Current Pharmaceutical Research (CPR)
Vol 2, Issue 2, April-June 2026
Journal Homepage: https://cpr.org.in/

Pharmacological and Nutritional Insights of *Lagenaria Siceraria* Seeds: A Comprehensive Review

[1]Quazia Ifaq Wani*, [1]Hema Rani, [2]Puja Gulati1, Rahil Mir

[1] Department of Pharmacology, School of Pharmacy, Desh Bhagat University, Mandi Gobindgarh, Punjab-147301, India.
[2] Department of Pharmacy, Maharaja Ranjit Singh Punjab Technical University, Bathinda, Punjab, India.

Keywords

Lagenaria siceraria, bottle gourd seeds, phytochemistry, pharmacological activities, nutraceutical potential, bioactive compounds, traditional medicine.

Abstract

Lagenaria Siceraria (bottle gourd) is a medicinal and nutritionally valuable plant widely used in traditional systems of medicine. Among its various parts, the seeds have gained increasing scientific attention due to their rich nutritional profile and diverse bioactive constituents. L. siceraria seeds are abundant in proteins, essential fatty acids, sterols, flavonoids, phenolic compounds, and other phytochemicals that contribute to their therapeutic potential. Experimental studies have reported multiple pharmacological activities, including antioxidant, anti-inflammatory, hepatoprotective, hypolipidemic, antimicrobial, and antidiabetic effects. Nutritionally, the seeds represent a valuable source of edible oil, amino acids, and essential minerals, supporting their potential role in promoting metabolic and cardiovascular health. Despite these promising findings, most evidence is derived from preclinical studies, with limited mechanistic and clinical validation. This review comprehensively summarizes the nutritional composition, phytochemical constituents, pharmacological activities, safety profile, and nutraceutical potential of *Lagenaria Siceraria* seeds. The available evidence highlights their promise as functional food ingredients and candidates for nutraceutical development. However, further mechanistic studies, standardized formulations, and well-designed clinical trials are essential to establish their efficacy, safety, and translational applicability in modern healthcare.

***Corresponding Author:**
Mr. Quazia Ifaq Wani (quaziaifaq@gmail.com)
ORCID: 0009-0009-5475-4805

Article Info
Received: 08 April 2026, Received in revised form: 26 June 2026, Accepted: 28 June 2026, Available online: 30 July 2026; Volume: 2; Issue: 2; Pages: 218–233.

ISSN: 3049-2955/
DOI: https://doi.org/10.63785/2026.2.2.218233

1. Introduction

Lagenaria Siceraria (Molina), commonly known as bottle gourd, is an important medicinal and nutritional plant belonging to the family Cucurbitaceae. It is widely cultivated across Asia, Africa, and tropical regions for its edible fruit and traditional therapeutic applications. In Ayurveda, Unani, and other traditional systems of medicine, different parts of the plant, including fruits, leaves, pulp, and seeds, have long been used for managing conditions such as diabetes, jaundice, fever, hypertension, and liver disorders [1].

In recent years, the growing consumer preference for plant-based functional foods and nutraceuticals has accelerated interest in medicinal plants with nutritional and therapeutic value. Among various plant-derived materials, seeds have emerged as valuable reservoirs of bioactive compounds due to their dense nutritional composition and diverse pharmacological properties. In this context, *L. siceraria* seeds have gained considerable scientific attention because of their rich content of proteins, essential fatty acids, flavonoids, phenolic compounds, sterols, and other phytoconstituents [2].

Nutritionally, the seeds represent a promising source of edible oil, proteins, amino acids, and essential minerals. Their oil is particularly rich in unsaturated fatty acids, such as linoleic acid and oleic acid, which are associated with improved cardiovascular health, lipid regulation, and anti-inflammatory effects. Additionally, the phytochemicals present in the seeds contribute significantly to their antioxidant, anti-inflammatory, antimicrobial, hypolipidemic, antidiabetic, and hepatoprotective activities. Although several studies have reported encouraging pharmacological effects of *L. siceraria* seed extracts and seed oil, most available evidence has been derived from *in vitro* experiments and animal models. Clinical studies remain limited, and the mechanistic understanding of many reported biological activities is still incomplete. Furthermore, variability in extraction methods, dosage regimens, and phytochemical standardization complicates the interpretation and comparison of existing findings, posing challenges for translating preclinical evidence into clinical applications [3].

While previous reviews have broadly discussed the medicinal properties of *L. siceraria*, relatively little attention has been devoted specifically to its seeds as a distinct nutraceutical and pharmacological resource. Information regarding their nutritional composition, phytochemical profile, pharmacological mechanisms, safety considerations, and translational potential remains fragmented throughout the literature. Therefore, this review comprehensively summarizes the current evidence on the nutritional composition, phytochemical constituents, pharmacological activities, safety profile, and nutraceutical potential of *Lagenaria siceraria* seeds. It also highlights existing research gaps, mechanistic limitations, and future opportunities for the development of seed-based functional foods, nutraceuticals, and therapeutic products [4].

2. Botanical Overview

2.1 Classification

Lagenaria siceraria (Molina) Standl., commonly known as bottle gourd, belongs to the family Cucurbitaceae, which comprises numerous edible vegetables and medicinally important plant species. It is an annual climbing herb that grows with the aid of slender tendrils, enabling it to attach to surrounding supports. The plant is characterized by a vigorous vine, broad heart-shaped leaves, attractive white flowers, and fruits that exhibit considerable variation in size and shape. Its seeds are flat, oval, and enclosed within a hard seed coat, while seed germination proceeds through distinct stages involving radicle emergence, shoot development, and seedling establishment. These morphological and developmental characteristics contribute to the successful growth, propagation, and identification of *L. siceraria* and are illustrated in Figure 1 [5].

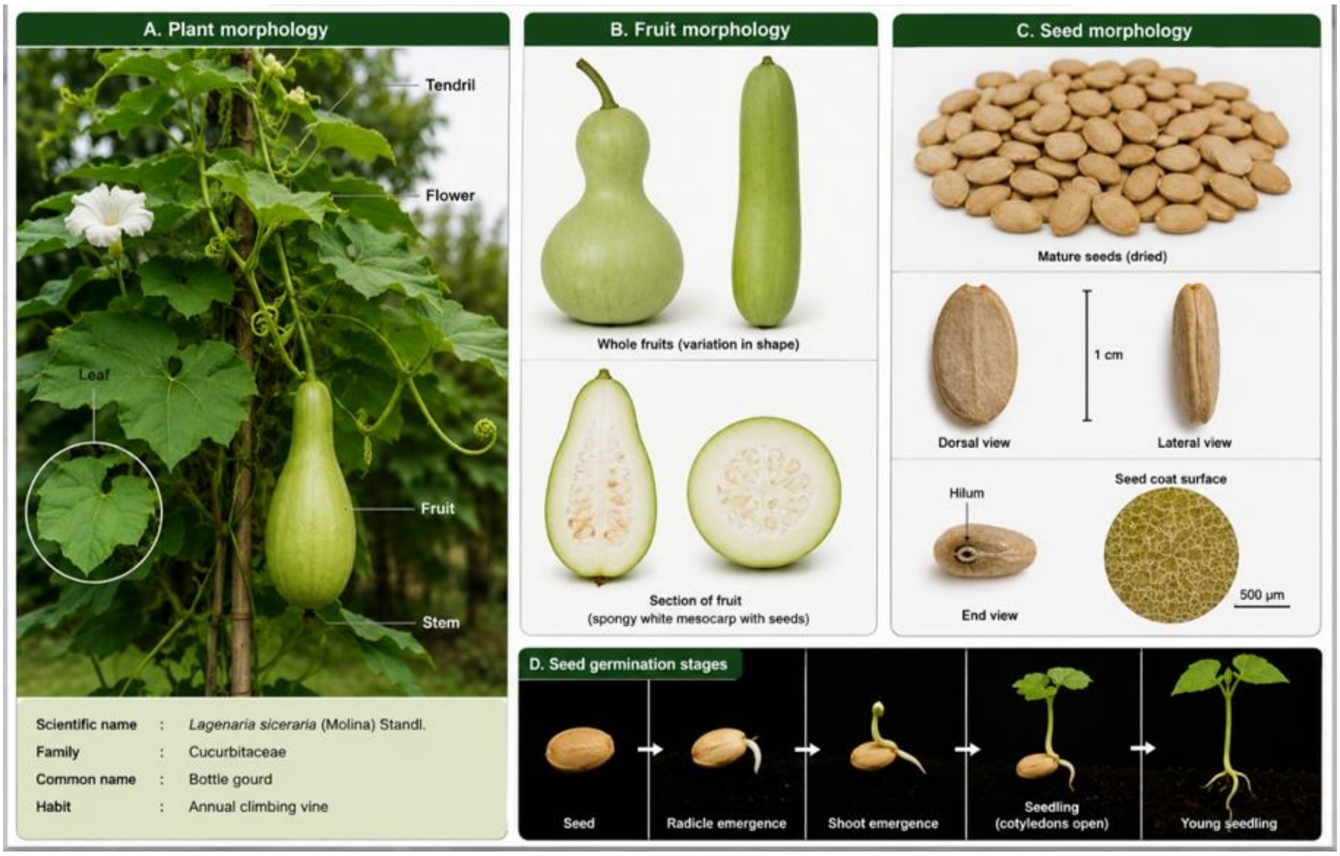

Figure 1: Morphological characteristics of *Lagenaria siceraria* plant, fruit, and seeds.

Lagenaria siceraria (Molina) Standl., commonly known as bottle gourd, belongs to the family

Cucurbitaceae and is an important medicinal and nutritional plant. Taxonomically, it is classified under the kingdom Plantae, division Magnoliophyta, class Magnoliopsida, order Cucurbitales, family Cucurbitaceae, genus *Lagenaria*, and species *Lagenaria siceraria* (Molina) Standl. The plant is widely cultivated in tropical and subtropical regions and is recognized for its rich nutritional profile, diverse phytochemical constituents, and extensive therapeutic applications in traditional and modern medicine. The Cucurbitaceae family also includes economically and medicinally important crops such as cucumber (*Cucumis sativus*), pumpkin (*Cucurbita* spp.), and bitter gourd (*Momordica charantia*), highlighting the significance of *L. siceraria* as a valuable food and medicinal plant. Morphologically, *L. siceraria* is characterized by a vigorous climbing vine with tendrils, broad leaves, white flowers, and fruits of varying shapes and sizes. Its seeds are flat and oval with a distinct seed coat, and germination proceeds through radicle emergence, shoot development, and seedling establishment, illustrating the characteristic reproductive and developmental stages of the species (Figure 1) [6].

2.2 Morphology of the Plant

Lagenaria siceraria is a fast-growing annual climbing vine with long, slender stems that can extend several meters in length. The plant possesses broad, heart-shaped leaves with a rough surface and bears large white flowers that typically bloom during the evening and night, facilitating pollination by insects such as bees and beetles. The fruits exhibit considerable variation in shape and size, ranging from spherical to elongated bottle-shaped forms depending on the cultivar. Although the immature fruit is widely consumed as a nutritious vegetable, the mature seeds enclosed within the fruit are of particular scientific interest because of their high nutritional value and rich content of bioactive phytochemicals, which contribute to their diverse pharmacological and nutraceutical properties [7].

2.3 Morphology of Seeds

The seeds of *Lagenaria siceraria* are numerous, flat, and oval to oblong in shape, typically measuring 1–2 cm in length. They are enclosed within a hard, whitish to light-brown seed coat that protects the nutrient-rich kernel. The kernel contains substantial amounts of proteins, lipids, and a variety of bioactive phytochemicals. Anatomically, the cotyledons are densely packed with oil bodies and storage proteins, serving as an energy reserve during seed germination while also providing a valuable source of essential fatty acids for human consumption. On average, the seeds contain approximately 30–35% oil and 20–25% protein, along with important phytoconstituents such as phytosterols, flavonoids, and phenolic acids. These nutritional and phytochemical characteristics make *L. siceraria* seeds a promising raw material for the development of nutraceuticals and functional food products. The morphological characteristics of the plant, fruit, and seeds are illustrated in Figure 1 to facilitate botanical identification and seed characterization [8].

2.4 Distribution and Cultivation

Lagenaria siceraria is believed to have originated in Africa and subsequently spread to Asia, Europe, and the Americas through migration and trade. At present, it is extensively cultivated in tropical and subtropical regions, particularly in countries such as India, China, Egypt, and several African nations, where it serves as both an important vegetable crop and a medicinal plant. The species thrives under warm climatic conditions, with optimum temperatures ranging from 25–35°C, and grows best in well-drained, fertile soils receiving adequate irrigation and sunlight. It is commonly propagated through direct seed sowing, with fruit maturity generally occurring within 60–120 days depending on the cultivar and environmental conditions. Although the fruits are widely consumed, the seeds remain relatively underutilized despite their considerable nutritional and therapeutic potential. Agronomic fon, and harvesting stage, significantly influence seed yield, oil content, and phytochemical composition. Optimizing these cultivation parameters is essential for improving seed quality and maximizing their utilization in nutraceutical and pharmaceutical applications [9].

3. Nutritional Profile

The seeds of *Lagenaria siceraria* possess an excellent nutritional composition, making them valuable not only as a food source but also as promising ingredients for nutraceutical and functional food formulations. They are rich in proteins, healthy lipids, carbohydrates, dietary fiber, vitamins, minerals, and a wide range of bioactive phytochemicals that collectively contribute to their health-promoting properties. Owing to this balanced nutritional profile, *L. siceraria* seeds have attracted considerable scientific interest and, in several aspects, compare favorably with other edible oilseeds such as pumpkin and sunflower seeds [10].

3.1 Macronutrients

Proteins constitute approximately 20–25% of the total seed weight of *L. siceraria*, making the seeds a valuable plant-based protein source. These proteins contain essential amino acids, including lysine, leucine, and valine, which are important for muscle growth, tissue repair, and numerous metabolic processes. The major protein fractions, including albumins and globulins, have also been reported to exhibit antioxidant and antimicrobial activities, further enhancing the nutritional and therapeutic value of the seeds. Carbohydrates are present in relatively lower amounts and primarily serve as an energy source, while the dietary fiber, particularly the insoluble fraction, supports gastrointestinal health, promotes regular bowel function, and contributes to improved glycemic regulation [11].

3.2 Lipids and Seed Oil

The seeds contain approximately 30–35% edible oil, which is predominantly composed of nutritionally beneficial unsaturated fatty acids. Linoleic acid (omega-6) and oleic acid (omega-9) are the principal fatty acids and are recognized for their cardioprotective, cholesterol-lowering, and anti-inflammatory properties. Smaller quantities of saturated fatty acids, including palmitic acid and stearic acid, contribute to a favorable unsaturated-to-saturated fatty acid ratio. The oil is further enriched with natural antioxidants such as tocopherols and phytosterols, which improve oxidative stability and enhance its nutraceutical potential. Mechanistically, these unsaturated fatty acids may promote cardiovascular health by reducing low-density lipoprotein (LDL) oxidation, enhancing high-density lipoprotein (HDL)-mediated cholesterol transport, modulating inflammatory cytokines, improving endothelial function, and regulating lipid metabolism through activation of peroxisome proliferator-activated receptor (PPAR)-mediated signaling pathways. Owing to these beneficial characteristics, *L. siceraria* seed oil has been considered a promising edible oil comparable to commonly consumed vegetable oils such as sunflower and soybean oil. The major fatty acid composition and nutritional significance of *L. siceraria* seed oil are illustrated in Figure 2 [12]

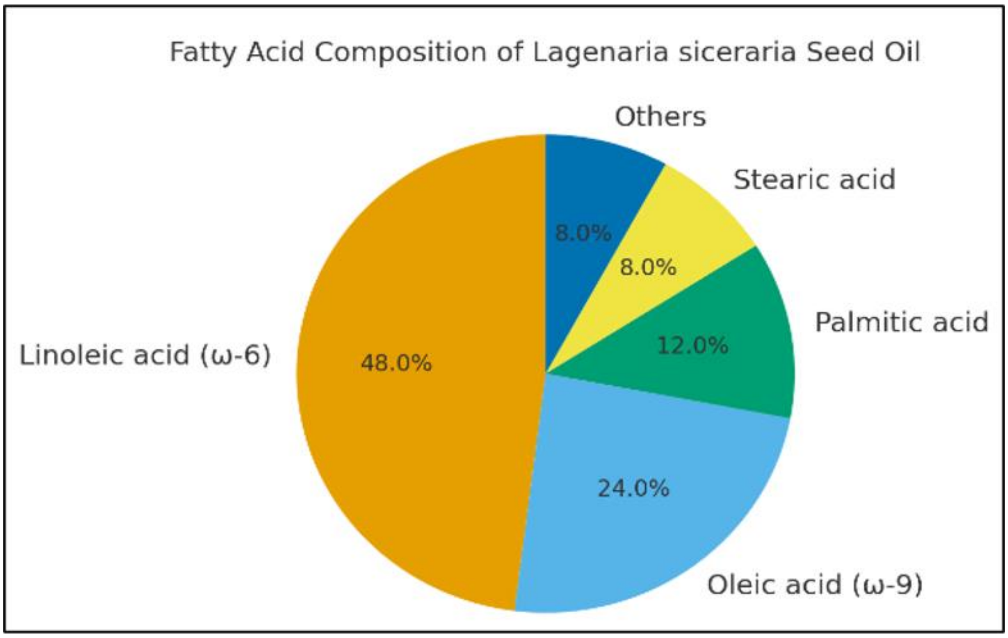

Figure 2: Major fatty acids identified in *Lagenaria siceraria* seed oil and their nutritional significance.

3.3 Micronutrients

In addition to macronutrients, *Lagenaria siceraria* seeds are a rich source of essential vitamins and minerals that contribute to their nutritional and therapeutic value. The seeds contain appreciable amounts of magnesium, potassium, calcium, iron, and zinc, all of which are indispensable for maintaining normal physiological functions and metabolic processes [13]. Magnesium plays a crucial role in energy metabolism, neuromuscular function, and enzyme activation, whereas zinc is essential for immune regulation, wound healing, and numerous enzymatic reactions. The seeds also provide vitamin E (α-tocopherol), a potent natural antioxidant that protects cellular membranes and lipids against oxidative damage, along with small quantities of B-complex vitamins involved in energy production and cellular metabolism. The combined presence of these micronutrients further enhances the health-promoting potential of *L. siceraria* seeds and supports their application as a functional food ingredient.[14]

3.4 Comparative Nutritional Value

The nutritional composition of *Lagenaria siceraria* seeds compares favorably with that of other cucurbit seeds, including pumpkin (*Cucurbita pepo*) and watermelon (*Citrullus lanatus*). They possess comparable levels of proteins and lipids while containing relatively higher concentrations of phytosterols, phenolic compounds, and other bioactive constituents. This distinctive nutritional profile enhances their nutraceutical value by supporting cardiovascular health, improving lipid metabolism, reducing oxidative stress, and promoting overall metabolic well-being. Owing to these characteristics, *L. siceraria* seeds represent a promising alternative source of nutrients and bioactive compounds for the development of functional foods and nutraceutical products. Table 1 summarizes the nutritional composition of *L. siceraria* seeds, highlighting their major macronutrients, fatty acids, vitamins, and minerals [15].

Table 1: Nutritional composition of *Lagenaria siceraria* seeds.

S. No.	Nutrient/Component	Amount (Approx.)	Unit	References
	Protein	20-25	g/100 g	[16]
1.	Lipids (Oil Content)	30-35	g/100 g	[17]
2.	Carbohydrates	10-12	g/100 g	[18]
3.	Crude Fiber	5-7	g/100 g	[19]
4.	Linoleic Acid	45-50	% total fatty acids	[20]
5.	Oleic Acid	20-25	% total fatty acids	[21]
6.	Palmitic Acid	10-12	% total fatty acids	[22]
7.	Stearic Acid	7-8	% total fatty acids	[23]
8.	Magnesium (Mg)	Present in significant amounts	mg/100 g	[24]
9.	Calcium (Ca)	Present in significant amounts	mg/100 g	[25]
10.	Potassium (K)	Present in significant amounts	mg/100 g	[26]
11.	Iron (Fe)	Present in significant amounts	mg/100 g	[27]
12.	Zinc (Zn)	Present in significant amounts	mg/100 g	[28]
13.	Vitamin E (α-tocopherol)	Present	mg/100 g	[29]
14	B-complex Vitamins	Trace amounts	mg/100 g	[30]

4. Phytochemical Constituents

Lagenaria siceraria seeds are a rich source of bioactive phytochemicals that contribute significantly to their nutritional and pharmacological properties. Phytochemical analyses using advanced analytical techniques, including gas chromatography–mass spectrometry (GC–MS) and high-performance liquid chromatography (HPLC), have identified a diverse range of secondary metabolites with important biological activities. GC–MS studies have shown that linoleic acid is the predominant fatty acid, accounting for approximately 45–50% of the total fatty acid content, followed by oleic acid (20–25%), emphasizing the nutritional and cardioprotective value of the seed oil. HPLC profiling has further confirmed the presence of key phytochemicals such as quercetin, gallic acid, and β-sitosterol, which are recognized for their antioxidant, anti-inflammatory, and hypolipidemic effects [31].

4.1 Flavonoids and Phenolic Compounds

Flavonoids and phenolic acids are among the principal bioactive constituents of *L. siceraria* seeds. Important compounds, including quercetin, kaempferol, gallic acid, and ferulic acid, exhibit potent antioxidant activity by scavenging reactive oxygen species and reducing oxidative stress. These phytochemicals play a significant role in protecting against chronic diseases such as diabetes, cardiovascular disorders, and cancer. In addition to their antioxidant properties, phenolic compounds possess antimicrobial and anti-inflammatory activities that support the traditional medicinal use of *L. siceraria* in managing infections and inflammatory disorders [32].

4.2 Sterols and Triterpenoids

The seeds contain several phytosterols, including β-sitosterol, campesterol, and stigmasterol, which structurally resemble cholesterol and help reduce its intestinal absorption, thereby contributing to improved lipid profiles and cardiovascular health. These sterols also exhibit immunomodulatory and anti-inflammatory activities. Furthermore, small amounts of triterpenoids and cucurbitacins have been identified in the seeds. Although present in relatively low concentrations, these compounds possess cytotoxic, hepatoprotective, and potential anticancer properties, highlighting their therapeutic importance [33].

4.3 Saponins and Alkaloids

Saponins are naturally occurring glycosides that contribute to the characteristic bitterness of *L. siceraria* seeds while also providing several health benefits. They exhibit cholesterol-lowering, anti-inflammatory, and antimicrobial activities, making them valuable bioactive constituents. Alkaloids are present in comparatively smaller quantities but may contribute to the antimicrobial properties of the seeds and support their traditional use in the treatment of infectious diseases [34].

4.4 Fatty Acids and Tocopherols

The seed oil is characterized by a high proportion of nutritionally beneficial unsaturated fatty acids, particularly linoleic acid (omega-6) and oleic acid (omega-9). These fatty acids are essential for maintaining cell membrane integrity, regulating lipid metabolism, supporting cardiovascular health, and modulating inflammatory responses. The oil also contains considerable amounts of tocopherols, especially α-tocopherol (vitamin E), which function as natural antioxidants by protecting the oil from oxidative deterioration and reducing oxidative damage in biological tissues [35].

4.5 Other Secondary Metabolites

In addition to the major phytochemical classes, *L. siceraria* seeds contain several other secondary metabolites, including tannins, glycosides, and trace amounts of terpenes. Although these compounds occur in relatively low concentrations, they may act synergistically with other phytochemicals to enhance the overall antioxidant, anti-inflammatory, antimicrobial, and therapeutic potential of the seeds. Table 2 summarizes the major phytochemical constituents of *L. siceraria* seeds and their associated biological relevance [36].

Table 2: Phytochemical constituents of *Lagenaria siceraria* seeds

S. No.	Class of compound	Major examples	Biological relevance	References
1.	Flavonoids	Quercetin, Kaempferol	Antioxidant, anti-inflammatory	[37]
2.	Phenolic acids	Gallic acid, Ferulic acid	Free-radical scavenging, antimicrobial	[38]
3.	Phytosterols	β-sitosterol, Campesterol, Stigmasterol	Cholesterol-lowering, immunomodulatory	[39]
4.	Triterpenoids	Cucurbitacins	Hepatoprotective, anticancer	[40]
5.	Saponins	Glycosidic compounds	Hypocholesterolemic, antimicrobial	[41]
6.	Alkaloids	Minor alkaloids	Antimicrobial, bitter principles	[42]
7.	Tocopherols	α-Tocopherol	Antioxidant, oil stability	[43]

5. Pharmacological Activities

The seeds of *Lagenaria siceraria* exhibit a wide spectrum of pharmacological properties, which can be attributed to their rich phytochemical profile. Both crude extracts and isolated constituents have been evaluated in various *in vitro*, *in vivo*, and limited clinical studies. The following subsections summarize the major pharmacological effects of *L. siceraria* seeds, supported by experimental evidence. Figure 3 illustrates the major pharmacological activities of *L. siceraria* seeds and their therapeutic relevance [44].

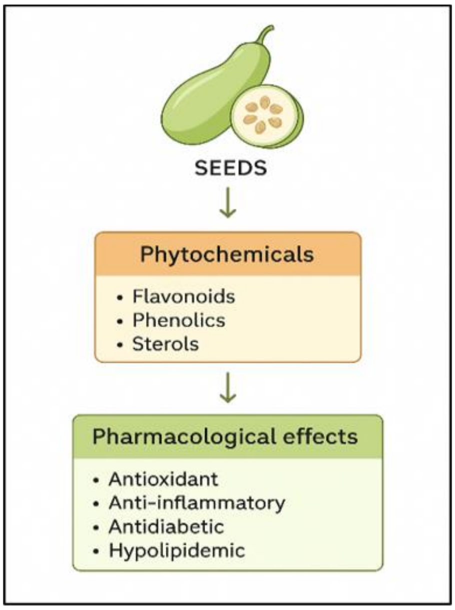

Figure 3: Overview of major pharmacological activities of *Lagenaria siceraria* seeds.[32]

5.1 Antioxidant Activity

Oxidative stress plays a central role in the development of numerous chronic diseases, including diabetes, cardiovascular disorders, cancer, and neurodegenerative conditions. *Lagenaria siceraria* seed extracts exhibit potent antioxidant activity owing to their high content of flavonoids, phenolic compounds, tocopherols, and unsaturated fatty acids. *In vitro* studies have demonstrated significant free-radical scavenging activity against DPPH and ABTS radicals, with antioxidant efficacy comparable to standard antioxidants. Experimental animal studies have further shown that administration of seed extracts reduces lipid peroxidation while enhancing the activity of endogenous antioxidant enzymes, including superoxide dismutase, catalase, and glutathione peroxidase. These findings suggest that regular consumption of *L. siceraria* seeds or their oil may help protect cells against oxidative damage and reduce the risk of oxidative stress-related diseases [45].

5.2 Anti-inflammatory Activity

The anti-inflammatory activity of *L. siceraria* seeds is primarily attributed to flavonoids, phytosterols, phenolic compounds, and saponins. Experimental studies have demonstrated that seed extracts suppress the production of pro-inflammatory mediators, including tumor necrosis factor-α (TNF-α), interleukin-6 (IL-6), and prostaglandins. Mechanistic investigations indicate that these effects are mediated through inhibition of nuclear factor-kappa B (NF-κB) signaling and cyclooxygenase (COX)-dependent inflammatory pathways, resulting in reduced cytokine production and inflammatory responses[36]. In carrageenan-induced paw edema models, administration of seed extracts significantly reduced tissue swelling, confirming their efficacy against acute inflammation [46].

5.3 Antimicrobial Activity

Lagenaria siceraria seeds possess broad-spectrum antimicrobial activity that is largely associated with their phenolic compounds, flavonoids, alkaloids, and saponins. Seed extracts have demonstrated inhibitory effects against several pathogenic microorganisms, including *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa*, along with moderate antifungal activity against *Candida albicans*. These antimicrobial effects are believed to result from disruption of microbial cell membranes, inhibition of essential metabolic processes, and interference with microbial enzyme systems. Although their activity is generally lower than that of conventional antibiotics, *L. siceraria* seed extracts show promise as natural antimicrobial agents and potential food preservatives [47].

5.4 Hypolipidemic Activity

The seed oil of *L. siceraria* has demonstrated significant lipid-lowering activity in experimental studies. Supplementation with the oil has been shown to reduce serum total cholesterol, triglycerides, and low-density lipoprotein (LDL) cholesterol while increasing high-density lipoprotein (HDL) cholesterol. These beneficial effects are mainly attributed to the presence of unsaturated fatty acids and phytosterols, particularly β-sitosterol, which improve lipid metabolism and reduce intestinal cholesterol absorption. The favorable lipid profile produced by the seed oil highlights its potential as a natural dietary intervention for dyslipidemia and cardiovascular disease prevention [48].

5.5 Antidiabetic Activity

Several experimental studies have demonstrated the antidiabetic potential of *L. siceraria* seeds. Ethanolic seed extracts significantly reduce fasting blood glucose levels in streptozotocin-induced diabetic animal models by enhancing insulin secretion, improving peripheral glucose utilization, and restoring glycogen storage in hepatic and muscle tissues. These effects are mainly attributed to flavonoids, phenolic compounds, and saponins, which regulate glucose metabolism and reduce oxidative stress associated with diabetes. Despite these promising findings, most evidence remains preclinical, and further clinical studies are necessary to establish optimal dosage, long-term safety, and efficacy. Care should also be exercised when combining seed extracts with conventional antidiabetic medications because additive glucose-lowering effects may increase the risk of hypoglycemia [49].

5.6 Hepatoprotective Activity

The hepatoprotective effects of *L. siceraria* seeds have been demonstrated in chemically induced liver injury models. Treatment with seed extracts significantly decreases serum liver enzyme levels, including alanine aminotransferase (ALT) and aspartate aminotransferase (AST), while restoring antioxidant defense systems within hepatic tissues. Histopathological examinations have revealed reduced hepatocellular necrosis, diminished inflammatory cell infiltration, and improved liver architecture following treatment. These protective effects are attributed to flavonoids, phytosterols, and triterpenoids, which stabilize cellular membranes, inhibit lipid peroxidation, enhance endogenous antioxidant defenses, and promote hepatic detoxification [50].

5.7 Other Reported Activities

In addition to the major pharmacological effects, *L. siceraria* seeds have demonstrated several other biological activities. Experimental studies have reported mild diuretic and analgesic effects, supporting their traditional use in the management of urinary disorders and pain. Preliminary *in vitro* investigations have also indicated potential anticancer activity through induction of apoptosis and inhibition of cancer cell proliferation. Although these findings are encouraging, further mechanistic investigations and well-designed clinical studies are required to validate these therapeutic applications and determine their clinical relevance [51].

Table 3 summarizes the experimentally reported pharmacological activities of *Lagenaria siceraria* seeds. Available evidence demonstrates significant antioxidant, anti-inflammatory, antimicrobial, hypolipidemic, antidiabetic, hepatoprotective, analgesic, diuretic, and preliminary anticancer activities in both *in vitro* and *in vivo* models. These pharmacological effects are primarily attributed to flavonoids, phenolic compounds, phytosterols, tocopherols, and unsaturated fatty acids, which collectively modulate oxidative stress, inflammatory signaling, lipid metabolism, glucose homeostasis, membrane integrity, and apoptosis pathways [52].

Table 3: Pharmacological activities of *Lagenaria siceraria* seeds with study models and evidence type.

S. No.	Activity	Extract/Compound	Study Model	Evidence Type	Proposed Mechanism	References
1.	Antioxidant	Methanol/Ethanol extract	DPPH, ABTS assay; animal models	*In vitro* & *In vivo*	Free radical scavenging, ↑ antioxidant enzymes	[53]
2.	Anti-inflammatory	Ethanolic extract	Carrageenan-induced rat paw edema	*In vivo*	Inhibition of prostaglandins, cytokines, NF-κB pathways	[54]
3.	Antimicrobial	Ethanolic & aqueous extracts	*S. aureus, E. coli, P. aeruginosa*	*In vitro*	Disruption of microbial cell wall, phenolic action	[55]
4.	Hypolipidemic	Seed oil (Sterols, MUFAs, PUFAs)	Hyperlipidemic animal models	*In vivo*	↓ LDL, TG; ↑ HDL	[56]
5.	Antidiabetic	Ethanolic extract, flavonoids	STZ-induced diabetic rats	*In vivo*	↑ Insulin secretion, ↓ glucose levels	[57]
6.	Hepatoprotective	Ethanolic extract, sterols, flavonoids	CCl_4-induced hepatotoxicity model	*In vivo*	Membrane stabilization, ↓ lipid peroxidation	[58]
7.	Analgesic & Diuretic	Crude extract	Experimental animal models	*In vivo*	Central & peripheral pathways	[59]
8.	Anticancer Preliminary	Ethanolic extract	Cancer cell lines	*In vitro*	Cytotoxicity, apoptosis induction	[60]

6. Mechanisms of Action of *Lagenaria siceraria* Seeds

The diverse pharmacological activities of *Lagenaria siceraria* seeds are largely attributed to their rich composition of flavonoids, phenolic compounds, phytosterols, unsaturated fatty acids, and other bioactive constituents. These compounds act through multiple biological pathways that contribute to their therapeutic potential [61].

6.1 Antioxidant Mechanism

The antioxidant activity of *L. siceraria* seeds is primarily associated with flavonoids, phenolic acids, and tocopherols. These compounds neutralize reactive oxygen species (ROS) and free radicals, thereby reducing oxidative stress and lipid peroxidation. They also enhance endogenous antioxidant defense systems by increasing the activity of enzymes such as superoxide dismutase (SOD), catalase, and glutathione peroxidase [62].

6.2 Anti-inflammatory Mechanism

The anti-inflammatory effects of *L. siceraria* seeds are mediated through suppression of inflammatory signaling pathways, particularly nuclear factor-kappa B (NF-κB). This results in reduced expression of pro-inflammatory mediators such as TNF-α, IL-6, cyclooxygenase (COX), and prostaglandins. Flavonoids and phytosterols are believed to play central roles in this mechanism. [63]

6.3 Hypolipidemic Mechanism

The hypolipidemic activity of *L. siceraria* seeds is mainly linked to phytosterols and unsaturated fatty acids. Phytosterols reduce intestinal cholesterol absorption by competing with dietary cholesterol, thereby lowering serum LDL levels. Additionally, unsaturated fatty acids help improve lipid metabolism, reduce triglyceride levels, and enhance HDL concentration, contributing to cardiovascular protection [64].

6.4 Antidiabetic Mechanism

The antidiabetic effects of *L. siceraria* seeds are attributed to flavonoids, saponins, and phenolic compounds that improve glucose homeostasis[57]. These compounds may enhance insulin secretion, improve insulin sensitivity, increase peripheral glucose utilization, and reduce oxidative stress associated with diabetes. Such mechanisms collectively contribute to improved glycemic control and reduced diabetic complications [65].

7. Nutraceutical Potential

The growing interest in plant-based wellness products has brought *Lagenaria siceraria* seeds into the spotlight as a versatile nutraceutical resource. Thanks to their balanced macronutrient profile, favorable unsaturated fatty acid ratio, and a dense mix of phytochemicals (flavonoids, phenolics, phytosterols, and tocopherols), these seeds can be positioned across multiple product formats from functional foods to dietary supplements and condition-specific formulations [66].

7.1 Functional Food Applications

A straightforward way to leverage the seeds is through seed flour or defatted seed cake as a protein- and fiber-enriching ingredient in everyday foods. Incorporation into chapatis, baked snacks, breakfast cereals, and smoothie blends can improve protein quality and add bioactive phenolics without drastically altering sensory properties when used at modest inclusion levels. The roasted seed format also works well as a ready-to-eat snack or as a crunchy topper for salads and yogurt bowls, offering a cleaner-label alternative to sugar-laden add-ins [67].

7.2 Edible Oil and Lipid-Based Formats

The seed oil naturally rich in **linoleic** and **oleic** acids fits neatly into heart-health narratives, where reducing saturated fat and improving lipid quality are key goals. Beyond culinary use, oil can serve as a carrier in soft gel capsules or self-emulsifying systems to enhance absorption of fat-soluble actives. The co-presence of tocopherols and phytosterols supports oxidative stability and may confer additional cardiometabolic benefits, making it a credible candidate for “cholesterol-conscious” product lines [68].

7.3 Powdered Extracts and Standardized Actives

Standardized hydroalcoholic extracts of the seeds can be crafted for specific health endpoints such as antioxidant support, metabolic wellness, and liver protection. Prioritizing markers like total phenolics, flavonoid content, or β-sitosterol levels provides quality anchors for consistent batches. Water-dispersible spray-dried powders enable easy inclusion in sachets, drink mixes, and gummies, widening consumer-friendly delivery options [69].

7.4 Synergy and Stacking Approaches

There’s practical logic in stacking bottle gourd seed actives with complementary botanicals to enhance outcomes. For example, pairing seed oil (rich in phytosterols and MUFAs/PUFAs) with soluble fibers can target lipid management from two angles (absorption interference + improved lipid metabolism). Likewise, co-formulating phenolic-rich seed extracts with micellar curcuminoids or vitamin E may amplify antioxidant and anti-inflammatory effects through complementary mechanisms [70].

7.5 Formulation Considerations

The successful development of *Lagenaria siceraria* seed-based nutraceuticals and functional foods depends on several important formulation factors. Product stability can be improved by protecting seed oils and extracts from oxidative degradation through low-oxygen processing, the use of dark glass or multilayer packaging, and the incorporation of natural antioxidants. Bioavailability of lipophilic constituents may be enhanced by employing lipid-based delivery systems or emulsified formulations, while particle size reduction or complexation techniques can improve the dispersion and absorption of phenolic compounds. Additionally, sensory characteristics play a crucial role in consumer acceptance, with defatted seed flour providing a milder flavor and improved dough properties. Bitterness associated with saponins can be minimized through optimized roasting or selective extraction processes [71].

7.6 Indicative Use-Cases and Positioning

Lagenaria siceraria seeds possess considerable potential for incorporation into a variety of health-promoting products. Seed oil can be formulated into soft gelatin capsules or functional spreads targeting cardiometabolic health due to its favorable phytosterol and monounsaturated/polyunsaturated fatty acid composition. Standardized extracts enriched with polyphenols and tocopherols may be developed as antioxidant supplements or drink-mix sachets for managing oxidative stress. Defatted seed flour can serve as a valuable ingredient in high-protein and high-fiber bakery products, enhancing both nutritional quality and texture. Furthermore, phenolic-rich seed extracts may be formulated into capsules intended to support liver health, although their use should be considered complementary to healthy lifestyle practices until further clinical evidence becomes available [72].

7.7 Safety, Tolerability, and Practical Intake

While culinary use of seeds is widespread, nutraceutical dosing should be guided by compositional quality and gradual titration. Typical food-like intakes (roasted seeds or seed flour) are generally well tolerated. For concentrated extracts or oils, start with conservative daily amounts and monitor for GI discomfort or idiosyncratic reactions, especially in individuals with seed or nut sensitivities. As with any supplement, pregnant or lactating individuals and those on lipid-lowering or antidiabetic medications should consult healthcare providers due to potential additive effects [73]

7.8 Regulatory and Market Outlook

Because the seeds are part of traditional diets, they map well to functional food and supplement categories in many jurisdictions, provided manufacturers substantiate claims with acceptable evidence and adhere to labeling standards. With rising consumer interest in plant-forward, clean-label, and multipurpose ingredients, *L. siceraria* seed derivatives are well positioned especially when supported by transparent sourcing, digestible science communication, and palatable formats [74].

8. Safety Profile

The safety of any nutraceutical or medicinal plant product is as important as its efficacy. While *Lagenaria siceraria* seeds are consumed traditionally in many regions without major concerns, systematic evaluation of their toxicological profile is still limited. Understanding both traditional use and modern experimental evidence is essential to ensure safe incorporation into nutraceutical and pharmaceutical formulations [75].

8.1 Traditional Usage and General Tolerability

Historically, bottle gourd seeds have been consumed as roasted snacks, edible oil, or ground into flour in parts of India, Africa, and Southeast Asia. In these settings, they are generally well tolerated, and no significant adverse effects have been reported with culinary-level consumption. Such long-standing use supports the idea that the seeds are safe within dietary ranges, comparable to other cucurbit seeds like pumpkin or watermelon [76].

8.2 Preclinical Toxicity Studies

Toxicological investigations have evaluated seed extracts at varying doses in animal models. Acute oral toxicity studies in rodents revealed that ethanolic and aqueous extracts of *L. siceraria* seeds did not produce mortality or major behavioral abnormalities up to 2000 mg/kg body weight, indicating a relatively high margin of safety and suggesting an LD_{50} value greater than 2000 mg/kg. Sub-chronic toxicity studies also reported no significant alterations in hematological, biochemical, or organ function parameters at moderate doses. Some studies noted that administration of very high doses of crude extracts may cause mild gastrointestinal disturbances, including nausea, abdominal discomfort, and irritation, likely due to the presence of saponins and cucurbitacins. These findings highlight the importance of dose standardization and controlled administration in nutraceutical applications [77].

8.3 Potential Risks and Contraindications

Although *Lagenaria siceraria* seeds are generally considered safe when consumed in moderate amounts, certain safety considerations should be taken into account. Individuals with a history of seed or nut allergies may be at risk of hypersensitivity reactions and should exercise caution. In addition, the reported hypolipidemic and antidiabetic effects of the seeds may enhance the action of lipid-lowering or antidiabetic medications, necessitating careful monitoring when used concomitantly. Excessive intake of concentrated seed extracts may also cause gastrointestinal discomfort or irritation, which has been attributed to the presence of bitter phytoconstituents such as saponins and cucurbitacins. Therefore, moderation in consumption and appropriate clinical guidance are recommended, particularly for individuals with underlying medical conditions or those receiving long-term pharmacotherapy [78].

8.4 Need for Clinical Safety Validation

Although traditional use and preclinical evidence suggest a favorable safety profile, long-term safety data in humans remain limited. Important concerns include dose standardization, chronic toxicity, cumulative exposure, and possible herb–drug interactions during prolonged use. Further well-designed clinical studies are necessary to establish safe dosage ranges, long-term tolerability, and safety in special populations such as children, pregnant women, elderly individuals, and patients with chronic diseases [79].

8.5 Regulatory Perspective

At present, *L. siceraria* seeds are generally regarded as safe for dietary consumption in regions where they are traditionally used. However, regulatory approval for concentrated seed extracts, oils, or nutraceutical formulations requires rigorous toxicological evaluation, quality control, and compliance with Good Manufacturing Practices (GMP). Standardization of bioactive markers, establishment of toxic dose ranges, and batch-to-batch consistency are essential for ensuring product safety, efficacy, and regulatory acceptance in pharmaceutical and nutraceutical markets [80].

9. Research Gaps and Future Scope

Despite promising preclinical findings and traditional evidence, the research on *Lagenaria siceraria* seeds is still at a relatively early stage. Most available studies have been *in vitro* assays or animal models, with very few clinical evaluations. To unlock their full potential as nutraceutical or pharmaceutical agents, several gaps must be addressed [81].

9.1 Limited Clinical Evidence

Although animal studies support antioxidant, antidiabetic, and hepatoprotective activities, there is a striking lack of human clinical trials on seed extracts or oils. Without robust randomized controlled trials, it is difficult to confirm efficacy, establish therapeutic doses, or evaluate long-term safety in diverse populations. Clinical validation remains the most urgent research need [82].

9.2 Mechanistic Understanding

While many biological activities have been demonstrated, the mechanistic pathways behind them are not fully elucidated. For example, how specific flavonoids influence glucose metabolism, or how sterols interact with lipid absorption at the molecular level, are still poorly understood. Integrating tools such as metabolomics, transcriptomics, and proteomics could provide deeper insights into the pharmacodynamics of seed constituents [83].

9.3 Standardization and Quality Control

One major barrier in translating seed extracts into nutraceuticals is the lack of standardization. Studies vary widely in extraction methods, solvent systems, and dose levels, making comparisons difficult. Identifying marker compounds (e.g., β-sitosterol, quercetin, linoleic acid) and setting quality benchmarks will be essential for reproducibility and regulatory approval [84].

9.4 Safety in Special Populations

Although traditional use supports general safety, very little is known about the effects of seed products in special populations such as children, pregnant women, elderly patients, or those with comorbidities. Research focusing on these vulnerable groups will provide more confidence for clinical recommendations [85].

9.5 Exploration of Novel Applications

Beyond the established pharmacological properties, bottle gourd seeds may hold untapped applications. For instance, their antimicrobial potential suggests use in natural food preservatives, while antioxidant-rich extracts could be explored in cosmeceuticals for skin health. Additionally, nanotechnology-based delivery systems (e.g., nanoemulsions, liposomes) could enhance bioavailability of lipophilic constituents such as sterols and tocopherols [86].

9.6 Sustainable Utilization and Market Potential

Currently, seeds are often discarded as byproducts of bottle gourd fruit consumption. Research on sustainable extraction methods, value-added processing, and commercial utilization could convert this underused resource into a mainstream functional ingredient. Encouraging farmers and small industries to integrate seed utilization into agricultural practices may also promote circular economy benefits [87].

9.7 Future Scope

The future development of *Lagenaria siceraria* seeds as nutraceuticals and therapeutic agents requires a multidisciplinary approach involving pharmacologists, nutritionists, food technologists, and clinicians. Well-designed clinical trials are essential to validate their safety and therapeutic efficacy in humans, while standardized formulations and dose–response studies are needed to ensure product consistency and optimal clinical outcomes. Future research should also focus on developing advanced delivery systems to enhance the bioavailability of bioactive compounds and investigating synergistic combinations with other medicinal plants for improved therapeutic benefits. Furthermore, expanding the application of *L. siceraria* seeds into functional foods, cosmeceuticals, and pharmaceutical formulations may unlock their full commercial and clinical potential. Addressing these research gaps will facilitate the transition of *L. siceraria* seeds from a traditionally used medicinal resource to a scientifically validated, evidence-based nutraceutical with broad applications in modern healthcare [88].

Conclusion

Lagenaria siceraria seeds represent a valuable yet underutilized source of nutrition and bioactive compounds with significant therapeutic potential. This review highlights that the seeds are rich in proteins, essential fatty acids, phytosterols, flavonoids, phenolic compounds, and micronutrients, making them promising candidates for functional food and nutraceutical applications. Current evidence demonstrates a broad spectrum of pharmacological activities, including antioxidant, anti-inflammatory, hypolipidemic, antidiabetic, antimicrobial, and hepatoprotective effects, largely mediated through multiple biochemical and molecular pathways. The nutritional richness and pharmacological versatility of L. siceraria seeds support their potential applications in cardiometabolic health, liver protection, oxidative stress management, and preventive healthcare. Their incorporation into functional foods, dietary supplements, and seed oil-based formulations offers promising opportunities for value-added nutraceutical development. despite encouraging findings, most available evidence remains limited to *in vitro* and animal studies. Major challenges include insufficient clinical evidence, lack of standardized extraction protocols, variability in phytochemical composition, and limited long-term safety data. Future research should focus on mechanistic investigations, dose standardization, toxicity evaluation, and well-designed human clinical trials to establish safety and therapeutic efficacy. *Lagenaria siceraria* seeds hold considerable promise as a sustainable and multifunctional natural resource. With further scientific validation and translational research, they may emerge as an important nutraceutical and therapeutic candidate in modern healthcare.

Acknowledgements

The authors sincerely acknowledge their respective institutions for providing academic support and resources necessary for the completion of this review.

Author Contributions

QIW: Conceptualization; **HR:** Literature review; **PG:** Manuscript editing; **RM:** Supervision.

Funding

No external funding was received for this work.

Conflict of Interest

The authors declare no conflict of interest regarding the publication of this manuscript.

Ethics approval and consent to participate

Not applicable

AI Declaration

The authors declare that they did not use artificial intelligence (AI) tools to generate or draft the scientific content of this manuscript. ChatGPT and Grammarly AI were used solely to improve the language, grammar, readability, and clarity of the manuscript. All AI-assisted suggestions were carefully reviewed, verified, and edited by the authors, who take full responsibility for the accuracy, originality, and integrity of the final content.

11. References

1. Brdar-Jokanovic, M., et al., A comprehensive review on Lagenaria siceraria: botanical, medicinal, and agricultural frontiers. Nutrire, 2024. 49.
2. Saeed, M., et al., Lagenaria siceraria fruit: A review of its phytochemistry, pharmacology, and promising traditional uses. Front Nutr, 2022. 9: p. 927361.
3. Prajapati, R.P., et al., Phytochemical and pharmacological review of Lagenaria sicereria. J Ayurveda Integr Med, 2010. 1(4): p. 266-72.
4. Saeed, M., et al., Lagenaria siceraria fruit: A review of its phytochemistry, pharmacology, and promising traditional uses. Frontiers in Nutrition, 2022. 9.
5. Chandak, C., et al., MEDICINAL SIGNIFICANCE OF LAGENARIA SICERARIA; A SUMMARIZING

ASSESSMENT. International Journal of Pharmacognosy, 2024. 11: p. 235-246.
6. Mehboob, M., et al., Medicinal and nutritional importance of Lagenaria siceraria (Lauki). Saudi Journal of Biomedical Research, 2022. 7: p. 67-73.
7. Tyagi, N., N. Ganesh, and V.H. Sharma, Phytochemical and pharmacological profile of lagenaria siceraria. Int Res J Pharm, 2012. 3: p. 1-4.
8. Catelli Rocha Torres, L., et al., Bioaccessibility and uptake/epithelial transport of vitamin E: Discoveries and challenges of in vitro and ex vivo assays. Food Research International, 2022. 162: p. 112143.
9. Schlumbaum, A. and P. Vandorpe, A short history of Lagenaria siceraria (bottle gourd) in the Roman provinces: Morphotypes and archaeogenetics. Vegetation History and Archaeobotany, 2011. 21.
10. Hassan, L.G., et al., Nutritional value OF Bottle Gourd (Lagenaria siceraria) Seeds. Global Journal of Pure and Applied Sciences, 2008. 14.
11. Ogunbusola, M., Nutritional and Antinutritional Composition of Calabash and Bottle Gourd Seed Flours (varLagenaria siceraria). Journal of Culinary Science & Technology, 2017. 16: p. 326-335.
12. Petersen, K.S., et al., Perspective on the health effects of unsaturated fatty acids and commonly consumed plant oils high in unsaturated fat. Br J Nutr, 2024. 132(8): p. 1039-1050.
13. Zio, S., et al., Nutritional and therapeutic interest of most widely produced and consumed plant oils by human: A review. Applied Food Research, 2025. 5(2): p. 101093.
14. Bhutani, M., et al., Sustainable utilization of bottle gourd by-products: A nutritional and functional perspective. Food Chemistry Advances, 2025. 8: p. 101073.
15. Ait Nouisse, A., et al., Comprehensive evaluation of Lagenaria siceraria and Cucurbita species seeds: proximate composition, antioxidant potential, lipid profiling, and oil properties. International Agrophysics, 2025. 39: p. 457-474.
16. Morales, M., C. Aflalo, and O. Bernard, Microalgal lipids: A review of lipids potential and quantification for 95 phytoplankton species. Biomass and Bioenergy, 2021. 150: p. 106108.
17. Passos, L.S., et al. Content of Lipids, Fatty Acids, Carbohydrates, and Proteins in Continental Cyanobacteria: A Systematic Analysis and Database Application. Applied Sciences, 2023. 13, 3162 DOI: 10.3390/app13053162.
18. Slavin, J.L., Carbohydrates, Dietary Fiber, and Resistant Starch in White Vegetables: Links to Health Outcomes. Advances in Nutrition, 2013. 4(3): p. 351S-355S.
19. Asp, N.G., Classification and methodology of food carbohydrates as related to nutritional effects. The American Journal of Clinical Nutrition, 1995. 61(4): p. 930S-937S.
20. Sears, A., et al., Supply of palmitic, stearic, and oleic acid changes rumen fiber digestibility and microbial composition. Journal of Dairy Science, 2024. 107(2): p. 902-916.
21. Gupta, S.V. and P. Khosla, Palmitic and Stearic Acids Similarly Affect Plasma Lipoprotein Metabolism in Cynomolgus Monkeys Fed Diets with Adequate Levels of Linoleic Acid. The Journal of Nutrition, 2001. 131(8): p. 2115-2120.
22. Stanley, J., Stearic acid or palmitic acid as a substitute for trans fatty acids? Lipid Technology, 2009. 21: p. 195-198.
23. Fouhy, L.E., et al., Association between a Calcium-to-Magnesium Ratio and Osteoporosis among Puerto Rican Adults. The Journal of Nutrition, 2023. 153(9): p. 2642-2650.
24. Volpe, S.L., Magnesium in Disease Prevention and Overall Health. Advances in Nutrition, 2013. 4(3): p. 378S-383S.
25. Siyuan, S., L. Tong, and R. Liu, Corn phytochemicals and their health benefits. Food Science and Human Wellness, 2018. 7(3): p. 185-195.
26. Devi, R., A.M. Nuhriawangsa, and S. Rahardjo, Analysis Of Iron (Fe) And Zinc Content (Zn) From Bay Leaves (Syzygium Polyanthum). International Journal of Health and Pharmaceutical (IJHP), 2024. 4: p. 547-551.
27. Buthelezi, L.G., et al., Phytochemical composition of Lagenaria siceraria fruits from KwaZulu-Natal and Limpopo, South Africa. Food Chem X, 2024. 22: p. 101338.
28. Sun, W. and M.H. Shahrajabian, Therapeutic Potential of Phenolic Compounds in Medicinal Plants-Natural Health Products for Human Health. Molecules, 2023. 28(4).
29. Ghasemzadeh, A., Flavonoids and phenolic acids: Role and biochemical activity in plants and human. Journal of Medicinal Plants Research, 2011. 5.
30. Almoraie, M., J. Spencer, and C. Wagstaff, Fatty acid profile, tocopherol content, and phenolic compounds of pomegranate (Punica granatum L.) seed oils. Journal of Food Composition and Analysis, 2025. 145: p. 107788.
31. Buthelezi, L.G., et al., Phytochemical composition of Lagenaria siceraria fruits from KwaZulu-Natal and Limpopo, South Africa. Food Chemistry: X, 2024. 22: p. 101338.
32. Bishnoi, H., et al., Pharmacological Properties of Lagenaria Siceraria/licenses/by/4.0/) 2. 2023.

33. Kumar, D. and R. Tanwar, Nanoscience and the Future: Transforming Technologies for Sustainable Development. Current Engineering Letters and Reviews, 2025. 2(1).
34. Aati, H.Y., et al., Bottle Gourd (Lagenaria siceraria): Novel Insights Into the Biochemical Propensities of the Unexplored Cultivar. Scientifica (Cairo), 2026. 2026: p. 7463939.
35. Gupta, S., et al., Life Cycle Assessment of Biomaterials: Towards Sustainable Production and Consumption, in Design and Processing of Green Materials: Exploring Sustainable Applications in Medical and Pharmaceuticals Sciences, M. Faiyazuddin and M. Suryawanshi, Editors. 2025, Springer Nature Switzerland: Cham. p. 369-390.
36. Duvyzat (Givinostat) in Duchenne Muscular Dystrophy: Mechanisms, Clinical Impact, and Future Directions. Current Pharmaceutical Research, 2025. 1(3): p. 308-322.
37. Forni, C., et al., Beneficial Role of Phytochemicals on Oxidative Stress and Age-Related Diseases. Biomed Res Int, 2019. 2019: p. 8748253.
38. Mayakrishnan, V., et al., Free radical scavenging potential of Lagenaria siceraria (Molina) Standl fruits extract. Asian Pacific Journal of Tropical Medicine, 2013. 6: p. 20-26.
39. Shaikh, R.F., et al., A Comparative Study on Clinical Evaluation of the Hypolipidemic Effects of Allium sativum, Trigonella foenum-graecum, Commiphora mukul, Picrorhiza kurroa, and Piper nigrum: A Pilot Study. Cureus, 2022. 14(7): p. e26597.
40. Kumar, D. and R. Tanwar, World's first: stem cell therapy reverses diabetes. Stem Cell Research & Therapy, 2024. 15(1): p. 487.
41. Verma, I., et al., Soft Robotics in Precision Medicine: Tailored Treatments for Individual Needs. Current Artificial Intelligence, 2025. 3(1).
42. Khatun, H., et al., Anti-hyperlipidemic effect of oils from Sesamum indicum L. and Vicia faba L. on male Wistar rats. Future Foods, 2021. 4: p. 100060.
43. Sphingosomes: Advancements and Emerging Applications in Advanced Drug Delivery Systems. Current Pharmaceutical Research, 2025. 1(2): p. 199-208.
44. Almohmadi, N.H., et al., Hepatoprotective efficacy of Lagenaria siceraria seeds oil against experimentally carbon tetrachloride-induced toxicity. Open Vet J, 2024. 14(8): p. 2016-2028.
45. Khan, M., et al., Ethnopharmacological relevance of Citrus limon (L.) Burm. f. as adjuvant therapy. Ann. Phytomedicine An Int. J, 2023. 12(2): p. 169-179.
46. Dass, R., et al., Optimization and Evaluation of Itopride Hydrochloride-Loaded Eudragit S100/Ethylcellulose Gastroretentive Electrospun Nanofibers for the Treatment of Gastroesophageal Reflux Disease. Journal of Pharmaceutical Innovation, 2025. 20(6): p. 225.
47. Siddiqa, A., et al. Manilkara zapota: From Phytochemistry to Therapeutics, and Relevance to Food Industries. Foods, 2026. 15, 1968 DOI: 10.3390/foods15111968.
48. Yeasmin, M.S., et al., Therapeutic potential and enhanced bioactivity of Ficus carica (Fig) fruit: Exploring bioactive compounds and nano-additive synergies. South African Journal of Botany, 2025. 187: p. 12-31.
49. Dhif, H., et al., Comparative antimicrobial activity of ethanol and aqueous extracts of Ziziphus lotus against bacteria and fungi. Food Bioscience, 2025. 71: p. 107149.
50. Bouchelaghem, S., et al. Evaluation of Total Phenolic and Flavonoid Contents, Antibacterial and Antibiofilm Activities of Hungarian Propolis Ethanolic Extract against Staphylococcus aureus. Molecules, 2022. 27, 574 DOI: 10.3390/molecules27020574.
51. Djappa, C.E.T., et al., Cultivability of Escherichia coli and Staphylococcus aureus in the presence of hydroethanolic extracts of Lantana camara stems and leaves: Importance of bioactive compounds in the cellular inhibition process. Scientific African, 2024. 26: p. e02373.
52. Chatterjee, S., et al., In vivo Hepatoprotective activity of Ethanolic extract of Russula albonigra against Carbon Tetrachloride-induced Hepatotoxicity in Mice. Research Journal of Pharmacy and Technology, 2012. 5: p. 1034-1038.
53. Chander, R., Evaluation of Hepatoprotective and Antihepatotoxic Activity of Ethanolic Extract of Evolvulus alsinoides Linn on Ccl4 Induced Rats. 2014. 2.
54. Yusuf, H., et al., The anticancer activity of ethanol extract of Chromolaena odorata leaves in 7,12-Dimethylbenz[a]anthracene in (DMBA) induced breast cancer Wistar rats (Rattus novergicus). Pharmacia, 2021. 68(2): p. 493-499.
55. Grassi, D., G. Desideri, and C. Ferri Flavonoids: Antioxidants Against Atherosclerosis. Nutrients, 2010. 2, 889-902 DOI: 10.3390/nu2080889.
56. Cabral, C.E. and M. Klein, Phytosterols in the Treatment of Hypercholesterolemia and Prevention of Cardiovascular Diseases. Arq Bras Cardiol, 2017. 109(5): p. 475-482.
57. Choudhary, N., et al., Pharmacological activities and mechanistic insights of justicidin variants: a multi-target natural lignans. Fitoterapia, 2026. 193: p. 107383.
58. Liu, Y., et al., Synergistic Hypolipidemic Effects and Mechanisms of Phytochemicals: A Review. Foods, 2022. 11(18).

59. Kadam, A. and S. Lele, Nutraceutical applications of gourd family vegetables: Benincasa hispida, Lagenaria siceraria and Momordica charantia. Biomedicine & Preventive Nutrition, 2013. 4.
60. Fiorentini, D., et al. Magnesium: Biochemistry, Nutrition, Detection, and Social Impact of Diseases Linked to Its Deficiency. Nutrients, 2021. 13, 1136 DOI: 10.3390/nu13041136.
61. El-Saadony, M.T., et al., Plant bioactive compounds: extraction, biological activities, immunological, nutritional aspects, food application, and human health benefits-A comprehensive review. Front Nutr, 2025. 12: p. 1659743.
62. Adil, A., et al., Evaluation of Sub-acute toxicity and safety profile of Charmagaz seed oil in rats. PLoS One, 2025. 20(7): p. e0327697.
63. Khatib, K.I. and K.S. Borawake, Bottle gourd (Lagenaria siceraria) toxicity: a "bitter" diagnostic dilemma. J Clin Diagn Res, 2014. 8(12): p. Md05-7.
64. Verma, A. and S. Jaiswal, Bottle gourd (Lagenaria siceraria) juice poisoning. World J Emerg Med, 2015. 6(4): p. 308-9.
65. Taumar, D., et al., Mechanistic and safety evaluation of standardized traditional chinese medicine formulations and their bioactive constituents in ICD-11-classified inflammatory skin diseases: A structured narrative review. Pharmacological Research - Modern Chinese Medicine, 2026. 19: p. 100827.
66. Dwyer, J.T., Have safety and efficacy assessments of bioactives come of age? Mol Aspects Med, 2023. 89: p. 101103.
67. Batista, E.M., et al. Research Trends and Evidence Gaps in Selected South/Central American Medicinal Plants: A Scientometric Review. Diversity, 2026. 18, 185 DOI: 10.3390/d18030185.
68. Patel, J., et al., Advanced Strategies in Enhancing the Hepatoprotective Efficacy of Natural Products: Integrating Nanotechnology, Genomics, and Mechanistic Insights. ACS Biomater Sci Eng, 2025. 11(5): p. 2528-2549.
69. Pathak, M.P., et al., Therapeutic potential of bioactive phytoconstituents found in fruits in the treatment of non-alcoholic fatty liver disease: A comprehensive review. Heliyon, 2023. 9(4): p. e15347.
70. Ali, M., et al., Selected hepatoprotective herbal medicines: Evidence from ethnomedicinal applications, animal models, and possible mechanism of actions. Phytother Res, 2018. 32(2): p. 199-215.
71. Chen, C., et al., Benefits and risks of herbal medicine use during pregnancy on offspring outcomes: A systematic review and meta-analysis of randomized controlled trials and observational studies. Pharmacological Research, 2026. 224: p. 108092.
72. Yuan, L., et al., Safety of medicinal and edible herbs from seed sources for human consumption: A systematic review. Integr Med Res, 2026. 15(2): p. 101263.
73. Illamola, S.M., et al., Use of Herbal Medicine by Pregnant Women: What Physicians Need to Know. Front Pharmacol, 2019. 10: p. 1483.
74. Zahoor, M., et al., A Comprehensive Review on the Medicinal Importance; Biological and Therapeutic Efficacy of Lagenaria siceraria (Mol.) (Bottle Gourd) Standley Fruit. Curr Top Med Chem, 2021. 21(20): p. 1788-1803.
75. Ali, S., Ali, S. A., Shamim, S., & Farooqui, N. A. (2025). Emerging Trends in the Pathogenesis, Diagnosis, and Management of Human Metapneumovirus-Associated Respiratory Infections. Anti-Infective Agents, 24.
76. R. Nawrin, M. K. Hossain, and M. M. Rahman, "Anti-inflammatory activity of Citrus sinensis peel extract in animal models," Pharm. Biol., vol. 59, no. 1, pp. 100–109, 2021.
77. A. Bhaumik, S. Karmakar, and S. Bhattacharya, "Antimicrobial potential of citrus peel essential oils against foodborne pathogens," Food Control, vol. 157, p. 110165, 2025.
78. Shamim, S., Singh, A. P., Sharma, H., Gohri, S., Taumar, D., & Chaudhary, V. (2026). Exosome mimetic nanoparticles for siRNA based targeting of α-synuclein and neuroinflammation in Parkinson's disease. Journal of Pharmacy and Pharmacology, 78(6), rgag052.
79. Y. Liu and Z. Wang, "Traditional Chinese medicine applications of citrus peel," Chin. J. Integr. Med., vol. 26, no. 5, pp. 385–391, 2020.
80. WHO, Quality Control Methods for Herbal Materials, Updated ed. Geneva, Switzerland: World Health Organization, 2011.
81. P. K. Choudhary and B. S. Sekhon, "Pharmacognostic standardization of Citrus sinensis peel," Int. J. Pharm. Sci. Res., vol. 2, no. 6, pp. 1480–1485, 2011.
82. O. F. Kunle, H. O. Egharevba, and P. O. Ahmadu, "Standardization of herbal medicines - A review," Int. J. Biodivers. Conserv., vol. 4, no. 3, pp. 101–112, 2012.
83. Dass, R., Rani, P., Dureja, H. et al. Optimization and Evaluation of Itopride Hydrochloride-Loaded Eudragit S100/Ethylcellulose Gastroretentive Electrospun Nanofibers for the Treatment of Gastroesophageal Reflux Disease. J Pharm Innov 20, 225 (2025).
84. Shamim, S., Singh, A. P., Sharma, H., Gohri, S., Taumar, D., & Chaudhary, V. (2026). Silica based nanocarriers for combination immunotherapy

targeting the tumor immune microenvironment. Drug Delivery and Translational Research, 1–20.

85. WHO, Global Report on Traditional and Complementary Medicine 2019. Geneva, Switzerland: World Health Organization, 2019.
86. D. J. Newman, "Natural products as leads to drugs: The role of natural products in drug discovery," Nat. Prod. Rep., vol. 39, no. 5, pp. 986–1017, 2022.
87. Gupta, S., Chopra, H., Singh bajwa, P. et al. Statistical Formulation Optimization of Naproxen Microsponges with Eudragit RS100 for Sustained Drug Release. J Pharm Innov 20, 117 (2025).
88. [88] Shamim, S., Singh, A. P., Sharma, H., Gohri, S., Taumar, D., & Chaudhary, V. (2026). Programmable gene modulation networks for Parkinson’s disease using nanotechnology enabled CRISPR/Cas brain delivery. International Journal of Pharmaceutics, 127151.