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Comprehensive Review of Beta vulgaris (Amaranthaceae): Pharmacognosy, Phytochemistry, Traditional Uses, and Pharmacological Activities

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Abstract: *Beta vulgaris, sometimes referred to as beetroot and a member of the Amaranthaceae family, is a significant nutritional and medicinal plant that is frequently utilized in both traditional and contemporary medicine. The plant's many medicinal qualities are attributed to its abundance of bioactive components, which include betalains, flavonoids, phenolic compounds, saponins, tannins, alkaloids, vitamins, and minerals. The purpose of this paper is to provide an overview of the pharmacognostical traits, phytochemical components, traditional use, and pharmacological actions of *Beta vulgaris*. Important macroscopic and microscopic characteristics that are helpful for plant identification and standardization are revealed by pharmacognostical investigations. Anemia, liver diseases, hypertension, digestive issues, inflammation, and general weakness have all historically been treated with beetroot. Significant pharmacological effects, such as antioxidant, anti-inflammatory, anti-diabetic, hepatoprotective, cardioprotective, anti-cancer, and antibacterial properties, have been shown in a number of experimental and clinical investigations.*

Keywords: Beta vulgaris; Beetroot; Amaranthaceae; Pharmacognosy; Phytochemicals; Traditional Uses; Pharmacological Activities; Antioxidant Activity; Anti-inflammatory Activity; Anti-ulcer Activity; Herbal Medicine; Betalains; Nutraceuticals.

I. INTRODUCTION

Vegetables contain critical minerals, vitamins, and fiber needed for optimal health. Vegetables contain large amounts of essential nutrients in an appropriate proportion. India is the second-largest producer of veggies. According to the Indian Horticulture database released by the Ministry of Agriculture, India produced 175 million metric tons of vegetables during 2016 and 2017. [1] *Beta Vulgaris*, or *beetroot*, is a significant edible and therapeutic member of the Amaranthaceae family. Because it can thrive in a variety of soil types and needs comparatively fewer chemical inputs than certain other crops, beetroot supports sustainable agriculture. [2] Because of the plant's natural hues, nutritional worth, and medicinal qualities, it is widely grown all over the world. [3] *Garden beet, sugar beet, fodder beet,* and *Swiss chard* are some of the cultivated variants of *Beta vulgaris*. The pharmacological and health-promoting benefits of

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beetroot are attributed to its abundance of betalains, flavonoids, phenolic compounds, vitamins, minerals, and dietary nitrates. [4] *Beta vulgaris* has substantial industrial and commercial value in addition to its nutritional and therapeutic benefits. The food and beverage industry uses beetroot's natural pigments extensively as food coloring. Additionally, juices, salads, pickles, soups, and dietary supplements are made with *beta vulgaris*. [4-5] The family Amaranthaceae is known for the presence of diverse secondary metabolites including betalains, flavonoids, terpenoids, and phenolic acids. This family of plants has strong antibacterial, anti-inflammatory, antioxidant, and anti-ulcer properties. One of the significant genera in this family, the genus *Beta* has drawn a lot of scientific interest due to its nutritional and therapeutic uses. [6-7]

Due to its diverse chemical constituents and wide range of biological activities, *beta vulgaris* has become an important subject of study in fields such as pharmacognosy, nutrition, agriculture, and food science. [8] Traditionally, *beta vulgaris* has been used in various systems of medicine for the management of anemia, hypertension, liver disorders, digestive problems, inflammation, and general weakness. *Beta vulgaris* has been shown in recent pharmacological investigations to have antioxidant, anti-diabetic, hepatoprotective, anti-ulcer, antibacterial, anti-cancer properties. The presence of betalains and other phytoconstituents is primarily responsible for these biological actions. [9-10] The identification, authenticity, and standardization of the crude medication and its formulations depend on the pharmacognostical and phytochemical analysis of *Beta vulgaris*. [11-12] The plant has drawn a lot of interest in pharmaceutical and nutraceutical research because of its exceptional medicinal and nutritional potential. [13-14]

Thus, the goal of this review is to give a thorough analysis of *Beta vulgaris's* pharmacognostical traits, phytochemical components, traditional applications, and pharmacological activity. [15-16]

The current review emphasizes the significance of Beta vulgaris as a medicinal and nutraceutical plant by concentrating on its pharmacognostical traits, phytochemical components, traditional uses, and pharmacological activity.

II. LITERATURE REVIEW:

1. **Clifford et al. (2015)** reviewed the therapeutic potential of beetroot and concluded that beetroot supplementation possesses antioxidant, anti-inflammatory, and gastroprotective properties due to the presence of nitrates and betalains.
2. **Georgiev et al. (2010)** demonstrated that betalain-rich extracts of beetroot showed significant free radical scavenging activity and may help in the prevention of oxidative damage-related disorders.
3. **Wootton-Beard and Ryan (2011)** reported that beetroot juice is an excellent source of bioavailable antioxidants and contributes to cellular protection against oxidative injury.
4. **El-Beltagi and Mohamed (2010)** studied the antioxidant potential of beetroot roots and confirmed the presence of flavonoids, phenolics, and betalains responsible for medicinal properties.
5. **Singh and Hathan (2014)** described the nutritional composition and pharmacological importance of beetroot and highlighted its role as a functional food with therapeutic applications.
6. **Tesoriere et al. (2004)** investigated the antioxidant activity of betalains and reported that betalains effectively inhibit lipid peroxidation and oxidative stress in biological systems.
7. **Kapadia et al. (2003)** evaluated the chemopreventive activity of beetroot extract and found that beetroot pigments possess significant biological and antioxidant activities.
8. **Ravichandran et al. (2013)** reported that betalains from beetroot are stable natural pigments with potent antioxidant and anti-inflammatory effects useful in pharmaceutical formulations.
9. **Pavlov et al. (2005)** studied betalain biosynthesis in *Beta vulgaris* and confirmed that betacyanins and betaxanthins are the principal pigments contributing to its medicinal value.
10. **Mroczek et al. (2012)** identified saponins and phenolic constituents in beetroot and suggested that these phytochemicals may contribute to its therapeutic activity.
11. **Ninfali and Angelino (2013)** reviewed the health benefits of beetroot and concluded that regular consumption of beetroot may reduce inflammation and oxidative stress-associated diseases.

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12. **Vulić et al. (2014)** investigated the antioxidant and antimicrobial activity of beetroot extracts and found significant activity due to phenolic compounds and flavonoids.
13. **Kazimierczak et al. (2014)** compared organic and conventional beetroot cultivation and observed that organically grown beetroot possessed higher antioxidant and flavonoid content.
14. **Sawicki et al. (2016)** reported that beetroot is rich in natural antioxidants including betalains and phenolics, making it beneficial in prevention of chronic diseases and gastrointestinal disorders.
15. **Rahimi et al. (2019)** suggested that natural plant-derived antioxidants like beetroot may provide gastroprotective effects against peptic ulcer through reduction of oxidative stress and enhancement of mucosal defense.
16. **Chhikara et al. (2019)** reviewed the nutraceutical importance of beetroot and highlighted its role in improving digestive health, cardiovascular protection, and antioxidant defense mechanisms.
17. **Kanner et al. (2001)** reported that betalains from beetroot possess higher antioxidant potential than several common dietary antioxidants and may protect gastric mucosa from free radical damage.
18. **Azeredo (2009)** studied the stability and applications of betalains and concluded that beetroot pigments are valuable natural antioxidants with pharmaceutical and food applications.
19. **Pitalua et al. (2010)** evaluated the antioxidant and anti-inflammatory properties of beetroot extracts and found significant reduction in oxidative stress markers due to phenolic compounds and flavonoids.

III. PLANT PROFILE

Beta vulgaris or *beetroot*, belongs to the Amaranthaceae family and is frequently used as a natural food coloring. Water-soluble pigments called betalains, which contain nitrogen, give it its unique color. Proteins, sugar, carbs, vitamins (B complex and vitamin C), minerals, fiber, and other nutrients are all abundant in beetroot. (17) Additionally, they have a significant concentration of antioxidants and phenolic compounds, including coumarins, carotenoids, sesquiterpenoids, triterpenes, and flavonoids (astragalin, tiliroside, rhamnocitrin, kaempferol, and rhamnetin). Consuming beetroot has been shown in recent research to have positive physiological effects, including improved liver damage, hepatic steatosis, cancer, diabetes, hypertension, and cardiovascular illnesses. (18) This study provides information on beetroot's development as an innovative and promising component for a variety of food applications as well as the most recent global research. (19)

Figure 1: ***Beta Vulgaris Plant***

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- **Synonyms:**

Beta rapacea Koch , *Beta altissima* Döll , *Beta saccharifera* Alef, *Beta vulgaris* subsp. *Cicla, Beta vulgaris* subsp. *Vulgaris, Beta vulgaris* var. *Rubra, Beta vulgaris* var. *Cicla, Beta vulgaris* var. *Altissima.* [20]

- **Taxonomical Classification;**

Table 1: Taxonomical Classification of *Beta Vulgaris.* [21]

Taxonomical Rank	Classification
Kingdom	Plantae
Subkingdom	Tracheobionta (Vascular Plants)
Division	Magnoliophyta (Angiosperms / Flowering Plants)
Class	Magnoliopsida (Dicotyledons)
Order	Caryophyllales
Family	Amaranthaceae
Genus	*Beta*
Scientific Name	*Beta Vulgaris*

- **Common Names of *Beta Vulgaris:***

Beetroot, Beet, Garden Beet, Red Beet, Table Beet, Sugar Beet, Chard Beet. [22]

An Overview on its Worldwide Distribution:

Because of its great nutritional, agricultural, and economic value, beta vulgaris is widely distributed and grown throughout temperate and subtropical regions of the world. Through cultivation and trade routes, the plant is said to have originated in the Mediterranean region and then migrated to Europe, Asia, North America, South America, and Africa. [23] Beta vulgaris subsp. maritima, sometimes known as sea beet, is the wild parent of cultivated beets and is found naturally along the shores of the Mediterranean, Europe, North Africa, and various Atlantic islands. Spain, France, Italy, Greece, Turkey, Tunisia, and the Atlantic coast that stretches to Northern Europe are among the nations where it is frequently seen. [24-25] India, China, Germany, France, Russia, the United States, Turkey, Egypt, Iran, and the United Kingdom are among the numerous nations where Beta vulgaris is currently grown. The plant thrives in a variety of soil and climate conditions, especially cool temperate regions with rich, well-drained soils. [26] Additionally, research show that human domestication, agricultural activities, and ecological adaptability have greatly increased the range of both wild and cultivated beet species. In Europe and North Africa, wild populations are still found in disturbed areas, salt marshes, and coastal habitats. [27-28]

Botanical Description:

Beta vulgaris is characterized as an annual or biennial herbaceous plant of the Amaranthaceae family. The plant has an erect-decumbent stem with a fleshy taproot that can reach a height of 100–120 cm, depending on the cultivar and surrounding circumstances. [29] The root has a globular or cylindrical shape and is plump, smooth, and meaty. Because betalain pigments are present in cultivated species, the roots are typically dark red, purple, yellow, or white. The roots of wild forms are woody and fibrous. During vegetative growth, the stem stays compact, but during the flowering stage, it lengthens. Erect, branching, ribbed, and striated are the characteristics of flowering stems. [30-31] Small, sessile, greenish, bisexual flowers are grouped in dense, interrupted inflorescences that resemble spikes. Five tepals, five stamens, and a semi-inferior ovary with two to three stigmas are often seen in each bloom. According to research on floral ontogeny, the flowers grow along an unknown primary axis in dichasial inflorescence units. [32] The fruit is a hard utricle made of fused floral components that contains tiny kidney-shaped, reddish-brown seeds with a diameter of two to three millimeters. [33] The cultivated varieties of Beta vulgaris, including table beet, sugar beet, fodder beet, and

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Swiss chard, differ significantly morphologically, especially in terms of root size, root color, leaf morphology, and sugar content. [34]

Chemical Constituents of *Beta vulgaris:*

Phytochemical studies of Beta vulgaris have revealed the existence of various biologically active chemicals that contribute to its nutritional and pharmacological qualities. According to some researches beetroot contains betalains, flavonoids, phenolic compounds, alkaloids, saponins, tannins, glycosides, vitamins, minerals, amino acids, carbohydrates, and dietary nitrates. [35] These phytochemicals considerably enhance its antioxidant, anti-inflammatory, hepatoprotective, cardioprotective, and anti-ulcer properties. [36]

Table 2: Phytochemical Constituents of *Beta vulgaris* [37- 42]

Sr.No.	Chemical Constituents	Extract Type	Pharmacological Activity
1.	Carbohydrates	Methanol, Chloroform, Ethanol	Immunomodulatory, Antioxidant, Anti-ulcer
2.	Alkaloids	Methanol, Chloroform, Ethanol	Analgesic, Antimicrobial, Anti-ulcer
3.	Proteins	Ethanol	Nutritional and tissue repair activity
4.	Flavonoids	Methanol, Chloroform, Petroleum Ether	Antioxidant, Anti-inflammatory, Anti-ulcer
5.	Tannins	Ethanol	Antioxidant, Antimicrobial, Anti-inflammatory, Anti-ulcer
6.	Phenolic Compounds	Methanol, Ethanol	Antioxidant, Anti-inflammatory, Cardio-protective

Traditional Uses of *Beta vulgaris:*

Beta vulgaris has been utilized in traditional medicine for ages in many cultures, most notably in Iranian, Mediterranean, and Asian systems of medicine. Traditionally, beetroot was used to cure constipation, digestive issues, stomach pain, joint pain, dandruff, fever, wounds, and general weakness. The plant is known as "Selgh" or "Choghondar" in Iranian Traditional Medicine, and its leaves and roots have long been utilized as medicinal remedies. The leaves were used to treat inflammatory diseases and skin ailments, and the roots were used as a blood purifier and tonic. Beetroot remedies were also utilized by traditional healers to improve appetite, treat liver diseases, and boost overall health. [43] *Beta vulgaris* has also been traditionally used to treat anemia due to its high iron and folate levels. Beet juice has been used in folk medicine to improve blood circulation, cure hypertension, and alleviate weariness. *Beta vulgaris* decoctions were used in numerous traditional systems to treat constipation and gastrointestinal pain because of their laxative characteristics. Additionally, poultices made from beet leaves were administered externally to promote wound healing and inflammation. [44-45] Historical ethnomedicinal records also show that Beta vulgaris was used to treat psychological and nervous diseases, fever, and diminished libido, albeit some of these traditional claims require scientific proof. Many of these traditional uses are supported by modern pharmacological studies because beetroot has antioxidant, anti-inflammatory, hepatoprotective, cardioprotective, and antimicrobial properties attributed to the plant's betalains, flavonoids, phenolics, and dietary nitrates. [46-48]

Pharmacological Activity of *Beta vulgaris*:

Anti-oxidant Activity:

Carcinogenesis is one of the known adverse consequences of synthetic antioxidants. Natural antioxidants found in plant extracts have the potential to successfully substitute synthetic antioxidants and act as therapeutic agents against

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oxidative stress-related diseases. [49-52] *Beta vulgaris* has been shown to have strong antioxidant activity in numerous studies. [53] High antioxidant activity correlates with higher phenolic content. Young roots exhibit increased oxygen radical absorbance capacity (ORAC) in hairy areas. *Beta vulgaris* cultivation produced 4100 µm of Trolox equivalent per gram of DE, while mature roots produced 1250 µm of TE. Young root culture demonstrated higher DPPH radical scavenging activity (90.7% inhibition with EC05=0.11 g) compared to mature root culture (14.2% inhibition with EC50=0.70), possibly due to higher phenolic content. [54-56] *Beta vulgaris* has significant antioxidant activity. The young root culture of *beta vulgaris* has higher DPPH inhibitory activity compared to its leaf extract. Artemisia annua, a medicinal herb, has a DPPH scavenging activity of 80.2%. [52] Czapski et al. reported that beetroot cv. Czerwona Kula had the highest red pigment level (1.37 mg/kg).Among 11 cultivars, Chrobry had the highest antioxidant capacity (21.7 µmolTrolox/mL) and the highest red pigment concentration (1.63 mg/ml), which correlated with the best antioxidant activity (20.6 µmolTrolox/mL). [57]

Anti-microbial Activity:

The agar well diffusion method evaluates the antibacterial properties of *beta vulgaris* peels and pulp extract against Staphylococcus aureus, Listeria monocytogenes, Pseudomonas aeruginosa, Escherichia coli, and Candida albicans. Methanolic pulp extracts, particularly 50% methanolic, are highly effective.The lowest inhibitory concentration is 4 mg/ml. The 50% methanolic peel extract is more effective against gram-negative bacteria (MIC=4 mg/ml) than gram-positive bacteria and fungal strains (MIC=8 mg/ml). The aqueous extract of peels and pulp has a MIC=8 mg/ml for all bacterial and fungal strains. However, the methanolic peel extract is more effective against E. coli (4 mg/ml) than other microbes. The minimum bactericidal concentration ranged from 4 to 16 mg/mL. [58-61] Beetroot pomace extract effectively inhibited all gram-negative bacterial strains in an antimicrobial assay, with the exception of Salmonella typhimurium, which showed a significant inhibition zone (25.0). Among gram positive strains. Bacillus cereus is very sensitive, with a 20.33 inhibition zone of extract. However, pomace extract was not effective against wild bacterial strains (Bacillus sp., Enterococcus faecalis, and Listeria monocytogenes), mold, or yeast. [62] Many investigations have found that bacterial strains are highly susceptible, although fungal strains are resistant. *Beta vulgaris* possesses anti-mycotoxin efficacy against TeA and AME, with a higher inhibition rate of 95.60-99.91%. Compared to methanolic extract, with 66.99-99.79% inhibition. [63]

Anti-inflammatory Activity:

Microglial cell activation can lead to neuro-inflammation by releasing free radicals and pro-inflammatory cytokines. Betanin, derived from red beetroot, has been shown to alleviate this. Suppresses lipopolysaccharide-induced cytokines. Molecular docking has showed negative binding energy against active regions of cytokines and nitric oxide synthase, limiting microglial cell activation. [64] *Beta vulgaris* has been shown to have anti-inflammatory properties in both animal models and human experiments. [65] In vitro investigations on human polymorphonuclear neutrophils show that betanin has anti-inflammatory properties by lowering free radical generation, DNA damage, and apoptosis. [66] *Beta vulgaris* compounds, in addition to pure betanin, have been shown to be effective anti-inflammatory agents in a research on obese individuals' neutrophils. Chips and juice suppress neutrophil oxidative metabolism in a concentration-dependent manner. A dose of 0.1-10% beetroot has been demonstrated to promote apoptosis in 24-hour stimulated neutrophil cultures. [67-68] Another study found that over-expression of lipoxygenase (LOX) and xanthine oxidase (XO) is linked to inflammation. Betanin inhibits these enzymes in both white and red types. *Beta vulgaris* and Swiss chard suppress LOX through uncompetitive processes, while XO is inhibited by uncompetitive mechanisms. [69]

Diuretic and Anti-hypertensive Activity:

Nitrate-rich supplements have been shown to effectively treat hypertension. [70] A placebo-controlled, double-blind trial found that nitrate-rich *beta vulgaris* juice+placebo was more effective than nitrate-eliminated beetroot juice

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supplementation+placebo for lowering blood pressure. Dietary nitrate has a favorable impact on decreasing blood pressure (NBJ+placebo study). [71]

III. CONCLUSION

Beta vulgaris belonging to the family *Amaranthaceae* is an important medicinal and nutritionally valuable plant with significant therapeutic potential. Pharmacognostical studies provide essential information for the identification, authentication, and standardization of the plant material. Phytochemical investigations reveal the presence of various bioactive constituents such as betalains, flavonoids, phenolic compounds, tannins, saponins, alkaloids, carbohydrates, vitamins, and dietary nitrates, which are responsible for its diverse pharmacological activities. *Beta vulgaris* has historically been used to treat anemia, hypertension, liver ailments, digestive issues, inflammation, wounds, and overall weakness. Scientific research have corroborated many of these traditional claims, demonstrating that beetroot has antioxidant, anti-inflammatory, anti-diabetic, hepatoprotective, cardioprotective, antibacterial, anti-ulcer, and anticancer properties. Among its phytoconstituents, betalains and phenolic compounds play a significant role in free radical scavenging and biological protection. *Beta vulgaris* has received a lot of attention in pharmaceutical, nutraceutical, and functional food research because of its unique nutritional composition and medical value. However, more advanced phytochemical research, toxicological evaluations, and clinical studies are still needed to isolate active elements, define specific mechanisms of action, and demonstrate safety and efficacy profiles for medicinal uses. Overall, *Beta vulgaris* is a promising natural source for the creation of safe and efficacious plant-based pharmaceutical formulations and health-promoting products.

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