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ANTIHYPERTENSIVE AND POTENTIAL ANTIHYPERLIPIDEMIC ACTIVITY OF BEETROOT (Beta vulgaris L.)

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ABSTRACT

Hypertension and dyslipidemia are major modifiable risk factors for cardiovascular disease. Alongside established medicines, dietary approaches containing bioactive plant compounds have attracted attention as supportive strategies for cardiovascular health. Beetroot (Beta vulgaris L.) is a widely consumed root vegetable that contains inorganic nitrate, betalain pigments, polyphenols, flavonoids, dietary fibre, vitamins and minerals. The best-characterised cardiovascular pathway involves the conversion of dietary nitrate to nitrite and then nitric oxide (NO), a signalling molecule that relaxes vascular smooth muscle and supports endothelial function. Clinical studies of beetroot juice have reported reductions in systolic blood pressure in some populations, although findings are not uniform and the size of the response varies with study design, nitrate dose, duration and participant characteristics. Beetroot has also shown potential effects on lipid metabolism in experimental models. Animal studies have reported improvements in total cholesterol, triglycerides and low-density lipoprotein cholesterol, with possible contributions from antioxidant compounds, fibre and effects on hepatic lipid handling. However, the evidence for a clinically meaningful antihyperlipidemic effect in humans remains limited. This review summarises the botanical features, nutritional and phytochemical composition of beetroot, the proposed mechanisms underlying its antihypertensive and potential antihyperlipidemic actions, and the available experimental and clinical evidence. The literature indicates that beetroot may be a useful component of a balanced dietary pattern, but it should not be considered a substitute for prescribed antihypertensive or lipid-lowering treatment. Larger, well-controlled human studies are required to establish effective preparations, doses, long-term safety and clinical relevance.

Keywords: Beetroot; Beta vulgaris L.; dietary nitrate; nitric oxide; hypertension; dyslipidemia; betalains; cardiovascular health.

1. INTRODUCTION

Cardiovascular diseases remain a major cause of illness and premature death worldwide. Hypertension and dyslipidemia frequently occur together and contribute to endothelial injury, atherosclerosis, myocardial infarction and stroke. Hypertension is a sustained elevation of arterial blood pressure, whereas dyslipidemia refers to an abnormal concentration or distribution of circulating lipids and lipoproteins. Both conditions are influenced by genetic, metabolic, environmental and lifestyle factors. Regular physical activity, weight management, reduced sodium intake, a diet rich in vegetables and fruits, and appropriate medical treatment form the foundation of risk reduction.

Interest in functional foods has increased because some commonly consumed foods contain compounds that may influence physiological pathways relevant to chronic disease. Beetroot is one such food. The red root of Beta vulgaris L. has a long history of

culinary use and is consumed fresh, cooked, pickled, dried or as juice. Its characteristic colour is mainly due to betalain pigments, while its inorganic nitrate content has become particularly important in cardiovascular research [1–4].

Unlike a conventional antihypertensive medicine, beetroot is a complex food matrix. Its effects cannot be attributed to one constituent alone, and the composition of the final product depends on cultivar, soil, growing conditions, storage, processing and preparation. Nitrate-rich juice, whole beetroot and dried powder are therefore not interchangeable interventions. This distinction is important when comparing research findings [1,2,5].

The strongest mechanistic rationale relates to the nitrate–nitrite–nitric oxide pathway. After ingestion, nitrate is absorbed and a proportion is concentrated in saliva. Oral bacteria reduce nitrate to nitrite, which is swallowed and can subsequently be converted to nitric oxide in the acidic stomach and in tissues, particularly under low-oxygen conditions. Nitric oxide promotes vascular smooth-muscle relaxation and may improve blood flow and endothelial function [6–9].

Evidence for lipid-lowering activity is less mature. Experimental studies have investigated beetroot powder, juice and extracts in animals with diet-induced dyslipidemia or diabetes. Some report improvements in serum lipid parameters and liver lipid accumulation, but these results cannot be directly translated into a therapeutic claim for humans [10–13]. This review therefore distinguishes established physiological mechanisms, promising preclinical observations and clinical findings that still require confirmation.



Figure 1:Botanical Appearance of Beetroot (Beta vulgaris L.)

2. OBJECTIVES OF THE REVIEW

- To describe the botanical identity, nutritional composition and major phytochemical constituents of beetroot.
- To explain the proposed nitrate-dependent mechanism through which beetroot may influence blood pressure.
- To discuss possible mechanisms by which beetroot constituents may affect lipid metabolism.
- To summarise relevant experimental and human studies and identify limitations in the available evidence.
- To highlight research gaps and the possible role of beetroot as a supportive food within cardiovascular risk-reduction strategies.

3. REVIEW METHODOLOGY

This narrative review was prepared by consulting peer-reviewed research articles, systematic reviews, meta-analyses and relevant scientific literature concerning Beta vulgaris L., dietary nitrate, nitric oxide, blood pressure, betalains and lipid metabolism.

Searches were conducted using combinations of the terms “beetroot”, “Beta vulgaris”, “beetroot juice”, “dietary nitrate”, “nitric oxide”, “hypertension”, “blood pressure”, “dyslipidemia”, “hyperlipidemia”, “cholesterol” and “betalains”. Bibliographic records were checked for author names, journal details, year, volume, pages and DOI where available. Human clinical evidence was considered separately from animal and in-vitro findings. Because this is a narrative review rather than a registered systematic review, no formal PRISMA selection process or quantitative risk-of-bias assessment was undertaken. The references should be rechecked against the final journal template and original full texts before submission.

4. BOTANICAL PROFILE AND CLASSIFICATION

Beetroot belongs to the species Beta vulgaris L. and is cultivated as a root vegetable. In current botanical classifications it is placed in the family Amaranthaceae; older literature may list it under Chenopodiaceae, a family now generally treated as included within Amaranthaceae. The edible storage root is commonly deep red or purple, although yellow and other coloured cultivars also exist. The plant has a basal rosette of leaves and a swollen root formed by the hypocotyl and upper root region.

Parameter	Description
Botanical name	Beta vulgaris L.
Common name	Beetroot / red beet
Family	Amaranthaceae (historically Chenopodiaceae)
Order	Caryophyllales
Plant part commonly consumed	Fleshy storage root; leaves are also edible
Common preparations	Fresh root, cooked root, juice, powder, pickles and extracts
Important colour compounds	Betacyanins and betaxanthins (betalains)

The concentration of nitrate and pigments differs substantially between cultivars and growing conditions. The red-rooted forms are commonly used in juice and food products, but colour intensity alone should not be used as a reliable measure of nitrate concentration or pharmacological potency [1,2,14].

5.NUTRITIONAL AND PHYTOCHEMICAL COMPOSITION

5.1 Nutritional composition

Beetroot provides water, carbohydrate, dietary fibre and small amounts of protein. It also supplies folate, vitamin C, potassium, manganese and other micronutrients. Potassium contributes to normal electrolyte balance and may be relevant to blood-pressure regulation as part of an overall healthy diet. The actual nutrient content varies with cultivar, maturity and cooking method. Beetroot should therefore be considered a nutrient-containing vegetable rather than a standardised drug product.

5.2 Inorganic nitrate

Nitrate (NO_3^-) is the constituent most directly linked with the proposed blood-pressure effect. Following ingestion, nitrate is absorbed from the gastrointestinal tract and enters the circulation. A proportion is actively taken up by the salivary glands and secreted into saliva. Commensal oral bacteria reduce nitrate to nitrite; after swallowing, nitrite can be converted to nitric oxide and other nitrogen oxides. This enterosalivary pathway provides an alternative source of nitric oxide that may be particularly useful when oxygen availability is low or endogenous nitric-oxide synthase activity is impaired [6–9].

5.3 Betalains

Betalains are water-soluble nitrogen-containing pigments characteristic of plants in the order Caryophyllales. They are divided into red-violet betacyanins and yellow-orange betaxanthins. Betanin is a major betacyanin in red beetroot. These pigments contribute to the vegetable’s colour and have demonstrated antioxidant activity in chemical and experimental systems. Their stability is influenced by temperature, light, oxygen, pH and processing conditions. Although antioxidant and anti-inflammatory actions are biologically plausible, their direct contribution to blood-pressure or lipid changes in humans has not been established [1–5,18–20].

5.4 Polyphenols and flavonoids

Beetroot contains a range of phenolic compounds and flavonoids. These compounds can participate in redox reactions and may influence inflammatory signalling and vascular function. Their amount depends on the plant part, cultivar and extraction method.

Polyphenols may also interact with other constituents in the food matrix. It is therefore more appropriate to discuss them as potential contributors to the overall biological activity of beetroot rather than as proven independent antihypertensive agents [1,2,14].

5.5 Dietary fibre and other constituents

Dietary fibre in whole beetroot may influence satiety, intestinal transit and the gut environment. Fibre can also affect the absorption and metabolism of dietary components. Juice generally contains less fibre than the intact root, depending on whether pulp is retained. Organic acids, saponins, minerals and other minor constituents have also been reported. These compounds may contribute to the nutritional value of beetroot, but their specific roles in human lipid regulation require further investigation.

Constituent	Examples / characteristics	Potential relevance
Inorganic nitrate	NO_3^-; converted to nitrite and nitric oxide	Vasodilation; possible reduction in systolic blood pressure
Betalains	Betanin, isobetanin, betaxanthins	Antioxidant activity; possible protection against oxidative stress
Polyphenols	Phenolic acids and related compounds	Antioxidant and possible anti-inflammatory effects
Flavonoids	Various flavonoid derivatives reported in beet tissues	Possible effects on oxidative stress and lipid-related pathways
Dietary fibre	Soluble and insoluble fractions	May support a healthy dietary pattern and intestinal function
Minerals and vitamins	Potassium, folate, vitamin C and others	General nutritional support; potassium contributes to electrolyte balance

6.HYPERTENSION: OVERVIEW

Blood pressure is the force exerted by circulating blood against arterial walls. It is commonly expressed as systolic blood pressure (SBP), measured during ventricular contraction, and diastolic blood pressure (DBP), measured during relaxation. Hypertension is diagnosed using repeated, properly performed measurements and thresholds defined by the relevant clinical guideline. A single elevated reading is not sufficient to establish a diagnosis.

The development of hypertension is multifactorial. Increased peripheral vascular resistance, altered renal sodium handling, sympathetic nervous system activity, activation of the renin–angiotensin–aldosterone system, vascular stiffness, endothelial dysfunction and genetic predisposition may all contribute. Long-standing uncontrolled hypertension increases the risk of stroke, coronary artery disease, heart failure, chronic kidney disease and retinopathy.

6.1 Major classes of antihypertensive medicines

Drug class	Examples	Principal action
Diuretics	Thiazide / thiazide-like agents	Increase renal sodium and water excretion; reduce circulating volume and vascular resistance over time
ACE inhibitors	Enalapril, ramipril	Reduce formation of angiotensin II
Angiotensin receptor blockers	Losartan, valsartan	Block angiotensin II at AT1 receptors
Calcium-channel blockers	Amlodipine, diltiazem	Reduce calcium entry into vascular smooth muscle or cardiac cells
Beta blockers	Metoprolol, bisoprolol	Reduce heart rate and renin release
Other agents	Alpha blockers, central sympatholytics, direct vasodilators	Reduce sympathetic tone or directly relax vessels

These medicines have established clinical roles and should be selected according to a patient's blood pressure, comorbidities and clinical guidelines. Beetroot is not a replacement for any prescribed medicine.

7.ANTIHYPERTENSIVE MECHANISM OF BEETROOT

The proposed antihypertensive action of beetroot is mainly associated with dietary nitrate. The pathway is commonly described as the nitrate–nitrite–nitric oxide pathway. Nitric oxide activates soluble guanylate cyclase in vascular smooth-muscle cells, increases cyclic guanosine monophosphate (cGMP), reduces intracellular calcium signalling and promotes relaxation. Relaxation of resistance vessels can reduce peripheral vascular resistance and, consequently, systolic blood pressure.

Step	Physiological event
1	Nitrate-rich beetroot is consumed.
2	Nitrate is absorbed into the bloodstream.
3	A portion of circulating nitrate is concentrated in saliva.
4	Oral bacteria convert nitrate (NO_3^-) into nitrite (NO_2^-).
5	Swallowed nitrite is converted to nitric oxide (NO) in the stomach and tissues.
6	NO activates soluble guanylate cyclase in vascular smooth muscle.
7	cGMP signalling promotes smooth-muscle relaxation and vasodilation.
8	Peripheral vascular resistance may fall, producing a modest reduction in blood pressure.

Figure 1. Text-based flowchart of the proposed nitrate-dependent antihypertensive mechanism. Oral antiseptic mouthwash may reduce nitrate-reducing oral bacteria and can interfere with this pathway; this is one reason why oral microbiota are relevant to dietary nitrate research [6–9].

7.1 Possible additional mechanisms

Betalains and polyphenols may reduce oxidative stress in experimental systems. Since excess reactive oxygen species can inactivate nitric oxide and impair endothelial signalling, antioxidant activity could theoretically support nitric-oxide bioavailability. Beetroot also provides potassium, which is associated with blood-pressure regulation when consumed as part of an appropriate diet. These mechanisms are plausible but should be interpreted cautiously: the contribution of each constituent to the clinical blood-pressure response has not been isolated convincingly.

7.2 Evidence from human studies

Early controlled studies reported that beetroot juice could lower blood pressure over several hours. Coles and Clifton observed a reduction in systolic blood pressure in a subgroup of male participants after beetroot-and-apple juice, although the overall group result was less conclusive [13]. Webb and colleagues demonstrated acute blood-pressure-lowering and vascular effects after dietary nitrate, supporting the biological pathway [9].

Subsequent systematic reviews and meta-analyses have generally found a small average reduction in systolic blood pressure after beetroot or nitrate supplementation. A meta-analysis by Siervo and colleagues reported a greater effect on systolic than diastolic pressure [12]. Another systematic review focused on hypertensive patients reported a reduction in systolic pressure, but not a statistically significant reduction in diastolic pressure [16]. A 2024 meta-analysis of 11 trials involving 349 hypertensive participants estimated a mean reduction of approximately 5.3 mmHg in clinical systolic pressure; certainty was rated low and heterogeneity was substantial [17].

Not all trials have shown benefit. Bondonno and colleagues found that one week of nitrate-rich beetroot juice increased nitrate and nitrite biomarkers but did not reduce home or 24-hour ambulatory blood pressure in treated hypertensive participants [14]. Fejes and colleagues also reported that four weeks of beetroot juice altered nitrate metabolism but did not improve vascular function or blood pressure in older adults with treated hypertension [15]. These findings show why beetroot should not be described as a proven treatment for hypertension.

Study	Design / population	Main finding	Interpretation
Coles & Clifton, 2012 [18]	Randomised, placebo-controlled crossover; 30 healthy adults	Overall SBP result was a trend; a male subgroup showed a 4–5 mmHg reduction at 6 h	Acute response; small study
Webb et al., 2008 [19]	Acute dietary nitrate intervention	Reported blood-pressure-lowering and vascular effects	Supports nitrate–NO mechanism
Siervo et al., 2013 [20]	Systematic review and meta-analysis	Greater pooled effect on SBP than DBP	Evidence supports modest average effect
Bondonno et al., 2015 [23]	Double-blind crossover in treated hypertensive adults	No difference in home or 24-h ambulatory BP after 1 week	Negative trial; treatment status may matter
Silva et al., 2022 [21]	Systematic review / meta-analysis in hypertension	SBP decreased; DBP change was not significant	Promising but limited evidence
Fejes et al., 2024 [24]	Randomised placebo-controlled crossover; older adults with treated hypertension	Nitrate biomarkers increased without significant BP improvement	Biochemical exposure does not guarantee clinical effect
2024 meta-analysis [22]	11 trials; 349 hypertensive participants	Clinical SBP reduced by about 5.3 mmHg; no clear DBP or 24-h BP effect	Low-certainty evidence; interpret cautiously

8. HYPERLIPIDEMIA AND DYSLIPIDEMIA: OVERVIEW

Lipids are essential components of cell membranes and serve as energy stores and precursors for steroid hormones and bile acids. Because lipids are not water-soluble, they circulate in blood within lipoprotein particles. Dyslipidemia is a broad term describing abnormal levels of cholesterol, triglycerides or lipoproteins. Hyperlipidemia commonly refers to elevated circulating lipid concentrations.

Common patterns include elevated low-density lipoprotein cholesterol (LDL-C), elevated triglycerides, reduced high-density lipoprotein cholesterol (HDL-C), or a combination of these abnormalities. LDL particles deliver cholesterol to peripheral tissues; excess LDL-C is causally associated with atherosclerotic cardiovascular disease. HDL participates in reverse cholesterol transport, although HDL-C concentration alone is not a complete measure of HDL function.

8.1 Classification of dyslipidemia

Type / pattern	Typical lipid abnormality	Clinical relevance
Hypercholesterolemia	Raised total cholesterol and/or LDL-C	Increases atherosclerotic risk
Hypertriglyceridemia	Raised serum triglycerides	Associated with metabolic risk; very high levels can cause pancreatitis
Mixed dyslipidemia	Raised LDL-C and triglycerides, often with low HDL-C	Common in insulin resistance and metabolic syndrome
Low HDL-C pattern	Reduced HDL-C	Often accompanies elevated triglycerides and insulin resistance
Familial dyslipidemia	Inherited defects affecting lipoprotein metabolism	May cause markedly elevated lipids and premature cardiovascular disease

Management depends on the overall cardiovascular risk profile and may include dietary modification, physical activity, weight management and lipid-lowering medicines such as statins, ezetimibe, fibrates or other agents when indicated. A dietary ingredient should not be assumed to replace these treatments.

9. POTENTIAL ANTIHYPERLIPIDEMIC ACTIVITY OF BEETROOT

The possible lipid-modifying activity of beetroot has been investigated mainly in animal models. Several studies have reported reductions in total cholesterol, triglycerides or LDL-C after beetroot powder or extract administration. These findings are encouraging, but the available evidence is not yet sufficient to establish beetroot as a clinically effective lipid-lowering intervention in humans.

9.1 Proposed mechanisms

Antioxidant activity is one proposed mechanism. Oxidative modification of LDL contributes to atherogenesis, and beetroot betalains and phenolic compounds can scavenge reactive species in experimental systems. This may help explain some protective findings in preclinical models, although antioxidant activity in a test tube does not necessarily translate into reduced cardiovascular events.

A second possibility relates to hepatic lipid metabolism. Experimental work in diabetic rats has suggested that beetroot extract may reduce hepatic lipid accumulation and alter expression of genes involved in lipid synthesis and oxidation, including SREBP-related pathways and PPARα [28]. These results offer a hypothesis for future research; they do not establish the same molecular effects in humans.

Dietary fibre may contribute when whole beetroot is consumed. Viscous soluble fibre can influence bile-acid handling and cholesterol metabolism, while a fibre-rich dietary pattern may improve overall metabolic health. However, beetroot juice that has been filtered may contain substantially less fibre than the whole root. Product type should therefore be considered when interpreting results.

Flavonoids, saponins and other phytochemicals have also been proposed to contribute to lipid effects. Possible actions include modulation of intestinal lipid absorption, antioxidant protection and changes in hepatic lipid handling. These mechanisms remain incompletely characterised in beetroot-specific studies and should be described as potential rather than confirmed.

Proposed contributor	Possible action	Strength of current evidence
Betalains and phenolics	Antioxidant activity; may limit oxidative stress and LDL oxidation	Mainly chemical and preclinical evidence
Flavonoids / saponins	Possible effects on lipid absorption and metabolism	Limited beetroot-specific mechanistic evidence
Dietary fibre	May influence bile-acid excretion and dietary lipid handling	Established general fibre physiology; beetroot-specific clinical effect uncertain
Hepatic pathways	Possible changes in lipid synthesis, oxidation and storage	Preclinical animal evidence
Whole-food dietary pattern	Displacement of energy-dense foods; contribution of fibre and micronutrients	Consistent with general healthy-diet principles

9.2 Experimental evidence

Al-Dosari and colleagues investigated an aqueous beetroot extract in rats with cholesterol-rich diet-induced hypercholesterolemia and reported antihypercholesterolemic and antioxidant potential [26]. Wroblewska and colleagues examined beetroot crisps in rats receiving standard or dyslipidemic diets, assessing gastrointestinal function, antioxidant status and blood and liver lipid profiles [27]. Sarfaraz and colleagues evaluated lyophilised beetroot powder in rabbits and reported improvements in cholesterol, LDL, triglycerides and HDL at the tested doses [28].

More recently, Rohman and colleagues compared beetroot extract and juice in a dyslipidemic rat model. Their study reported reductions in total cholesterol and triglycerides, with greater changes in groups receiving beetroot alongside simvastatin [29]. Yuniarti and colleagues also examined beetroot extract in rats and reported a hypocholesterolemic effect [30]. These studies provide preclinical signals, but differences in animal species, induction methods, preparation, dose and outcome measures limit direct comparison.

A study of beetroot extract in a type 2 diabetes model also reported reductions in serum and hepatic cholesterol and triglycerides and changes in markers related to oxidative stress and hepatic lipid regulation [28]. The study is relevant because diabetes and dyslipidemia frequently coexist, but it cannot be interpreted as evidence that beetroot treats human dyslipidemia.

Reference / model	Preparation and model	Reported observation	Main limitation
Al-Dosari et al. [26]	Aqueous extract; cholesterol-rich diet-induced hypercholesterolemia in rats	Antihypercholesterolemic and antioxidant potential reported	Animal model; dose and extract not equivalent to food intake
Wroblewska et al. [27]	Beetroot crisps in standard and dyslipidemic rat diets	Investigated blood/liver lipid profile and antioxidant status	Dietary model; translation to humans uncertain
Sarfaraz et al. [28]	Lyophilised beetroot powder in rabbits	Reported improved lipid profile at 500 and 1000 mg/kg	Small animal study; no human dose equivalence
Rohman et al. [29]	Beetroot juice / extract in dyslipidemic rats	Reported reductions in total cholesterol and triglycerides	Preclinical; combination with simvastatin complicates interpretation
Yuniarti et al. [30]	Beetroot extract in rats	Reported hypocholesterolemic effect	Limited generalisability beyond the experimental model
Beetroot extract in diabetic rats [25]	Methanolic extract in STZ/high-fat diet model	Reduced serum and liver lipid accumulation; altered hepatic markers	Diabetic animal model, not a clinical trial

10. COMBINED CARDIOVASCULAR RELEVANCE

Hypertension and dyslipidemia often coexist and share several pathophysiological features, including endothelial dysfunction, oxidative stress, inflammation and metabolic disturbances. A food that supports a healthy dietary pattern and supplies nitrate, fibre and antioxidant compounds may therefore be of interest in cardiovascular risk reduction. Beetroot is particularly attractive because it can be incorporated into meals in several forms and is relatively accessible.

However, the evidence must be interpreted according to the endpoint measured. A short-term reduction in systolic blood pressure is not the same as prevention of stroke or myocardial infarction. A change in cholesterol in a rat model is not proof of reduced atherosclerotic events in humans. The available literature supports further investigation of beetroot as a supportive food, not a claim that it is an established cardiovascular drug.

11. SAFETY, LIMITATIONS AND PRECAUTIONS

Beetroot is commonly consumed as a food and is generally well tolerated by most people. Its red pigments can colour urine or stools (beeturia), which is usually harmless but may be alarming if unexpected. Beetroot contains oxalate; individuals with a history of calcium-oxalate kidney stones may need personalised dietary advice from a healthcare professional. Concentrated juice and supplements may deliver nitrate and other constituents in amounts that differ from ordinary food portions.

People taking antihypertensive medicines should not use concentrated beetroot products as a reason to reduce or stop prescribed treatment. Because beetroot nitrate may lower blood pressure in some settings, people with low blood pressure or those taking several blood-pressure-lowering medicines should discuss regular concentrated supplementation with their clinician. Product nitrate content is variable, and commercial supplements are not necessarily standardised.

The major limitations of the evidence include small sample sizes, short intervention periods, variation in nitrate dose and beetroot preparation, differences in baseline blood pressure, inconsistent measurement methods and the possibility of publication bias. For lipid outcomes, much of the evidence comes from animal studies rather than well-powered human trials. The lack of standardisation makes it difficult to identify a reproducible dose or formulation.

12. FUTURE RESEARCH DIRECTIONS

- Conduct adequately powered, long-duration randomised controlled trials in people with clearly defined hypertension and dyslipidemia.
- Compare whole beetroot, fibre-containing juice, filtered juice and standardised extracts while measuring nitrate, betalain and polyphenol content.

- Report clinic, home and 24-hour ambulatory blood pressure to distinguish acute changes from sustained effects.
- Measure a complete lipid profile, including LDL-C, HDL-C, triglycerides, non-HDL cholesterol and relevant apolipoproteins.
- Investigate the influence of oral microbiota, diet, medication use, age and baseline nitrate intake on response.
- Establish product quality, stability, dose consistency and safety in people with kidney-stone risk or those using cardiovascular medicines.
- Separate mechanistic biomarkers from clinically meaningful outcomes and avoid interpreting animal findings as proven human efficacy.

13. RESULTS AND DISCUSSION

The literature reviewed indicates that the cardiovascular potential of beetroot is supported by a plausible biochemical mechanism and a growing, although mixed, body of human evidence. The nitrate–nitrite–nitric oxide pathway provides the clearest explanation for a possible blood-pressure effect. Nitric oxide-mediated vasodilation can reduce vascular resistance, and several trials and meta-analyses have reported modest reductions in systolic blood pressure after beetroot juice or nitrate supplementation [9,12–17].

The clinical findings are not uniform. Some trials have reported no improvement in ambulatory or home blood pressure despite clear increases in nitrate and nitrite biomarkers [23,24]. This suggests that biochemical conversion alone is not sufficient to predict the clinical response. Baseline blood pressure, concurrent antihypertensive therapy, intervention duration, dose, oral bacterial activity and participant characteristics may all influence the outcome. Current evidence is therefore more consistent with a possible adjunctive dietary effect than with a reliable therapeutic effect.

For lipid regulation, the evidence is more preliminary. Animal studies using beetroot powder, juice or extracts have reported improvements in selected lipid parameters [25–30]. The proposed explanations include antioxidant activity, fibre-related effects and modulation of hepatic lipid metabolism. Nevertheless, the number of controlled human studies specifically designed to test beetroot for dyslipidemia is limited. The findings should not be used to recommend beetroot as a substitute for statins or other evidence-based lipid-lowering therapy.

An important strength of beetroot is that it provides several potentially active constituents in a food matrix. At the same time, this complexity is a challenge for research: the effects of nitrate cannot automatically be attributed to betalains, and results from a concentrated extract cannot be assumed to apply to ordinary cooked beetroot. Future studies should use chemically characterised preparations and report both the amount consumed and the measured content of relevant bioactive compounds.

Overall, beetroot is a promising functional food for further cardiovascular research. The strongest current support concerns a modest, variable effect on systolic blood pressure. Its potential antihyperlipidemic activity remains supported mainly by experimental studies and requires confirmation in human clinical trials.

14. CONCLUSION

Beetroot (Beta vulgaris L.) is a nutrient-rich vegetable containing inorganic nitrate, betalains, polyphenols, flavonoids, fibre and essential micronutrients. Its nitrate content can contribute to nitric oxide formation through the nitrate–nitrite–NO pathway, providing a sound biological basis for a possible blood-pressure-lowering effect. Human trials and meta-analyses suggest that beetroot juice may produce a modest reduction in systolic blood pressure in some populations, although the results are heterogeneous and not all studies demonstrate benefit.

Beetroot also shows potential antihyperlipidemic activity in experimental models, where improvements in cholesterol and triglyceride levels have been reported. Proposed mechanisms include antioxidant effects, fibre-related actions and modulation of hepatic lipid metabolism. However, the clinical evidence in humans is currently insufficient to establish beetroot as a lipid-lowering treatment. Beetroot may be included as part of a balanced diet, but it should not replace prescribed medicines or professional medical advice. Well-designed clinical trials are needed to determine the most effective preparation, dose, duration and long-term safety.

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