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Exploring *Benincasa hispida* (Thunb.) Cogn.: A Medicinal Plant with Antioxidant, Antimicrobial, and Nanotechnological Properties

Gargi Meena and Rishi Kesh Meena
Plant Pathology, Tissue Culture and Biotechnology Laboratory, Department of Botany, University of Rajasthan, Jaipur.

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***Corresponding Author Email:** rishi_1180@yahoo.com

Abstract

Benincasa hispida, a versatile medicinal herb, has been traditionally used in Ayurvedic medicine for its therapeutic benefits. Recent research has underscored the potential of plant bioactive compounds in managing various health conditions, including diabetes, hypertension, and obesity. These compounds demonstrate antioxidant, anti-inflammatory, and antimicrobial activities. Green-synthesized nanoparticles from *Benincasa hispida* have shown promise in the fields of agriculture, medicine, and environmental sustainability. These nanoparticles also have potential applications in water purification, food packaging, and cosmetics. This review explores the multifaceted potential of *Benincasa hispida*, highlighting its green-synthesized nanoparticles, pharmacological activities, phytochemical profile, and antioxidant and antimicrobial properties. The therapeutic applications and bioactive compounds of this fruit make it an attractive candidate for functional foods and nutraceutical development.

Keywords

Benincasa hispida, Cucurbitaceae, nanotechnology, green synthesis, biomedical applications, pharmacological activities, phytochemical Evaluation, antioxidant activity, antimicrobial activity.

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INTRODUCTION

Nanotechnology is a multidisciplinary field that focuses on the controlled creation, manipulation, and exploitation of materials at the nanoscale, resulting in innovative structures, devices, and systems with unique properties (Abobatta *et al.,* 2018)[1]. Nanotechnology explores the intersection of atomic, molecular, and macromolecular sciences, facilitating the precise engineering of structures or devices at the nanoscale, with profound implications for innovation. At this scale, nanoparticles show distinct properties and functions that differ from those of their bulk-scale counterparts. Nanotechnology leverages these unique characteristics to create practical solutions by harnessing the special chemical and physical properties of nanomaterials for societal advancement. As a transformative technological approach, nanotechnology enables innovative material management at the nanoscale and is poised to redefine our perspectives and expectations. By addressing pressing global challenges, nanotechnology has the potential to profoundly impact the world (Bhushan, 2017)[2].

Nanotechnology has immense potential in plant sciences and production systems, particularly in phyto nanotechnology. This emerging field facilitates the precise delivery of biomolecules, including nucleotides and proteins, and enables the controlled release of agrochemicals such as fertilizers and pesticides. Elucidating the intricate relationships between nanoparticles and plant physiological processes, encompassing uptake, sequestration, and biochemical activity, allows researchers to enhance

plant disease resistance, improve nutrient use efficiency, and increase crop productivity. A deeper understanding of these relationships could revolutionize agricultural production, transform traditional plant production systems, and foster sustainable food security (Wang *et al.,* 2016)[3].

Recent advancements have underscored the profound impact of nanotechnology in various disciplines, particularly medicine. Oncology has emerged as a key beneficiary, with nanotechnology-enhanced applications in drug delivery, therapy, detection, and diagnosis. Despite the burgeoning interest, the translation of nanotechnology to clinical cancer care remains in its nascent stages. This study provides an overview of the advancements in cancer therapy, explores the transformative potential of nanotechnology in cancer care, and identifies the challenges that must be overcome to fully harness its benefits (Gharpure *et al.,* 2015)[4].

NANOMATERIALS

Nanomaterials, measuring 1-100 nm, encompass natural substances such as carbon and minerals such as silver, engineered into nano-sized particles. Nanomaterials are tiny substances with at least one dimension smaller than 100 nanometers, making them too small to see with the naked eye or even with common lab microscopes. Certain types of nanomaterials, like carbon, silver, silica, and aluminosilicates, are used to fight plant diseases. For instance, Silver has emerged as a viable agrochemical alternative for controlling pathogenic microorganisms in the soil. Nanoparticles also serve as effective pesticides, delivering chemicals directly into plant tissues for protection against pests. The agricultural industry has greatly benefited from nanotechnology, which has improved soil quality, enhanced productivity, stimulated plant growth, and enabled precise farming practices.

APPLICATIONS OF NANOBIOTECHNOLOGY IN GREEN SYNTHESIS

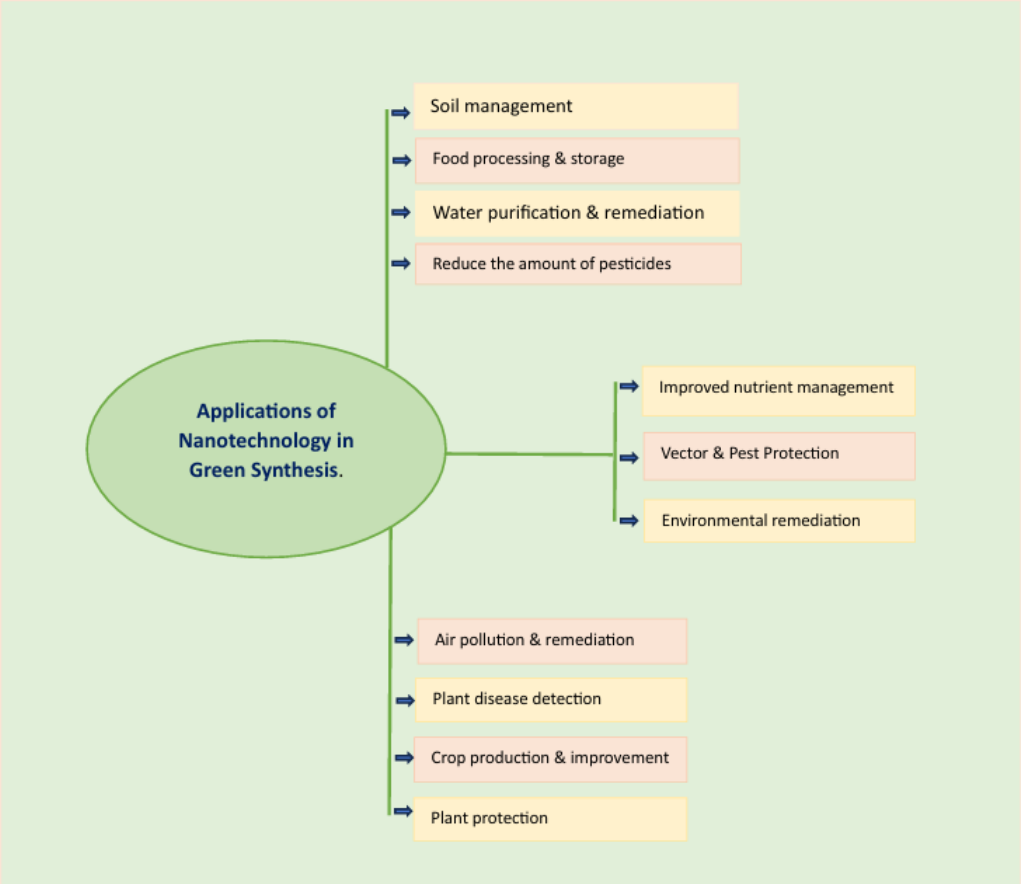

Fig. 1. Applications of Nanotechnology in Green Synthesis.

The use of nanotechnology in agriculture has recently grown and is a useful tool in the global effort to produce food sustainably. Numerous nanomaterials have been employed to create delivery strategies for bioactive compounds to increase crop protection and productivity (Ocsoy *et al.,* 2018)[5].

Nanotechnology has revolutionized plant research by leveraging nanoparticles as versatile tools to enhance plant health. These tiny particles serve as

pest control agents, targeted transporters, promote plant growth, prevent disease, and optimize resource utilization, nutrient delivery. Beyond improving crop yields through innovative agrochemical agents and delivery systems, nanotechnology also promises to reduce pesticide usage, offering a more sustainable future for agriculture (Sekhon, 2014)[6].

Nanotechnology has the potential to transform a wide range of industries, including agriculture, biomedicine, environmental engineering, security, water management, and energy production. By manipulating matter at the molecular level, nanotechnology can address complex challenges that conventional methods have struggled to resolve, leading to breakthroughs in agricultural productivity and beyond (Manjunatha *et al.,*2016)[7].

Nanotechnology, the science of manipulating materials at the nanoscale, holds promise for revolutionizing agricultural productivity by addressing long-standing challenges. In soil management, nanotechnology aims to enhance fertility by releasing locked nutrients and optimizing fertilizer effectiveness using nanoclays and zeolites. Precision farming and agriculture benefit from satellite systems and nano-biosensors, which identify crop input requirements in real time, enabling targeted and timely delivery. Furthermore, researchers are developing nano-herbicides to combat perennial weeds and deplete weed seed banks, thereby addressing persistent management issues (Manjunatha *et al.,* 2019)[8].

The applications of nanotechnology in plant production have transformative potential, enhancing scientific management and conservation efforts. Innovative nanodevices and nanocapsules enable efficient wastewater treatment, targeted delivery of active ingredients, disease detection and treatment, and improved nutrient absorption. Precision nanoparticle delivery minimizes environmental contamination and non-target tissue damage, rendering this technology environmentally benign and contributing to pollution reduction (Dhewa, 2015)[9].

Nanotechnology has emerged as a groundbreaking solution for boosting agricultural productivity by enhancing nutrient efficiency and optimizing plant protection strategies. Furthermore, this innovative field offers promising solutions to pressing agricultural challenges, including the development of resilient crop varieties, effective plant protection measures, precise disease detection, and real-time growth monitoring (Abobatta *et al.,* 2018)[1]. Nanotechnology-based agricultural solutions, including nanoparticles and nanotools, offer promising alternatives for efficient pest management and plant nutrition (Chhipa 2019)[10]. By reducing pesticide and fertilizer residues, protecting the soil, and reducing groundwater pollution, nanotechnology can greatly increase agricultural productivity, improve fruit quality, and increase output per unit area. It can also make agricultural products more competitive (Al-Hadede *et al*, 2020)[11]. Nanotechnology shields food and agriculture from bacteria, fungi, and viral agents. Plant diseases are detected early using nanosensors. Nanotechnology has demonstrated promising possibilities for advancing sustainable agriculture (Usman, 2020)[12]. Nanotechnology can be used to detect and break down contaminants to increase agricultural output while maintaining long-term environmental protection (Baruah *et al.,* 2009)[13]

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DESCRIPTION OF PLANT

Fig. 2. Ash gourd (*Benincasa hispida*) fruit.

As one of the most genetically diverse plant families, Cucurbitaceae exhibits unique traits, including drought tolerance and sensitivity to frost, and requires well-drained soils for optimal growth (Whitaker & Bohn, 1950)[14]. *Benincasa hispida*, a cucurbit species, has significant potential for developing functional foods owing to its unique nutritional profile. The plant is a monocotyledon that produces large green fruits. If the fruits are not damaged, one of the special qualities of Kundur fruit

is its ability to be kept in dry, cool environments for several months or even a year.

The Cucurbitaceae family's *Benincasa hispida*, or ash gourd, has its roots in the Indo-China region, with a rich linguistic diversity reflected in names such as Kushmanda (Sanskrit), Agra Ka Petha (Hindi), Kohla (Marathi), Kumbalang (Malayalam), and numerous English synonyms (Zaini, 2011)[15]. This vigorous herb boasts sturdy, angular stems with coarse hairs, either climbing or trailing in habit, producing fruit that transforms from fleshy and hairy in youth to thickly hairy with a removable waxy coating at maturity (Grover *et al.,* 2001)[16]. In traditional Chinese medicine, white gourd is valued for treating fever, cough, and urinary issues, while its low-calorie count makes it beneficial for diabetes management. The wax gourd's surface wax crystals serve as a protective shield, accumulating chemical compounds and safeguarding against water loss, UV damage, and pests, despite posing preservation challenges owing to their high pH.

Systematic position: (According to the Bentham and Hooker classification)

Kingdom: *Plantae*

Division: *Magnoliophyta* (Angiosperms)

Class: *Magnoliopsida* (Dicotyledons)

Subclass: *Polypetalae*

Series: *Calyciflorae*

Order: *Cucurbitales*

Family: *Cucurbitaceae*

Genus: *Benincasa*

Species: *B. hispida*

Binomial Name: *Benincasa hispida* (Thunb.) Cogn.

Synonyms: - *Cucurbita hispida* Thunb

- *Benincasa cerifera* Savi

***Benincasa hispida*: A Comprehensive Review of Its Medicinal and Pharmacological Properties**

Benincasa hispida has been revered in Ayurvedic medicine, yoga, and Indian spiritual traditions for its therapeutic properties, particularly its ability to alleviate urinary retention. This versatile plant has been traditionally used to address various health concerns, including internal haemorrhaging, respiratory disorders, epileptic seizures, and involuntary hiccup spasms. Research has revealed the multifaceted pharmacological profile of *Benincasa hispida*, showcasing its potential in modulating the central nervous system. The anxiolytic, muscle relaxant, and antidepressant properties of the fruit make it a potential therapeutic agent for managing Alzheimer's disease and opioid withdrawal (Kumar & Singh, 2016)[17].

The fruit of *Benincasa hispida* has been a cornerstone of traditional Chinese, Ayurvedic, and Naturopathic medicine, prized for its medicinal and functional properties. Rich in vitamins B1 and C, moisture, and nutrients, this fruit has been cultivated for its therapeutic and nutritional values. Phytochemical analysis has revealed a diverse composition of bioactive compounds in the plant, including volatile oils, flavonoids, and glycosides (Zaini *et al.,* 2011)[15]. Phytochemical studies on *Benincasa hispida* have highlighted the potential of its bioactive ingredients to induce cytolytic, inflammation-modulating, and tumour-suppressing effects. Additionally, phytochemical analysis of the fruit peels has detected the presence of galactose, glucose, xylose, and sorbose as the predominant sugars (Snafi & Esmail, 2013)[18].

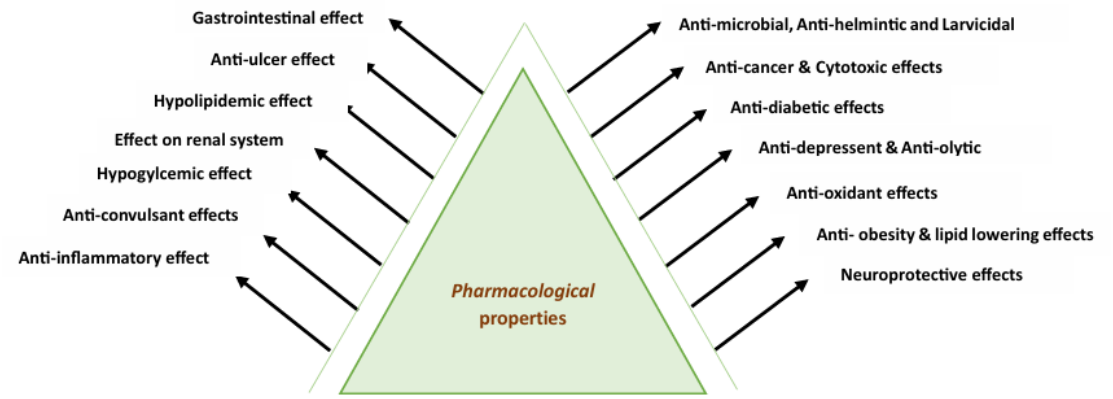

Fig. 3. Pharmacological and medicinal properties

Nutritional and Phytochemical Composition

Alkaloids: diverse therapeutic activities

Glycosides: digestive, cardiovascular support

Carotenoids: colon cancer protectors

Saponins: anti-inflammatory, antidiabetic effects

Flavonoids: antioxidant activity, cancer cell spread inhibitors and carcinogen neutralizers

Water-soluble polysaccharides: Arabinogalactans, β-(1 → 4)-d-galactan, homogalacturonan, acidic arabinan

Terpenes: antioxidant powerhouses and carcinogen blockers-β-carotene: a powerful free radical scavenger and anticancer agent.

Antioxidant vitamins: Carcinogenic inhibitors, oxidant neutralizers, and tumour growth suppressors.

Antioxidants: Ash gourd antioxidants may lower the risk of developing chronic illnesses (Zote *et al.,* 2024)[19].

Vitamins: Ash gourds are an excellent nutritional choice, providing essential vitamins and antioxidants for skin vitality, immune function, and optimal overall health. (Zote *et al.,* 2024)[19].

Minerals: It contains important minerals, including calcium, phosphorus, iron, and potassium, which are necessary for healthy bones, strong muscles, and blood pressure control. (Zote *et al.,* 2024)[19].

Dietary Fibre: Ash gourd's high dietary fibre content promotes healthy digestion, regulates bowel movements, and helps prevent constipation, while also reducing the risk of chronic conditions, such as diabetes, cardiovascular disease, and certain gastrointestinal disorders. (Vyawhare *et al*. 2024)[20].

Pathogenesis-related (PR) protein, identified as an osmotin-like protein (OLP), was purified from

Phenolics: free radical scavenging

Tannins: antimicrobial, anti-inflammatory

Benincasa hispida seeds using acid treatment and chromatography. This protein has a molecular mass of approximately 28 kDa and shares sequence similarity with thaumatin-like proteins. Genomic cloning revealed a single-copy gene encoding a mature protein with a molecular mass of 24.8 kDa and an isoelectric point of 7.67. The protein structure, with 17 cysteine residues, is similar to that of thaumatin and other PR-5 proteins. OLPs are known for their antifungal activity, which inhibits fungal growth and increases membrane permeability. *Benincasa hispida*, a member of the Cucurbitaceae family, is a medicinal plant with limited PR protein studies. This study provides the first identification of a PR protein and gene sequence from this species, contributing to the understanding of plant defence mechanisms. (Shih *et al.,* 2001)[21].

Polysaccharides: Pectic polysaccharides were extracted from *Benincasa hispida* (chalkumra) fruit using ammonium oxalate, dilute acid, and cold dilute alkali solutions. The extracts yielded polysaccharides that were rich in galacturonic acid and galactose. Characterization revealed homogalacturonans and β-(1→4)-D-galactans as the major components. The polysaccharides exhibited varying intrinsic viscosities, with the alkali-extracted pectins exhibiting the highest viscosity. These findings suggest the potential industrial applications of *Benincasa hispida* pectins as gelling, thickening, or stabilizing agents. Further research is needed to explore their gelling abilities and valorization. (Mazumder *et al.,* 2004)[22].

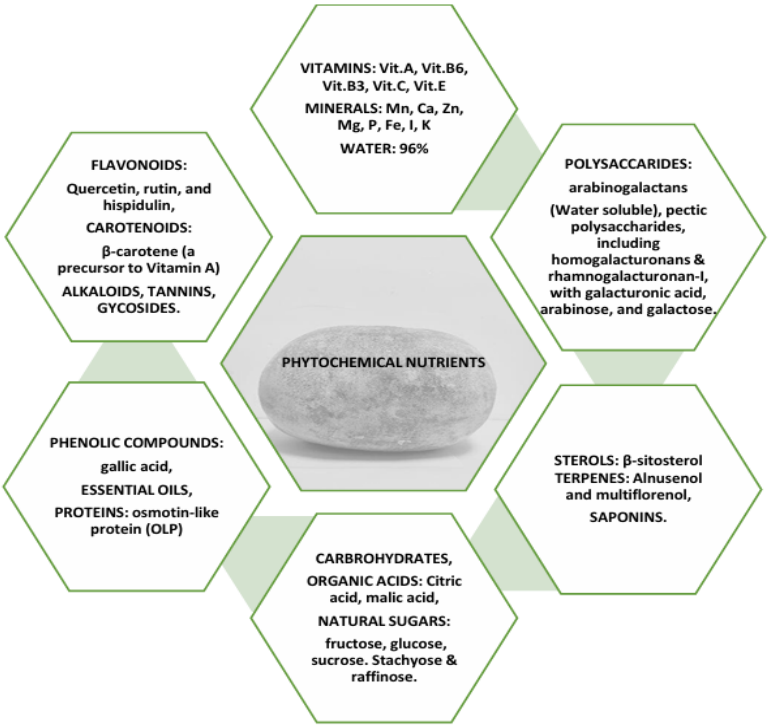

Fig. 4. Phytochemical Nutrients.

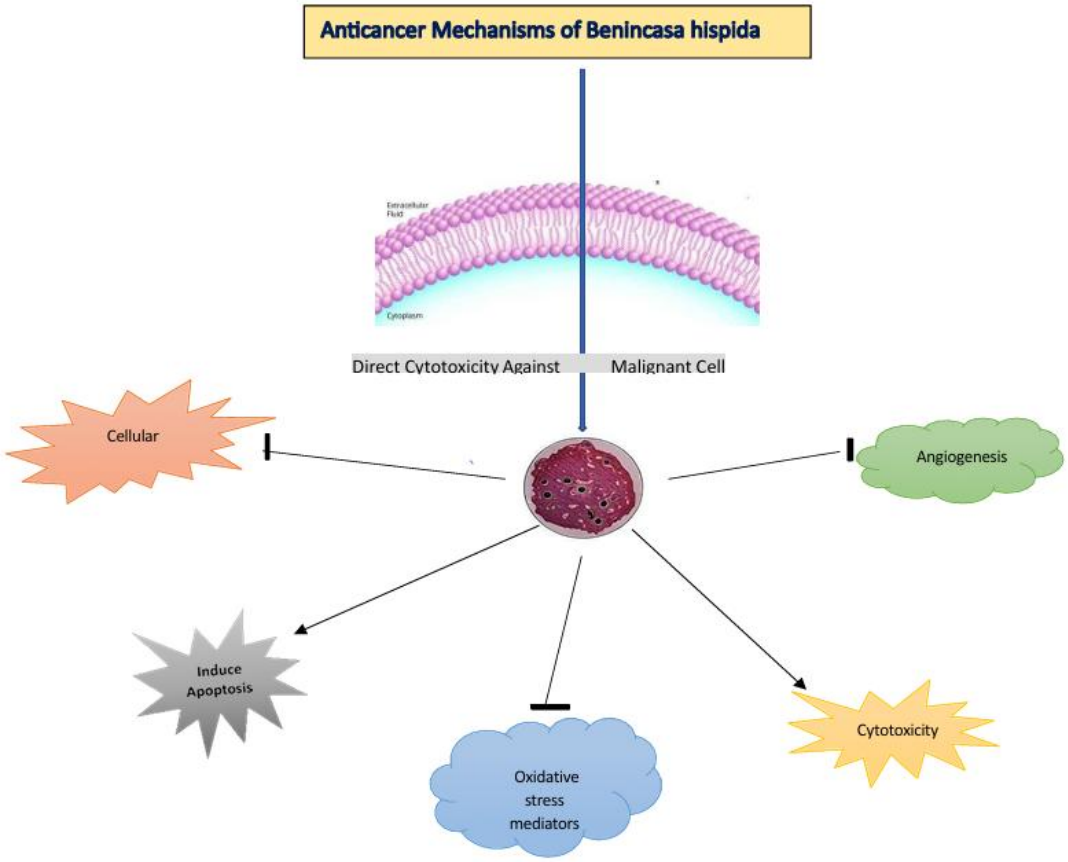

Fig. 5. Anticancer Mechanism of Ash gourd (Bh)

REVIEW OF LITERATURE:

International status:

Lakshmanagowda *et al.* (2024)[23] investigated the efficacy of *Benincasa hispida* fruit extract in alleviating anxiety-like behavior in Neurobehavioral models, shedding light on its neuroprotective potential. *Benincasa hispida,* a time-honoured natural rejuvenating agent, is used to alleviate brain dysfunction and other neurological disorders.

Yusoff *et al.* (2023)[24] found that watermelon (*Citrullus lanatus*) and winter melon (*Benincasa hispida*) rinds, which are typically discarded as waste, contain valuable bioactive compounds. Ultrasound-assisted extraction effectively extracts these compounds, yielding higher total phenolic and flavonoid contents than maceration. The antioxidant activity of *Benincasa hispida* rind extract (IC50:20872.19 mg/mL was stronger than that of *Citrullus lanatus* (IC50:23514.47 mg/mL). Phytochemical analysis revealed that phenolic acids, flavonoids, and other compounds contribute to the antioxidant properties. Utilizing these fruit wastes as antioxidant sources can reduce environmental pollution and create new income-generating opportunities in agriculture and food industries.

Choi *et al.* (2023)[25] evaluated the therapeutic potential of BHE in preventing osteoporosis and bone metabolic disorders in female mice with osteoporosis. The present study revealed that *Benincasa hispida* extract administration effectively suppressed bone degradation and promoted bone regeneration, indicating its potential as a natural remedy for osteoporosis and bone-related disorders.

Ahmad *et al.* (2022)[26] discovered that an extract with antioxidant properties modified amino acid metabolism and reduced hypertension in Dahl salt-sensitive rats. The antihypertensive effects of the extract, owing to its glycine, aspartic acid, and malic acid content, suggest its potential as a therapeutic agent for preventing kidney damage in salt-induced hypertension.

Alam *et al.* (2021)[27] reported that *Benincasa hispida,* or winter melon, exhibits antimicrobial properties, making it a potential natural agent against bacterial and fungal infections. Studies have shown that extracts from its peel, pulp, and waxy coating inhibit the growth of pathogens such as *Bacillus subtilis, Escherichia coli,* and *Fusarium oxysporum.* Methanol extracts demonstrated higher efficacy than ethyl acetate and chloroform extracts. The antimicrobial activity of the fruit is attributed to its bioactive compounds, suggesting its potential as a natural preservative or therapeutic agent. Further research is needed to identify the specific compounds and mechanisms responsible for its antimicrobial effects.

Alsaadi *et al.* (2020)[28] *Benincasa hispida*, a nutrient-rich vegetable, exhibits diverse pharmacological activities, including central nervous system effects, antioxidant, anti-inflammatory, analgesic, and antimicrobial properties. Its extracts have shown anxiolytic, antidepressant, and anti-compulsive activities and may aid in the treatment of Alzheimer's disease. *Benincasa hispida* also demonstrates antiulcer, antidiarrheal, and hypoglycemic effects and may support urinary system health. Its antioxidant properties contribute to its potential therapeutic effects. Overall, *Benincasa hispida* is a valuable source of bioactive compounds with potential applications in medicine and nutrition.

Waidyarathna *et al.* (2020)[29] reported that *Benincasa hispida* has been a valued medicinal herb in Ayurvedic and traditional Sri Lankan medicine for centuries, utilized in various preparations to treat a range of health conditions. Its different parts, including the pericarp, fruits, seeds, stems, roots, and leaves, are used to address issues such as urinary system disorders, digestive problems, anaemia, jaundice, diabetes, and respiratory diseases, and it is also applied externally to treat skin conditions and burns. *Benincasa hispida* has been discovered to exhibit a multitude of beneficial properties, including Immunomodulatory, Age-defying, Pathogen-suppressing, and free radical-scavenging effects. These attributes render it a highly valued botanical for enhancing overall health and wellness, particularly by facilitating blood purification and rejuvenation.

Samad *et al.* (2013)[30] reported that *Benincasa hispida* seeds exhibit antioxidant activity, attributed to their phenolic and flavonoid content, making them a potential natural antioxidant source in the food industry. The water extracts of the seeds demonstrated dose-dependent scavenging activity against DPPH, ABTS, and hydroxyl radicals, and inhibited linoleic acid oxidation and nitrite formation. The rich bioactive compounds in *Benincasa hispida* seeds may help counter oxidative stress-related diseases and promote overall health, supporting their traditional use in managing various health conditions.

Khan *et al.* (2000)[31] assessed the resistance of *Benincasa hispida* to the phytophagous aphid Aphis gossypii and its role in preventing aphid-borne viral diseases. The study evaluated four distinct ash gourd genotypes: Local Sylhet, Local Round, High Female, and CQ-10-90, and discovered that Local Sylhet exhibited superior resistance, characterized by the highest trichome density and minimal susceptibility to aphid infestation. Notably, this genotype also displayed the lowest incidence of virus infection. The

study revealed that trichome density significantly impacted aphid populations, with higher densities on terminal and young leaves deterring aphid infestation. Ash gourd trichomes play a crucial role in defending against aphid infestation and reducing the transmission of viruses.

National Status:

Singh *et al.* (2026)[32] reported that *Benincasa hispida*, a medicinal plant, shows promise in treating diabetic kidney disease. These compounds help reduce kidney damage, inflammation, and oxidative stress. The plant regulates genes and proteins that support kidney function, maintaining electrolyte balance. This study supports the traditional use of T. tuberosa and suggests its potential for developing new treatments for kidney diseases.

Acharya *et al.* (2025)[33], Alzheimer's disease (AD) is a complex neurodegenerative disorder characterized by the accumulation of abnormal proteins, including β-amyloid plaques and tau tangles, leading to neuronal damage and brain atrophy. Given the need for alternative therapeutic approaches, research has focused on identifying phytochemicals from natural sources with potential anti-AD activities. A recent study investigated the phytochemical composition of *Benincasa hispida* (Thunb.) Cogn. seeds, identifying 51 compounds using chromatography-mass spectrometry. Molecular docking studies against five AD-associated targets revealed promising candidates, including BH_P19, BH_P20, BH_P30, BH_P18/BH_P31, and BH_P17. Further evaluation of drug-likeness profiles and molecular dynamics simulation studies identified BH_P19 as a lead compound, demonstrating its stability with acetylcholinesterase (AChE) over 100 nanoseconds. These findings underscore the potential of *Benincasa hispida* seeds as a rich source of bioactive compounds for AD therapy, supporting the exploration of natural products for the treatment of neurodegenerative diseases.

Das Gupta *et al.* 2025[34], *Benincasa hispida* (Thunb.) Cogn. (Cucurbitaceae) possesses significant antihyperglycemic and antihyperlipidemic properties, making it a valuable food plant in India. Research has shown that the microwave-assisted extraction of B. hispida fruits yields fractions with potent α-glucosidase and α-amylase enzyme inhibition potential, particularly the ethyl acetate fraction. UHPLC-QToF-MS/MS analysis identified 17 metabolites, which network pharmacology analysis suggests may work synergistically to ameliorate non-insulin-dependent diabetes mellitus through multiple pathways, including insulin resistance, AMPK signalling, PPAR signalling, and PI3K-Akt signalling. These findings support the traditional use of Benincasa hispida in managing diabetes and highlight its potential as a source of bioactive compounds for developing effective treatments for non-insulin-dependent diabetes mellitus (NIDDM). Further investigation is needed to develop high-quality, safe, and effective products using B. hispida extracts.

Pahari *et al.* (2024)[35] *Benincasa hispida*, a traditional Ayurvedic medicine, has been used to treat various health conditions, including epilepsy, haemorrhage, and digestive issues. Studies have shown that plant extracts possess antiepileptic, anti-inflammatory, antioxidant, and antimicrobial properties. Toxicological assessments revealed that *Benincasa hispida* leaf extract was safe for oral administration, with no significant adverse effects observed in acute and subacute toxicity studies. The safety profile and potential therapeutic benefits of the extract warrant further research, including genotoxicity and chronic effect studies, to confirm its efficacy and safety for human use.

Lakshmanagowda *et al.* (2024)[36] showed that *Benincasa hispida* exhibits anxiolytic and stress-reducing properties in zebrafish (Danio rerio) models (Life, 14(3), 379). Traditionally, the fruit extract of *Benincasa hispida* has been employed in Ayurvedic medicine for managing mental health disorders, including schizophrenia. A study investigated the anxiolytic effects of the extract in zebrafish models, revealing significant reductions in stress and anxiety behaviours. The antioxidant properties and phytochemical composition of the extract, including its phenolic compounds, may contribute to its therapeutic effects. Molecular docking studies suggested that the homogalactaconan molecule in the extract binds stably to the AChE receptor, supporting its potential as a natural treatment for stress and anxiety disorders. These results emphasize the necessity for continued investigation to develop a safe and efficacious pharmaceutical formulation utilizing *Benincasa hispida* fruit extract.

Chaital *et al.* (2022)[37] highlighted the diverse medicinal applications of *Benincasa hispida*, attributed to its rich phytoconstituents. Notably, the fruit is extensively utilized for therapeutic purposes and exhibits promising outcomes. Additionally, other plant parts have medicinal efficacy, leveraging the plant's anti-inflammatory properties. Furthermore, *Benincasa hispida's* pharmacological profile reveals a range of beneficial effects, including Free radical-scavenging, antitumoral, hypoglycemic, neuro-modulatory, worm-eliminating, and neuro-stabilising activities.

Mall *et al.* (2022)[38] discovered that *Benincasa hispida* plants displayed characteristic signs of witches'-

broom disease and phytoplasma-induced virescence, marking the first global report of a 16SrIX-J subgroup phytoplasma infection in this plant species.

Islam *et al.* (2021)[39] reviewed the pharmacological effects of *Benincasa hispida*, traditionally used in Chinese medicine for fever and urinary issues, and in Ayurveda for respiratory and neurological conditions. A review of in vivo and in vitro studies confirmed the molecular mechanisms underlying its ethnopharmacological uses, validating its potential in modern medicine and paving the way for further research.

Kumar and Singh (2021)[40] emphasized the sustainability of *Benincasa hispida* in India, requiring proactive conservation and monitoring due to emerging pressures from habitat destruction and changing land use. Ongoing research aims to improve *the* yield and disease resistance of Benincasa hispida and unlock its bioactive compounds for pharmaceutical use, underscoring its significance in India's agriculture and medicine sectors.

Sharma *et al.* (2020)[41] found that the fruit is packed with vitamins, minerals, and beneficial compounds like flavonoids and carotenoids, making it a valuable resource for health. Recent research has shown that it may help manage conditions such as diabetes, high blood pressure, and obesity due to its low-calorie count and antioxidant properties.

Firke *et al.* (2019)[42] explored the potential of Kushmanda fruit (*Benincasa hispida*) in combating malnutrition. The results showed that malnourished children who received Kushmanda Kalpa in addition to their regular diet experienced greater weight gain compared to those on a standard diet alone, indicating that Kushmanda Kalpa is a more effective solution for addressing malnutrition in children.

Shakya *et al* (2019)[43] *Benincasa hispida, a* revered herb in Ayurveda, contains fruits with significant rutin content, a bioactive compound renowned for its cognitive-enhancing, tonic, and diuretic properties. This led to the establishment and validation of an HPTLC method for rutin quantification in hydroalcoholic fruit pulp extracts.

Mohammad *et al.* (2019)[44] *Benincasa hispida* seed oil is a potential source of high-value vegetable oil that is rich in linoleic acid and antioxidants. The bioactive profile of the oil, including tocochromanols and phenolic compounds, varies depending on the cultivar and extraction solvent. Aqueous ethanol (80%) is the most efficient solvent for extracting antioxidant phenols, whereas methanolic extracts show strong radical-scavenging activity. The oil's antioxidant properties and nutrient profile make it a promising ingredient for the functional food and nutraceutical industries, warranting further exploration of its potential uses.

Vinaya *et al.* (2015)[45] Chronic dyspepsia affects a substantial number of individuals globally, with estimates ranging from 1.8% to 57% annually. *Benincasa hispida* fruit juice has been found to alleviate common dyspepsia symptoms, including heartburn, pain, nausea, bloating, bowel movements, postprandial fullness, and vomiting, offering a potential natural remedy for this prevalent health issue.

Dey *et al.* (2014)[46] noted that in Ayurveda, *Benincasa hispida* has been traditionally used to treat conditions such as epilepsy, respiratory issues, and gastrointestinal disorders.

Sharma, R. K., *et al.* (2014)[47] evaluated the antioxidant activity of *Benincasa hispida* seeds, a traditional Ayurvedic ingredient, using a hydrogen peroxide scavenging model. The acetone extract exhibited significant scavenging activity (80.1%), followed by the chloroform extract (79%), compared to ascorbic acid (94.5%). The seeds exhibit antioxidant activity due to the presence of phenolic compounds, flavonoids and alkaloids, suggesting potential therapeutic applications. This study supports the traditional use of *Benincasa* hispida seeds as a tonic, aphrodisiac, and brain tonic, highlighting their potential in managing oxidative stress-related diseases.

Sharma *et al.* (2014)[48] *Benincasa hispida*, commonly known as wax gourd, has been employed in traditional Indian medicine to treat various health issues, including gastrointestinal problems, mental health, pain relief, fever reduction, and antimicrobial activity. *Benincasa hispida* seeds contain a peptide called hispidalin, which has strong antibacterial and antifungal properties. " Hispitalin is a bioactive peptide with a unique structure that allows it to effectively target and interact with bacterial membranes. Its dual nature, with both water-repelling and water-attracting regions, enables efficient binding to negatively charged bacterial membranes. Research has demonstrated that *Benincasa hispida* exhibits potent antibacterial properties, effectively inhibiting the growth of *Salmonella enterica* and other bacterial strains, while also displaying strong antifungal activity against various fungal species, including *Aspergillus flavus, Curvularia geniculate, Fusarium solani, Penicillium chrysogenum, and Colletotrichum gloeosporioides.* Its effectiveness is comparable to that of common antibacterial and antifungal drugs, such as ciprofloxacin and griseofulvin. Notably, Hispidalin is the first peptide from *Benincasa hispida* to demonstrate antibacterial activity against human

pathogens. Its broad-spectrum activity makes it a promising candidate for plant protection and therapeutic applications, offering potential solutions for combating diseases in humans and plants.

Nadhiya *et al.* (2014)[49] *Benincasa hispida* fruit extracts have shown a remarkable ability to inhibit superoxide anion radicals, surpassing other antioxidants. This indicates that *Benincasa hispida* is a valuable source of naturally occurring antioxidants, offering a promising alternative for protecting cells against free radical damage. The study demonstrated that the ethanolic extract of *Benincasa hispida* contains high amounts of phenolic and flavonoid compounds, exhibiting enhanced antioxidant activity.

Das *et al.* (2012)[50] investigated the liver-protective potential of *Benincasa hispida* pulp extract in mitigating diclofenac sodium-induced hepatotoxicity in rats through modulation of oxidative stress and cellular defence.

Mishra *et al.* (2012)[51] Ash gourd, commonly referred to as winter melon, is a highly valued plant in India, prized for its rich nutritional profile and medicinal properties. Native to tropical Asia, it is commonly cultivated in states such as Kerala, Tamil Nadu, and Assam during the monsoon season. The culinary and medicinal applications of this plant converge in Ayurveda, where its anti-inflammatory, calming, and neuroprotective attributes are leveraged for holistic well-being.

Patel *et al.* (2011)[52] Urinary calculi, primarily composed of calcium phosphate and calcium oxalate, are the third most prevalent urological condition. The present study assessed the therapeutic potential of the ethanolic extract of *Benincasa hispida* seeds (BHE) in reducing kidney cell damage and hyperoxaluria, which are frequent consequences of urinary stone formation. These findings suggest that BHE may inhibit kidney stone formation by reducing urinary retention and stone-forming components, thereby decreasing the solubility product of crystallisation.

Das *et al.* (2011)[53]. This study evaluated the hepatoprotective effects of *Benincasa hispida* pulp aqueous extract in a nimesulide -induced liver damage model using adult male albino rats. The results demonstrated that BH extract significantly mitigated nimesulide-induced hepatotoxicity through antioxidant modulation, serum enzyme activity alteration, and reduction of oxidative stress and lipid peroxidation.

Mandal *et al.* (2011)[54] found that *Benincasa hispida* fruit extract effectively treats hypochlorhydria (low stomach acid) in Male Wistar rats. A combination of water, hydro-methanol, and ethyl acetate was used to extract the bioactive compounds from the fruit. The aqueous extract demonstrated efficacy in correcting hypochlorhydria in rats, as evidenced by increased vitamin C, chloride, and pepsin levels and reduced pH and acidity. The study suggests that *Benincasa hispida* fruit has antioxidant and anti-hypochlorhydric properties, likely due to its phytochemicals, such as alkaloids and flavonoids.

Gill *et al.* (2010)[55] investigated the methanolic extract of *Benincasa hispida* seeds (MEBH) for its antioxidant, anti-inflammatory, and analgesic properties. The extract demonstrated significant free radical scavenging activity, with the highest radical scavenging activity of 79.8% at 300 µg mL-1 concentration. MEBH also exhibited anti-inflammatory effects, reducing paw oedema by 59.7% at a 300 mg kg-1 dose, and analgesic activity, decreasing pain in mice. These findings suggest MEBH's potential as a natural antioxidant for treating inflammation and pain

Sew *et al.* (2010)[56] *Benincasa hispida* (Kundur) seeds are a valuable source of nutrition, containing high amounts of dietary fibre (58.43%) and crude fat (20.70%). The seed oil is rich in linoleic acid (67.37%), an essential fatty acid, and has a favourable fatty acid profile comparable to other wholesome seed oils. The nutritional composition and fatty acid profile suggest potential health benefits, including lowering cholesterol levels and reducing the risk of coronary heart disease. The high polyunsaturated fatty acid content of the seed oil indicates its potential industrial applications, such as in the food and pharmaceutical industries. Further research is needed to explore the commercial and functional food applications of Kundur seeds and seed oil.

Verma et al. (2007)[57]**,** Ash gourd (*Benincasa hispida*) is a nutrient-rich vegetable with medicinal properties that is widely cultivated in Asia. Research has focused on assessing genetic diversity among inbred lines using molecular markers such as RAPD and ISSR. A study evaluating 10 inbred lines and 45 F1 hybrids revealed significant heterosis for yield and growth-related traits. Genetic distance measurements indicated wide genetic diversity, with ISSR markers showing higher polymorphism (80%) than RAPD markers (46%). However, genetic distance measures did not effectively predict hybrid performance, highlighting the need for further research to develop a standard reference for genetic analysis and hybrid selection.

Kumar *et al.* (2004)[58]**,** *Benincasa hispida* fruit extract has shown potential anorectic effects in mice, significantly reducing food intake without affecting gastric emptying, suggesting a central mechanism of action. The antidepressant activity of the extract,

possibly related to serotonin reuptake inhibition, may contribute to its anorectic effects. Further studies are needed to elucidate the underlying mechanisms and explore its therapeutic potential as an anti-obesity agent.

ANTIMICROBIAL ACTIVITY OF NANOPARTICALES OF BENINCASA HISPIDA

S.NO.	GREEN SYNTHESIS OF NANOPARTICLES	APPLICATIONS
1.	Green Synthesis of Silver Nanoparticles using *Benincasa hispida* Peel: Phytochemical and Nanotechnological Insights.	*Benincasa hispida* Peel extract was used to make herbal soap, which was discovered to be useful in treating athlete's foot infection. The antifungal properties of silver nanoparticles were demonstrated against *Trichophyton sp*., the pathogen responsible for athlete's foot infections. H_2O_2 can be detected using silver nanoparticles (Neha, 2019),[59].
2.	Synthesis of Selenium Nanoparticles Using *Benincasa hispida* Peel Extract.	Microbial Inhibition and Tumour Suppression Properties (Khan *et al.,* 2023)[60]
3.	*Benincasa hispida* Peel-Enabled Synthesis of Silver Nanoparticles.	Microbial Inhibition and Tumour Suppression Properties: AgNPs have demonstrated pronounced antimicrobial activity against a broad spectrum of microorganisms, including G+ and G- bacteria, protozoa, fungi, and viruses, prompting the investigation of their antibacterial effects against *Micrococcus luteus, Klebsiella pneumoniae, Staphylococcus aureus, and Escherichia coli* (Ahmad *et al.,* 2022)[26].
4.	*Benincasa hispida* Seed-Enabled Ecofriendly Synthesis of Gold Nanoparticles: Investigation of Nonlinear Optical Properties.	Gold nanoparticles exhibit remarkable properties, positioning them as vital components in emerging technologies and medical applications, including electronics, catalysis, and nonlinear optics (Aromal *et al.,* 2012)[61].
5.	Sustainable Synthesis of Gold Nanoparticles Using *Benincasa hispida* Peel Extract.	Biosynthesized gold nanoparticles (GNPs) using *Benincasa hispida* peel extract demonstrated remarkable antibacterial efficacy against diverse bacterial strains and exhibited targeted anticancer activity against HeLa cells through reactive oxygen species (ROS)-mediated cytotoxicity (Saqr *et al.,* 2021)[62].
6.	*Benincasa hispida* pulp was used to synthesize calcium carbonate nanoparticles ($CaCO_3$ NPs).	which have strong anti-inflammatory, antioxidant, and photocatalytic properties (Sani *et al.,* 2024)[63].
7.	Silver nanoparticles were synthesized via a biogenic route using *Benincasa hispida* fruit extract.	This enables the rapid colourimetric detection of H_2O_2 (Roy *et al.,* 2016)[64].
8.	Green synthesis of Gold NPs.	The anticancer properties were evaluated using an oral cancer cell line (Subbiah *et al.,* 2024)[65].

9.	*Benincasa Hispida* peel extract-mediated green synthesis yielded Au/AgCl nanoparticles with potential applications.	The photocatalytic efficacy of Au/AgCl NPs was evaluated under solar irradiation, demonstrating remarkable degradation (98%) of a toxic dye (Devi *et al.,* 2016)[66].

FUTURE PROSPECTS

The Kundur fruit has untapped potential, with its skins, seeds, and core awaiting nutritional study, while its thickening properties make it a valuable resource for the food industry." The present study will investigate the biochemical composition of *Benincasa hispida*, and its chemical makeup could be a promising source for the development of pharmaceutical products. The nanoparticles of *Benincasa hispida* hold significant potential in future plant disease management. Their enhanced bioactivity can improve the delivery and effectiveness of phytochemicals against pathogens. This innovative approach offers a sustainable and eco-friendly alternative to chemical pesticides. This paves the way for advanced solutions in agricultural health and productivity.

CONCLUSIONS

Nanotechnology's role in precision agriculture involves harnessing satellite systems, nano-biosensors, and nano-herbicides to optimize crop inputs, reduce waste, and enhance yields. Nanoparticles can make farming more sustainable by delivering pesticides in a more targeted and efficient way, reducing waste and environmental harm, and helping plants absorb nutrients more effectively, making fertilizers more efficient and reducing excess use.

"*Benincasa hispida* is a versatile medicinal herb with a range of health benefits, including anti-ageing, antioxidant, and antimicrobial properties, making it valuable for blood purification and rejuvenation." Despite some research on the surface wax crystals of *Benincasa hispida* (Ash gourd), their chemical composition remains unclear. However, the multifunctional nature of ash gourd makes it a promising source for developing pharmaceutical products. Understanding the genetic factors that control wax production in plants under stress can help enhance crop resilience to environmental challenges, ultimately improving their potential. *Benincasa hispida* fruit extracts have demonstrated remarkable antioxidant potential, making them a promising natural source for combating oxidative stress and cell damage. The *Bh* fruit, used in Ayurvedic medicine to treat schizophrenia and other mental illnesses, exhibits antioxidant properties and contains vital vitamins, minerals, and volatile oils, making it a valuable remedy for combating oxidative stress. Bh pulp aqueous extract shows promise as a hepatoprotective agent against nimesulide-induced liver damage. showed encouraging results as a liver-protecting agent, potentially offering a natural countermeasure against diclofenac-induced hepatotoxicity. The ethanolic extract of *Citrullus colocynthis* seeds demonstrated anti-urolithiatic properties by reducing urinary stone-forming components and kidney retention. *Benincasa hispida* nanoparticles have vast potential in agriculture, medicine, and environmental fields; however, to fully harness their benefits, challenges such as large-scale production, safety, and performance optimization need to be addressed. Further research and development are crucial to unlock their diverse applications and ensure sustainable use. Unlocking the power of *Benincasa hispida-derived* nanoparticles can revolutionize drug delivery, cancer treatment, and environmental sustainability, paving the way for a healthier future. A new, eco-friendly method uses *Benincasa hispida* peel extract to produce gold nanoparticles (GNPs) in a single step. These GNPs possess antibacterial and anticancer properties. When exposed to sunlight, the GNPs efficiently break down toxic dyes. Additionally, calcium carbonate nanoparticles (CaCO3 NPs) synthesized using this method exhibit strong antioxidant, anti-inflammatory, and photocatalytic properties, effectively combating harmful azo-dyes such as trypan blue and Congo red. The application of ash gourd juice in Ayurvedic medicine yields substantial health benefits, including: consumed first thing in the morning, this potent detoxifier effectively absorbs and eliminates toxins, bacteria, and contaminants accumulated throughout the day. By incorporating ash gourd juice into their daily routine, individuals can efficiently flush out waste and promote overall well-being. Current studies are optimizing the cultivation of *Benincasa hispida* and exploring its medicinal properties, highlighting its value in India's agricultural and healthcare industries.

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