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Exploring the nutritional spectrum and culinary applications of basil seeds (*Ocimum basilicum* L.) in the food industry: A comprehensive review

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Abstract
Basil seeds (*Ocimum basilicum* L.) have gained increasing attention in recent years due to their diverse nutritional profile and versatile applications in the food industry. This comprehensive review synthesizes the current body of knowledge surrounding basil seeds, focusing on their nutritional composition, health-promoting properties and culinary applications. The review begins by highlighting the nutritional content of basil seeds, including essential nutrients such as proteins, fibers, vitamins, and minerals. Special emphasis is placed on unique bioactive compounds present in basil seeds, elucidating their potential health benefits and therapeutic applications. Furthermore, the paper delves into the functional properties of basil seeds, exploring their role in food formulation and product development. The gel-forming ability of basil seeds, in particular, is discussed for its relevance in creating innovative food textures and structures. The review explores traditional and contemporary uses of basil seeds in diverse cuisines, ranging from beverages and desserts to savory dishes. Innovations in culinary techniques that harness the unique properties of basil seeds for enhancing food quality and sensory experiences are highlighted. Moreover, the paper discusses the potential challenges and future directions in the utilization of basil seeds in the food industry. Considerations related to sourcing, quality control, and consumer acceptance are addressed to provide a holistic perspective for industry stakeholders. In conclusion, this comprehensive review serves as a valuable resource for researchers, food scientists, and industry professionals interested in understanding the nutritional spectrum and culinary applications of basil seeds. The synthesis of existing knowledge provides a foundation for future research and development, paving the way for the widespread adoption of basil seeds as a functional ingredient in the food industry.

Keywords: Culinary, therapeutic, gel-forming, beverages, food industry, nutritional spectrum

Introduction
The basil plant (*Ocimum basilicum* L.), commonly known as sweet basil, is an annual herbaceous member of the *Lamiaceae* family, also referred to as the mint family. Characterized by an oval and ellipsoid shape, the basil seeds measure between 2.31 and 3.11 mm in length, 1.3 to 1.82 mm in width, and 0.99 to 1.34 mm in thickness. Surface analysis through scanning electron microscopy (SEM) indicates a porous structure. Originating in warm and tropical regions such as India, Africa, and Southern Asia, sweet basil has expanded its presence worldwide, including countries like France, Hungary, Greece, North and South America (Calderón Bravo *et al*., 2021) [1]. Rich in proteins (11.4-22.5 g/100 g), dietary fibre (soluble and insoluble) ranging from 7.11 to 26.2 g/100 g, and various lipids, including linoleic (12-85.6 g/100 g) and linolenic fatty acids (0.3-75 g/100g), sweet basil is a nutritionally significant herb (Nazir *et al*., 2017) [2]. Bioactive components research identifies phenolic acids and flavanol-glycosides as the primary phenolic compounds in basil. Fatty acids such as stearic acid, oleic acid, palmitic acid, linoleic acid, myristic acid, α-linolenic acid, capric acid, lauric acid, and arachidonic acid dominate basil species (Lim and Lim, 2013) [3]. Major antioxidants in basil include caffeic, vanillic, rosmarinic, quercetin, rutin, apigenin, chlorogenic, and p-hydroxybenzoic acids. Basil's essential oils consist of eugenol, chavicol, and terpenoid (Shahrajabian *et al*., 2020) [4].

Basil seed gum, also known as basil seed mucilage, is composed of galacturonic acid, galactose, rhamnose, mannose, arabinose, and glucuronic acid (Nasir and Wani, 2022) [5]. As a hydrocolloid, it serves various functions, such as thickening, stabilizing, fat replacement, texturizing, emulsifying, and surface activity. Extracted easily, it has become a notable commercial hydrocolloid in the food industry (Shahrajabian *et al*., 2020) [4]. Basil seed

mucilage finds applications in low-salt meat products, sponge cakes, ice cream, and low-fat yogurt, acting as a gelling and stabilizing agent in custard and enhancing the quality of frozen foods.

Acknowledged as a functional food, basil seeds are considered healthier alternatives to traditional foods, with studies supporting their effectiveness in treating and preventing conditions like cardiovascular disease and hypertension (Bower *et al*., 2016) [6]. The food industry continues to innovate, particularly in the realm of functional beverages, which are easily consumable sources of healthy compounds. Fruits and vegetables, rich in bioactive compounds, are ideal ingredients for such beverages (Bączek *et al*., 2019) [7] and (Puiggròs *et al*., 2017) [8]. Basil seeds are incorporated into a variety of drinks, including lemonade, iced tea, and smoothies, offering a refreshing and nutritious boost. When soaked in water, the seeds create a gelatinous texture, making them suitable for use as a healthier alternative to tapioca in puddings and desserts. They are also added to fruit salads, ice cream, and used in health supplements due to their high fiber and antioxidant content, aiding in blood sugar regulation.

Basil's medicinal benefits span a range of pharmacological effects, including anti-cancer, antibacterial, radioprotective, anti-microbial, anti-inflammatory, immunomodulatory, anti-stress, anti-diabetic, anti-pyretic, anti-arthritic, and antioxidant properties. Traditional uses encompass treating renal issues, warts, worms, coughs, headaches, and constipation (Naji-Tabasi & Razavi, 2017) [9]. Beyond its medicinal applications, basil serves as a flavoring agent in food, as well as in dental and oral care products and fragrances. Iranians, leveraging their extensive agricultural sector, have long employed basil for both culinary and medical purposes. The seeds, a source of nutritional fiber, are integrated into Asian beverages and desserts in traditional medicine (Shahrajabian *et al*., 2020) [4].

Despite the extensive research on basil seeds, certain gaps persist, including limited human studies, a lack of standardization, limited safety research, and the need for more mechanistic studies. With increasing interest in their potential health benefits, future research directions may include investigations into gastrointestinal health, cardiovascular health, diabetes management, anticancer properties, and the development of functional foods (Calderón Bravo *et al*., 2021) [1]. This work aims to provide a systematic review of current knowledge on basil seeds, covering their nutritional profile, bioactive components, pharmacological uses, and benefits in the food industry. Emphasis is placed on its significance as a functional food and its potential applications in treating various health issues.

The structural attributes of basil seeds

The structural attributes of basil seeds, despite their significance as a commercial plant, have been relatively understudied. The lack of information regarding seed shape and physical characteristics necessitates a thorough investigation, particularly in understanding the relationship between seed morphology and the design of equipment for crop production, storage facilities, and potential food applications. Calderón Bravo *et al*. (2021) [1] classified basil seeds as oval, ellipsoid, and tiny, with measurements ranging between 2.31 and 3.11 mm in length, 1.3 to 1.82 mm in width, and 0.99 to 1.34 mm in thickness. Their porous surface was identified through scanning electron microscopy (SEM) experiments on Thai basil seeds. The size of basil seeds exhibits variability depending on their planting location. Conversely, a study by Choi *et al*. (2020) [11] revealed that Iranian basil seeds were larger than Serbian basil seeds, and these size variations were associated with moisture content, where larger sizes correlated with higher moisture levels.

Furthermore, research conducted by Hosseini-Parvar *et al*. (2010) [13] and Razavi *et al*. (2010) [14] delved into the diameters of Iranian basil seeds. Notably, seeds of similar size exhibited varying moisture content, with readings of 9.1% and 5.5%, respectively. The SEM images of basil seeds depicted porous surfaces and a dark coloration. Various authors, including Kišgeci *et al*. (2011) [15], Hosseini-Parvar *et al*. (2010) [13], and Mostafavi *et al*. (2019) [16], have discussed these traits for distinguishing different varieties. Additionally, Choi *et al*. (2020) [11] explored the color of basil seeds and concluded that only Singaporean seeds could be distinguished from those of India, Pakistan, and Vietnam.

Basil seed gum (BSG) exhibits unique structural characteristics that make it a valuable and versatile substance. When submerged in water, the exterior pericarp or outer epidermis of basil seeds swells into a gelatinous mass, forming a mucilaginous layer. **(**Naji-Tabasi & Razavi, 2017) [9] highlight that this mucilaginous layer is composed of a pectinous matrix containing a significant amount of unesterified galacturonic acid, imparting high water-holding capacity to BSG. Optimal conditions for BSG extraction from O. basilicum include a temperature of 69 °C, pH of 8, and a water-to-seed ratio of 65:1. Extraction conditions significantly influence BSG's apparent viscosity, extraction yield, and protein content. Hosseini-Parvar *et al*. (2015) [12] propose an improved extraction procedure that involves purifying and drying BSG using a freeze-drier instead of a hot air drier at 50 °C. Ethanol purification enhances BSG's consistency coefficient, solubility, and reduces major contaminants, including protein, tannin, trace elements, and natural colors, improving the overall quality of the gum **(**Naji-Tabasi & Razavi, 2017) [9].

Alterations in the BSG extraction process, as suggested by Osano *et al*. (2014) [17], can lead to changes in apparent viscosity, total carbohydrate content, ash content, and the reduction of fat and protein. Higher temperature extraction can accelerate the mass transfer of water-soluble polysaccharides from the cell wall, easing the extraction process and simultaneously reducing the gum's viscosity (Zameni *et al*., 2015) [18]. Further purification and enhancement of BSG's rheological and functional characteristics involve treating the gum solution with ethanol and a protease enzyme (Naji-Tabasi *et al*., 2016) [10]. BSG, with a molecular weight of 2320 kDa, is primarily composed of high molecular weight polysaccharides. Molecular weight categorizes BSG into two main groups, with PER-BSG exhibiting the highest molecular weight (5980 kDa) and yield (69%), while SUPER-BSG has a lower yield (31%) and molecular weight (104.5 kDa).

BSG is characterized as an acidic polysaccharide, with a uronic acid value of 6.51%, and its composition includes D-glucose, D-galactose, D-mannose, L-arabinose, and D-fructose. The approximate ratios of these components contribute to the unique composition of BSG in O. basilicum. Fractionation studies reveal the diversity of BSG, with hexosan-rich fractions and a pentosan fraction high in uronic

acids. Graded hydrolysis with diluted sulfuric acid produces a polysaccharide with an acid-stable core, primarily constituted of glucose and mannose in a specific ratio (Tharanathan & Anjaneyalu, 1972) [19]. The existence of uronic acid is further supported by FTIR spectra, revealing characteristic absorptions at wavenumbers 1400 and 1600 cm-1, corresponding to symmetric and asymmetric stretching of the C-OO, respectively.

Nutritional composition and bioactive components in basil

Basil seeds exhibit a diverse nutritional profile, with variations influenced by factors such as geographical location, agronomic practices, and environmental conditions. The composition includes moisture, ash, lipids, proteins, carbohydrates, and bioactive compounds.

Carbohydrates

Carbohydrates are a significant component of basil seeds, providing a considerable energy source. The carbohydrate content ranges from 43.9% to 63.8% in different countries (Yu *et al*., 2005) [20]. The seeds contain non-starchy polysaccharides, including cellulose, hemicellulose, and lignin. The high fibre content makes basil seeds a novel source of dietary fibre, contributing to improved characteristics in food products such as baguette bread (Sharma *et al*., 2019) [21].

Proteins

Basil seeds are a noteworthy source of proteins, essential for various physiological functions. The amino acid composition includes essential and non-essential amino acids, with glutamic acid and aspartic acid being the most prevalent. Basil seeds are considered a valuable plant-based protein source, particularly relevant with the increasing popularity of vegetarian and vegan diets (Doke & Guha, 2014) [22].

Fats

Basil seeds are rich in lipids, with a fat content ranging from 9.7% to 33.0%. The fatty acid composition includes essential fatty acids like linoleic acid (LA), linolenic acid (ALA), and arachidic acid. Polyunsaturated fatty acids, especially omega-3 fatty acids, are present in basil seeds, contributing to potential health benefits and making them a promising source for vegetarians and vegans (Shahrajabian *et al*., 2020) [4].

Minerals

Minerals are crucial for overall health, and basil seeds contain essential macro and micronutrients. The mineral composition includes calcium, phosphorus, magnesium, sulfur, potassium, chloride, sodium, zinc, iron, silicon, manganese, copper, fluoride, iodine, and chromium (Tako 2022) [23]. These minerals play vital roles in cellular metabolism, structural components, and the activity of hormones, vitamins, and enzymes. The mineral content can vary between basil species, with *Ocimum basilicum* showing lower levels compared to *Ocimum tenuiflorum* (Ciriello *et al*., 2022) [24]. These variations can be attributed to factors such as growth conditions, genetics, geographic differences, and analytical techniques.

Before exploring the myriad health benefits of basil seeds, it is crucial to understand their impressive nutritional composition. In every 100g of basil seeds, these tiny powerhouses offer a well-balanced blend of macronutrients and micronutrients in Figure 1. With 63.8g of carbohydrates, basil seeds provide a quick energy source, complemented by a substantial 22.6g of fiber, promoting digestive health and a feeling of fullness. The protein content stands at 14.8g, contributing to muscle health and overall bodily functions. While basil seeds contain 13.8g of fats, they are predominantly of the healthy variety, and the 9358mg of omega-3 fatty acids further enhance their nutritional profile with anti-inflammatory properties (Wall *et al*., 2010) [25].

Essential minerals are abundant in basil seeds, with 2.27mg of iron crucial for hemoglobin production, 31.55mg of magnesium supporting muscle and nerve function, and 1.58mg of zinc, playing a vital role in immune function (Khursheed *et al*., 2023) [26]. The seeds also deliver a dose of vitamins, with 18g each of Vitamin A and Vitamin C contributing to immune support and overall health, and 0.8mg of Vitamin E with antioxidant properties. Despite these nutritional riches, basil seeds are relatively low in calories, providing only 60 calories per 100g. This holistic nutritional overview positions basil seeds, also known as sabja seeds, as a valuable addition to a well-rounded and nutrient-dense diet.

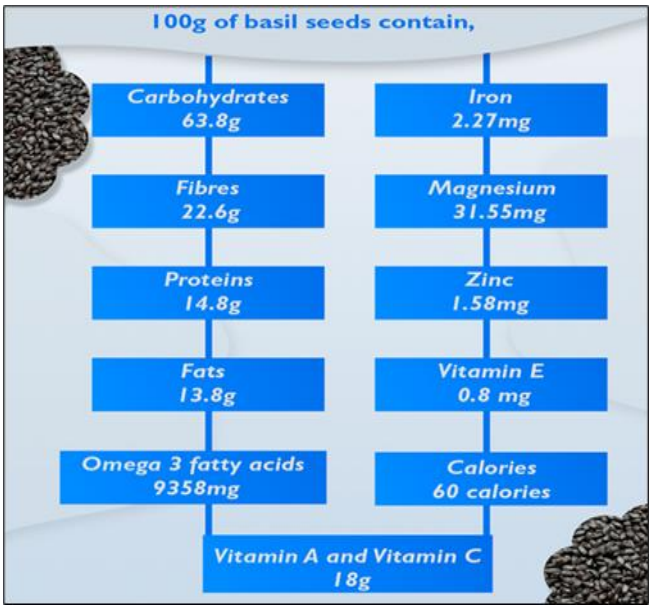
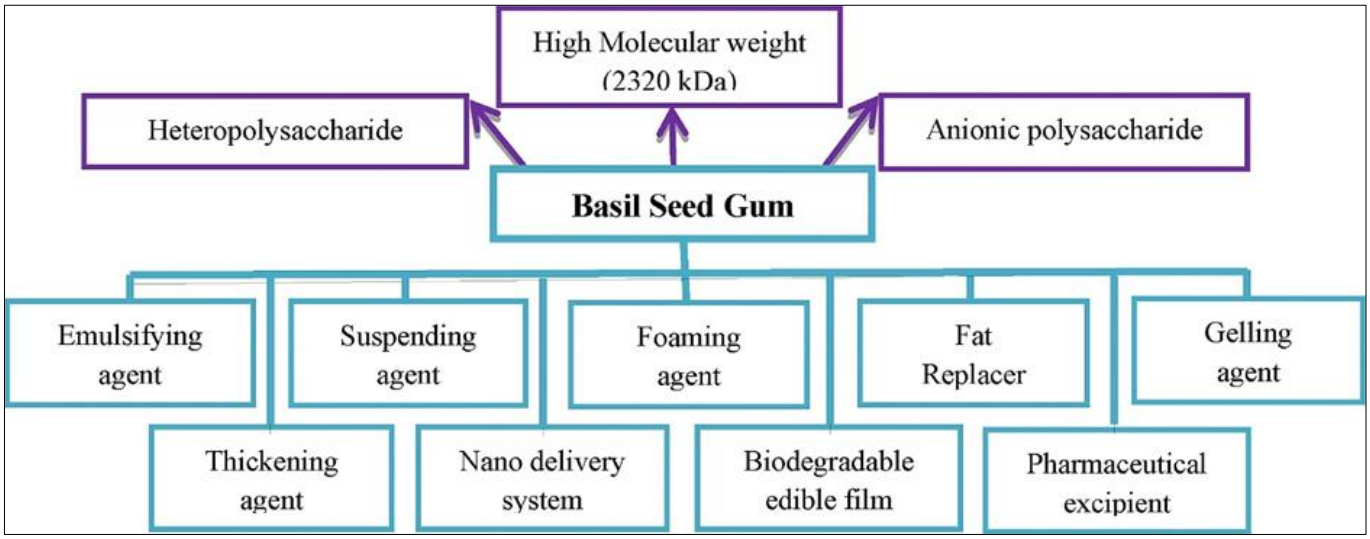


Fig 1: Nutritional Riches of Basil Seeds per 100 g (*Source: https://sprintmedical.in/blog/basil-seeds*) Functional Properties and Versatile Applications of Basil Seed Gum

Basil seed gum (BSG), derived from basil seeds (*Ocimum basilicum*), has gained prominence in various industries due to its diverse functional properties. One notable attribute is its emulsifying capacity, making it a valuable ingredient in the food industry for stabilizing emulsions and improving the texture of products such as salad dressings and mayonnaise. The gum's thickening properties further enhance its application in food formulations, providing viscosity to sauces, soups, and dairy products (Himashree *et al*., 2022) [27]. Beyond its role in the food sector, BSG exhibits film-forming properties that have found applications in the production of edible films and coatings. These films, when supplemented with plasticizers and fatty acids, showcase improved functional qualities, including enhanced flexibility and barrier properties. Such advancements make BSG-based films suitable for extending the shelf life of perishable products like fruits and vegetables (Sharma *et al*., 2019) [28].

The biocompatibility and hydrophilicity of BSG contribute to its applicability in the pharmaceutical industry. Its use as a pharmaceutical excipient facilitates the conversion of active pharmaceutical ingredients into dosage forms. Additionally, BSG has demonstrated potential in the development of cryo-protective agents, offering stability to products during freezing processes, as seen in ice cream formulations. In the realm of nanotechnology, basil seed gum stands out for its ability to form thermostable ultra-thin nanofibers. These nanofibers find application in various fields, including drug delivery systems and the creation of nanocomposites. The multifunctional nature of basil seed gum, encompassing emulsification, thickening, film formation, and compatibility with pharmaceutical formulations, underscores its versatility across industries (Said *et al*., 2023) [29]. As research continues to unveil more applications and refine extraction processes, basil seed gum is poised to play an increasingly pivotal role in various sectors, contributing to advancements in food technology, pharmaceuticals, and materials science in Figure 2.



Source: Naji-Tabasi and Razavi (2017) [9]

Fig 2: Functional properties and applications of basil seed gum

Role of basil seed gum as functional food

Basil seeds, derived from the herb Ocimum basilicum L., possess notable nutritional and functional attributes, making them an emerging component in the realm of functional foods. The seeds are rich in essential amino acids, proteins, dietary fibers, and lipids, including linoleic and linolenic fatty acids. Their consumption has been associated with various health benefits, such as preventing type 2 diabetes, cardio-protection, anti-inflammatory effects, anti-ulcer properties, anticoagulant features, and even antidepressant qualities (Meena *et al*., 2021) [30].

Functional Food Potential

Basil seeds are increasingly recognized as a functional food, offering a healthier alternative to traditional foods. Studies have demonstrated their efficacy in preventing and treating diseases such as cardiovascular diseases and hypertension. The food industry is responding with innovative products, with beverages being a popular choice for incorporating basil seeds.

Beverages and Food Products

1. **Ready-to-Drink Functional Beverages:** Basil seeds are often added to beverages like lemonade, iced tea, smoothies, and health drinks, providing a refreshing and nutritious boost. The gelatinous nature of soaked basil seeds makes them an ideal ingredient for beverages.
2. **Desserts and Sweets:** Basil seeds serve as a healthier substitute for tapioca in puddings and sweets. They find application in ice cream, fruit salads, and the production of jelly, enhancing both texture and nutritional content.
3. **Health Supplements:** Due to their high fiber and antioxidant content, basil seeds are used in health supplements. They contribute to controlling blood sugar levels and offer an additional nutritional boost.

Functional Ingredients in Food Processing

1. **Bread Production:** Basil seed gum has been incorporated into bread formulations, impacting physicochemical and rheological properties. It has been observed to enhance volume, specific volume, and sensory qualities, making bread a potential carrier for basil seed gum.
2. **Beverage Stability:** In beverages, the addition of basil seeds affects absolute Z (a measure of color), taste satisfaction, and color variables. Basil seeds, with their high protein to fiber ratio, contribute to enriched beverages, and the inclusion of hydrocolloids improves stability and appearance.

Bioremediation and Other Applications

1. **Metal Absorption:** Basil seeds exhibit the ability to absorb metals such as selenium, copper, cesium, and strontium. This unique characteristic positions them as a potential solution for bioremediating contaminated water.
2. **Biodegradable Film:** Basil seed mucilage is utilized as a biodegradable film and in active packaging for various food applications. Its excellent tensile and deformation capacity make it suitable for enhancing packaging materials.

3. **Processed Cheese:** In processed cheese, basil seed gum influences meltability and firmness. It helps emulsify oil, creating a unique structure in processed cheeses, leading to increased firmness and reduced meltability.

Basil seeds, particularly their gum, exhibit immense potential in the food industry as functional ingredients, contributing to both the nutritional and structural aspects of various food products. Their diverse applications, from beverages to processed cheeses, underscore their versatility and growing significance in the functional food landscape.

Bioactive components and their pharmacological activities

The bioactive components within Ocimum basilicum exhibit a diverse range of pharmacological activities, contributing to its multifaceted health benefits. In a study by Calderón Bravo *et al*. (2021) [1], the anti-inflammatory properties of basil oil were demonstrated, significantly reducing paw edema with higher α-linolenic acid content. This effect held promise for potential applications in managing inflammatory conditions. The anti-asthmatic activity of basil oil was evident, with a maximum effect observed at a dose of 0.5 mL/kg in histamine and acetylcholine-induced bronchospasm, showcasing its potential in respiratory health (Calderón Bravo *et al*., 2021) [1]. The pharmacological profile of basil oil extends to antipyretic, analgesic, and antiarthritic activities, with significant effects observed at doses ranging from 1.0 to 3.0 mL/kg (Calderón Bravo *et al*., 2021) [1]. Furthermore, the oil demonstrated antiulcer action, hypocholesterolemic impact after five weeks of consumption, and anti-coagulant properties, lengthening blood clotting time (Calderón Bravo *et al*., 2021) [1]. Notably, basil oil exhibited promising anticancer activity at a dose of 100 mL/kg, comparable to the impact of vitamin E (Calderón Bravo *et al*., 2021) [1].

Additionally, Gajendiran *et al*. (2016) [31] highlighted the antioxidant capacity of phenolic compounds in O. basilicum seeds, emphasizing their potential role in mitigating oxidative stress. Moreover, other studies point to antimicrobial activity against various organisms, including S. aureus and P. aeruginosa, showcasing basil oil's potential in combating infections (Calderón Bravo *et al*., 2021) [1]. The antidiabetic potential of basil components is underscored by their inhibitory action on protein tyrosine phosphatase 1B (Ali *et al*., 2016) [33], while α-amylase inhibitory activity suggests a role in managing oxidative stress and preventing type-2 diabetes (Nurul Hidayatul Afifah *et al*., 2016) [32]. This comprehensive analysis provides insights into the diverse pharmacological activities of bioactive components in Ocimum basilicum, highlighting its potential in various therapeutic applications.

Table 1: Bioactive components with their pharmacological activity and their outcomes

Pharmacological Activity	Outcomes	References
Anti- inflammatory	With a dose of 3.0 mL/kg, paw oedema was significantly reduced. Greater paw oedema inhibition was obtained by higher α-linolenic acid content	(Calderón Bravo *et al*., 2021) [1]
Anti-asthmatic	For histamine and acetylcholine-induced bronchospasm, maximum action was seen at a dose of 0.5 mL/kg of fixed oil.	(Calderón Bravo *et al*., 2021) [1]
Antipyretic	The oil showed a pronounced antipyretic effect at doses of 1.0 mL/kg or above. The action was comparable to aspirin at a dose of 3.0 mL/kg.	(Calderón Bravo *et al*., 2021) [1]
Analgesic	The oil demonstrated considerable inhibition using an acetic acid-induced writhing method in a dose-dependent manner indicating that its potential mechanism involves the peripheral system.	(Calderón Bravo *et al*., 2021) [1]
Anti-arthritics	At a dose of 3.0 mL/kg, the fixed oil showed stronger anti-arthritis action, which was comparable to aspirin's effects.	(Calderón Bravo *et al*., 2021) [1]
Antiulcer	At a dose of 3.0 mL/kg, the fixed oil has better antiulcer action.	(Calderón Bravo *et al*., 2021) [1]
Anti-hyperlipidemic and antioxidant	After being consumed for five weeks, the fixed oil had a hypo cholesterolemic impact.	(Calderón Bravo *et al*., 2021) [1]
Antimicrobial	S. aureus was the most susceptible organism (zone of inhibition 0.8 mm), and fixed oil has strong antibacterial activity against B. pumilus, P. aeruginosa, and S. aureus.	(Calderón Bravo *et al*., 2021) [1]
Anti-coagulant	Blood clotting time was lengthened by fixed oil, and the percentage increase was similar to that of aspirin	(Calderón Bravo *et al*., 2021) [1]
Anticancer	At a dose of 100 mL/kg, the fixed oil demonstrated chemo preventive activity that was comparable to the impact of vitamin E.	(Calderón Bravo *et al*., 2021) [1]
Antioxidant	In O. basilicum seeds, phenolic compounds account for 73.85% of the antioxidant capacity.	(Gajendiran *et al*., 2016) [31]
Anticancer	Maximum activity was seen for the cell viability % at a lower concentration, or 12.5 g/mL	(Calderón Bravo *et al*., 2021) [1]
Antimicrobial	*P. aeruginosa'* s highest zone of inhibition was seen at a dose of 100 mg/mL.	(Calderón Bravo *et al*., 2021) [1]
Antidiabetic	Protein tyrosine phosphatase 1B has an IC50 of 8.20 g/mL, which indicates its inhibitory action.	(Ali *et al*., 2016) [33]
Antioxidant activity α-amylase inhibitory activity	To lower the risk of oxidative stress and prevent type-2 diabetes, peptides can be employed as therapeutic agents.	(Nurul Hidayatul Afifah *et al*., 2016) [32]

Pharmacological Applications of Basil Seeds

Basil seeds (*Ocimum basilicum*) have long been recognized for their pharmacological versatility, contributing to a wide array of traditional medicinal practices. (Shahrajabian *et al*., 2020) [4] highlight the traditional uses of basil seeds in various applications, including food, dental and oral products, and fragrance. Beyond their culinary role, basil seeds are employed to treat diverse conditions such as skin diseases,

worms, diarrhea, and cough (Shahrajabian *et al*., 2020) [4]. Notably, basil's pharmacological significance extends to the realm of Traditional Chinese Medicine, where basil polysaccharides are employed in cancer treatment (Yang *et al*., 2021) [34]. Twilley *et al*. (2018) [35] showcase basil's effectiveness in treating conditions like anxiety, infections, and constipation, while also emphasizing its anti-spasmodic, anti-diabetic, and blood glucose-regulating properties. (Saracino *et al*., 2022) [36] underscore the therapeutic potential of eugenol, present in basil, against fungal, nematocidal, and bacterial activities, particularly in combating food-borne pathogenic microorganisms.

Beyond traditional medicine, basil seeds and their derivatives offer promising applications in pharmaceutical and food industries. Kurd *et al*. (2017) [37] emphasize the benefits of basil seed mucilage, including its hydrophilicity, biocompatibility, low manufacturing cost, and suitability for film formation. Feng *et al*. (2019) [38] highlight the multifaceted advantages of basil polysaccharides, ranging from diabetes treatment to anti-tumor and anti-aging properties. Basil seed gum (BSG) emerges as a versatile hydrocolloid with applications in emulsification, stabilization, fat replacement, texturization, and thickening in the food industry Osano *et al*. (2014) [17] and (Naji-Tabasi *et al*., 2016) [10]. Additionally, basil gum's potential as a cryo-protection agent and stabilizer in ice cream formulations further expands its utility (Hosseini-Parvar *et al*., 2015) [12]. This comprehensive overview underscores the pharmacological richness of basil seeds, positioning them as valuable contributors to both traditional medicine and modern pharmaceutical and food applications.

Table 2: Pharmacological uses of basil seeds

S. No.	Pharmacological Uses	Reference
1.	Traditional uses of this plant include use as an ingredient in food, dental and oral products, and fragrance	(Shahrajabian *et al*., 2020) [4]
2.	It is also used to treat skin diseases, worms, diarrhoea, and cough.	(Shahrajabian *et al*., 2020) [4]
3.	Traditional Chinese medicine has employed basil polysaccharides to treat cancer, and they are still commonly used today	(Wang *et al*., 2016) [34]
4.	It has been used to cure conditions like anxiety, pyrexia, infections, arthropod stings, stomach aches, coughs, headaches, and constipation;	(Twilley *et al*., 2018) [35]
5.	With anti-spasmodic and anti-diabetic characteristics, it can also regulate and lower blood glucose	Twilley *et al*., 2018) [35]
6.	The anti-fungal, nematocidal, and antibacterial activities of eugenol present in basil fight against food-borne pathogenic microorganisms are its most significant therapeutic properties	(Saracino *et al*., 2022) [36]
7	In traditional medicine, basil leaves are used as an antispasmodic, stomachic, and carminativ	(Sajjadi *et al*., 2006) [39]
8	Antioxidative, anti-inflammatory, and anti-microbial properties are included in basil essential oil component	(Kamelnia *et al*., 2023) [40]
9.	Numerous advantages of basil seed mucilage include its hydrophilicity, biocompatibility, low cost of manufacturing, suitability for film formation, edibility, and viscoelastic qualities.	Kurd *et al*. (2017) [37]
10.	Basil polysaccharides are beneficial in the treatment of diabetes mellitus and have anti-tumour, anti-oxidant, and anti-aging properties. They also have anti-bacterial, anti-atherosclerotic, immunity-boosting, and anti-atherosclerotic benefits	(Feng *et al*., 2019) [38]
11.	BSG is a hydrocolloid that can be used for emulsification, stabilisation, fat replacement, texurization, and thickening. Food quality for frozen goods can be improved via BSG	Osano *et al*. (2014) [17] (Naji-Tabasi & Razavi, 2017) [9]
12.	Basil seed mucilage can make thermostable ultra-thin nanofibers and BSM/Polyvinyl alcohol can produce edible films for use in the food industry.	Zeynali *et al*., 2019)
13.	For use in various food applications or to deliver active ingredients in functional foods, the addition of BSG may result in tougher heat-induced egg albumin gels. It is a potential new source of ingestible hydrocolloids for the food secto	Mirarab Razi *et al*., 2018) [41]
14.	Its seeds are used as a source of dietary fibre in Asian drinks such as faloodah and desserts that are used in traditional medicine	Hajmohammadi *et al*.,2016) [42]
15.	*Ocimum americanum* Linn. gum that has been isolated is a very effective disintegrant that can be employed in tablet formulations	(Naji-Tabasi & Razavi, 2017) [9]
16.	Basil gum can be used as cryo-protection agent. Mixture of BSG (Basil seed gum)) GG (Guar gum) and carboxymethyl cellulose (CMC) has been investigated in the formulation of ice cream as stabilizers	Hosseini-Parvar *et al*., 2015) [38].

Basil Seeds in Food Products: Diverse Applications and Health Benefits

Basil seeds, derived from the Ocimum basilicum plant, have emerged as versatile ingredients with notable applications in the food industry. The integration of basil essential oil microcapsules (BEOMC) into chitosan-based edible films, as pioneered by Amor *et al*. (2021) [43], introduces a novel packaging approach designed to extend food shelf life. Additionally, basil seeds serve as effective fat alternatives, as demonstrated by Kim *et al*. (2020) [44], enhancing the physical and antioxidant qualities of reduced-fat and nonfat yogurt. This application positions basil seeds as a valuable ingredient to elevate the nutritional profile of dairy products.

Further exploration of basil seeds reveals their impact on bread quality and the creation of arachin-based gel products (Yang *et al*., 2021) [34], and the enrichment of fruit-based beverages with hydrocolloids (Larki *et al*., 2022) [46]. Moreover, innovative approaches such as selenium-biofortified basil seed microgreens and basil seed gum-based edible coatings for strawberries (Puccinelli *et al*., 2019) [47] showcase the potential of basil seeds to enhance nutritional value and prolong the shelf life of fresh produce. Collectively, these findings underscore the diverse applications of basil seeds, positioning them as valuable contributors to both the sensory and nutritional aspects of various food products.

Table 3: Uses of basil seed food products and there benefits

Basil use	Benefits	References
Essential oil	Chitosan based edible films were produced, grafted with BEOMC (Basil essential oil microcapsules, a new type of packaging system designed to extend the food shelf life.	(Amor *et al*., 2021) [43]
used as a fat alternative	Reduced-fat and non fat yogurt's physical and antioxidant qualities can be raised to the level of FFY(Yoghurt made from full fat milk) by adding BSG to them	(Kim *et al*., 2020) [44]
heat induced arachnid gels	Gives important data for the creation of novel arachin-based gel products and the expansion of arachin's useful applications in the food business	(Yang *et al*., 2020) [34]
OEO (*Origanum vulgare* subsp. *Viride*) essential oil as an edible coating in fresh apricots	OEO BSG film and coating could significantly increase odour and general acceptance and could be used to preserve the freshness of fresh apricot cuts, edible film provides promising antibacterial and antioxidant characterstics	(Qian *et al*., 2021) [45]
Basil seed used in a fruit-based beverage with addition of hydrocolloids	basil seeds increase the amount of nutrients specially fiber content utilising basil seeds	(Larki *et al*., 2022) [46]
Basil seeds treated with selenium to produce selenium-biofortified microgreens	A promising method for obtaining microgreens with a high nutritional value could be the manufacture of microgreens from Se-enriched seeds.	(Puccinelli *et al*., 2019) [47]

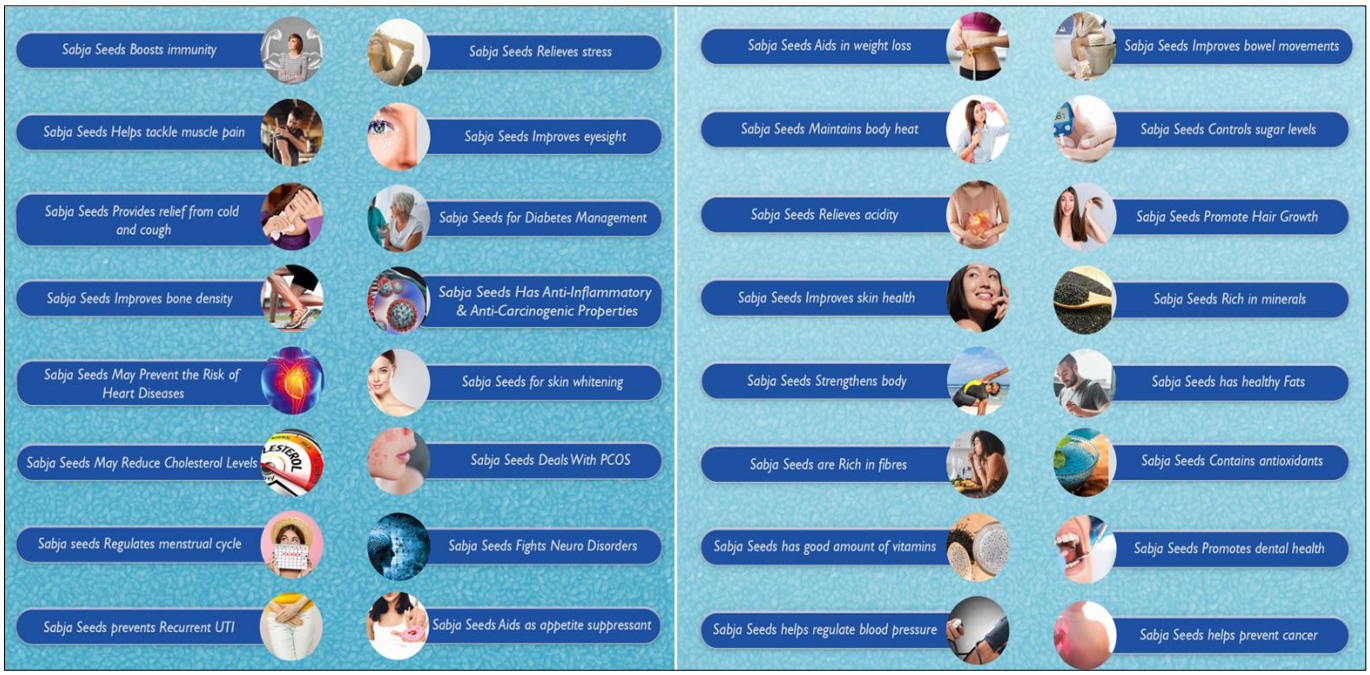
Multifaceted benefits of basil seeds

Sabja seeds, extracted from the basil plant (*Ocimum basilicum*), emerge as a nutritional powerhouse with an impressive array of health benefits. These tiny seeds, rich in dietary fibers, play a pivotal role in weight loss by promoting a sense of fullness, preventing overeating, and curbing mindless snacking. Beyond aiding in weight management, Sabja seeds act as a natural coolant, widely utilized in tropical regions to prepare refreshing drinks that lower body heat, offering an immediate and revitalizing effect. Their blood sugar-controlling properties make them valuable in diabetic treatment, inhibiting the body's overall metabolism and reducing glucose levels. With a notable impact on digestive health, Sabja seeds regulate bowel movements, cleanse the stomach and lower abdominal organs, and alleviate indigestion. The seeds also serve as a relief for acidity and heartburn, controlling HCL secretion in the stomach. Furthermore, Sabja seeds contribute to skin and hair health by promoting collagen production and nourishing hair follicles, fostering vibrant and healthy skin and hair. Their role in muscle relaxation, stress reduction, relief from cold and cough, and promotion of eye health further underline the holistic well-being benefits of Sabja seeds. Rich in vitamins, minerals, and antioxidants, these seeds boost immunity, prevent cancer, and contribute to heart health. Sabja seeds also prove beneficial for bone density improvement, diabetes management, and anti-inflammatory and anti-carcinogenic properties. Their appetite-suppressant qualities, skin-whitening benefits, and regulatory effects on the menstrual cycle make Sabja seeds a versatile and comprehensive addition to overall health and wellness illustrated in Figure 3.

Future Prospects in Exploring the Nutritional Spectrum and Culinary Applications

Basil seeds (*Ocimum basilicum* L.) have emerged as a focal point of interest in recent years, captivating both scientific and culinary communities alike. This forward-looking review not only consolidates the existing wealth of knowledge on basil seeds but also outlines promising future prospects in their exploration within the food industry. The initial focus of the paper lies in unraveling the nutritional richness of basil seeds, accentuating essential components such as proteins, fibers, vitamins, and minerals. A deeper dive into unique bioactive compounds sheds light on their potential health benefits and therapeutic applications, positioning basil seeds as more than just a culinary ingredient. The narrative extends to the functional properties of basil seeds, with a keen exploration of their impact on food formulation and product development. Of particular interest is the gel-forming ability of basil seeds, offering a canvas for innovative food textures and structures. Traditional and contemporary culinary applications are intricately woven into the narrative, spanning diverse cuisines and encompassing beverages, desserts, and savory dishes. The paper not only captures current uses but also unveils emerging culinary techniques that leverage the unique properties of basil seeds to elevate food quality and sensory experiences.

As the food industry continues to evolve, the review anticipates and discusses potential challenges and future directions in the utilization of basil seeds. Sourcing dynamics, quality control considerations, and the imperative of consumer acceptance are thoughtfully addressed, providing a well-rounded perspective for industry stakeholders. In conclusion, this comprehensive review not only serves as an invaluable resource for current researchers, food scientists, and industry professionals but also lays the groundwork for future research and development endeavors. By bridging the gap between knowledge and application, the review envisions a trajectory where basil seeds emerge as a sought-after functional ingredient, contributing to the dynamic landscape of the food industry.



(**Source:** https://sprintmedical.in/blog/health-benefits-of-sabja-seeds)

Fig 3: Multifaceted benefits of basil seeds

Conclusion

This comprehensive review underscores the burgeoning significance of basil seeds in the food industry. Their remarkable nutritional richness, encompassing proteins, fibers, vitamins, and minerals, positions them as not only culinary staples but potential contributors to health and wellness. The exploration of unique bioactive compounds unveils promising therapeutic applications, enhancing the allure of basil seeds beyond their gastronomic appeal. As we peer into the future, the gel-forming prowess of basil seeds presents exciting avenues for innovative food structures. While delving into traditional and contemporary culinary uses, this review also anticipates challenges, addressing sourcing intricacies, quality control imperatives, and the critical factor of consumer acceptance. By bridging existing knowledge with future possibilities, this review not only serves as a vital resource for researchers and industry professionals but paves the way for the widespread integration of basil seeds as a functional and health-enhancing component in the dynamic landscape of the food industry.

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