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A Review of the Phytochemical Composition and Antihypertensive Efficacy of Garlic (*Allium sativum*), Hibiscus (*Hibiscus sabdariffa*), and Ginger (*Zingiber officinale*)

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Abstract

Garlic (*Allium sativum*) and Hibiscus (*Hibiscus sabdariffa*) have been well known in conventional medicine and hold great promise not only to treat but to prevent the development of hypertension, while Ginger (*Zingiber officinale*) is gaining more attention in herbal circles. In this review, we present the phytochemical composition, antihypertensive effectiveness, and the mechanisms of actions of these natural remedies, with the implications in the clinical setting, also explored. Garlic is abundant in organosulfur compounds, with allicin being the most notable. These have been shown to contribute to vasodilatory effects and are associated with a numerical reduction in blood pressure. Hibiscus calyces carry in themselves anthocyanins and protocatechuic acid, which are associated with antioxidant activities and vasorelaxation properties that could act as a blood pressure regulator. The action mechanism of gingerols and shogaols, active components in ginger, suggests their possible role in strengthening blood circulation and causing the antihypertensive effect. A detailed reading of the currently available literature strongly indicates the potency of these herbs in fighting hypertension. Random clinical trials (RCTs) have demonstrated that garlic intake can bring about a modest - yet not great - reduction in blood pressure, whereas hibiscus extracts have shown diuretic, and Angiotensin-converting Enzyme (ACE) -inhibitory effects, both in animal and human experiments. Furthermore, ginger supplementation has improved blood pressure parameters, although the consensus is not as solid as those mentioned above. However, despite increased scientific evidence concerning their efficacy on health, some hurdles still exist. These challenges consist of variability in phytochemical composition, dosage standardization, poor knowledge of mechanisms, drug interactions, and safety considerations that need to be addressed through further scientific investigation. Garlic (*Allium sativum*), ginger (*Zingiber officinale*), and hibiscus (*Hibiscus sabdariffa*) have been used since ancient times to treat hypertension. Continued research efforts are needed to overcome these challenges to provide comprehensive therapeutic potentials and ensure safe uses in clinics for garlic, hibiscus and ginger as natural interventions for hypertension management.

Keywords: Phytochemicals, Angiotensin-converting Enzyme, Antihypertensive, Vasodilatory, Anthocyanins

Introduction

Hypertension (elevated blood pressure) is one of the great public health worries around the world which is an important contributor to the burden of cardiovascular disease, morbidity and mortality assessment. The World Health Organization has approximated that a total of 1.28 billion adults aged 30-79 years globally had hypertension in the year 2019, representing a prevalence of a quarter (24%) among men, and (20%) among women (WHO, 2021). Being a key risk factor for cerebrovascular accidents, myocardial infarction, heart failure, and kidney disease, highlights the urgency of the enactment of effective preventive and management measures (Mills et al., 2020). Hypertension is a problem of worldwide spread. On the one hand, some parts of the world suffer from its higher prevalence, while low-income countries bear the biggest burden. For example, across Africa, the level of prevalence of hypertension is reportedly higher, at 27%, compared to the Americas (Zhou et al., 2017; WHO 2021). However, the East Mediterranean region being the second highest region in the global point estimate had a prevalence of 20.8% to 35.5% across all nations (Kayar et al., 2021). The

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ranges of this condition are a result of multiple factors; genetic, environmental, and behavioural as well as their links to social status and medical access (Mills et al., 2020). As effective as pharmacological treatments are, they often have side effects and term maintenance costs, and these make them affordable in resource-limited settings.. It has resulted in a big rise in the popularity to try out other complementary alternative therapies such as the ones that are derived from plants with possible anti-hypertensive effects. Herbs/spices like Garlic (*Allium sativum*), hibiscus (*Hibiscus sabdariffa*), and ginger (*Zingiber officinale*) are the ones most scientifically studied proving that they indeed can lower blood pressure as well as other mechanisms (Ried et al., 2013; Serban et al., 2015; Aktan et al., 2014). However, the occurrence of cardiovascular diseases is also very high, and as such, hypertension has become a major world health problem due to increased measurement of blood pressure (Kearney et al., 2005). As evidence underscored in recent studies on antihypertensive treatment, patients are increasingly showing the desire to use natural remedies as opposed to pharmacological interventions for hypertension management (Wang et al., 2014).

This comprehensive review takes a critical look at the current scientific literature on the different phytochemicals and antihypertensive aggressiveness of garlic, hibiscus, and ginger mentioned in the latest research works. The review critically assesses both in-vitro, animal, and human studies to give insights into the possible modulation of hypertension via these natural products regarding the proposed mechanisms of action and therapeutic applications as well as their limitations. Also, this could be of benefit in detecting the places where more research may be needed and will involve the integration of these complementary therapies into evidence-based approaches for hypertension prevention and therapy. Garlic is one of the most useful medicinal herbs that is traditionally employed for the treatment of a variety of health problems in the whole world. Its effectiveness on many diseases has been proven medically, because of the synergies from its bioactive compounds (Rahman et al., 2003). Beneficially against cardiovascular diseases, garlic expresses its pharmacological properties owing to the presence of vasodilators, antioxidants, and anti-inflammatory components such as allicin, sulfur compounds, and flavonoids which are responsible for high active rate (Ried et al., 2008). An independent lab-based study and several clinical trials have already substantiated a relationship between garlic supplementation and blood pressure reduction, proposing the use of garlic as a possible therapy for hypertension (Ried et al., 2013). *Hibiscus sabdariffa*, has been used for thousands of years primarily to treat cardiovascular conditions such as high blood pressure and elevated cholesterol levels (Hopkins et al., 2013). Hibiscus is among the richest plants known for phytochemicals like polyphenols, anthocyanins, and organic acids, and these phytonutrients have been reported to be responsible for antihypertensive activities such as vasodilation, diuretic action, and inhibition of renin-angiotensin (Ojeda et al., 2010). Ginger may be considered a common spice, however, it has distinctive chemical compounds, so it can be used for different pharmacological purposes (Bode & Dong, 2011). Ginger components contain gingerol and shogaol which is linked to anticipated antihypertensive outcomes by mechanisms like calcium channel blocking; vasodilatation; and moderation inflammatory pathways (Mahomoodally et al., 2013). Unlike a comprehensive synthesis, there has not been any research that considers the chemical composition, mechanisms of action, and clinical efficacy of hibiscus and ginger in the context of the burgeoning body of evidence on garlic's function in treating hypertension. Therefore, to fill the gap this review aims to bridge it by a deep investigation of the phytochemical composition and antihypertensive activity of the garlic, hibiscus, and ginger, and this investigation will be subject to focus on patients with high blood pressure.

Importance of Natural Remedies

In recent times, new natural remedies have become a great subject, which may help to fight various disorders like high blood pressure. There are several good reasons for this because their results are plant and herb-based and are capable of controlling blood pressure. In addition, natural remedies are frequently seen as less dangerous substitutes for synthetic drugs with minimal side effects and no drug interactions (Wang et al., 2014). This attribute is more relevant in the management of hypertension wherein blood pressure medication adherence is chronic and fears over these effects may hinder patients from seeking medical help (Ried et al., 2013). Again, unlike conventional medicine that treats symptoms only; natural remedies offer comprehensive health solutions by addressing both the symptoms and causes of hypertension (Mahomoodally et al., 2013). For instance, garlic (*Allium sativum*), hibiscus (*Hibiscus sabdariffa*) and ginger (*Zingiber officinale*) possess different phytochemical compositions with antioxidants, anti-inflammatory agents, vasodilators respectively (Rahman et al., 2003; Bode and Dong, 2011). The active ingredients will target many mechanisms involved in determining blood pressure such as oxidative stress, and endothelial function leading thus having hypotensive effect. Moreover, natural remedies are given to the patients following the guidelines of personalized and integrated medicine, that is a medical approach to health that takes into account patient particularities and preferences to provide suitable heal solutions (Rahman, et al., 2003). This is also about bringing nature-based therapies in the context of a blood pressure control plan, so the practitioner has more solutions available to choose from aside from comprehensive health factors of the patient and shared decision-making (Ried et al.,

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2013). Natural treatments were studied for their effect on the general health and well-being of individuals with high blood pressure. These remedies have validated the ability to reduce blood pressure and enhance cardiovascular fitness. Herbal drug treatments have been used for loads of years and are favoured with the aid of many due to their tolerability and minimal side effects (Akram et al., 2023).

Medicinal plants which include *Hibiscus sabdariffa, and Allium sativum* were scientifically combined to have hypotensive and antihypertensive effects (Khatoon et al., 2022). Moreover, natural antioxidants discovered in these plants, inclusive of caffeic acid, curcumin, and quercetin, have been shown to lessen oxidative stress and enhance endothelial function, contributing to the prevention and treatment of high blood pressure (Umaru et al., 2022). This research spotlights the capability of herbal treatments in handling high blood stress and improving regular health. Further research is needed to come to the knowledge of active compounds, set up stable doses, and increase these treatments into effective anti-hypertensive treatments (Queiroz et al., 2022). Scientific evidence supporting the utilization of garlic, hibiscus, and ginger as natural options to control hypertension is enormous. The administration of garlic extract was observed to have reduced blood pressure in mice fed at high-fat diet (Ahern, 2023). Hibiscus extract had cardioprotective effects and reduced aortic remodelling in rats with renovascular hypertension (ShamsEldeen et al. 2023). This has also shown to be effective in the management of hypertension in those with mild-severe hypertension (Upendra & Gopal, 2022), and ginger has been shown to modulate or enhance various cardiovascular risk factors such as cholesterol levels, hypertension, and atherosclerosis (Roudsari et al., 2021).

Botanical Classification of Garlic, Hibiscus, and Ginger

Plant classification systems place plants in groups that have common evolutionary ancestry and have a similar set of features. Here, we explore the taxonomic placement of three common antihypertensive plants; garlic (*Allium sativum* L.), hibiscus (Hibiscus spp.), and ginger (*Zingiber officinale* Rosc.). Garlic is a part of the family Amaryllidaceae, subfamily Allioideae, and the genus Allium (Mabberley, 2008). This genus is identified by the presence of a powerful pungent odour that comes from compounds like allicin (Block, 2010). Garlic is an herbaceous plant with narrow leaves and thinner stems that flowers with little, white blossoms in the bunch (Facciola, 1998). Hibiscus is a genus from the family Malvaceae (Mabberley 2008). The members of the genus include different types such as trees, shrubs, and perennial herbs (Fryxell, 1992). Hibiscus flowers tend to be quite large and the colour of the flowers varies from red to yellow or pink (Storck et al., 2010). Huge variety within a genus is the main reason the specific morphological characteristics are greatly variable. Ginger belongs to the family Zingiberaceae, genus *Zingiber*, Mabberley (2008). This distinct family is famous for its aromatic rhizomes (underground stems) that are used in the production of spices and condiments (Rahman et al., 2007). The *zingiber officinale* culture is native as a perennial herb with long narrow leaves, and yellow flowers found in a spike-like inflorescence (Grubben and Denton, 2004). The ginger plant brings significant value to the industry as its underground stout and fleshy rhizome, called the root, is the most important part.

Fig. 1: Garlic Source: t4.ftcdn.net

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Fig. 2: *Hibiscus sabdariffa* Source: media.istockphoto.com

Fig. 3: Ginger Source: awsimages.detik.net.id

Therapeutic Potential of Garlic, Hibiscus, and Ginger

Garlic is considered one of the members of the well-known Alliaceae family based on its pungent taste and smell. This led to several medicinal implicit evaluations of their bioactive compounds similar to allicin, diallyl sulfide, and diallyl disulfide (Rahman et al., 2003). Cardiac health, cancer prevention, antimicrobial activity, and immune modulation are some of the areas where garlic has been used (Rahman et al., 2003; Ried et al., 2008). Another merit of garlic is that it possesses antioxidants like flavonoids and polyphenols. These phytochemicals can play a part in reducing oxidative stress, inflammation, and cell damage leading to dropped cases of persistent conditions including heart-related issues and cancer (Banerjee et al., 2007; Rahman et al., 2003). Garlic has applied preclinical models as well as clinical trials to understand its effects against conditions ranging from hypertension, hyperlipidemia, and atherosclerosis to cancer (Rahman et al., 2003). The blood pressure-lowering parcels of this condiment are exceptional due to vasodilation besides increased nitric oxide-producing capacity (Ried et al., 2013).

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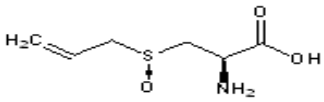

Fig. 4: Chemical structure of Allicin (drugfuture.com)

The *hibiscus sabdariffa*, a plant that is known for its attractive flower and sour flavour, is now popular because of its condition-beneficial properties. This specific interest, as explained, is because plant contains lots of active compounds like anthocyanins, polyphenols, and organic acids (Hopkins et al., 2013). It is thought that these substances not only help in the plant's powerful antioxidant and anti-inflammatory activities but also their great efficacy (Hopkins et al., 2013). The recently emerging evidence demonstrates that *H. sabdariffa*, also known as roselle, might be important for the health of cardiovascular disease. The research literature shows its effects and therefore helps to decrease blood pressure, improve the lipid profile, and have beneficial effects on the vascular endothelium (Ojeda et al., 2010; Hopkins et al., 2013). Anthocyanins, the ones that are red and owe their colour to hibiscus, are known to have antioxidant capacities. These characteristics are thought to facilitate the plant's anti-ageing function and the combat it has with the stresses of the body (Hopkins et al., 2013) Apart from this, Polyphenols, which is another popular class of phytochemicals in *Hibiscus sabdariffa* give impressive health benefit (Hopkins et al. 2013). The sharp-flavoured acidic taste of the plant is formed by certain organic acids like citric and malic acids, and may even be capable of functioning biologically.

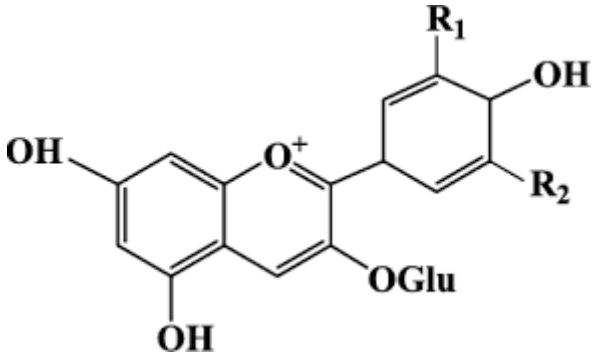

Fig. 5: Chemical structure of Anthocyanin (ResearchGate.net)

Zingiber officinale, rhizomatous of Zingiberaceae family, characterizes itself by its spicy flavours and healing properties to list a few. Its bioactive compounds, mainly of which gingerols, shogaols and paradols contribute to its pharmacological spectrum of activity. It is gingerol, the main component, which exerts anti-inflammatory, antioxidant as well as antinausea actions. Shogaol, a gingerol derivative made during processing, retains similar bio-activities to that of gingerol and therefore helps to support ginger's medicinal value. Furthermore, an additional chemical substance, paradol, that was obtained from ginger also showed potent anti-inflammatory and anticancer properties. Ginger has been explored for the therapeutic properties lying against nausea, arthritis, gastrointestinal diseases, and cardiovascular diseases (Bode and Dong, 2011; Mahomoodally et al., 2013.

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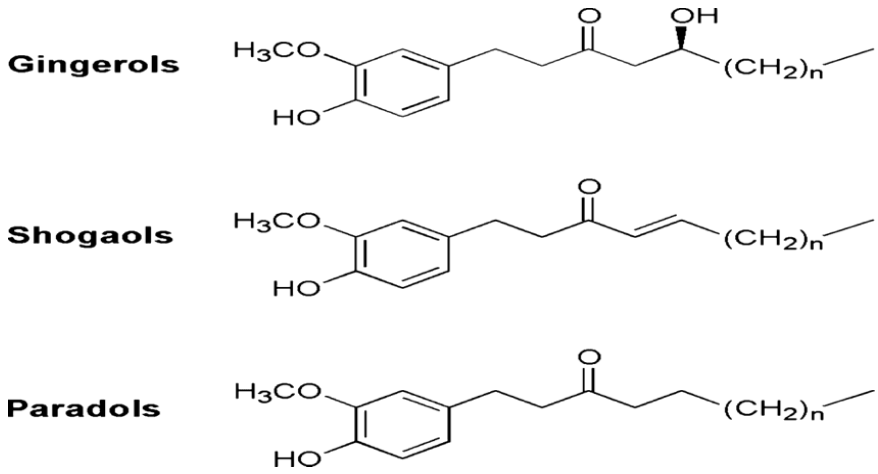

Fig. 6: Chemical structure of Gingerols, Shogaols, and Paradols (ResearchGate.net)

The commonplace medicinal applications across the globe, such as Ayurveda and Traditional Chinese Medicine, have confirmed that ginger is a plant that offers help with diverse ailments. It has served as a soothing agent for the improvement of nausea, gastrointestinal discomfort, as well as inflammation and some other conditions (Bode and Dong, 2011). Qualitative contemporary research provides empirical evidence of the efficacy of ginger use for traditional applications covering gastrointestinal problems, arthritis, cardiovascular disease and cancer as well as expansion of understanding of the therapeutic applications of ginger (Bode and Dong, 2011; Mahomoodally et al., 2013).

Mechanisms of Antihypertensive Action of Garlic

Humans have used garlic long ago as medicine. Many researchers have come to believe in many different ways that garlic can help us for good health. There has been extensive research on the curative value of garlic in the last few decades in which the role that it plays in lowering blood pressure and combating hypertension has been the main subject of study. Several clinical trials and meta-analysis data have made probably the clearest and most compelling case for garlic supplementation regarding the antihypertensive effects of the same (Ried et al., 2013; Rohner et al., 2015). On the other hand, the understanding of the molecular mechanisms by which garlic might trigger blood pressure-lowering response is an area for future study. The biologically active components present in garlic may include allicin as one of the well-researched in terms of both vasodilation and endothelial function (Shouk et al., 2014). The scientists also discovered that the organosulfur compounds found in garlic like allicin are in addition an important component in nitric oxide (NO) production, a vasodilator used to regulate blood pressure (Benavides et al., 2007). Moreover, garlic exerts the effect of inhibiting the angiotensin-converting enzyme (ACE), which is responsible for converting angiotensin I to angiotensin II, a powerful vasoconstrictor (Sharifi et al., 2003). Consequently, the cardiovascular system is protected. The suppression of ACE activity as a result of garlic intake can be the possible explanation for the decrease in vasoconstriction leading to lower blood pressure. Here, the other mechanisms include the anti-oxidant properties in garlic, which may play a role in the anti-hypertensive effects. Oxidation stress and inflammation are implicated in the beginning and progressive stages of hypertension (Vaziri & Rodriguez-Iturbe, 2006). Garlic has been proven to demonstrate a wonderful antioxidant activity. It can capture reactive oxygen species (ROS) and activate the action of antioxidant enzymes (Banerjee & Maulik, 2002). Garlic may also decrease oxidative stress and inflammation and thus become a guardian for the endothelium, with the purpose of preserving homeostasis in the blood vessels, resulting in blood pressure regulation. Moreover, garlic seems to be effective in the regulation of ion channels and calcium existing in vascular smooth muscle cells (VSMCs) (Shouk et al., 2014).

As a member of allicin group, garlic compounds, inhibit calcium influx into VSMCs, which allows vasodilation and reduced vascular resistance (Khatua et al., 2012). This calcium homeostasis dysfunction and VSMC contractility modification could be a factor towards the hypotensive effects of garlic. While the follow-up proposal of the mechanism of action for garlic's potential antihypertensive effect is complex and multifaceted, it is eventually composed of many physiological paths and cellular processes. Furthermore, the exact bioactive components with the best effect and their most optimal dosage and packaging remain research questions of ongoing study (Ried, 2016).

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Multiple mechanisms appear responsible for the antihypertensive actions of garlic; among them, including vasodilation, inhibition of ACE activity, antioxidant and anti-inflammatory effects as well as management of calcium homeostasis in VSMCs. While more extensive studies are needed to discern the exact molecular mechanisms, develop effective formulations and assess their adequacy as an alternative or complementary treatment protocol for hypertension, garlic appears to offer promising results in controlling blood pressure.

Mechanisms of Antihypertensive Action of Hibiscus

Hibiscus sabdariffa is a common plant with numerous medicinally therapeutic uses, in the management of blood pressure. Many scientific research studies have explored the observed antihypertensive effects of hibiscus; several clinical trials and meta-analyses now support its effectiveness in lowering blood pressure levels (Sarban et al., 2015; Askiz et al., 2021). Despite the existence of studies to challenge the efficacy of Hibiscus, research is ongoing to unravel the antihypertensive, its mechanism of action, and its therapeutic applications. The postulated mechanism includes the strong antioxidant activity of hibiscus that might also be involved in lowering of blood pressure through this pathway. Studies hinted at the importance of oxidative stress and inflammation for the development and advancement of hypertension (Montezano and Touyz, 2012). Hibiscus extracts are particularly rich in polyphenols, which encompasses anthocyanins and flavonoids, which are known to be very powerful antioxidants and anti-inflammatories (Ali, et al. 2005; Mohammedi & Chaouali, 2020). These bioactive constituents may help the body fight against oxidative stress and inflammation in the cells that make up the blood vessels. Consequently, a reduction in blood pressure will be a result of improved vasodilation which is an effect of endothelium function enhancement.

Another postulated pathway involves the inhibiting function of ACE activity by hibiscus components. ACE is a key element in the renin-angiotensin-aldosterone system (RAAS) system, which affects blood pressure (Abubakar et al., 2020). Therefore, hibiscus can act by limiting the ACE activity and thus the production of angiotensin II which is a strong vasoconstrictor so the blood vessel resistance decreases and thus blood pressure falls (Sayago-Ayerdi et al., 2014).

In a study carried out by Ajayi and others, it was established that Hibiscus was found to be able to influence ion channels and calcium homeostasis in vascular smooth muscle cells (VSMCs) (Ajayi et al., 2007). The reduced calcium influx of VSMCs by stimulating hibiscus extracts is the reason for the vasodilation or diminished vascular resistance. The modifying action of hibiscus on calcium homeostasis and VSMC contractility may be a reason behind its antihypertensive abilities. It is worth pointing out that the mechanisms behind the antihypertensive activity of hibiscus may be complex and consist of different factors such as the multiple cells and physiological pathways involved in the whole process. Besides, the exact bioactive compounds behind such remedies as well as their proper doses and form compositions are still topics of research (Joven et al., 2019).

The action of hibiscus as antihypertensive is known as multiple mechanisms which include antioxidant and anti-inflammatory components, ACE activity inhibition, and calcium homeostasis modulation in VSMCs. However, additional studies must be carried out to design the full scheme of biological actions, improve the pharmaceutical dosage forms and to set the indication for hypertension treatment.

Mechanisms of Antihypertensive Action of Ginger

Ginger (*Zingiber officinale*) belongs to a category of widely used plant foods and medicinal plants that possess extensive historical usage in traditional medicine systems, mainly for regulating hypertension levels. One of these actions can make trials and meta-analysis possible and studies indicated the antihypertensive effects of ginger (Aktan et al., 2014; Shukri et al., 2022). However, the mechanisms of how ginger lowers blood pressure are actively being researched. An acknowledged pathway is the high anti-inflammatory and antioxidant content of ginger. Chronic inflammation and oxidative stress have been claimed to be involved in the development of hypertension, where various factors, such as impaired vasodilation via endothelial dysfunction, are contributing to it (Rodrigo et al., 2011). Ginger is fortified with a large number of bioactive compounds, including gingerols, shogaols, and paradols which have as anti-inflammatory and antioxidant properties (Mashhadi et al., 2013; Semwal et al., 2015). These compounds are likely to keep oxidative stress from growing and also help to reduce the level of inflammation in the arteries and veins to improve endothelial function and put the body under more vasodilation, leading finally to lower blood pressure levels. Another mechanism suggested is how the RAAS is modulated, the main regulator of the blood pressure system. The ginger is an example of herb whose activity is to inhibit the angiotensin-converting enzyme (ACE) and thus to look at the reduction of angiotensin II, a high vasoconstrictor (Ghayur & Gilani, 2005). Ginger plays a part in the action of ACE and the RAAS pathways, which in turn helps in the widening of blood vessels and a reduction in vascular

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resistance, resulting in lower blood pressure. On the other hand, there has been some evidence that ginger affects the ion channels and in turn calcium uptake in the cells of smooth muscle, VSMC. Compounds provided from ginger in the form of gingerol and shogaol have been evidenced to retard calcium influx into VSMCs. Thus, as a result, vasodilation will occur, and vascular resistance is reduced (Ghayur et al., 2005; Ghayur & Gilani, 2005). Besides this, ginger can exert an impact on calcium metabolism and vascular smooth muscle contraction, resulting in antihypertensive actions.

It should be mentioned however that the regulation manner through which the antihypertensive property of ginger is attributed may be complex and multifaceted and is determined through several physiological pathways and cellular processes. This as well, as the particular bioactive substances responsible for those benefits, their effective dosages, and proper formulations remains an area of contemplation. It appears that anti-inflammatory and antioxidant processes mediating VSMC relaxation, decreased activity of the RAAS system, and alleviating intracellular calcium excess, also explain ginger's antihypertensive action. More studies may be needed to unravel the mechanism and formulate the appropriate dosage strengthening the possible ways that ginger can be used as an alternative antihypertensive agent.

Synergistic Effects of Garlic, Hibiscus and Ginger

Considering that these herbs work together, they have the potential to give a more effective and stronger effect on blood pressure regulation (Undefined). Allicin from garlic and anthocyanins from hibiscus can exert vasodilation synergistically resulting in improved blood flow through their combined effect on NO production and endothelial function (Al-Lawati et al., 2014; Crozier et al., 2010). Whilst garlic does not directly inhibit ACE, it is the organosulfur compounds that do. Therefore, the additive effects of these medicines could bring about better blood pressure control (Mousa et al., 2020). All three plants are anti-oxidant and anti-inflammatory effective. These properties could work to reduce blood pressure by opposing oxidative stress and inflammation in the blood vessels (Grzywacz et al., 2013; Mousa et al., 2020). Despite these synergies that we are hoping for, further research is warranted to identify the understanding of these mechanisms. Specific designs for in vitro and in vivo studies to investigate the combined effect of garlic, hibiscus, and ginger on blood pressure are highly recommended.

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Table 1. Phytochemical Composition and Antihypertensive Efficacy of Garlic, Hibiscus and Ginger

Note: SBP =systolic blood pressure, DBP = diastolic blood pressure.

Plant	Main Bioactive Compound	Other Relevant Phytochemicals	Mechanisms for Antihypertensive Effect	Antihypertensive Efficacy	References
Garlic *(alum sativum)*	Allicin	S-allylmercaptocysteine (SAMC), γ-Glutamyl cysteine, Adenosine, Polysulfides, Fructooligosaccharides (FOS), Prebiotic fibres, Quercetin, Ajoene, Allyl methyl.	Increased nitric Oxide production Vasodilation Angiotensin Converting Enzyme (ACE) inhibition	Modest Reductions in Systolic and Diastolic Reduction in SBP and DBP up to 10 mmhg	(Kyo et al., 2008) (Laher & Webb, 2013), Rajendrasozhan (2024)
Hibiscus (*hibiscus sabdariffa*)	Anthocyanins	Polyphenols, Phenolic acids Tannins' Glycosides, Steroids, protocatechuic acid, Delphinidin-3-sambubioside, Phytosterols.	Diuretic effect, Antioxidant Activity Improved Endothelial function	Potential reduction in blood pressure particularly in Prehypertensive and mildly hypertensive Individual reductions in SBP and DBP up to 20 mmHg	(Hegele et al., 2008) (Mozaffari-Okhovat et al., 2013), (Otunola et al., 2019).
Ginger (*Zingiber officinale*)	Gingerols Shogaols	Zingerone Paradols	Calcium channel Inhibition, Modulation of Inflammatory pathways	Mixed findings Some studies suggest potential benefits others inconclusive and other reductions in SBP and DBP up to 12 mmHg	(Zingiber, 2011) (Mansour et al., 2021), (Shahidi & Hossain, 2018)

Clinical Evidence for Antihypertensive Effects of Garlic

Researchers have provided evidence of garlic's efficacy as a therapeutic treatment for hypertension. Laboratory-based tests have clearly shown that people who have high blood pressure can control or reduce their pressure with garlic supplements. A meta-analysis involving 20 randomized controlled trials where 958 participants were included reported that by taking garlic supplements, reduction in both systolic and diastolic blood pressure can be significantly observed in comparison to the placebo groups (Ernst, 2005). The mean systolic blood pressure lowered by 8.4 mmHg, and diastolic blood pressure decreased by 5.5 mmHg from the baseline when garlic supplements were taken. The evidence presented in those studies proves that it can also be considered as an alternative option for treating hypertension. It sure can be one of the measures for minimizing or even entirely replacing the common antihypertensive medications. The study included data from several RCTs, namely a double-blind trial which investigated the action of garlic tablets in the case of preterm labour (Niroomanesh et al., 2023). In this study, 537 pregnant women with a history of threatened preterm delivery were randomly divided into two groups: the garlic tablets group and a blank tablet placebo group. The treated group received 500 mg garlic with each meal twice a day and 250 mg intramuscular progesterone shot per week up to 36 weeks or till the day of birth. The control group was also given a placebo pill with the same amount of intramuscular progesterone injections (250 mg weekly until 36 weeks gestation). The findings revealed that there was less incidence of preterm delivery in the treatment group than in the control group which may be attributed to the fact that garlic in the form of a supplement is beneficial against preterm labour (Niroomanesh et al., 2023).

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Another meta-analysis included a randomized, double-blind, placebo-controlled trial conducted by Méndez-Del Villar et al. (2022) with 50 patients having mild high blood pressure. The participants were assigned either garlic capsules (900 mg/day) or placebo for 12 weeks using randomization. The results displayed a statistically significant decrease in both systolic and diastolic blood pressures of subjects from the garlic supplementation group as compared to those who received placebos. Consequently, the researchers recommend taking garlic pills to treat mild hypertension. Garlic is backed so far by extensive clinical evidence from various randomized controlled trials revealing its antihypertensive effects which have constantly been reducing high blood pressure levels in hypertensive individuals. These discoveries indicate that garlic may be another way to lower or even keep for life blood pressure medicines used in the medical treatment of hypertension. This is because some studies have reported that garlic can help to prevent premature labour though more research should be done to establish effective dosages as well as duration of treatment when using it for hypertension management.

Table 2: Clinical Evidence for Antihypertensive Effect of Garlic, Hibiscus and Ginger

Plant	Clinical Trial Design	Dosage/Duration	Results	References
Garlic (*Allium Sativum*)	Randomized controlled trials	Varied (e.g., 400-1800mg aged garlic extract daily for 2-12 weeks)	Garlic has beneficial effects on metabolic diseases including antihypertensive properties.	(Pérez-Rubio et al., 2022), (Kochhar et al., 2009), (Ried et al., 2011)
Hibiscus (*Hibiscus Sabdariffa*)	Randomized controlled trials	Varied (e.g. 2-3 hibiscus tea bag daily for 1-4 weeks)	Hibiscus calyxes have antihypertensive effects along with other health benefits	(Montalvo-González et al., 2022), (Hegele et al., 2008), (Mozaffari-Okhovat et al., 2013)
Ginger (*zingiber officinale*)	Randomized controlled trials	Varied (e.g., 1-4g ginger powder daily for 2-12 weeks).	Ginger has cardioprotective effects including potential antihypertensive properties	Muneer et al., 2024), (Mousa et al., 2012)

Exploring the Antihypertensive Potential of Hibiscus (*Hibiscus sabdariffa*) Through Clinical Evidence

The role of hibiscus (*Hibiscus sabdariffa*) in blood pressure regulation as shown by several RCTs has been clinically proven with multiple RCTs. It was documented in a Journal of Hypertension study that those who usually have an intake of hibiscus tea would improve their systolic and diastolic blood pressure in patients who already have hypertension stage 1 when it comes to measuring blood pressure. The trial consisted of 46 patients who were assigned to one of two groups, one group drank two cups of sour tea (*Hibiscus sabdariffa*) every day during the month, while the control group took no medication. Various tests were conducted and there was a noticeable decrease in systolic and diastolic blood pressure in the hibiscus tea group in comparison to the placebo group (Jalalyazdi et al., 2019). Yet another study published in the Journal of Ethnopharmacology investigates the antihypertensive effect of hibiscus extract but finds that it decreases blood pressure as a dose. This is in rats (Adegunloye et al., 1996). Furthermore, the study discovered that hibiscus extracts suppress blood pressure via diverse methods such as acetylcholine-like and histamine-like, as they do not work by the peripheral nor by the central mechanisms of the sympathetic nervous system. This is in addition to the direct vasodilator effects (Adegunloye et al., 1996). An analysis of the black tea trials involving hibiscus tea that was from the Journal of Hypertension was done and published by Zanchetti in 2015, and it provided evidence that black tea impacts blood pressure. The evaluation indicated that black tea drinking lowered systolic and diastolic blood pressure by 2 to 3 mmHg globally in patients diagnosed with hypertension (Zanchetti, 2015).

Thus, the conclusion drawn from this study was that black tea, such as hibiscus tea, which happens to have a high content of flavonoids, is probably the cause of the lowering of blood pressure (Zanchetti, 2015). Along with fighting hypertension, hibiscus tea has demonstrated the possession of other well-being attributes. The study that appears in the Journal of Ethnopharmacology shows that rats with hibiscus tea intake were markedly less oxidative-stressed and had a lower lipid peroxidation (Pelliccia et al., 2014). In the course of the research, it has appeared that regular tea drinking significantly elevated the antioxidant enzyme activity in laboratory rats

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(Pelliccia et al., 2014). The clinical studies show the promising effect of *hibiscus sabdariffa* in the inhibition of blood pressure in both human and animal experiments. This depends mostly on its high flavonoid content. It is prone to enlarge the blood vessels (vasodilation). Moreover, the scientific data reveal that drinking of red herbal tea (*Hibiscus sabdariffa*) may be responsible for other cardiovascular benefits which include suppressing oxidative stress and decreasing lipid peroxidation. However, more research work is required to understand properly how this tea works to deal with hypertension and to also check if it can be a possible additional or alternative way to address the medications.

Insights from Clinical Trials and Systematic Reviews of the Antihypertensive Potential of Ginger (*Zingiber officinale*)

Among all of the different studies, ginger (*Zingiber officinale*) has shown its ability to become a powerful antihypertensive alternative in the condition of RCTs. For the controlled trial pyramids, a combined treatment with ginger and dietary supplements reduced both systolic and diastolic blood pressure in people who had borderline hypertension (Pelliccia et al. 2014). The segment involved 161 subjects who were double-blind to the placebo or a merged tablet composed of *allium sativum* and hibiscus twice every day. In the study where the subjects participated for 12 weeks, there was a significant difference in systolic blood pressure measured between 125±9 in the supplement group and 133±8 in the placebo group ($p = 0.0001$), and in diastolic blood pressure which was measured at 81±7 in the supplement group and 83±8 among the placebo group. Besides its being a potential nutraceutical; ginger shows relevant preclinical and clinical studies in migraine prevention. Researchers conducted a model of the randomized, double-blind, and placebo-controlled clinical trial that observed the positive impact of ginger consumption on hypertension and the duration of migraine attacks in comparison with the placebo group among patients with episodic migraine (Helli *et al*., 2022). The study had a randomized design in which 103 participants were allocated either to one of two groups. One group received twice a day a dry extract of ginger containing 5% active component (500 mg), whereas the other group took placebo tablets to the same dose for three months. The study concludes that, concerning MIDAS score, length of migraine attacks, and headache severity ($P < 0.05$), ginger group members significantly decreased compared to the placebo group (Helli, *et al*., 2022). It has been also shown in the combination of ginger with other herbs. A systematic review by Serban et al. considered whether the claimed antihypertensive action of black tea and hibiscus tea was either established or refuted by a meta-analysis of available randomized controlled trial data (Zanchetti, 2015). The study revealed that consumption of black tea beverages reduced both systolic as well as diastolic blood pressure significantly. However, the author cited the need for more well-designed studies (Zanchetti, 2015). In short, the clinical studies give positive signs about the anti-hypertensive role of ginger, regardless of whether as a dietary supplement or in combination with other herbs. However, we still need more research to shed light on these specific mechanisms and ascertain the best dosage and treatment regime.

Key findings on the phytochemical composition and antihypertensive potential

Garlic (*Allium sativum*), hibiscus (*Hibiscus sabdariffa*), and ginger (*Zingiber officinale*) might be the top three plants that traditional medicine in many countries apply for different purposes, one of which is high blood pressure (hypertension). The research shows that such effectiveness may come from presence of the specific bioactive substances with no drawbacks from synthetic simulators. Class of phytochemicals including flavonoids, tannins, terpenoids, saponins, and phenolics are shared among the plants under the family of the plants used as antihypertensives (Oloyede et al., 2004). While most plants have a wide variety of phytochemicals including vitamins, minerals, and low calories as their contents, garlic is rich in organosulfur compounds particularly allicin which is caused by the reaction from alliinase acting on alliin when the clover is crushed or chopped (Ajayi et al., 2017). Hibiscus calyces are enriched with anthocyanins and protocatechuic acid which are responsible for the deep red extracts as well as having anti-inflammatory, anticancer, and antimicrobial properties. The gingerol and shogaol found ginger world are the bioactive components that explain its spiciness. (Ajayi et al., 2017). Blood pressure can be reduced by moderate garlic consumption, which might be achieved by increasing blood vessels' diameter through the production of nitric oxide and relaxation of blood vessels as scientists prove (Ajayi et al., 2017). On the same side, experimental work on animals suggests that hibiscus extracts may lower blood pressure by either diuretic or angiotensin-converting enzyme (ACE) inhibitory mechanisms (Oloyede et al., 2004). It seems that ginger exhibits less pronounced antihypertensive properties, and according to other studies, it would be better to use this herb only in addition to taking the currently used drugs (Ajayi et al., 2017).

One must reckon with the fact that more studies are needed to be able to grasp how these plants affect BP in human beings. The research mentioned above mostly focused on concentrated extracts, and the observed effects might differ when related to the usual recommended daily amounts. Also, it is worthy to seek advice from a healthcare professional before trying any herbal remedy for high blood pressure, and in the event, you

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are already under medications as well. While solid conclusions necessitate closer study, we do know that among the phytochemicals that are contained in garlic, hibiscus, and ginger, are different potentials that could be of benefit to hypertensive patients.

Potential side effects and drug interactions

In all aspects of taking garlic, hibiscus, and ginger, it is indeed, more appropriate that you be well-informed about the consequences of the use of these natural remedies (Hudson et al., 2018). Garlic, known for its healing properties, may also cause some discomfort for the body, like bad breath, body odour, heartburn, and stomach upset. Sometimes in a small percentage, the more you eat garlic the more the chance you can trigger allergy or skin irritation. The issue of drug interactions requires particular attention as it can be life-threatening and one has to be careful while taking warfarin as it can lead to bleeding. In addition to travelling, this can affect how the herb interacts with HIV medicines, birth control pills, and certain antibiotics (Bayan et al., 2014). Hibiscus is tolerated well when taken in usual daily consumption and diarrhoea may be experienced when very high amounts are consumed. The features of hallucinations can also be seen at very high doses (Hopkins et al., 2013). It is always possible what allergic reactions to hibiscus may be for some people. The effect of hibiscus on drugs used to treat hypertension and diabetes has to do with diminishing the effectiveness of these medications, requiring awareness and monitoring among administered drugs (Hopkins et al., 2013). However, Ginger, the second most popular natural remedy, is not primarily reported to cause any serious side effects, although high doses may result in heartburn, diarrhoea, and irritation of the mouth (Marx et al., 2017).70 Important to note is, that ginger can negatively interfere with blood-thinning medications, diabetes medications, and high blood pressure medications, a case that further emphasizes the need to consult healthcare providers before using it as a complementary treatment option (Marx et al., 2017).

Limitations and Challenges

There still are challenges for the research about the role of garlic, hibiscus, and ginger in relaxing blood pressure. Clinical trials are not conducted properly and regularly, and the ways of making, stretching, and even using these all-natural herbs do not have the same quality. A lot of the older studies relied on small groups of participants and utilized a short research period, making their findings less translatable and weak. The problem is also that these herbal remedies vary in their processing/formula and dosage. As a result of that variation, one can get a quite different amount of biologically active compounds. For example, the effectiveness of a clinical trial testing garlic supplements for antihypertensive actions mainly relies on the growing condition and postharvest processes (from collection to product formulation) which is responsible for the fluctuations of allicin content. The first step in this respect is to set up standardized clinical trials because this is how only reliable results can be achieved. Along with this, is the fact that we hardly know about how the medicinal value of these herbs brings blood pressure down, whether they can interact with prescribed drugs, or even if there is significant individual variation in response to treatment. Whereas some studies suggested that mechanisms through which these natural products may decrease blood pressure were identified, a clearly defined overall picture hasn't been yet developed. There will be no rule to guide the selection of the therapy in this case and interactions with the currently active medications on antihypertension are quite challenging to predict, Moreover, the people as exposed in different manners towards the plant response to these botanical contributions. According to a recent study on the causes of this variation in efficiency, some genetic factors, dietary habits, or concurrent health states may be involved which in turn further impedes the medical use of the natural remedies.

The application of garlic, hibiscus, and ginger as hypertension management is still effective even with only short-term use. However, their long-term use needs further research. Though these natural remedies usually have mild to moderate side effects including nausea and vomiting as well as allergic reactions, they are generally well tolerated. In addition, the absence of long-term safety data will leave the seeds of doubt as far as knowledge concerning the medication is concerned. Well-organized studies to evaluate the profile of the adverse effects of the botanical remedies for long-term use are justified especially in patients who happen to be already taking the other medications for hypertension. The diffusion of these natural cures into clinics by their being labelled as potential antihypertensive drugs is impeded by problems of accessibility, regulatory supervision, and public awareness. Some ingredients such as garlic, hibiscus, and ginger may be abundant in some places, and the fact that distribution channels are often unequal, and may hinder many people who live in rural areas or have limited medical resources from accessing the ingredients. Additionally, the unregulated nature of these products as such, the absence of robust regulatory frameworks, especially by the Food and Drug Administration (FDA), raises valid concerns about their quality and consistency. Such variations as cultivation methods, processing approaches and final formulations affect not only biological content but also the possible extent of the impact of botanical remedies. Aggravating these limitations is a low degree of understanding of

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their possible therapeutic effect. Some patients with hypertension are likely to be unaware of the blood pressure-lowering capabilities of those natural products, and the physicians may not consider them as a component of the medical management of hypertension regularly. It is essential to raise education and knowledge about the results of the research as these are very significant tools to close the knowledge gap between patients and medical professionals.

Conclusion

Extensive studies extracted from this review shed light on the huge therapeutic capacities of garlic, hibiscus and ginger in the treatment of hypertension. The individual phytochemical compositions from the plethora of these plants including organosulfur compounds in garlic, anthocyanins and flavonoids in hibiscus, and phenolic gingerols and shogaols have a multipronged antihypertensive mode of action. These include the inhibition of ACE and the renin-angiotensin system, and calcium channel blockade that makes vasodilation and nitric oxide bioavailability increase. Particularly, the clinical studies and meta-analysis show that the consumption of garlic, hibiscus infusions/extracts, and ginger in appropriate formulations is significantly associated with the clinically marked decrease in the level of systolic and diastolic blood pressure among the hypertensives, pre-hypertensives, and persons who are borderline hypertensives. As demonstrated by their good safety profiles, they can be used as cost-effective, accessible, and well-tolerated, alternative or supportive therapeutic measures, besides conventional antihypertensive medications. However, well-designed, long-term, randomized controlled trials need to be conducted for conclusive measurements of safe and effective dosages in addition to the preferred formulations to be established. Given the results reviewed above, the evidence-based strategies of hypertension management and cardiovascular disease risk reduction are undoubtedly incomplete without these botanicals. Polypharmacy is a consequence of the fact that their multi-target action creates an opportunity to use a phytotherapy combinational approach which enhances their therapeutic effects.

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