thermally stable compounds	[37]
LC–MS/MS	Structural elucidation and	Detection of trace bioactives with	Mapping of polyphenolic	Ultra-high sensitivity;	[38]

	targeted quantification	high sensitivity	subclasses and alkaloid diversity	targeted analysis possible	
^1H-NMR / 2D-NMR	Structural confirmation and metabolomics	Stereochemical characterization of triterpenoid saponins	Metabolomic fingerprinting; confirmation of glycoalkaloid structures	Non-destructive; simultaneous multi-compound analysis	[39]
FTIR Spectroscopy	Functional group identification	Confirmation of carbonyl and hydroxyl groups in phenolics	Identification of functional groups in glycosides	Rapid screening; minimal sample preparation	[40]
Chemometric Analysis	Data interpretation and pattern recognition	Differentiation of seed batches by geographical origin	Classification of seed varieties based on metabolite profile.	Enhances discrimination and quality assessment	[41]

5. PHARMACOLOGICAL POTENTIAL

Antioxidant Properties

Seeds of *Nigella sativa* and *Solanum melongena* exhibit potent antioxidant activities due to their rich phytochemical composition, particularly polyphenols, flavonoids, and phenolic acids. Antioxidant mechanisms primarily involve radical scavenging, metal ion chelation, and inhibition of lipid peroxidation, thereby mitigating oxidative stress in biological systems. In vitro studies employing DPPH (2,2-diphenyl-1-picrylhydrazyl), ABTS (2,2'-azino-bis-(3-ethylbenzothiazoline-6-sulfonic acid)), and FRAP (Ferric Reducing Antioxidant Power) assays have consistently demonstrated dose-dependent free radical neutralization by both seeds [42]. Thymoquinone in *Nigella sativa* exhibits superior scavenging activity, whereas nasunin in *Solanum melongena* effectively prevents lipid peroxidation in cellular membranes, highlighting complementary antioxidant mechanisms, the pharmacological mechanisms of these seeds are summarized in Figure 2.

Anti-inflammatory Activity

Both seeds demonstrate significant anti-inflammatory potential through the modulation of key pro-inflammatory pathways, including cyclooxygenase (COX) and lipoxygenase (LOX) cascades. Preclinical studies report that thymoquinone suppresses the expression of pro-inflammatory cytokines such as TNF-α, IL-1β, and IL-6, thereby attenuating edema and inflammatory tissue damage. Similarly, *Solanum melongena* phenolic compounds inhibit COX-2 expression and reduce prostaglandin E2 production in macrophage models. Limited clinical studies on *Nigella sativa* supplementation have confirmed reductions in systemic inflammatory markers, indicating translational relevance for chronic inflammatory disorders [43].

Antimicrobial Effects

Nigella sativa and *Solanum melongena* seeds exhibit broad-spectrum antimicrobial activities against bacterial, fungal, and viral pathogens. Essential oil and thymoquinone from Nigella sativa demonstrate bactericidal effects against Staphylococcus aureus, Escherichia coli, and Pseudomonas aeruginosa, along with antifungal activity against Candida albicans [44]. Solanum melongena extracts, rich in phenolic compounds, display inhibitory effects against Gram-positive and Gram-negative bacteria and exhibit antiviral activity in preliminary in vitro models. Comparative studies suggest that Nigella sativa exhibits stronger antimicrobial potency, likely due to the synergistic action of volatile and non-volatile bioactive compounds [45].

Metabolic and Cardio protective Effects

Both seeds exert modulatory effects on metabolic syndrome parameters. *Nigella sativa* supplementation has been reported to improve glycaemic control, reduce fasting blood glucose and HbA1c levels, and enhance insulin sensitivity. *Solanum melongena* extracts demonstrate antihyperlipidemic activity by lowering serum cholesterol, triglycerides, and low-density lipoprotein (LDL) while increasing high-density lipoprotein (HDL) levels. Anti-obesity effects are observed via inhibition of adipogenesis and promotion of lipid metabolism. Cardiovascular protective mechanisms involve reduction of oxidative stress, amelioration of endothelial dysfunction, and improvement in blood pressure, suggesting the utility of these seeds as functional food ingredients in cardiovascular health management [46].

Neuroprotective and Cognitive Benefits

The neuroprotective properties of *Nigella sativa* and *Solanum melongena* are attributed to a combination of antioxidant, anti-inflammatory, and anti-apoptotic effects. Preclinical models of neurodegeneration reveal that thymoquinone reduces neuronal cell death, attenuates oxidative stress in hippocampal regions, and enhances cognitive performance in memory and learning assays. Nasunin from Solanum melongena seeds exhibits protective effects against oxidative injury in neuronal membranes and improves synaptic plasticity. Collectively, these bioactivities suggest potential applications in neurodegenerative disorders such as Alzheimer's and Parkinson's diseases [47].

Anticancer Potential

Extensive in vitro and in vivo studies have demonstrated the anticancer potential of both seeds. Thymoquinone induces apoptosis through caspase activation, promotes cell cycle arrest at G1/S and G2/M phases, and inhibits angiogenesis by downregulating VEGF expression. Solanum melongena phenolics exert cytotoxicity against multiple cancer cell lines, including breast, colon, and hepatic carcinoma, primarily via apoptosis induction and oxidative stress modulation. Both seeds modulate tumor suppressor pathways and exhibit synergistic potential with conventional chemotherapeutic agents, emphasizing their chemopreventive and adjunctive therapeutic utility [48].

Other Reported Activities

Additional pharmacological effects include hepatoprotective, nephroprotective, immunomodulatory, and anti-allergic activities. Nigella sativa reduces liver enzyme levels in chemically induced hepatotoxicity models, while Solanum melongena mitigates renal oxidative damage. Immunomodulatory effects are observed through enhancement of T-cell proliferation, natural killer cell activity, and modulation of cytokine production. Anti-allergic properties, demonstrated via inhibition of histamine release and IgE-mediated responses, further expand the therapeutic relevance of these seeds [49].

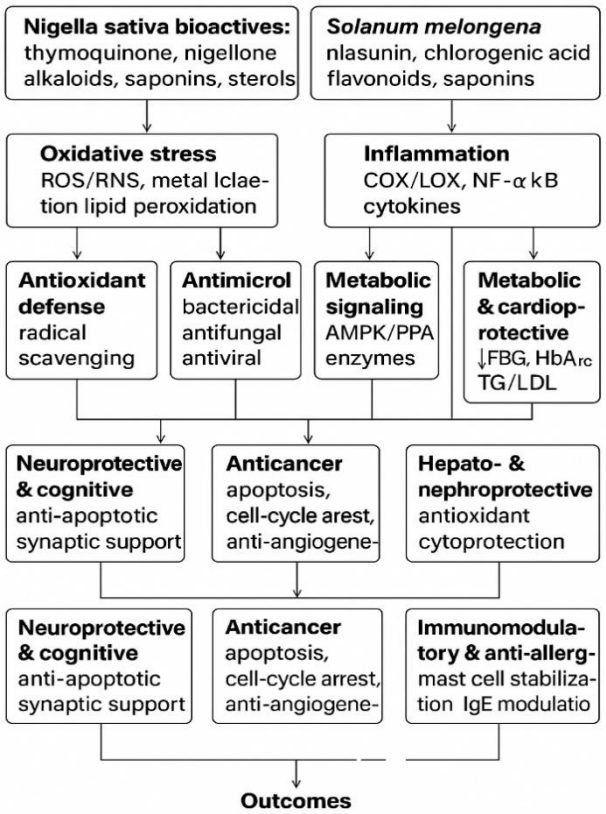

Figure 2. Pharmacological of *Nigella sativa* and *Solanum melongena* seeds [50, 51].

Nutraceutical and Functional Food Applications

The seeds of *Nigella sativa* and *Solanum melongena* possess significant nutraceutical potential owing to their dense profile of bioactive compounds and well-documented pharmacological activities. Their application in functional food development is supported by both ethnobotanical tradition and contemporary formulation technologies aimed at delivering measurable health benefits [52].

Seed oils, powders, and extracts in food supplements

Nigella sativa seed oil, rich in thymoquinone and essential fatty acids, is widely marketed in soft gel capsules, liquid preparations, and blended oils for antioxidant, anti-inflammatory, and metabolic health support. *Solanum melongena* seed extracts, containing nasunin and chlorogenic acid, are less common as single-ingredient supplements but are increasingly used in polyherbal formulations targeting cardiovascular and cognitive functions. Seed powders from both species are incorporated into encapsulated forms, protein mixes, and instant beverages to deliver concentrated phytochemicals in consumer-friendly formats [53].

Fortification in bakery, dairy, and beverage products

Fortification of conventional foods with these seeds or their derivatives is a growing approach in functional food design. *Nigella sativa* seeds are used whole or ground in breads, crackers, and snack bars, adding bioactivity and characteristic flavour. Cold-pressed black seed oil is applied to yogurt, cheese, and functional dairy drinks to enhance antioxidant content and product stability. *Solanum melongena* extracts, with their mild flavour, are suitable for smoothies, plant-based milks, and functional beverages targeting cardiovascular health. Both species' inclusion in bakery products can increase phenolic content and improve texture and moisture retention [54].

Bioavailability and formulation strategies for functional foods

Clinical efficacy of seed-derived bioactives depends on their bioavailability, often hindered by low solubility and rapid metabolism. Strategies such as nanoemulsions, microencapsulation, and phospholipid complexes have improved stability and absorption of *Nigella sativa* thymoquinone. Liposomal formulations and encapsulation of *Solanum melongena* nasunin and phenolics protect against degradation and enhance uptake. Synergistic carriers like omega-3-rich oils can further improve efficacy within functional food matrices [55].

Market trends and commercial nutraceutical products

The global nutraceutical market for *Nigella sativa* is mature, with products ranging from black seed oil capsules and honey blends to fortified teas and confectionery. Its strong consumer recognition, especially in Middle Eastern and South Asian markets, has supported its expansion into Western markets. *Solanum melongena* seed-based nutraceuticals are newer but emerging, especially as polyphenol-rich extracts marketed for heart health and anti-aging. Consumer demand for plant-based, clean-label ingredients with validated health benefits is expected to accelerate the diversification of products based on these seeds [56]. Nutraceutical applications of both species is presented in Table 3 and Figure 3.

Table 3. Nutraceutical and Functional Food Applications [57, 58, 59]

Application	***Nigella sativa***	***Solanum melongena***
Food supplements	Soft gel capsules of cold-pressed seed oil; powder-filled capsules; liquid oil blends; polyherbal formulations for antioxidant, metabolic, and immune health	Extract powders or polyphenol-rich concentrates in blended capsules; limited single-ingredient products
Seed powders	Finely ground seed powder in protein mixes, granules, instant drink sachets	Milder-tasting seed powder suitable for blends with plant-based proteins and cereals
Bakery fortification	Whole or ground seeds in bread, crackers, biscuits, snack bars; contributes Flavour, antioxidants, and texture	Polyphenol-rich extract or seed flour in bread and pastries to improve phenolic content and moisture retention
Dairy fortification	Black seed oil or powder in yogurt, cheese, functional milk drinks	Extracts incorporated into yogurt or plant-based dairy alternatives
Beverage fortification	Oil emulsions in herbal teas, juices, sports drinks; powdered extracts in instant drink mixes	Polyphenol-rich extracts in smoothies, plant-based milks, functional waters
Bioavailability strategies	Nanoemulsion, microencapsulation, phospholipid complexes to enhance thymoquinone absorption	Liposomal delivery, microencapsulation to protect nasunin and phenolic.
Commercial products	Black seed oil capsules, honey blends, fortified teas, functional confectioneries	Emerging products: polyphenol-rich extracts for heart health, anti-aging blends

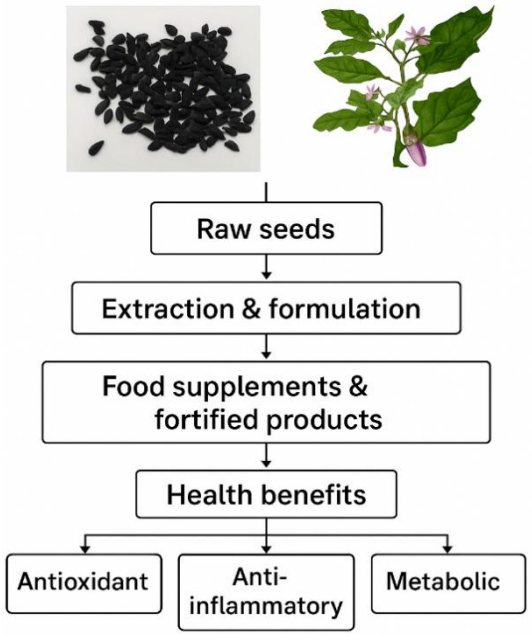

Figure 3. Nutraceutical and functional food applications.

Safety, Toxicity, and Regulatory Aspects

Toxicological evaluations in animals and humans

Preclinical safety studies on *Nigella sativa* have consistently reported low acute and subchronic toxicity, with oral LD_{50} values in rodents exceeding 2 g/kg body weight for seed oil and 5 g/kg for seed powder. Repeated-dose studies in animals show no significant alterations in hematological, hepatic, or renal markers at moderate dosages. *Solanum melongena* seeds, although less extensively studied, have demonstrated low toxicity in animal models, with no major adverse effects reported at dietary inclusion levels up to 5–10% of total feed weight. Human studies on *Nigella sativa* supplementation (oil or powder) have generally reported good tolerability, with occasional mild gastrointestinal symptoms at higher doses. Human safety data for *Solanum melongena* seed preparations are limited, but consumption through traditional diets suggests a favorable safety profile [60].

Safe dosage ranges

In human clinical trials, *Nigella sativa* seed powder is typically administered at 1–3 g/day, and seed oil at 500 mg to 2 g/day, without significant adverse events. For *Solanum melongena*, no standardized dosage has been established for concentrated seed extracts; however, intake from whole food sources is considered safe. For future nutraceutical formulations, adherence to doses that deliver bioactive concentrations without exceeding traditional dietary exposure levels is recommended, with careful monitoring for potential allergenic or idiosyncratic reactions [61].

International regulatory frameworks for herbal seeds in nutraceuticals

Nigella sativa is recognized as a traditional herbal medicine or food ingredient in several jurisdictions, including approval by the European Food Safety Authority (EFSA) for use in food supplements, and listing in the United States as Generally Recognized as Safe (GRAS) for certain preparations. In India, it is included in the AYUSH pharmacopeia. *Solanum melongena* seeds are not widely registered as standalone nutraceutical ingredients, but are permitted as part of the edible fruit in global food regulations. Regulatory acceptance for concentrated extracts may require safety dossiers including toxicological data and proof of traditional use. Compliance with Codex Alimentarius labeling standards, Good Manufacturing Practices (GMP), and limits on contaminants (pesticides, heavy metals, aflatoxins) is mandatory for both species in commercial nutraceutical production [62].

Comparative Analysis of *Nigella sativa* vs. *Solanum melongena*

The seeds of *Nigella sativa* and *Solanum melongena* share several phytochemical classes, including phenolic acids, flavonoids, saponins, and fatty acids, yet exhibit distinct bioactive signatures that influence their pharmacological and nutraceutical profiles. *Nigella sativa* is characterized by the presence of thymoquinone, nigellone, and high levels of fixed and volatile oils, which underpin its strong antioxidant, anti-inflammatory, antimicrobial, and anticancer activities. *Solanum melongena* seeds, on the other hand, are distinguished by nasunin and chlorogenic acid, which are potent antioxidants with

additional membrane-protective and cardioprotective properties. In terms of bioactivity, *Nigella sativa* generally demonstrates stronger antimicrobial and anticancer potency, while *Solanum melongena* shows greater suitability for cardiovascular health applications and milder flavor profiles that favor incorporation into diverse functional food matrices. Both species display complementary pharmacological activities, suggesting potential synergistic benefits if combined in nutraceutical formulations. A comparative radar chart (Figure 4) visually give the relative strengths of each seed across major pharmacological categories, while Table 3 presents a side-by-side matrix comparing key phytochemicals, dominant bioactivities, and nutraceutical applications. Together, these visual tools facilitate an integrative understanding of their respective strengths and application niches [63].

Table 3. Comparative Matrix of *Nigella sativa* and *Solanum melongena* Seeds

Parameter	*Nigella sativa*	*Solanum melongena*	Reference
Phytochemicals	Thymoquinone, nigellone, alkaloids, saponins, flavonoids, fixed and volatile oils, essential fatty acids	Nasunin, chlorogenic acid, phenolic acids, flavonoids, saponins, sterols, fatty acids	[64]
Dominant bioactivities	Strong antioxidant, anti-inflammatory, antimicrobial, anticancer, metabolic and cardioprotective	Strong antioxidant, cardioprotective, anti-inflammatory, moderate antimicrobial, neuroprotective	[65]
Unique strengths	Potent antimicrobial and anticancer effects; broad traditional medicinal use	Membrane-protective antioxidant (nasunin); favorable sensory profile for functional food fortification	[64]
Nutraceutical potential	Capsules, oil blends, fortified foods, honey blends, functional teas, metabolic health products	Polyphenol-rich extracts, functional beverages, bakery and dairy fortification, heart health and anti-aging formulations	[62]
Synergistic opportunities	Combination products for oxidative stress, inflammation, and metabolic syndrome.	Combination with *Nigella sativa* to enhance cardiovascular, cognitive, and antioxidant benefits	

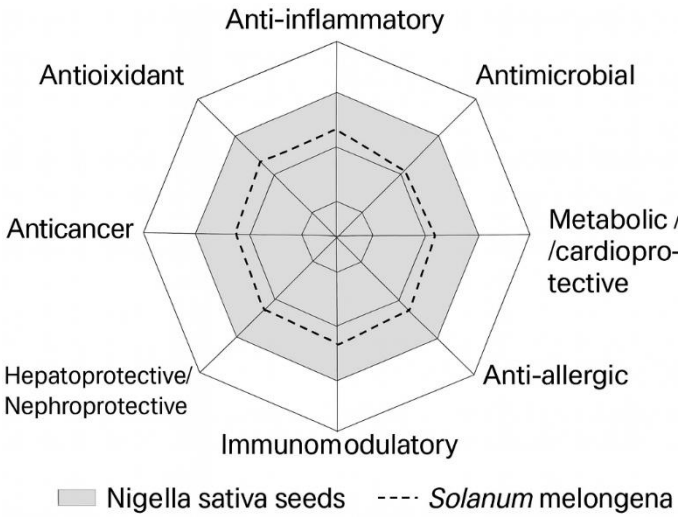

Figure 4. Radar Chart showing relative pharmacological strengths

6. FUTURE PERSPECTIVES

Despite the growing body of literature on the bioactive composition and pharmacological properties of *Nigella sativa* and *Solanum melongena* seeds, several gaps remain that limit their full translational potential. Many pharmacological domains are underexplored, particularly in relation to neurodegenerative disorders, gut microbiota modulation, immunomodulatory pathways, and long-term metabolic health outcomes. While in vitro and in vivo studies provide strong mechanistic insights, the number of well-designed, large-scale, randomized clinical trials remains insufficient, especially for *Solanum melongena*

seed preparations. This lack of high-quality clinical evidence hinders the substantiation of health claims in regulatory contexts. Standardization and quality control pose additional challenges, as variations in seed genotype, cultivation conditions, post-harvest processing, and extraction methods can significantly influence phytochemical profiles and bioactivity [66]. The development of validated analytical markers, along with harmonized quality specifications, is essential to ensure reproducibility and consumer safety. Furthermore, there is a strong opportunity to explore synergistic formulations that combine *Nigella sativa* and *Solanum melongena*, leveraging their complementary antioxidant, anti-inflammatory, cardioprotective, and neuroprotective activities. Such combinations could be particularly valuable in multi-targeted nutraceutical interventions for complex chronic diseases. Future research should prioritize integrating advanced formulation technologies, precision nutrition approaches, and regulatory-compliant clinical trials to bridge the gap between traditional use, experimental findings, and market-ready functional products [67].

7. CONCLUSION

Nigella sativa and *Solanum melongena* seeds represent valuable botanical resources with diverse phytochemical compositions and a wide spectrum of pharmacological activities. Their bioactive constituents, including thymoquinone, nasunin, chlorogenic acid, flavonoids, and saponins, contribute to antioxidant, anti-inflammatory, antimicrobial, metabolic, neuroprotective, and anticancer effects, many of which have been validated through in vitro and in vivo studies, and to a lesser extent, in clinical settings. Beyond their therapeutic promise, both seeds hold considerable potential as functional food ingredients and nutraceutical components, supported by applications in supplements, bakery, dairy, and beverage fortification. While *Nigella sativa* benefits from extensive traditional use and a well-established commercial presence, *Solanum melongena* seeds remain comparatively underexplored, offering opportunities for novel applications, particularly in cardiovascular health and mild-flavor functional food formulations. The integration of both seeds in synergistic nutraceutical designs could yield multi-targeted benefits, addressing oxidative stress, inflammation, metabolic dysregulation, and neurodegeneration in a complementary manner. To fully realize their translational value, future research should focus on generating high-quality clinical evidence, establishing standardized quality control protocols, and optimizing formulation strategies to enhance bioavailability. Strengthening the regulatory recognition of these seeds through comprehensive safety data will further support their acceptance in global nutraceutical markets. Collectively, *Nigella sativa* and *Solanum melongena* seeds exemplify the potential of integrating traditional botanical wisdom with modern scientific validation to create innovative, effective, and safe nutraceutical solutions.

REFERENCES

[1] Pandey R, Pandey B, Bhargava A. An updated review on the phytochemistry and pharmacological activity of black cumin (Nigella sativa L.). Adv Chin Med. 2025;2(1):13–29.

[2] Gupta M, Mehta BK. A comprehensive review on secondary metabolites of Nigella sativa L (Seeds). Res J Chem Sci. 2017;7(12):16–29.

[3] Begum A, Afrose S, Azeez RA, Syed T, Ansari US, Tazneem B. Phytochemistry and pharmacological review: Nigella sativa. Indian J Pharm Biol Res. 2021;9(2):7–11.

[4] Eid A. A review on the cosmeceutical and external applications of Nigella sativa. J Trop Med. 2017;2017:7092514.

[5] Narra J, Kulsum K, Syahrul S, et al. Phytocompounds of Nigella sativa seeds extract and their neuroprotective potential via EGR1 receptor inhibition: a molecular docking study. Narra J. 2023;3(2):e173.

[6] Almatroodi SA, Almatroudi A, Khan AA, et al. Nigella sativa: a comprehensive review of its therapeutic potential. Int J Mol Sci. 2024;25(24):13410.

[7] Hamed ES, Toaima WI, Abd El-Aleem WH. Impact of different planting locations on Nigella sativa L. yield in Egypt. Egypt J Desert Res. 2023;73:23–38.

[8] Hannan MA, Rahman MA, Sohag AAM, et al. Black cumin (Nigella sativa L.): a comprehensive review on phytochemistry, health benefits, molecular pharmacology, and safety. Nutrients. 2021;13(6):1784.

[9] Yimer EM, Tuem KB, Karim A, et al. Nigella sativa L. (black cumin): a promising natural remedy for wide range of illnesses. Evid Based Complement Altern Med. 2019;2019:1528635.

[10] Belgaumi U, Patil S, Gandhi J, Shete A. The many therapeutic applications of Nigella sativa—A review. J Evol Med Dent Sci. 2020;9:2151–7.

[11] Mathur K. The pharmacological actions of the seeds of Nigella sativa. J Pharm Educ. 1995;29:111–6.

[12] Ahmad A, Husain A, Mujeeb M, et al. Nigella sativa: a review on therapeutic potential. Phytother Res. 2013;27(8):1137–48.

[13] Dalli M, Bekkouch O, Azizi S, et al. Nigella sativa L. phytochemistry and pharmacological activities: a review (2019–2021). Biomolecules. 2021;12(1):20.

[14] Rahman A, Abdullah A, Mansour B, Yahya G, Faisal S. Unlocking the therapeutic potential of Nigella sativa extract: phytochemical analysis and pharmacological insights. Biomed Res Int. 2024;2024:1124195.

[15] Randhawa MA, Alghamdi MS. Anticancer activity of Nigella sativa (black seed) – a review. Am J Chin Med. 2011;39(6):1075–91.

[16] Fekry MI, Ezzat SM, Salama MM, et al. Bioactive glycoalkaloides from Solanum melongena fruit peels with anticancer properties against hepatocellular carcinoma. Sci Rep. 2019;9:1746.

[17] Alighadri T, Tabibiazar M, Mohammadi M, et al. Nasunin, an amazing chemical constituent in eggplants: occurrence, chemistry, biosynthesis, stability, and applications. ACS Food Sci Technol. 2024;4:16–35.

[18] Raigón MD, Prohens J, Muñoz-Falcón JE, Nuez F. Characterization of eggplant (Solanum melongena L.) for bioactive compounds: phenolics, minerals, dry matter and protein. J Food Compos Anal. 2008;21(6):370–6.

[19] Plazas M, López-Gresa MP, Vilanova S, et al. Diversity and relationships in key traits for functional and apparent quality in a collection of eggplant: fruit phenolics content, antioxidant activity, and browning. J Agric Food Chem. 2013;61(37):8871–9.

[20] Stommel JR, Whitaker BD. Phenolic acid content and composition of eggplant fruit in a germplasm core subset. J Am Soc Hortic Sci. 2003;128(5):704–10.

[21] Kumar, S., Saha, S., Singh, K., Singh, T., Mishra, A. K., Dubey, B. N., & Singh, S. (2024). Beneficial effects of spirulina on brain health: A systematic review. Current Functional Foods, 3(1), Article e120124225622. https://doi.org/10.2174/0126668629269256231222092721

[22] RaviKKumar VR, Rathi S, Singh S, Patel B, Singh S, Chaturvedi K, Sharma B. A Comprehensive Review on Ulcer and Their Treatment. Zhongguo Ying Yong Sheng Li Xue Za Zhi. 2023 Dec 21;39:e20230006. doi: 10.62958/j.cjap.2023.006. PMID: 38755116.

[23] Singh, V., Arora, S., Akram, W., Alam, S., Kumari, L., Kumar, N., Kumar, B., Kumar, S., Agrawal, M., Singhal, M., Kumar, S., Singh, S., Singh, K., Saha, S., & Dwivedi, V. (2024). Involvement of molecular mechanism and biological activities of Pemirolast: A therapeutic review. New Emirates Medical Journal, 5, Article e02506882308410. https://doi.org/10.2174/0102506882308410240607053814

[24] Rajput DS, Gupta N, Singh S, Sharma B. A Comprehensive Review: Personalized Medicine for Rare Disease Cancer Treatment. Zhongguo Ying Yong Sheng Li Xue Za Zhi. 2023 Dec 23;39:e20230008. doi: 10.62958/j.cjap.2023.008. PMID: 38830754.

[25] Singh S, Chaurasia A, Rajput DS, Gupta N. Mucoadhesive Drug Delivery System and There Future Prospective: Are a Promising Approach for Effective Treatment? Zhongguo Ying Yong Sheng Li Xue Za Zhi. 2023 Dec 20;39:e20230005. doi: 10.62958/j.cjap.2023.005. PMID: 38751344.

[26] Kumar, S., Saha, S., Sharma, B., Singh, S., Shukla, P., Mukherjee, S., Agrawal, M., Singh, K., & Singh, T. (2023). The role of resveratrol in Alzheimer's disease: A comprehensive review of current research. Current Functional Foods, 2(2), Article e121223224364, 13 pages. https://doi.org/10.2174/0126668629269244231127071411

[27] Patel S, Ismail Y, Singh S, Rathi S, Shakya S, Patil SS, Bumrela S, Jain PC, Goswami P, Singh S. Recent Innovations and Future Perspectives in Transferosomes for Transdermal Drug Delivery in Therapeutic and Pharmacological Applications. Zhongguo Ying Yong Sheng Li Xue Za Zhi. 2024 Oct 24;40:e20240031. doi: 10.62958/j.cjap.2024.031. PMID: 39442957.

[28] Vaghela MC, Rathi S, Shirole RL, Verma J, Shaheen, Panigrahi S, Singh S. Leveraging AI and Machine Learning in Six-Sigma Documentation for Pharmaceutical Quality Assurance. Zhongguo Ying Yong Sheng Li Xue Za Zhi. 2024 Jul 18;40:e20240005. doi: 10.62958/j.cjap.2024.005. PMID: 39019923.

[29] Patel S, Ismail Y, Singh S, Rathi S, Shakya S, Patil SS, Bumrela S, Jain PC, Goswami P, Singh S. Recent Innovations and Future Perspectives in Transferosomes for Transdermal Drug Delivery in Therapeutic and Pharmacological Applications. Zhongguo Ying Yong Sheng Li Xue Za Zhi. 2024 Oct 24;40:e20240031. doi: 10.62958/j.cjap.2024.031. PMID: 39442957.

[30] Kumar, S., Saha, S., Pathak, D., Singh, T., Kumar, A., Singh, K., Mishra, A. K., Singh, S., & Singh, S. (2024). Cholesterol absorption inhibition by some nutraceuticals. Recent Advances in Food, Nutrition & Agriculture, 16(1), 2–11. https://doi.org/10.2174/012772574X285280240220065812

[31] Singh, S., Chaurasia, A., Rajput, D. S., & Gupta, N. (2024). An overview on mucoadhesive buccal drug delivery systems & approaches: A comprehensive review. African Journal of Biological Sciences (South Africa), 6(5), 522–541, DOI: 10.33472/AFJBS.6.5.2024.522-541

[32] Kumar, S., Singh, S., Rajput, D., Sharma, B., Chaturvedi, K., Singh, N., Saha, S., Singh, K., & Mukherjee, S.

(2024). Pharmacological approaches and herbal interventions for Alzheimer's disease. The Natural Products Journal, 14(8), Article e220124225945. https://doi.org/10.2174/0122103155275266231123090138

[33] Ravikkumar VR, Patel BD, Rathi S, Parthiban S, Upadhye MC, Shah AM, Rehan SSA, Samanta S, Singh S. Formulation and Evaluation of Drumstick Leaves Tablet as An Immunomodulator. Zhongguo Ying Yong Sheng Li Xue Za Zhi. 2024 Jun 21;40:e20240004. doi: 10.62958/j.cjap.2024.004. PMID: 38902996.

[34] Sharma, A., Bara, G., Keshamma, E., Sharma, B., Singh, S., Singh, S. P., Parashar, T., Rathore, H. S., Sarma, S. K., & Rawat, S. (2023). Cancer biology and therapeutics: A contemporary review. Journal of Cardiovascular Disease Research, 14(10), 1229-1247.

[35] Dewangan, H. K., Singh, S., Mishra, R., & Dubey, R. K. (2020). A review on application of nanoadjuvant as delivery system. International Journal of Applied Pharmaceutics, 12(4), 24–33. https://doi.org/10.22159/ijap.2020v12i4.36856

[36] Singh S, Chaurasia A, Gupta N, Rajput DS. Effect of Formulation Parameters on Enalapril Maleate Mucoadhesive Buccal Tablet Using Quality by Design (QbD) Approach. Zhongguo Ying Yong Sheng Li Xue Za Zhi. 2024 Jun 27;40:e20240003. doi: 10.62958/j.cjap.2024.003. PMID: 38925868.

[37] Patel S, Alam MI, Shirole RL, Kulkarni PA, Nath J, Prasad M, Singh S, Rathi S. Formulation and optimization of piroxicam loaded nanoparticles for topical application using design of experiments (DoE). Cuest Fisioter. 2025;54(4):109-119. DOI: https://doi.org/10.48047/bsa4k692

[38] Patel SK, Prathyusha S, Kasturi M, Godse KC, Singh R, Rathi S, Bumrela S, Singh S, Goswami P. Optimizing Irbesartan Fast Dissolving Tablets Using Natural Polysaccharides for Enhanced Drug Delivery and Patient Compliance. Int Res J Multidiscip Scope (IRJMS). 2025;6(1):1181-1190. https://doi.org/10.47857/irjms.2025.v06i01.02542

[39] Prince Patel, Piyush Jain, Hetvarth Patel, Aman Tiwari, Sanjesh Rathi and Shubham Singh (2025) Formulation, optimization and evaluation of mucoadhesive buccal tablets of ondansetron for enhanced bioavailability and sustained drug release. Biochem. Cell. Arch. 25, 1063-1069. DOI: https://doi.org/10.51470/bca.2025.25.1.1063

[40] Singh S, Rathi S, Singh S, Sharma B, Dwivedi V. CD3-Bispecific Monoclonal Antibodies: A Novel Therapeutic Approach for Complex and Multifactorial Diseases. Zhongguo Ying Yong Sheng Li Xue Za Zhi. 2025 Aug 4;41:e20250019. doi: 10.62958/j.cjap.2025.019. PMID: 40754469.

[41] Singh S, Rajput DS, Gupta N, Sharma B, Rathi S, Singh A. A Brief Review on Transdermal Patches. Zhongguo Ying Yong Sheng Li Xue Za Zhi. 2025 Jun 23;41:e20250013. doi: 10.62958/j.cjap.2025.013. PMID: 40545439.

[42] Sanjesh G. Rathi, Kaushik Kamani, Bhoomi Patel, Shubham Singh, Yash Patel. Formulation and Evaluation of Voriconazole Emulgel. Research Journal Pharmacy and Technology. 2025;18(8):3917-2. doi: 10.52711/0974-360X.2025.00563

[43] Azuma K, Ohyama A, Ippoushi K, et al. Structures and antioxidant activity of anthocyanins in many accessions of eggplant and its related species. J Agric Food Chem. 2008;56(21):10154–9.

[44] Noda Y, Kneyuki T, Igarashi K, et al. Antioxidant activity of nasunin, an anthocyanin in eggplant peels. Toxicology. 2000;148(2–3):119–23.

[45] Sadilova E, Stintzing FC, Carle R. Anthocyanins, color and antioxidant properties of eggplant (Solanum melongena L.) and violet pepper (Capsicum annuum L.) peel extracts. Z Naturforsch C. 2006;61(7–8):527–35.

[46] Singh AP, Luthria DL, Wilson T, et al. Polyphenols content and antioxidant capacity of eggplant pulp. Food Chem. 2009;114(3):955–61.

[47] Lo Scalzo R, Fibiani M, Francese G, et al. Cooking influence on physico-chemical fruit characteristics of eggplant (Solanum melongena L.). Food Chem. 2016;194:835–42.

[48] Prohens J, Rodríguez-Burruezo A, Raigón MD, Nuez F. Total phenolic concentration and browning susceptibility in a collection of different varietal types and hybrids of eggplant: implications for breeding for higher nutritional quality and reduced browning. J Am Soc Hortic Sci. 2007;132(5):638–46.

[49] Hanson PM, Yang RY, Tsou SC, et al. Diversity in eggplant (Solanum melongena L.) for superoxide scavenging activity, total phenolics, and ascorbic acid. J Food Compos Anal. 2006;19(6–7):594–600.

[50] Stommel JR, Whitaker BD. Phenolic composition of eggplant fruit varies with developmental stage. J Am Soc Hortic Sci. 1999;124(6):599–603.

[51] Matsubara K, Kaneyuki T, Miyake T, Mori M. Antiangiogenic activity of nasunin, an antioxidant anthocyanin in eggplant peels. J Agric Food Chem. 2005;53(16):6272–5.

[52] Kaur C, Nagal S, Nishad J, et al. Functional quality in eggplant: anthocyanins, phenolics and antioxidant activity. Int J Food Prop. 2014;17(1):61–77.

[53] Cao G, Sofic E, Prior RL. Antioxidant capacity of tea and common vegetables. J Agric Food Chem. 1996;44(11):3426–31.

[54] Whitaker BD, Stommel JR. Distribution of hydroxycinnamic acid conjugates in fruit of commercial eggplant (Solanum melongena L.) cultivars. J Agric Food Chem. 2003;51(11):3448–54.

[55] Plazas M, Andújar I, Vilanova S, et al. Breeding for chlorogenic acid content in eggplant: interest and prospects. Not Bot Horti Agrobo. 2013;41(1):26–35.

[56] Hanson PM, Yang RY, Tsou SCS, et al. Content of carotenoids, ascorbic acid, total phenolics, and antioxidant activity in eggplant (Solanum melongena L.) and related species. J Food Compos Anal. 2006;19(6–7):594–600.

[57] Singh AP, Wilson T, Luthria DL, et al. Polyphenols and antioxidant capacity of eggplant pulp. Food Chem. 2009;114(3):955–61.

[58] Raigón MD, Rodríguez-Burruezo A, Prohens J. Effects of organic and conventional cultivation methods on composition of eggplant fruits. J Agric Food Chem. 2010;58(11):6833–40.

[59] Lo Scalzo R, Fibiani M, Francese G, et al. Cooking effects on antioxidant activity and bioactive compounds in eggplant. Food Chem. 2016;194:835–42.

[60] Concellón A, Añón MC, Chaves AR. Effect of chilling on eggplant fruits: browning and enzymatic activity. Postharvest Biol Technol. 2004;31(3):389–97.

[61] Whitaker BD, Lester GE. Polyamine biosynthesis in ripening eggplant. Phytochemistry. 1989;28(12):3607–12.

[62] Stommel JR, Whitaker BD. Phenolics in eggplant fruit tissue: genetics and breeding strategies. Acta Hortic. 2008;782:437–43.

[63] Noda Y, Kaneyuki T, Mori A, Packer L. Antioxidant activities of nasunin in eggplant. Free Radic Biol Med. 1998;24(7–8):1209–14.

[64] Plazas M, Prohens J, Cuñat AN, et al. Diversity for chlorogenic acid content in eggplant. J Food Compos Anal. 2014;35(1):25–32.

[65] Sadilova E, Stintzing FC, Carle R. Anthocyanin profiles of eggplant cultivars. Eur Food Res Technol. 2006;222(3–4):321–9.

[66] Azuma K, Ohyama A, Ippoushi K, et al. Structures and antioxidant activity of anthocyanins from eggplant peels. J Agric Food Chem. 2008;56(21):10154–9.

[67] Lo Scalzo R, Fibiani M, Francese G, et al. Anthocyanin profile and antioxidant activity of eggplant cultivars. Food Chem. 2010;119(2):627–33.