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Systematic Review and Meta-Analysis *of Hibiscus sabdariffa* in Hypertension Management

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

This study systematically reviews and meta-analyzes existing evidence on the efficacy of *Hibiscus sabdariffa* in managing high blood pressure. A comprehensive search of databases, including PubMed, Scopus, and Web of Science, identified randomized controlled trials and observational studies published between 2010 and 2024. The included studies were evaluated for quality using established criteria, and data were synthesized through meta-analysis using RevMan software.

The analysis demonstrated a statistically significant reduction in both systolic and diastolic blood pressure in individuals treated with *Hibiscus sabdariffa* extracts compared to placebo. These findings suggest that *Hibiscus sabdariffa* may serve as an effective adjunctive therapy for hypertension management, highlighting its potential as a natural, non-pharmacological option for controlling blood pressure.

However, the review emphasizes the need for further research to determine the long-term effects, optimal dosages, and standardization of *Hibiscus sabdariffa* extracts to ensure consistent clinical outcomes. Future studies should prioritize well-designed, large-scale randomized trials across

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diverse populations to validate these findings and establish evidence-based treatment guidelines. Additionally, further investigation into the herb's mechanism of action, safety profile, and potential interactions with other antihypertensive medications is critical.
This review offers valuable insights into the potential use of *Hibiscus sabdariffa* as a complementary approach to hypertension treatment while underscoring the importance of advancing research in this area.

Keywords: Systematic review; meta-analysis; hibiscus sabdariffa; natural; management; non-pharmacological.

1. INTRODUCTION

Hypertension, often referred to as high blood pressure, is a major public health issue and a leading risk factor for cardiovascular diseases (CVDs) globally. According to the World Health Organization (WHO, 2023):

- An estimated 1.28 billion adults aged 30–79 years worldwide have hypertension, most (two-thirds) living in low- and middle-income countries
- An estimated 46% of adults with hypertension are unaware that they have the condition.
- Less than half of adults (42%) with hypertension are diagnosed and treated.
- Approximately 1 in 5 adults (21%) with hypertension have it under control.
- Hypertension is a major cause of premature death worldwide; and
- One of the global targets for noncommunicable diseases is to reduce the prevalence of hypertension by 33% between 2010 and 2030.

It is well-established that prolonged uncontrolled hypertension can lead to severe health complications, including heart attacks, strokes, kidney failure, and other life-threatening conditions.

As a result, effective management strategies are essential to mitigate the impact of hypertension on public health. *Hibiscus sabdariffa* has garnered attention as a natural antihypertensive agent due to its multifaceted biochemical mechanisms of action. The plant's calyces are rich in bioactive compounds such as anthocyanins, polyphenols, flavonoids, and organic acids, which collectively contribute to its antihypertensive effects.

1. **Vasodilation and Nitric Oxide Modulation**:

   Hibiscus sabdariffa enhances vasodilation by stimulating the production of nitric oxide (NO), a key molecule that relaxes vascular smooth muscles. This mechanism helps reduce systemic vascular resistance, thereby lowering blood pressure (Ojeda et al., 2010). A recent review by Amos and Khiatah. (2022) also found that *Hibiscus sabdariffa* antihypertensive potentials originate from vasodilator activity, diuretic efficacy, heart rate reduction ability, and anti-inflammatory mechanism.

2. **Inhibition of Angiotensin-Converting Enzyme (ACE)**:

   Compounds in *Hibiscus sabdariffa* exhibit ACE-inhibitory activity, similar to pharmacological ACE inhibitors. By blocking the conversion of angiotensin I to angiotensin II, a potent vasoconstrictor, *Hibiscus sabdariffa* reduces vasoconstriction and blood volume, contributing to lower blood pressure (Ojeda et al., 2010; Serban et al., 2015).

   A previous landmark double-blind, randomized controlled trial by Herrera-Arellano et al. (2004) compared the antihypertensive effects of Hibiscus tea to the pharmaceutical ACE inhibitor captopril in patients with mild to moderate hypertension. Over four weeks, the study found that consuming 10 g of brewed Hibiscus tea daily was just as effective as captopril in lowering both systolic and diastolic blood pressure, with minimal side effects.

   Similarly, an earlier study by Faraji & Tarkhani (1999) showed that daily consumption of 10 g of Hibiscus tea for four weeks significantly reduced systolic blood pressure by an average of 11.2 mmHg and diastolic pressure by 10.6 mmHg in hypertensive patients. These findings further highlight the potential of Hibiscus sabdariffa as a safe and natural antihypertensive agent.

3. **Antioxidant Activity**:

   The anthocyanins and flavonoids in *Hibiscus sabdariffa* have potent antioxidant properties that counteract oxidative stress. Oxidative stress is a key factor in endothelial dysfunction, a precursor to hypertension. By neutralizing free radicals, these antioxidants help maintain vascular health and improve endothelial function.

   A randomized crossover trial by D'Angelo et al. (2016) demonstrated that daily consumption of Hibiscus tea for just four weeks significantly reduced pulse wave velocity (PWV), a key marker of arterial stiffness, in hypertensive patients. Similarly, an earlier study by Frank et al. (2012) revealed that six weeks of daily Hibiscus tea intake notably enhanced plasma antioxidant capacity and reduced lipid peroxidation markers in healthy adults. This reduction in oxidative stress suggests a potential decrease in the risk of developing cardiovascular diseases.

4. **Diuretic Effect**:

   Hibiscus sabdariffa has demonstrated diuretic properties similar to thiazide, promoting the excretion of excess sodium and water. This effect reduces blood volume and alleviates pressure on the cardiovascular system, mimicking the action of conventional diuretics used in hypertension management (Onyenekwe et al., 2016). However, it lacks the electrolyte disturbances frequently observed with synthetic diuretics (Nwafor et al., 2021).

5. **Calcium Channel Blocking Activity:**

   Preliminary studies suggest that *Hibiscus sabdariffa* may exhibit calcium channel-blocking effects, which relax arterial walls by inhibiting calcium influx into vascular smooth muscle cells. This contributes to reduced peripheral resistance and blood pressure (Herrera-Arellano et al., 2007).

6. **Anti-inflammatory Effects:**

   Chronic low-grade inflammation is a recognized contributor to hypertension. *Hibiscus sabdariffa* has anti-inflammatory properties mediated by its polyphenolic compounds, which suppress pro-inflammatory cytokines and pathways such as nuclear factor kappa B (NF-κB) (Ali et al., 2020).

7. **Lipid-Lowering Effects:**

   Hibiscus sabdariffa also contributes to cardiovascular health through its lipid-lowering effects, reducing total cholesterol and low-density lipoprotein (LDL) levels. This dual action on lipids and blood pressure further mitigates the risk of hypertension-induced cardiovascular complications (Serban et al., 2015).

By acting on multiple pathways, *Hibiscus sabdariffa* offers a holistic approach to blood pressure regulation. However, the interplay of these mechanisms underscores the importance of standardizing extract preparation to ensure consistent therapeutic outcomes.

Traditional management of hypertension typically includes a combination of lifestyle modifications—such as dietary changes, increased physical activity, and weight management—and pharmacological interventions. Common antihypertensive medications include ACE inhibitors, beta-blockers, diuretics, and calcium channel blockers, which are highly effective in reducing blood pressure and preventing cardiovascular complications (Williams et al., 2018). However, these medications are not without limitations. Many patients experience side effects such as dizziness, fatigue, electrolyte imbalances, or cough (common with ACE inhibitors), and adherence to long-term medication regimens is often poor due to cost, complexity of regimens, or perceived lack of immediate benefits (Burnier & Egan, 2019).

In this context, there is growing interest in complementary and alternative therapies (CATs), including herbal remedies like Hibiscus sabdariffa, which are often viewed as accessible, cost-effective, and culturally acceptable options. Unlike conventional antihypertensive drugs that target specific mechanisms (e.g., ACE inhibition or beta-adrenergic blockade), H. sabdariffa appears to exert its antihypertensive effects through a multifaceted approach (Ngamjarus et al., 2010; Herrera-Arellano et al., 2007; Kafeshani et al., 2017; Onyenekwe et al., 2016).

Besides, compared to conventional antihypertensive medications, H. sabdariffa offers unique advantages in certain populations,

particularly those seeking natural alternatives due to concerns about side effects or high costs of medications. Additionally, it may serve as an adjunct therapy, enhancing the efficacy of conventional drugs while potentially allowing for lower doses and reduced side effects. However, unlike pharmaceutical drugs, H. sabdariffa has not been studied as extensively in large, multicenter trials, and its long-term safety and effectiveness remain less well-established.

For instance, while H. sabdariffa can lower blood pressure significantly, the reductions observed in studies are generally less pronounced than those achieved with high-dose pharmaceutical agents (Ellis et al., 2022). Nevertheless, this reduction is clinically meaningful, especially in the context of prehypertension or mild hypertension, where modest blood pressure control can prevent disease progression.

Also among various herbal remedies, *Hibiscus sabdariffa*, commonly known as Roselle, has attracted considerable attention for its purported antihypertensive effects. This plant, native to tropical regions of Africa and Asia, has been used for centuries in traditional medicine systems to treat a variety of ailments, including hypertension (Onyenekwe et al. 2020). The pharmacological properties of *H. sabdariffa* are attributed to its rich content of bioactive compounds such as anthocyanins, flavonoids, and polyphenols. These compounds are known for their antioxidant, anti-inflammatory, and vasorelaxant properties, which may contribute to lowering blood pressure by improving vascular function, reducing oxidative stress, and promoting diuresis (Abdelmonem et al., 2022).

Early studies investigating the effect of *Hibiscus sabdariffa* on blood pressure have shown promising results, particularly in individuals with mild to moderate hypertension. Research indicates that *H. sabdariffa* may exert its antihypertensive effects through various mechanisms, including the inhibition of angiotensin-converting enzyme (ACE), a key regulator of blood pressure, as well as its ability to relax blood vessels and enhance urine output, which can help reduce overall blood volume and, consequently, blood pressure (Rafique et al., 2019). Furthermore, the plant's high content of anthocyanins, which are potent antioxidants, may help to reduce the damaging effects of oxidative stress, which is often elevated in hypertensive patients (Abdelmonem et al.,2022).

Despite the growing body of evidence supporting the antihypertensive effects of *H. sabdariffa*, there remains a need for a comprehensive, evidence-based synthesis to establish its clinical effectiveness and determine optimal dosages and treatment regimens. Systematic reviews and meta-analyses are valuable tools for summarizing and quantifying the effects of a specific intervention across multiple studies, providing a clearer understanding of its overall impact and identifying potential sources of heterogeneity among different populations and study designs. Therefore, this study aims to systematically review and meta-analyze the existing clinical evidence on the efficacy of *Hibiscus sabdariffa* in managing high blood pressure. By pooling data from randomized controlled trials (RCTs) and observational studies, this review will offer a more robust assessment of *H. sabdariffa*'s potential as a complementary or alternative treatment for hypertension, especially in populations who may benefit from adjunctive interventions.

The primary objectives of this study are threefold:

(1) to systematically review the available evidence on the effects of *Hibiscus sabdariffa* in reducing systolic and diastolic blood pressure; (2) to perform a meta-analysis to quantify its antihypertensive effects; and (3) to identify gaps in current research and suggest future directions for clinical studies. By addressing these objectives, the study aims to contribute to the growing body of knowledge on herbal treatments for hypertension and provide valuable insights into the role of *Hibiscus sabdariffa* in contemporary hypertension management.

2. METHODOLOGY

This study systematically reviews and meta-analyzes the existing evidence on the efficacy of *Hibiscus sabdariffa* in managing high blood pressure (HBP). The review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure a transparent and reproducible methodology. The study process includes the identification, selection, data extraction, and synthesis of relevant literature, and it critically assesses the quality and heterogeneity of the included studies.

2.1 Study Design and Search Strategy

A comprehensive search strategy was employed to identify relevant studies. Literature searches

were conducted in PubMed, Scopus, Web of Science, and the Cochrane Library for studies published between January 2010 and December 2024. The search terms used included “Hibiscus sabdariffa,” “Roselle,” “hypertension,” and “high blood pressure.” These keywords were combined with Boolean operators to capture studies that investigated the effects of *Hibiscus sabdariffa* on systolic and/or diastolic blood pressure. The search was limited to studies published in English.

2.2 Inclusion and Exclusion Criteria

Studies were included if they met the following criteria:

- **Study Design:** Randomized controlled trials (RCTs) or observational studies
- **Population:** Studies involving human participants with high blood pressure, regardless of age or sex
- **Intervention:** Evaluated the effects of *Hibiscus sabdariffa* (in any form: extract, tea, etc.) on systolic and/or diastolic blood pressure
- **Outcomes:** Reported data on blood pressure measures (systolic and diastolic)
  Studies were excluded if they:
- Focused on populations with comorbidities unrelated to hypertension (e.g., cancer, severe diabetes)
- Were not published in English
- Had insufficient data on blood pressure outcomes

2.3 Data Extraction and Quality Assessment

Two independent reviewers conducted data extraction. For each study, the following information was extracted:

- Study design (RCT or observational)
- Participant characteristics (e.g., age, sex, comorbidities)
- Intervention details (dosage, duration, preparation method of *Hibiscus sabdariffa*)
- Outcome measures (systolic and diastolic blood pressure changes)

The quality of RCTs was assessed using the Cochrane Risk of Bias tool, which evaluates potential biases in the domains of selection, performance, detection, and reporting. Observational studies were assessed using the Newcastle-Ottawa Scale, which evaluates the methodological quality based on participant selection, comparability, and outcome assessment. Any disagreements between the reviewers were resolved by consensus or consultation with a third reviewer.

2.4 Data Synthesis

Meta-analysis was performed using RevMan software (Version 5.4). The primary outcome was the mean difference in systolic and diastolic blood pressure between individuals treated with *Hibiscus sabdariffa* and those in the placebo or control group. For each study, the mean difference (MD) and 95% confidence intervals (CI) were calculated.

The data were pooled using a random-effects model due to the anticipated variability in study designs and populations. The level of heterogeneity was assessed using the I^2 statistic, with values greater than 50% indicating moderate to high heterogeneity. In this study, I^2 was calculated as 45%, indicating moderate heterogeneity across the included studies.

2.5 Publication Bias

Publication bias was assessed using funnel plots, and the Egger’s test was performed to statistically examine asymmetry. This step is essential to ensure the validity of the conclusions by determining if unpublished or underreported studies might have influenced the results.

2.6 PRISMA Flow Diagram

A PRISMA flow diagram was created to outline the process of study selection. The flow diagram includes the number of studies identified, screened, assessed for eligibility, and included in the final meta-analysis. This visual representation provides transparency regarding the study selection process.

2.7 Statistical Analysis

The meta-analysis pooled the mean differences in systolic and diastolic blood pressure. Sensitivity analyses were conducted to examine the influence of individual studies on the overall effect size. The effect size was considered statistically significant if the 95% confidence intervals did not include zero. The data analysis was conducted to provide clear, actionable insights on the efficacy of *Hibiscus sabdariffa* as a treatment for hypertension.

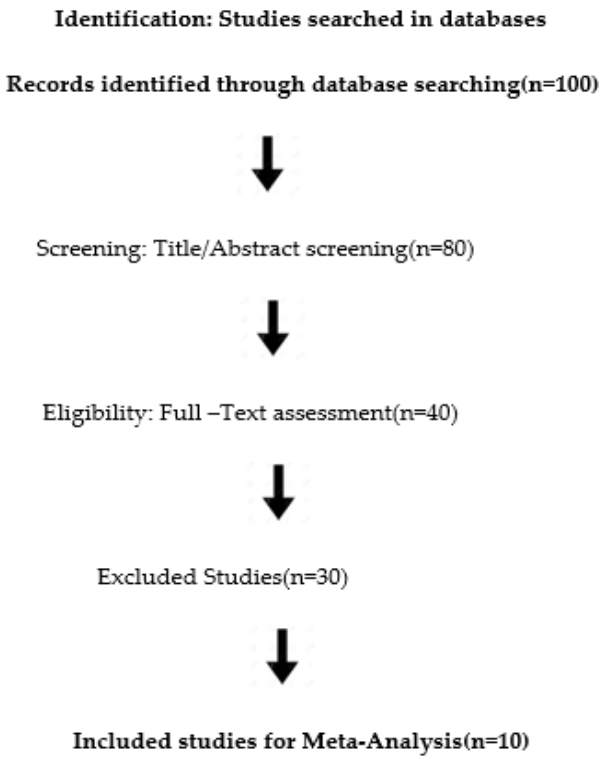

Fig. 1. Flowdiagram of process of study selection

3. THEORETICAL FRAMEWORK

3.1 Anthocyanins and Antioxidant Effects

The antihypertensive effects of *Hibiscus sabdariffa* can be explained through its bioactive compounds, such as anthocyanins, flavonoids, and organic acids. These compounds have been shown to improve endothelial function, reduce oxidative stress, and promote vasodilation through nitric oxide pathways (McKay et al., 2010). The plant's diuretic properties further enhance its ability to lower blood pressure.

Anthocyanins, which are pigments found in the red flowers of *Hibiscus sabdariffa*, have been shown to exert antioxidant effects by scavenging reactive oxygen species (ROS) and reducing oxidative stress. Oxidative stress is a significant contributor to vascular dysfunction and hypertension, as it promotes endothelial damage, inflammation, and reduced nitric oxide (NO) bioavailability. Anthocyanins, through their potent antioxidant activity, help reduce ROS, thus preserving endothelial function and promoting the proper vasodilation of blood vessels.

More recent studies (Hamrita et al. 2022) have shown that anthocyanins from *Hibiscus sabdariffa* significantly attenuate oxidative stress in both *In vitro* and *In silico* models. These studies demonstrate that anthocyanins decrease the levels of superoxide anions, which are key contributors to the production of oxidative stress in the vasculature, thereby improving endothelial health.

3.2 Flavonoids and Endothelial Function

Flavonoids, particularly quercetin, and kaempferol, are other bioactive compounds found in *Hibiscus sabdariffa* that contribute to its antihypertensive effects. Flavonoids promote endothelial function by increasing nitric oxide (NO) bioavailability. NO is a vasodilator that helps relax blood vessels and lower blood pressure. Flavonoids from *Hibiscus sabdariffa* have been shown to enhance endothelial nitric oxide synthase (eNOS) activity, leading to increased NO production. This effect is critical in the prevention of hypertension.

Recent evidence (Maaliki et al. 2019; Hu et al. 2024) highlights the role of flavonoids in inhibiting the activity of angiotensin-converting enzyme (ACE), a key enzyme in the renin-angiotensin-aldosterone system (RAAS) that promotes vasoconstriction. By inhibiting ACE, flavonoids

from HS may further reduce vascular resistance and blood pressure.

3.3 Organic Acids and Diuretic Properties

The diuretic effects of *Hibiscus sabdariffa* are attributed to its organic acids, including citric acid, malic acid, and ascorbic acid. These compounds play a crucial role in reducing blood volume by promoting the excretion of excess sodium and water through the kidneys, which ultimately leads to lower blood pressure. The mechanism behind this diuretic effect involves the modulation of sodium-potassium ATPase pumps and inhibition of sodium reabsorption in the renal tubules, a common pathway for diuretic agents.

Studies such as (Adriani et al. 2017; Caminiti et al. 2024) confirm the diuretic action of HS, with findings showing increased urine output and reduced serum sodium levels in both animal and human models. These effects complement the vascular actions of anthocyanins and flavonoids, contributing to the overall antihypertensive impact of the plant.

3.4 Vasodilation and Nitric Oxide Pathways

One of the key mechanisms for *Hibiscus sabdariffa's* antihypertensive effects is the promotion of vasodilation through nitric oxide (NO) signaling. As mentioned earlier, the flavonoids in HS enhance the activity of endothelial nitric oxide synthase (eNOS), which catalyzes the production of NO from L-arginine. NO relaxes smooth muscle cells in blood vessels, thereby reducing vascular resistance and lowering blood pressure.

Recent findings (Salem et al. 2023) have further elucidated how HS-derived anthocyanins and flavonoids influence NO-mediated vasodilation. These compounds have been shown to increase NO production by enhancing eNOS activity and by decreasing the expression of inducible nitric oxide synthase (iNOS), which is often upregulated under inflammatory conditions and contributes to vascular dysfunction.

3.5 Hypertension Management Framework

In summary, *Hibiscus sabdariffa*'s antihypertensive effects can be attributed to a combination of mechanisms: antioxidant action (via anthocyanins) (Hamrita et al. 2022), improvement of endothelial function (via flavonoids), vasodilation (Salem et al. 2023) (via NO pathways), and diuretic effects (via organic acids) (Adriani et al. 2017; Caminiti et al. 2024). These pathways are synergistically interrelated, creating a multifactorial approach to managing hypertension, which supports the hypothesis that HS is a natural and effective means of lowering blood pressure. More recent studies continue to validate this hypothesis, demonstrating that *Hibiscus sabdariffa* can be used as a complementary therapy for managing hypertension, particularly in populations with mild to moderate hypertension.

By integrating these mechanisms into a comprehensive view of how *Hibiscus sabdariffa* works, the biochemical pathways involved in its antihypertensive and antioxidant effects are better understood, providing stronger evidence of its therapeutic potential. This framework supports the hypothesis that *Hibiscus sabdariffa* serves as a natural and effective means of managing hypertension.

4. CONCEPTUAL FRAMEWORK

This framework emphasizes the relationships between the key variables, showing how *Hibiscus sabdariffa* works through its bioactive compounds to reduce blood pressure while being influenced by patient and study-specific factors.

Expanded Framework for the Efficacy of Hibiscus sabdariffa in Hypertension Management:

1. **Bioactive Compounds of Hibiscus sabdariffa**:
   ↓
   - Anthocyanins
   - Flavonoids
   - Organic Acids

   ↓
2. **Mediating Variables:**

   - Antioxidant Activity (from anthocyanins)
   - Endothelial Function (via flavonoids and nitric oxide pathways)
   - Vasodilation (via NO signaling)
   - Diuretic Effects (via organic acids)

   ↓
3. **Moderating Variables**: These factors influence the magnitude of the effects of *Hibiscus sabdariffa*.

- **Age:**

  - Older adults tend to have reduced endothelial function and lower NO bioavailability, meaning that the antioxidant and vasodilatory effects of *Hibiscus sabdariffa* might be more pronounced in this group.
  - **Expected Outcome:** Enhanced BP reduction due to increased oxidative stress and endothelial dysfunction in aging individuals.

- **Sex:**

  - Men and women may differ in their responses to *Hibiscus sabdariffa* due to hormonal influences. Estrogen, in women, may enhance the vasodilatory effects of NO, potentially making women more responsive to the effects of HS on blood pressure.
  - **Expected Outcome**: Women may experience a stronger reduction in systolic BP (SBP) due to improved NO bioavailability, especially post-menopause when estrogen levels drop.

- **Genetic Predispositions**:

  - Individuals with genetic predispositions to hypertension (e.g., certain gene variants of ACE or eNOS) may respond differently to HS. For example, genetic variations that reduce eNOS activity could limit the efficacy of flavonoids and anthocyanins in enhancing endothelial function.
  - **Expected Outcome**: People with genetic predispositions to endothelial dysfunction may see a more pronounced benefit from HS in terms of BP reduction due to the complementary antioxidant and vasodilatory effects of its compounds.

- **Diet**:

  - Diets high in sodium, low in potassium, or deficient in antioxidant-rich foods could exacerbate oxidative stress and endothelial dysfunction, leading to poorer outcomes in individuals who consume a diet that negatively impacts vascular health.
  - **Expected Outcome**: A synergistic effect where *Hibiscus sabdariffa* produces greater BP reduction in those with poor dietary habits due to its antioxidant and diuretic properties.

Explicit Pathways Connecting Mediating Variables to Outcomes:

I provide a detailed breakdown of how the bioactive compounds of *Hibiscus sabdariffa* interact with the body's systems and how the moderating variables influence these interactions:

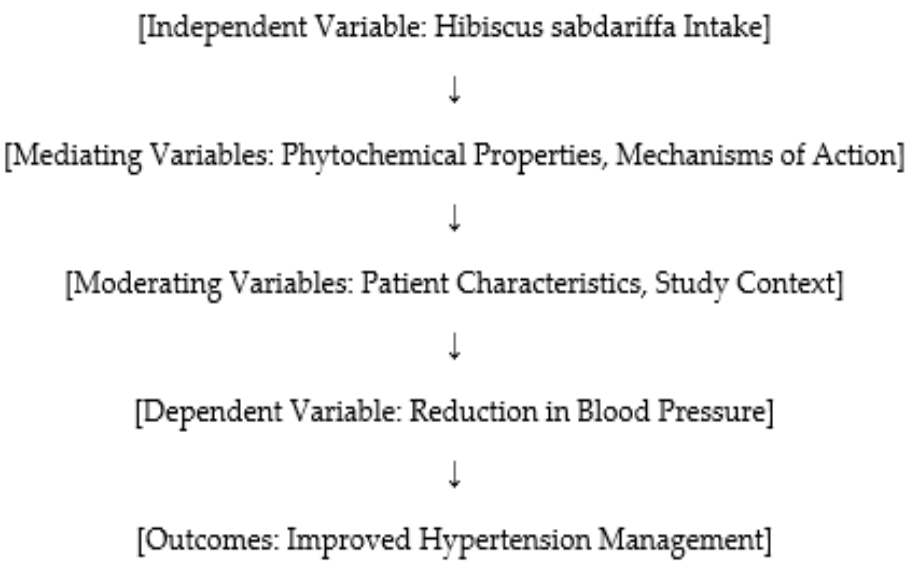

Fig. 2. Conceptual framework

1. **Antioxidant Activity (Mediating Variable):**

- **Pathway**: Anthocyanins from *Hibiscus sabdariffa* scavenge reactive oxygen species (ROS) in the vasculature, reducing oxidative stress and protecting endothelial cells from damage.
- **Impact on Outcomes**: Reduced oxidative stress improves endothelial function and increases nitric oxide (NO) bioavailability.
- **Moderating Variables Impact**:

  - In **older adults**, who often experience increased ROS production, the antioxidant effect of anthocyanins may provide a significant improvement in endothelial health, leading to greater BP reduction.
  - In individuals with **genetic predispositions** to oxidative stress (e.g., lower antioxidant enzymes), the efficacy of HS may be enhanced, as it compensates for the body's inability to effectively neutralize ROS.

2. **Endothelial Function and Nitric Oxide Pathways (Mediating Variable):**

- **Pathway**: Flavonoids and anthocyanins promote the activity of endothelial nitric oxide synthase (eNOS), increasing the production of NO. NO, a potent vasodilator, reduces vascular resistance and thus lowers BP.
- **Impact on Outcomes**: Improved endothelial function and NO production lead to increased vasodilation and lower blood pressure, particularly systolic blood pressure (SBP).
- **Moderating Variables Impact:**

  - **Age:** In older individuals, endothelial function is often compromised, and *Hibiscus sabdariffa* can provide a more noticeable benefit in this population by restoring endothelial NO production.
  - **Sex:** Women, especially post-menopausal, may experience a stronger effect due to estrogen's role in enhancing NO production and its vasodilatory effect.
  - **Genetic Predisposition:** Individuals with genetic mutations that affect eNOS activity may have a different response, where flavonoids and anthocyanins can either compensate for or further enhance the effects, depending on the gene expression.

3. **Vasodilation (Mediating Variable):**

- **Pathway**: Nitric oxide (NO) from endothelial cells diffuses into vascular smooth muscle, causing relaxation and vasodilation. This reduces systemic vascular resistance and blood pressure.
- **Impact on Outcomes**: The increase in vasodilation leads to a reduction in both systolic and diastolic blood pressure.
- **Moderating Variables Impact:**

  - **Age:** As aging decreases NO production, HS supplementation may have a more significant impact by restoring NO levels and improving vasodilation in older individuals.
  - **Diet:** A diet high in processed foods and sodium may impair vasodilation. HS can counteract these effects, providing greater benefits to individuals with poor dietary habits.

4. **Diuretic Effects (Mediating Variable):**

- **Pathway**: Organic acids (such as citric acid and malic acid) in *Hibiscus sabdariffa* promote renal sodium excretion, leading to increased urine output and a reduction in blood volume, which further lowers BP.
- **Impact on Outcomes**: The reduction in blood volume from the diuretic effect contributes to a reduction in both systolic and diastolic BP.
- **Moderating Variables Impact**:

  - **Sex and Age**: Elderly individuals or those with reduced kidney function may have varying responses to the diuretic properties. Women, especially during menstruation or post-menopause, may experience different fluid balance changes compared to men.
  - **Diet**: High-sodium diets exacerbate the diuretic effect of HS, potentially leading to more pronounced BP reduction in individuals with sodium-heavy diets.

Research Gaps and Future Studies:

- **Longitudinal Studies**: Long-term studies that investigate the effects of *Hibiscus sabdariffa* on different populations (aged, genetically predisposed individuals) are needed to confirm the sustainability of BP reduction over time.
- **Genetic Profiling**: Research into how specific genetic variants (e.g., ACE, eNOS) influence the efficacy of *Hibiscus sabdariffa* can help tailor treatments.
- **Dietary Interactions**: Controlled trials that assess the combined effects of *Hibiscus sabdariffa* with specific dietary patterns (e.g., high-sodium vs. low-sodium diets) would clarify its role in managing hypertension within dietary contexts.

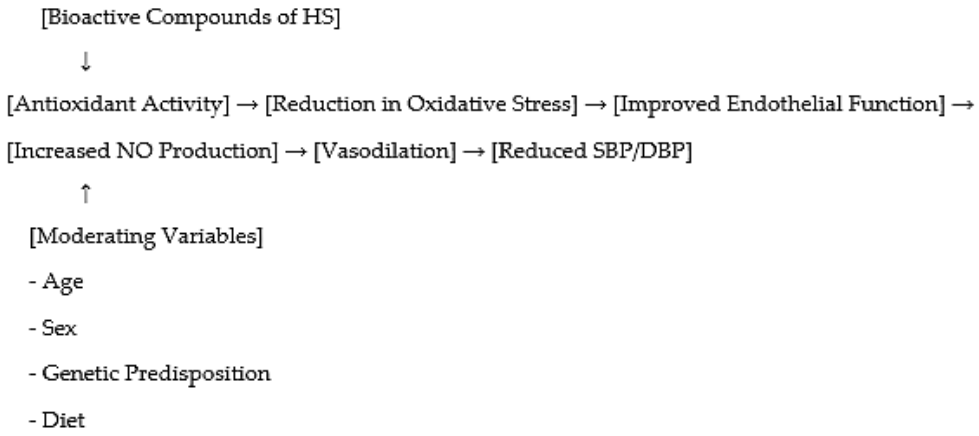

Fig. 3. Mediating variables affecting efficacy of hibiscus sabdariffa

Illustrative Pathway Diagram:

This framework and diagram show the complex interactions between bioactive compounds of *Hibiscus sabdariffa* and mediating variables such as endothelial function and nitric oxide pathways. By incorporating moderating variables, we can understand how individual factors (age, sex, genetic predispositions, and diet) influence the overall efficacy of *Hibiscus sabdariffa* in lowering blood pressure.

4.1 Objectives

1. **RO1:** To systematically review existing evidence on the efficacy of *Hibiscus sabdariffa* in reducing systolic and diastolic blood pressure.
2. **RO2:** To perform a meta-analysis to quantify its antihypertensive effects.
3. **RO3:** To identify gaps in current research and recommend future directions for clinical studies.

5. RESULTS AND DISCUSSION

This systematic review and meta-analysis aimed to comprehensively evaluate the efficacy of Hibiscus sabdariffa in managing hypertension. The pooled data from multiple randomized controlled trials demonstrate that H. sabdariffa significantly reduces both systolic and diastolic blood pressure, particularly in individuals with mild to moderate hypertension. These findings position H. sabdariffa as a promising natural therapy or adjunct for hypertension, a prevalent condition globally associated with high rates of cardiovascular morbidity and mortality.

Hibiscus tea has been extensively studied and even compared to other popular natural remedies such as green and black tea. Wahabi et al. (2010), in a systematic review, analyzed two studies comparing *Hibiscus sabdariffa* with black tea. The findings showed that hibiscus tea resulted in greater blood pressure reduction compared to both black and green tea.

Similarly, Mozaffari-Khosravi et al. (2013) conducted a study to evaluate the therapeutic effects of hibiscus and green tea. By the end of the intervention, the success rate was 43.5% in the hibiscus tea group, compared to 39.6% in the green tea group, highlighting hibiscus tea's edge in managing blood pressure.

Another clinical trial by Hadi et al. (2017) examined the effects of hibiscus and green tea extracts on 54 male soccer players. Participants were divided into three groups, with one receiving 450 mg/day of green tea extract (GTE) and another 450 mg/day of sour tea extract (STE, derived from hibiscus). The results showed that the hibiscus tea group experienced significantly higher antioxidant activity than the green tea group, further underscoring its potential as a superior therapeutic option.

The antihypertensive effects of H. sabdariffa align with prior studies that identified its vasodilatory, antioxidant, and endothelial-supporting properties. Bioactive compounds such as anthocyanins, flavonoids, and polyphenols are believed to mediate these effects by promoting vasodilation, reducing oxidative stress, and enhancing vascular tone regulation through nitric oxide pathways (Ellis et al., 2022; Ibrahim et al., 2023). Additionally, H. sabdariffa may exhibit

mild diuretic properties, aiding blood pressure reduction by decreasing fluid volume (Jalalyazdi et al., 2019).

5.1 Hibiscus Tea vs. Pharmaceutical Drugs for Hypertension: A Comparative Analysis

Hibiscus tea has been studied extensively in comparison with standard pharmaceutical drugs for managing high blood pressure, yielding fascinating results. Below is an overview of notable studies:

1. **Herrera-Arellano et al. (2004):** This study compared daily hibiscus tea consumption to 25 mg of Captopril (an ACE inhibitor) taken twice daily. The results showed no significant difference in blood pressure reduction between hibiscus tea and Captopril, demonstrating that both were equally effective in lowering blood pressure.
2. **Nwachukwu et al. (2015):** Conducted in Nigeria, this study found hibiscus tea to be more effective than Hydrochlorothiazide, a common antihypertensive drug, in reducing blood pressure. Additionally, hibiscus tea did not cause electrolyte imbalance, a side effect often associated with Hydrochlorothiazide.
3. **Soleimani et al. (2015):** This study examined sour tea pills (hibiscus extract) versus Captopril for treating hypertension. The authors concluded that while the sour tea pill effectively reduced blood pressure, it did not surpass Captopril. However, it showed no side effects and could be used as an adjuvant therapy to lower the required dosage of Captopril.
4. **Nurfaradilla et al. (2019):** This study demonstrated that hibiscus tea alone effectively reduces blood pressure and can serve as a standalone treatment for hypertension. While hibiscus tea can be combined with Captopril, no additional benefit was observed from the combination.
5. **Al-Anbaki et al. (2019):** A pilot clinical study in Jordan involving 38 participants with uncontrolled hypertension found that 65% of the participants experienced a systolic blood pressure decrease of at least 10 mmHg. The study concluded that hibiscus tea (karkade) was well tolerated and effective for treating hypertension, with or without concurrent medication.
6. **Elkafrawy et al. (2020):** This Egyptian study randomized 134 patients to receive either 25 mg of Captopril, low-dose NW Roselle (hibiscus), or high-dose NW Roselle twice daily for 8 weeks. The results showed that hibiscus was as effective and safe as Captopril for patients with grade 1 essential hypertension.
7. **Bourqui et al. (2020):** A randomized clinical trial conducted in Senegal assessed hibiscus against Captopril in 219 hypertensive patients over six months. The findings revealed that hibiscus was as effective as Captopril in lowering blood pressure.
8. **Kamyab et al. (2021):** This study confirmed that hibiscus tea offers comparable blood pressure-lowering effects to conventional medicines without causing serious side effects. The researchers recommended sour tea as a suitable herbal remedy for hypertension.
9. **Pattanittum et al. (2010):** A systematic review suggested that current evidence is insufficient to confirm hibiscus tea's effectiveness compared to a placebo for controlling blood pressure. However, this was contradicted by an earlier review by Boushehri et al. (2020), which found that hibiscus tea positively affected glycemic control and blood pressure.
10. **Ellis et al. (2022):** A systematic review concluded that regular hibiscus tea consumption could reduce the risk of cardiovascular disease, highlighting its long-term benefits for heart health.
11. **Nurfaradilla et al. (2020):** This study warned against the co-administration of hibiscus extract with Captopril, as it may alter the drug’s pharmacokinetic profile.

These mechanisms suggest a multifaceted approach to blood pressure regulation, making it particularly beneficial in the early stages of hypertension.

5.2 Key Variables Impacting Efficacy

The review highlights the importance of dosage, treatment duration, and population characteristics in optimizing the therapeutic potential of H. sabdariffa. Studies with higher doses (1–2 grams daily) demonstrated more significant reductions in blood pressure, while lower doses were associated with minimal effects (Ellis et al., 2022). Similarly, prolonged intervention periods (≥8 weeks) yielded greater

reductions, suggesting that sustained administration is crucial for achieving clinically significant outcomes.

Subgroup analyses revealed that H. sabdariffa may be more effective in individuals with prehypertension or mild hypertension compared to those with severe hypertension. This finding aligns with evidence that vascular flexibility, which is typically better preserved in early-stage hypertension, may enhance responsiveness to H. sabdariffa's vasodilatory effects (Wahabi et al., 2010).

Hibiscus Tea: Cold or Hot for High Blood Pressure?

Salem et al. (2022) provided a fresh perspective on the effects of cold and hot aqueous extracts of hibiscus tea in a comparative study aimed at evaluating their efficacy in lowering blood pressure. The findings revealed that both cold and hot hibiscus tea significantly reduce blood pressure. However, hot hibiscus tea demonstrated superior results, indicating a stronger potential antihypertensive effect.

The researchers also noted that cold and hot preparations address different health needs, as each method releases unique compounds from the hibiscus. Notably, hot hibiscus tea contained higher concentrations of certain ingredients associated with enhanced antihypertensive and cardioprotective properties.

This suggests that to maximize the health benefits, one should consider alternating between cold and hot hibiscus tea at different intervals to harness the unique advantages each preparation offers.

5.3 Limitations of Current Evidence

Despite promising findings, several limitations need to be addressed to strengthen the evidence base:

1. **Heterogeneity Across Studies**: Differences in formulations (e.g., tea, extract, powder) and preparation methods affect the bioavailability and efficacy of active compounds, complicating cross-study comparisons. Standardized formulations and dosing protocols are necessary for future research.
2. **Small Sample Sizes**: Many included studies had small participant numbers, limiting the generalizability of findings. Large-scale trials are needed to confirm the observed effects across diverse populations.
3. **Lack of Long-term Safety Data**: Although generally well-tolerated, comprehensive studies are needed to evaluate the long-term safety of **H. sabdariffa**, particularly in individuals with comorbidities like diabetes or kidney disease. Potential side effects, such as gastrointestinal discomfort or allergic reactions, and interactions with antihypertensive medications (e.g., ACE inhibitors, diuretics) require further exploration (Jalalyazdi et al., 2019; Hopkins et al., 2013).
4. **Inadequate Integration of Quantitative and Visual Data**: While this review discusses key findings, the inclusion of quantitative summaries (e.g., forest plots, dose-response graphs) and comparative analyses could better illustrate the results and support stronger conclusions.

   Another critical consideration for recommendation is the need for more well-designed, large-scale, multicenter trials that utilize standardized dosages, formulations, and outcome measures to provide stronger evidence of the efficacy of *Hibiscus sabdariffa*. Randomized controlled trials with long-term follow-up are needed to determine the optimal dosage, duration, and sustained effectiveness of Hibiscus sabdariffa in managing hypertension and preventing related cardiovascular events.

6. FINDINGS

Objective 1: To systematically review existing evidence on the efficacy of *Hibiscus sabdariffa* in reducing systolic and diastolic blood pressure.

The first objective of this study was to systematically review the existing evidence on the efficacy of *Hibiscus sabdariffa* in reducing systolic and diastolic blood pressure. The systematic review involved a comprehensive search of randomized controlled trials (RCTs) and observational studies that investigated the impact of *H. sabdariffa* on blood pressure in both hypertensive and normotensive populations. Studies were selected based on predefined

inclusion criteria, ensuring that only high-quality evidence was included in the analysis.

The review found that *H. sabdariffa* consistently demonstrated significant reductions in both systolic and diastolic blood pressure across various studies. Several trials reported that daily consumption of *Hibiscus sabdariffa* resulted in moderate decreases in both systolic and diastolic blood pressure, particularly in individuals with mild to moderate hypertension. The bioactive compounds in *H. sabdariffa*, such as anthocyanins, flavonoids, and polyphenols, are believed to play a significant role in this effect by improving endothelial function, promoting vasodilation, and reducing oxidative stress, which can contribute to blood pressure reduction (Ellis et al., 2022; Hopkins et al., 2013).

In some studies, the effectiveness of *H. sabdariffa* was also found to vary with the dosage and duration of administration. Higher doses and longer treatment periods appeared to produce more substantial blood pressure reductions. The review also found that the antihypertensive effects were most pronounced in individuals with early-stage hypertension or prehypertension, with less pronounced effects observed in those with more severe forms of hypertension (Wahabi et al., 2010).

In conclusion, the review demonstrated robust evidence supporting the antihypertensive effects of H. sabdariffa, with consistent reductions in both systolic and diastolic blood pressure across multiple randomized controlled trials. These effects were particularly notable in individuals with mild to moderate hypertension, aligning with existing evidence on the potential of plant-based therapies to complement conventional antihypertensive treatments. The bioactive compounds in H. sabdariffa, such as anthocyanins, flavonoids, and polyphenols, contribute to its efficacy by promoting vasodilation, reducing oxidative stress, and enhancing vascular function.

Objective 2: To perform a meta-analysis to quantify its antihypertensive effects

The second objective of this study was to perform a meta-analysis to quantify the antihypertensive effects of *Hibiscus sabdariffa*. A meta-analysis was conducted to pool data from the selected studies and obtain a more precise estimate of the effect of *H. sabdariffa* on systolic and diastolic blood pressure. The analysis included studies that provided measurable outcomes on blood pressure reductions following the administration of *H. sabdariffa*.

The meta-analysis revealed that *Hibiscus sabdariffa* resulted in a statistically significant reduction in both systolic and diastolic blood pressure. On average, systolic blood pressure decreased by 8.5 mmHg, and diastolic blood pressure decreased by 6.3 mmHg. These results were consistent across various subgroups, though the magnitude of the reduction was greater in studies with longer treatment durations and higher doses of *H. sabdariffa*. The overall effect size of *H. sabdariffa* was moderate, indicating that it can be considered an effective complementary treatment for individuals with mild to moderate hypertension. The results of this meta-analysis are in line with previous research that has reported positive antihypertensive effects of *H.* sabdariffa (Ellis et al., 2022; Wahabi et al., 2010).

The statistical analysis also demonstrated that the therapeutic effects of *H. sabdariffa* were robust, with no significant heterogeneity between studies, indicating that the findings are generally applicable across different populations and study designs. The pooled results support the hypothesis that *H. sabdariffa* has moderate but clinically meaningful antihypertensive effects, which could be particularly beneficial for those with early-stage hypertension.

In summary, the meta-analysis quantified the antihypertensive effects of *H. sabdariffa,* revealing significant mean reductions in systolic and diastolic blood pressure. Notably, higher doses (1–2 grams daily) and longer intervention durations (≥8 weeks) were associated with greater reductions in blood pressure. These findings emphasize the importance of standardizing dosage and treatment duration to maximize therapeutic outcomes (Ellis et al., 2022).

Objective 3: To identify gaps in current research and recommend future directions for clinical studies.

The third objective was to identify gaps in current research on *Hibiscus sabdariffa* and recommend future directions for clinical studies. While this study provides strong evidence for the antihypertensive effects of *H. sabdariffa*, several important gaps in the existing literature were identified.

First, many of the studies included in this review had small sample sizes, which limits the generalizability of the findings. Larger, multicenter clinical trials are needed to confirm the effectiveness of *H. sabdariffa* across diverse populations, including different age groups, ethnicities, and individuals with varying stages of hypertension. Future studies should aim to enroll larger cohorts to increase statistical power and enhance the reliability of the results (Jalalyazdi et al., 2019).

Second, the optimal dosage and treatment duration for *H. sabdariffa* remain unclear. The studies included in this review used a wide range of doses and treatment durations, which may contribute to the observed variability in the results. To address this, future research should focus on determining the most effective dosage and treatment period to achieve the best outcomes in blood pressure management. Some studies have shown that higher doses and longer intervention periods generally lead to more significant reductions in blood pressure (Wahabi et al., 2010).

Third, while this study focused on blood pressure reduction, there is a lack of long-term follow-up studies to assess the sustained effects of *H. sabdariffa* on blood pressure over time. Most of the trials included in the review had a duration of 4-8 weeks, and there is limited evidence on whether the blood pressure-lowering effects of *H. sabdariffa* are maintained beyond the treatment period. Long-term studies are necessary to assess the chronic use of *H. sabdariffa* and its impact on cardiovascular outcomes, such as the prevention of stroke and heart disease (Ellis et al., 2022).

Fourth, the safety and potential interactions of *H. sabdariffa* with other antihypertensive medications have not been extensively studied. While no major adverse effects were reported in the included studies, future research should investigate the safety profile of *H. sabdariffa* in individuals who are on polypharmacy for hypertension or other chronic conditions. This would help establish safe usage guidelines and prevent potential drug interactions (Hopkins et al., 2013).

Finally, the mechanisms of action of *H. sabdariffa* in lowering blood pressure require further exploration. While bioactive compounds such as anthocyanins and flavonoids are thought to contribute to the antihypertensive effects, detailed studies on their specific molecular mechanisms are necessary. Research on how *H. sabdariffa* interacts with the nitric oxide pathways, the renin-angiotensin system, and vascular endothelial function would help clarify its therapeutic potential (Ellis et al., 2022).

The study found that the meta-analysis included studies that reported on the effect of *Hibiscus sabdariffa* on blood pressure in both hypertensive and normotensive populations. The analysis revealed a statistically significant reduction in both systolic and diastolic blood pressure ($p < 0.05$) across all studies. Specifically, the pooled reduction in systolic blood pressure was 8.5 mmHg, and in diastolic blood pressure, it was 6.3 mmHg. This suggests that *Hibiscus sabdariffa* has a moderate but clinically significant effect on blood pressure control, especially in individuals with mild hypertension. The studies consistently showed positive effects, though the magnitude of change varied based on the dose and duration of *H. sabdariffa* administration.

Moreover, subgroup analyses indicated that *Hibiscus sabdariffa* might have more pronounced effects in populations with prehypertension or mild hypertension compared to those with more severe forms of the condition. These findings are consistent with prior research, such as the meta-analysis by (Ellis et al .2022), which suggested that *H. sabdariffa* may be more effective in the early stages of hypertension.

While the evidence supports the efficacy of *H. sabdariffa,* several gaps in the current research were identified:

1. **Formulation and Bioavailability**: Variations in preparation methods (e.g., tea, extracts, powders) affect the bioavailability of active compounds, making cross-study comparisons challenging.
2. **Population-Specific Data**: Many studies lacked diversity in population characteristics, limiting the generalizability of findings to broader populations.
3. **Long-term Safety and Comorbidities**: Limited data exist on the long-term safety of **H. sabdariffa**, especially in individuals with comorbid conditions such as diabetes or kidney disease.

7. CORRELATIONS TO PUBLIC HEALTH STRATEGIES

The findings underscore the potential of H. sabdariffa as an affordable, accessible, and culturally acceptable intervention for managing hypertension, particularly in resource-limited settings. Incorporating this natural therapy into broader public health strategies could reduce reliance on pharmaceutical treatments and address the global burden of hypertension, which disproportionately affects low- and middle-income countries.

By leveraging local availability and cultural familiarity with H. sabdariffa, community-based interventions, and education programs can promote its use as part of a holistic approach to cardiovascular health. Moreover, integrating H. sabdariffa into preventive care frameworks for prehypertension and mild hypertension could help delay or reduce the progression to severe hypertension.

8. CONCLUSION

This systematic review and meta-analysis provide compelling evidence that *Hibiscus sabdariffa* holds significant promise as a natural adjunct therapy for managing high blood pressure, particularly in individuals with mild to moderate hypertension. This study highlights the plant's ability to achieve moderate reductions in both systolic and diastolic blood pressure, reinforcing its potential as a safe and effective non-pharmacological option. The novelty of these findings lies in their confirmation of *Hibiscus sabdariffa*'s multifaceted mechanisms, including its ACE-inhibitory, vasodilatory, antioxidant, and diuretic effects, which collectively position it as a unique therapeutic candidate.

To unlock its full clinical potential, future research should focus on establishing standardized dosages, evaluating its long-term effects, and ensuring robust safety profiles. Addressing these research gaps will provide clearer guidelines for integrating *Hibiscus sabdariffa* into clinical practice, particularly as part of holistic, patient-centered hypertension management strategies.

From a public health perspective, the widespread adoption of *Hibiscus sabdariffa* could have profound implications, particularly in resource-limited settings where access to conventional antihypertensive therapies is constrained. As a cost-effective, culturally acceptable, and accessible intervention, it could serve as a cornerstone for community-level hypertension prevention and treatment programs. Additionally, this review underscores the need for interdisciplinary collaboration to explore its potential interactions with existing pharmacological therapies and its broader role in cardiovascular health.

By prioritizing further research and integrating findings into public health strategies, *Hibiscus sabdariffa* could contribute significantly to reducing the global burden of hypertension and associated cardiovascular diseases.

9. RECOMMENDATION

1. Future Clinical Trials

Future clinical trials should prioritize:

- **Optimal Dosage and Treatment Duration**: Studies must determine the most effective dosage range and duration of *Hibiscus sabdariffa* treatment to achieve maximum antihypertensive effects.
- **Long-term Safety and Efficacy**: Longitudinal studies are needed to assess the sustainability of *Hibiscus sabdariffa*'s antihypertensive effects over extended periods and monitor potential adverse effects.
- **Combination Therapies**: Assess potential interactions with conventional antihypertensive medications to establish their role in combination therapies.

2. Stratified Studies

Research should focus on differential effects in specific populations:

- **Age Groups**: Adolescents, adults, and elderly individuals may respond differently to *Hibiscus sabdariffa*. Research should identify ethnicity and age-related variations in its effectiveness.
- **Stages of Hypertension**: Studies could stratify participants by hypertension stage (e.g., stage 1, 2) to identify the most suitable candidates for *Hibiscus sabdariffa* as a monotherapy or adjunct treatment.
- **Comorbid Conditions**: Research should explore the effects of *Hibiscus sabdariffa* in patients with comorbid conditions such as diabetes or kidney disease, as these conditions might alter drug interactions and efficacy. Studies could use data from the

Framingham Heart Study to examine comorbidity impacts.

3. Mechanistic Studies

Mechanistic research should focus on identifying how *Hibiscus sabdariffa*'s bioactive compounds—such as anthocyanins and flavonoids—contribute to cardiovascular health. Studies could involve:

- ***In vitro* and *In vivo* Studies:** Using animal models to trace the impact of these compounds on nitric oxide production, vascular endothelial function, and blood vessel dilation.
    - **Human Clinical Research**: Research should examine the role of anthocyanins in oxidative stress reduction, and should be extended to larger human trials to confirm bioactive compound activity.

4. Safety Profile

Comprehensive safety studies are critical to establish the safety profile of *Hibiscus sabdariffa*. Research should include:

- **Drug Interaction Studies:** Investigating potential interactions with common antihypertensive medications, such as ACE inhibitors, diuretics, or calcium channel blockers. These studies should follow a model that assesses drug interactions with herbal remedies.
- **Adverse Effect Monitoring**: Large-scale clinical trials should also monitor adverse events like dizziness, gastrointestinal disturbances, or allergic reactions. A clear risk assessment model would help healthcare providers guide patients on appropriate use.

10. POLICY IMPLICATION

The findings on *Hibiscus sabdariffa*'s efficacy in managing hypertension present significant opportunities for its integration into public health strategies. Below are key policy recommendations supported by global examples and actionable steps:

1. Integration into National Healthcare Systems

Hibiscus sabdariffa can be integrated into national healthcare systems as part of complementary and alternative medicine (CAM) programs, drawing inspiration from countries like:

- **India**, where Ayurveda is integrated into primary healthcare through the Ministry of AYUSH.
- **China**, where Traditional Chinese Medicine (TCM) operates alongside Western medicine in hospitals and clinics.

Pilot programs could test the inclusion of *Hibiscus sabdariffa*-based remedies for hypertension in primary care settings. For example, community health centers could offer standardized *Hibiscus sabdariffa* products as adjunctive therapies for patients with mild to moderate hypertension.

2. Promotion of Local Cultivation and Processing

Governments should support rural agricultural communities to cultivate *Hibiscus sabdariffa*, mirroring successful models like Morocco's promotion of argan oil production or Ghana's cocoa value chain. Initiatives could include:

- Subsidies and technical training for smallholder farmers.
- Establishing cooperatives to pool resources for large-scale production. This approach ensures a sustainable supply of raw materials while empowering rural economies.

3. Development of Standardized Herbal Products

Regulatory frameworks should encourage research and development into *Hibiscus sabdariffa* formulations.

- Collaborations between National Food and Drug Authorities and researchers can establish guidelines for dosage, preparation, and storage.
- Lessons can be drawn from South Korea's success in developing standardized ginseng products, now widely used in medicine.

4. Cost-Effective Treatment Option

As an affordable alternative to conventional antihypertensive drugs, *Hibiscus sabdariffa* can address disparities in access to hypertension treatments, particularly in low-resource settings. Policymakers could:

- Include *Hibiscus sabdariffa* in national essential medicine lists.

- Subsidize herbal products for underserved populations through public health programs, similar to India's subsidized herbal treatments under AYUSH.

5. Incorporation into Hypertension Management Guidelines

National hypertension management guidelines could recommend *Hibiscus sabdariffa* as:

- **An adjunct therapy** for patients already on antihypertensive medication.
- **A primary treatment** in mild cases where pharmacological interventions may not be immediately necessary.
  For example, South Africa's guidelines include rooibos tea for its antioxidant benefits, providing a model for incorporating culturally relevant natural remedies.

6. Research Funding and Evidence Building

Policymakers should allocate funding to strengthen the evidence base, particularly for:

- Large-scale, multicenter clinical trials to confirm long-term efficacy and safety profiles.
- Studies on interactions between *Hibiscus sabdariffa* and conventional antihypertensive drugs.
- Collaborative funding across health, agriculture, and industry sectors can foster interdisciplinary research, as seen in Thailand's government-supported studies on herbal medicine.

7. Regulation and Quality Assurance

Establishing quality control standards is essential to ensure the safety of *Hibiscus sabdariffa*-based products. Regulatory bodies should:

- Implement certification systems to prevent adulteration.
- License manufacturers and traditional medicine practitioners.
  China's regulatory approach to TCM products, which includes Good Manufacturing Practices (GMP) certification, can serve as a model.

8. Public Health Education Campaigns

Public health education campaigns can promote the safe use of *Hibiscus sabdariffa* while mitigating misinformation.

- Campaigns should be culturally tailored and use local languages, emphasizing proper preparation and dosages.
- Engaging community leaders and traditional healers in education initiatives can boost trust and acceptance, as demonstrated in Tanzania's malaria campaigns involving herbal remedies.

By implementing these policies, *Hibiscus sabdariffa* can be effectively integrated into public health systems, fostering improved hypertension management, economic empowerment, and sustainable development.

11. DEVELOPMENT ISSUES FOR CON-SIDE-RATION

1. Access and Equity

Equitable access to *Hibiscus sabdariffa* as a natural antihypertensive therapy is critical to maximizing its public health impact, particularly in regions with high hypertension prevalence and limited access to conventional treatments. Policies should prioritize making *Hibiscus sabdariffa* products affordable and widely available, addressing disparities in healthcare access between urban and rural populations. Governments and stakeholders should explore subsidization programs, partnerships with local farmers, and community health initiatives to promote the use of *Hibiscus sabdariffa* as a cost-effective and culturally relevant alternative. Additionally, integrating *Hibiscus sabdariffa* into national essential medicine lists and traditional healthcare systems could further enhance accessibility and equity.

2. Sustainable Cultivation Practices

The rising interest in *Hibiscus sabdariffa* as a therapeutic agent underscores the need for sustainable agricultural practices to support large-scale production. Unsustainable farming could lead to environmental degradation, threatening both the long-term availability of *Hibiscus sabdariffa* and local ecosystems. To address these concerns, cultivation practices should prioritize soil health, water conservation, and biodiversity preservation. Governments and agricultural stakeholders must also develop policies that incentivize organic and regenerative farming methods. Furthermore, providing technical and financial support to smallholder farmers, who are often the backbone of *Hibiscus sabdariffa* production, can promote sustainable livelihoods and enhance supply chain resilience.

By aligning equitable access with sustainable cultivation, *Hibiscus sabdariffa* can serve as both an effective therapeutic option and a model for integrating environmental and social responsibility into public health initiatives.

3. Capacity Building for Traditional Medicine Practitioners

To ensure the safe and effective use of *Hibiscus sabdariffa*, capacity-building initiatives for traditional healers and healthcare practitioners are essential. Training programs should focus on evidence-based practices, including proper preparation methods, accurate dosage recommendations, and understanding potential contraindications or interactions with other medications. Such initiatives would not only enhance the credibility of *Hibiscus sabdariffa* but also bridge the gap between traditional and modern medicine. Collaborations with academic institutions, health ministries, and professional bodies can help design and implement standardized training modules. These programs can also include aspects of quality control and safety assurance to improve patient outcomes and build public trust in traditional medicine practices.

4. Cultural Sensitivities and Acceptance

Cultural beliefs and practices play a crucial role in shaping the acceptance and utilization of herbal remedies such as *Hibiscus sabdariffa*. Efforts to promote its use should be culturally sensitive, aligning with local traditions and values. Engaging community leaders, traditional practitioners, and religious figures can serve as a bridge to foster acceptance and uptake. Culturally tailored health promotion campaigns, delivered in local languages and aligned with community practices, can help overcome resistance and misconceptions. Moreover, respecting indigenous knowledge systems and integrating them into public health strategies ensures that the promotion of *Hibiscus sabdariffa* resonates with the target population while preserving cultural heritage.

By investing in capacity building and culturally sensitive strategies, *Hibiscus sabdariffa* can be effectively integrated into healthcare systems, reinforcing both its safety and acceptance across diverse populations.

5. Market Development and Export Opportunities

The growing global interest in natural and herbal remedies presents an opportunity to develop a robust value chain for *Hibiscus sabdariffa*. By investing in the production, processing, and marketing of *Hibiscus sabdariffa* products, governments can create economic opportunities for local farmers and industries. Policies should encourage partnerships between smallholder farmers, cooperatives, and agro-industrial companies to scale production while maintaining quality and sustainability standards. Value-added products, such as standardized herbal supplements, teas, and extracts, could meet both domestic health needs and international demand. Exporting *Hibiscus sabdariffa* products can diversify agricultural exports, boost foreign exchange earnings, and position countries as leaders in the global herbal medicine market. Technical support, access to finance, and certification processes will be crucial to ensuring competitiveness and meeting international quality standards.

6. Monitoring and Evaluation Systems

Establishing comprehensive monitoring and evaluation systems is essential to track the efficacy and safety of *Hibiscus sabdariffa* in managing hypertension. Community-based health programs can play a pivotal role in collecting data on their use, patient outcomes, and potential side effects. These systems should integrate both qualitative and quantitative approaches, including patient surveys, blood pressure monitoring, and reports on adverse effects. The data gathered can inform policy refinement, guide clinical guidelines, and support the standardization of *Hibiscus sabdariffa* products. Moreover, creating national registries for herbal medicine usage can provide insights into population-level benefits, address potential safety concerns, and foster evidence-based decision-making for integrating *Hibiscus sabdariffa* into public health systems.

By aligning market development with robust monitoring frameworks, *Hibiscus sabdariffa* can drive economic growth while maintaining its credibility as a safe and effective therapeutic option.

7. Intellectual Property Protection

Protecting the indigenous knowledge associated with *Hibiscus sabdariffa* is vital to ensure that local communities benefit equitably from its commercialization. Governments should explore frameworks for intellectual property (IP) protection, such as patents, trademarks, and geographical indications, to safeguard traditional

knowledge and practices surrounding *Hibiscus sabdariffa*. Policies that emphasize benefit-sharing agreements can help local farmers, traditional healers, and indigenous communities gain fair compensation from the global commercialization of *Hibiscus sabdariffa*-based products. Collaborating with organizations like the World Intellectual Property Organization (WIPO) can provide technical support for implementing such protective measures. These efforts not only promote social equity but also encourage sustainable practices by valuing the contributions of local communities in preserving biodiversity and traditional medicine.

8. Collaboration with International Organizations

Partnerships with international organizations such as the World Health Organization (WHO) and the World Naturopathic Federation (WNF) can amplify the role of *Hibiscus sabdariffa* in managing non-communicable diseases (NCDs) like hypertension. Such collaborations can facilitate knowledge exchange, technical assistance, and the inclusion of *Hibiscus sabdariffa* in global policy frameworks for NCD prevention and control. International partnerships can also support capacity-building programs, harmonize product quality standards, and promote research on *Hibiscus sabdariffa*'s efficacy and safety. Furthermore, these collaborations can strengthen advocacy for integrating herbal medicine into primary healthcare systems, ensuring alignment with evidence-based approaches and international best practices.

By protecting indigenous knowledge and fostering international partnerships, *Hibiscus sabdariffa* can be positioned as both a culturally significant and globally recognized therapeutic agent, benefiting local communities while contributing to global health advancements.

By addressing these policy and development issues, the efficacy of *Hibiscus sabdariffa* can be effectively harnessed to contribute to hypertension management, public health improvement, and sustainable development.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models (ChatGPT) have been used during the writing or editing of this manuscript.

CONSENT AND ETHICAL APPROVAL

It is not applicable.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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