ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24OCT1833

Beetroot as a Therapeutic Aid in Cardiovascular Health: An in-Depth Analysis

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Abstract:- Beetroot, a vibrant red vegetable, has emerged as a promising natural remedy for various health conditions, particularly cardiovascular diseases. Rich in essential nutrients, minerals, and unique plant compounds, beetroot offers a holistic approach to promoting overall well-being. This comprehensive analysis delves into the pharmacological properties of beetroot, highlighting its antioxidant, anti-inflammatory, antimicrobial, and anti-diabetic effects. Key phytoconstituents like betalains and nitrates contribute significantly to these beneficial properties. Betalains, the pigments responsible for beetroot's distinctive color, exhibit potent antioxidant and anti-inflammatory properties. They help combat oxidative stress, safeguard cells from damage, and reduce inflammation. Nitrates, another essential component, are converted into nitric oxide in the body, which plays a crucial role in vasodilation, improving blood flow and reducing blood pressure. By incorporating beetroot into a balanced diet, individuals may experience improved cardiovascular health, reduced risk of heart disease, and enhanced overall well-being. However, further research is necessary to fully understand the mechanisms of action and optimal dosage for various health conditions.

Keywords:- *Beetroot, Betalains, Nitrates, Nitric Oxide, Cardiovascular Health.*

I. INTRODUCTION

Nowadays, there is a growing worldwide trend towards eating healthier, including so-called ‘functional foods.’ People are seeking safer ways to improve their overall health and quality of life. The health benefits of a diet rich in fruits and vegetables are likely endless. These benefits include heart health and protection against free radicals (1).

Among them Beetroot is one of the potent dietary supplements, not only packed with minerals, nutrients, and vitamins but also containing unique plant compounds with various medicinal properties (2). Beetroot (Beta vulgaris Linnaeus) is a vibrant red vegetable belonging to the Chenopodiaceae family. It's renowned for its juice and health benefits and is also known by other names, such as beet, chard, and spinach beet (3).

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24OCT1833

Fig 1 Beetroot

Fig 2 Freshly Peeled Beetroot

Different parts of beetroot are used in medicine for their antioxidant, antidepressant, antimicrobial, antifungal, anti-inflammatory, diuretic, expectorant, and carminative effects (2). It is a natural food that can boost energy in athletes due to its high nitrate and sugar content (4, 5). The red beet (Beta vulgaris) is a unique source of betalains, a group of pigments that give it its characteristic red color. These pigments are primarily betanin and vulgaxanthin I. The red beet is grown globally and is a popular food item (6). Beetroot pigments are composed of approximately 75% to 95% betacyanins and the remaining 5% to 25% betaxanthins (7). The concentration of betalains in fresh red beets ranges from 200 to 2100 milligrams per kilogram. The amount of betalains can vary significantly between different beet varieties (8, 9).

- *Phytoconstituents: (7, 10-12)*

Table 1 Phytoconstituents

Sr. No.	Phytoconstituents	
1.	**Betalains**	Betacyanins (75-95%), and Betaxanthins (5-25%)
2.	**Nitrates**	Inorganic nitrates (NO3)
3.	**Alkaloids**	Calystegine B1, Calystegine B2, Calystegine B3, Calystegine C1, and Ipomine
4.	**Amino acids**	Threonine, Valine, Cystine, Methionine, Isoleucine, Leucine, Lysine, Phenylalanine, Histidine, Arginine, Glutamic acid, Proline, Alanine, and Tyrosine
5.	**Fatty acids**	Linolenic acid, Pentadecilic acid, Palmitic acid, Stearic acid, Palmitoleic acid, Oleic acid, and Vacenic acid
6.	**Flavonoids**	Astragalin, Kaempferol, Rhamnocitrin, Rhamnetin, and Tiliroside
7.	**Anthocyanins**	Carotenoids (beta-carotene)
8.	**Vitamins**	Choline, pantothenic acid, vitamin A, vitamin B1, vitamin B2, vitamin B3 (niacin), vitamin B6, vitamin C, vitamin E, and vitamin K
9.	**Minerals**	Calcium, Copper, Iron, Manganese, Magnesium, Phosphorus, Potassium, Sodium, and Zinc

Fig 3 Beetroot Juice

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24OCT1833

II. PHARMACOLOGICAL ACTIVITIES OF BEETROOT

- *Anti-Oxidant Activity*

Free radicals are produced as by-products of oxygen metabolism in body cells. These harmful molecules can damage enzymes, cell walls, DNA, lipids, and proteins, disrupting normal defence mechanisms. Antioxidants, often taken as dietary supplements or medications, can help protect against this damage.

Betalains, extracted from beetroot, have been shown in numerous in vitro studies to possess strong antioxidant properties. Experimental research has demonstrated that betalain and betanidin can reduce the damage caused by cytochrome C oxidase-induced linoleate damage and peroxide-activated metmyoglobin-induced lipid membrane oxidation (13).

Betanin, found in beetroot at concentrations of 300-600 milligrams per kilogram, exhibits exceptional antioxidant activity due to its ability to donate electrons and neutralize highly reactive radicals that target cell membranes. The antioxidant potential of beetroot is further enhanced by the synergistic action of other bioactive molecules, such as caffeic acid, epicatechin, and rutin (14).

Nitrates present in beetroot also have antioxidant properties, as they can damage free radicals like hydrogen peroxide and superoxide, suppressing radical formation and directly scavenging them (15, 16).

- *Anti-Inflammatory Activity*

The betalains often enhance resistance to oxidation, benefiting human metmyoglobin and low-density lipoproteins. When paired with phenolic compounds, they reduce the oxidative damage of lipids. Additionally, betalains can help decrease inflammation in joints, bones, and blood vessels, which may be beneficial for individuals with asthma and osteoporosis (10, 17, 18).

- *Anti-Microbial Activity*

Beet root extracts, containing betalains, were evaluated for their antibacterial activity against both Gram-positive and Gram-negative bacteria using the agar well diffusion method. A zone of inhibition was observed with a minimum betalain concentration of 1 mg. The extracts demonstrated activity against Enterococcus feacalis and Klebsiella pneumoniae. Notably, the betalains were found to be effective natural antibacterial agents against extended-spectrum ß-lactamase producing isolates (19).

- *Anti-Fungal Activity*

The antifungal activity of two proteins isolated from beet root leaves was assessed. It was determined that their antifungal effectiveness is concentration-dependent, and they were found to be active against Cercospora (20).

- *Cytotoxic Activity*

The betalains demonstrate antimutagenic effects in humans, particularly against the direct-acting mutagen Methyl-Nitro-Nitroso guanidine. This antimutagenic activity results from their ability to donate methyl groups (transmethylation) and act as osmolytes. The osmolyte effect of betalains helps protect vital cells, enzymes, and proteins by maintaining a high intracellular osmotic concentration, safeguarding them from environmental stress caused by extreme temperatures, increased salinity, or water reduction.

Betalains play a role in managing oxidative stress, a factor involved in the development and progression of cancer. This leads to their chemoprotective and antitumor effects. Additionally, betalains exhibit antiproliferative action by inducing cell apoptosis. Beet root extracts have been combined with doxorubicin, demonstrating significant synergistic potential in treating drug toxicity and cytotoxicity (21, 22).

- *Anti-Diabetic Activity*

In-vitro and preclinical studies have demonstrated the antidiabetic potential of beet root extracts (23). This pharmacological action is linked to the potent free radical scavenging ability of the bioactive molecules within the beet root extracts, which play a significant therapeutic role in various diseases and ailments.

Betanin, a component of beet root extract, was subjected to in-silico and in-vitro studies against aldose reductase, alpha-amylase, protein tyrosine phosphate, alpha-glucosidase, and dipeptidyl peptidase. The results indicated that betanin is active against all four of these enzymes, which play crucial roles in diabetes and its associated complications(24).

- *Anti-Ulcer Activity*

Beet root extracts demonstrated antiulcer activity in various rat models. In ethanol-induced, cold restraint stress-induced, and pylorus-ligated models, albino rats exhibited a significant reduction in ulcer potential when treated with beet root extracts. The methanolic extracts significantly lowered the ulcer score, ulcer index, free acidity, and total acidity in all these models (25).

- *Hematopoietic Activity*

Laboratory investigations have scientifically confirmed the hematopoietic effects of extracts from B. vulgaris (beet) leaves. An anaemia model was induced in albino rats using phenyl hydrazine, and the hematopoietic effects of various dilutions of B. vulgaris leaf extract were evaluated. The extracts significantly restored the levels of white blood cells, red blood cells, haemoglobin, and haematocrit in a dose- and time-dependent manner. Erythropoietin levels were maintained, and malondialdehyde (a biomarker of erythrocytic membrane oxidation) levels were significantly reduced compared to the untreated anaemic group (26).

- *Hepatoprotective Activity*

In-vitro and in-vivo studies of various extracts from B. vulgaris leaves demonstrated hepatoprotective effects against ethanol-induced hepatotoxicity in rat models. Serum marker enzymes were evaluated and compared to the standard silymarin, revealing that the n-butanol extract was

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24OCT1833

the most potent hepatoprotective extract against ethanol-induced hepatic toxicity (27).

➢ *Betalains*

Betalains are pigments found in approximately 17 plant families within the Caryophyllale order. These pigments can be classified into two subclasses: betacyanins, characterized by their red-violet color, and betaxanthins, known for their yellow to orange hue (28, 29). Betalains are water-soluble and accumulate in the vacuoles of plant cells, primarily in the epidermal and subepidermal tissues where these pigments are synthesized (30).

The most recognized edible sources of betalains within the Caryophyllales order include red beet roots (Beta vulgaris L.), grainy or leafy amaranth (Amaranthus sp.), fruits of cacti such as Opuntia sp., Eulychnia sp., and Hylocereus sp., among which dragon fruits, primarily Hylocereus polyrhizus (Web.) Britton and Rose and related species, are particularly noteworthy (31-34).

Red beet (Beta vulgaris), containing two primary betalain pigments, the red betanin and the yellow vulgaxanthin I, has long been regarded as the sole source of betalains. Red beet is cultivated globally and is widely consumed (6). Betacyanins comprise approximately 75-95% of beetroot pigments, while betaxanthins make up the remaining 5-25% (7).

➢ *Activities of Betalains*

Betalains, with their potent antioxidant and free radical-scavenging capabilities, may offer promising potential as natural compounds for combating oxidative stress and safeguarding cells from damage, The antioxidant and antiradical activities of betanin have been explained on its electron donor capacity, bond dissociation energy, and ionization potential(13, 35)

Betalains have demonstrated their ability to protect human erythrocytes from oxidative haemolysis, suggesting their potential role in combating oxidative stress-related diseases. These findings underscore the promising therapeutic potential of betalains as natural antioxidants and their potential applications in various health-promoting contexts (35).

➢ *Inflammation, Modulation Erythropoiesis and Betalain*

Betalains have been shown to have anti-inflammatory properties. They can remove harmful free radicals and regulate antioxidant enzymes. One betalain, betanin, has been found to be particularly effective in reducing inflammation. Chronic inflammation can interfere with the production of red blood cells. Chronic inflammation can lead to an increase in inflammatory molecules (cytokines) like IL-1, TNF-α, and interferon-γ. These cytokines can directly harm and interfere with the development of red blood cell precursors. Additionally, they can suppress the production of erythropoietin (EPO), a hormone essential for red blood cell formation. This decrease in EPO can lead to a lower concentration of EPO in the blood and increased cell death in the later stages of red blood cell development. By reducing inflammation, betalains may potentially stimulate the production of erythropoietin (EPO), a hormone that helps in the formation of red blood cells (36-40).

From this it can be suggested that betalains, by influencing inflammation, may stimulate the production of red blood cells. This might occur through an increase in erythropoietin, a hormone that regulates red blood cell production.

➢ *Beetroot and Nitrates*

Beetroot contains high levels of nitrate (41), which the body converts to nitric oxide. Nitric oxide helps blood vessels expand, making it easier for blood to flow through the circulatory system. The ability of nitric oxide to widen blood vessels is known to be particularly helpful during periods of limited blood flow and oxygen delivery, such as during a heart attack (42).

➢ *Nitric Oxide*

Nitric oxide (NO) is a molecule that acts as a messenger within and between cells. It plays a crucial role in various bodily functions, including blood vessel dilation, nerve signal transmission, heart muscle contraction, immune system regulation, and stem cell growth and development (43).

NO is particularly important for cardiovascular health. It inhibits the growth and movement of smooth muscle cells, promotes the growth and movement of endothelial cells (which line blood vessels), prevents blood clot formation, and reduces the adhesion of blood cells to the vessel walls.

➢ *Menopause*

Menopause is a natural biological process signalling the end of a woman's reproductive life. It occurs when the ovaries cease producing eggs, leading to a decline in estrogen and progesterone levels. The average age for menopause is 51, though it can vary.

➢ *Stages of Menopause:*

- **Perimenopause:** This transitional phase precedes menopause and can last several years. It's characterised by irregular periods, hot flushes, night sweats, mood swings, and disrupted sleep.
- **Menopause:** This marks the point when a woman hasn't had a period for 12 consecutive months.
- **Post menopause:** This stage follows menopause and continues until the end of a woman's life. During this period, the risk of health conditions like osteoporosis and heart disease increases.

➢ *Nitric Oxide and Post-Menopausal Women*

After menopause, women no longer produce estrogen, which helps maintain nitric oxide in the body. This loss of nitric oxide production contributes to the substantial increase in heart disease risk for post-menopausal women. Food that are rich in nitrate especially beets are being investigated as a natural, non-pharmaceutical way to protect the heart and blood vessels (44).

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➢ *Nitric Oxide in Prevention of Heart Disease*

Level of nitric oxide is lower in people with heart and circulatory conditions as the enzyme that produces it is less active. A regular intake of beetroot can reduce inflammation sign in blood vessels that are increased in people with coronary heart disease (45).

III. CONCLUSION

Beetroot emerges as a promising natural intervention in the management of cardiovascular diseases. Beetroot is impacted with antioxidants and anti-inflammatory compounds, which contribute to overall heart health. Its high content of betalains and nitrates not only enhances antioxidant and anti-inflammatory activities but also plays a pivotal role in various therapeutic applications, including cardiovascular health, blood sugar regulation, and oxidative stress management.

As research continues to uncover the multifaceted properties of beetroot, it emerges as a promising natural intervention in the management of various diseases. Regular consumption of beetroot, whether in juice form or as a dietary addition, can serve as a complementary strategy alongside conventional treatments for cardiovascular conditions. However, further research is essential to fully understand its long-term effects and optimal intake levels. By integrating beetroot into a balanced diet, individuals may take proactive steps toward better cardiovascular health.

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ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24OCT1833

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