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Review article

Hypertension in Africa and Medicinal Plants with Anti-Hypertensive Properties

Godwill Azeh Engwa[1], Edna Ngoakoana Matjuda[2], Benedicta Ngwenchi Nkeh-Chungag[1*]

[1]Department of Biological and Environmental Sciences, Faculty of Natural Sciences, Walter Sisulu University, Mthatha, South Africa.
[2]Department of Human Biology, Faculty of Health Sciences, Walter Sisulu University, Mthatha, South Africa.

Abstract

Hypertension presents a major threat to global health. The prevalence of the disease is high in the adult population but an increasing number of children are being diagnosed with raised blood pressure globally. Although pharmaceutical drugs are effective in the treatment of hypertension based on targeting blood pressure regulatory mechanisms, the use of these products has been associated with several side effects. As a result, there has been an increasing interest to find natural sources for treatment of hypertension. Several local plants in Africa have been used in folk medicine to treat hypertension. In this review, an extensive literature search in databases including ScienceDirect, PubMed, Scopus, Web of Science, and Google was performed to search plants with anti-hypertensive properties; the epidemiology of hypertension in Africa along with the mechanisms of regulation has been highlighted. The various classes of pharmaceutical drugs and medicinal plants used in treating hypertension in Africa with their anti-hypertensive properties were described. Several medicinal plants in Africa have been revealed with potential anti-hypertensive effects along with the phytochemical constituents and some potential mechanisms of action thus providing the scientific basis of their potential usefulness in hypertension treatment. However, further studies are needed for the exploration of these plants against hypertension.

Keywords: anti-hypertensive properties; hypertension; medicinal plants; phytochemicals; treatment

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Introduction

Hypertension is one of the primary risk factors for heart disease, kidney disease, stroke and other diseases. Hypertension affects over 1.4 billion people globally with Africa presenting the highest prevalence (27%) of the disease [1]. Furthermore, it remains the major cause of mortality worldwide, with over 10 million deaths each year [2]. The disease is also becoming a concern in children with high prevalence recorded in Africa. According to the International Society of Hypertension, blood pressure (BP) measured in mmHg is classified into categories: normal BP is when both systolic blood pressure (SBP) and diastolic blood pressure (DBP) are <120 and <80, respectively. Elevated BP is when the SBP of an individual is ≥120-129 and DBP is <80. A person is diagnosed with stage 1 hypertension if their SBP is ≥130-139 and/or DBP is ≥80-89. Stage 2 hypertension is when an individual has a SBP of ≥140 and/or DBP≥90 [2]. These categories are for people who are 18 years old and older [3]. In children and adolescents, normotensive is defined as SBP and DBP < 90th percentile, elevated BP as SBP and/or DBP >90th

*Corresponding author: bnkehchungag@wsu.ac.za

< 95th percentile while high BP is defined as SBP and/or DBP ≥95th percentile according to the American Academy of Paediatrics (AAP) 2017 guideline [4].

In Africa, the increasing prevalence of hypertension may be attributable to the change from the traditional ways of living to urbanisation. This involves consumption of western diets which are high in fat and calories and low in fibre, adoption of sedentary lifestyle accompanied by lack of physical activity, increased intake of carbohydrates and fatty foods, high intake of salt as well as stress and aging [5]. This change of lifestyle, physical inactivity and feeding habits affect the regulation of BP homeostasis mechanisms which includes both the nervous system and hormonal regulatory mechanisms [6]. Several of these regulatory mechanisms have been exploited to produce drugs that are used in the treatment of hypertension. However, though effective in treating hypertension, these pharmaceutical drugs have several adverse effects [7] which contribute to poor compliance of treatment regimens. This challenge has paved a way for the exploitation of other natural sources of hypertension treatment. There has been increased global concern in the use of medical plants to treat hypertension especially in Asia and Africa [8]. In Africa, several plants have been used in folk medicine for the treatment of hypertension. This review seeks to address the state of hypertension and plants with anti-hypertensive properties in Africa. It will highlight the epidemiology of hypertension in Africa and mechanisms of regulation. It further describes the various classes of known antihypertensive drugs with their associated side effects that pave a way for the use of medicinal plants. The present work finally describes some of the medicinal plants in Africa that have been shown in in vitro and in vivo animal studies to possess anti-hypertensive properties.

Methods

This present review highlights hypertension in Africa, mechanism of regulation and treatment of hypertension with emphasis on medicinal plants in the treatment of hypertension in Africa. Several databases including ScienceDirect, PubMed, Scopus, Web of Science, and Google Scholar were searched to obtain eligible articles. The search was performed using keywords or phrases which were used alone or in combination. They include “epidemiology of hypertension in Africa”, “mechanism of blood pressure regulation”, “treatment of hypertension”, “hypertension and medicinal plants in Africa”

Results and Discussion

From our findings hypertension is a major problem with increasing prevalence in Africa. There is rising prevalence of the disease in children. Several plants have been used locally for the treatment of hypertension and have shown to possess anti-hypertensive properties in vivo. The possible mechanism of action of some of these plants as well as their phytochemical content has been elucidated. The details of these findings are highlighted below.

Epidemiology of hypertension in Africa

Hypertension is one of the major causes of cardiovascular diseases (CVDs) and early mortality worldwide [9]. World Health Organisation (WHO) report in 2019 estimated that 1.3 billion people in the world are hypertensive of which two-thirds reside in low- and middle-income countries [10]. In this report, the African continent had the highest prevalence of 27% compared to 20% prevalence reported in 1990 according to a meta-analysis study [11]. This increase corresponds to the increase in risk factors for hypertension such as smoking and obesity in this region. A meta-analysis reported a 12.9% pooled prevalence of hypertension among smokers in Africa [12]. Another study showed that Africans with obesity were more than twice likely to be hypertensive and the odds of hypertension increased with increasing age in obese individuals [13]. Because blood pressure tends to rise with age, hypertension tends to disproportionately affect older people in all populations.

Hypertension prevalence differs across regions and countries in Africa. Northern regions of Africa have recorded high prevalence rates of hypertension. A study among adults at a primary health care center in Tunisia reported high prevalence of hypertension (47.4%) [14]; another study in Morocco showed a 39.8% prevalence of hypertension among individuals attending a health care clinic with a mean age of 49.6 ± 16.3 [15]. Similarly, a study conducted among a population in Meet E1 Moze village in Menofia, Egypt reported a prevalence of 38.2% [16]. In

East Africa, high prevalence rates though not as high as rates in the North of Africa have also been reported. A study conducted in Harar Town of Eastern Ethiopia among bank workers reported a 27.5% prevalence of hypertension [17]. Another study carried out among 18-69 years old individuals in Kenya, reported a 28.6% prevalence of hypertension [18]. In Uganda, 31.5% prevalence of high blood pressure was recorded [19].

Elevated prevalence of hypertension has also been recorded in Central and West Africa. A meta-analysis study in Nigeria showed that the crude prevalence of pre-hypertension and hypertension were 30.9% and 30.6%, respectively [20]. Another study reported a 38.1% prevalence of hypertension in Nigeria which varied across the various geo-political regions [21]. In Cameroon, a meta-analysis study reported an overall hypertension prevalence of 30.9% constituting a 29.6% in 1994–2010 and 32.1% in 2011–2018 [22] while a 31.1% prevalence of hypertension was reported in a rural community in Cameroon [23]. The prevalence of hypertension increased from 18% in 2012 to 19% in 2016 among Congolese adults in South Kivu, Congo [24]. A study conducted among Ghanaians at a dental clinic reported a 31.4% prevalence of hypertension [25].

Southern Africa countries like other African countries also face challenges with hypertension. In Mozambique, the prevalence of hypertension increased from 33.1% in 2005 to 38.9% in 2015 among individuals of 25-64 years old [26]. An overall pooled prevalence of hypertension was 30.0% in Zimbabwe [27]. A May Month study in 2019 in South Africa reported 31.9% prevalence of hypertension in adults above 18 years [28]. A 52% prevalence of high blood pressure was reported in a study conducted among 203 nurses in Eastern Cape Province, South Africa [29].

There are increasing reports of childhood hypertension in Africa which are known to track into adulthood. A study among 6-9 years old children in the Eastern Cape Province of South Africa reported a pre-hypertension/hypertension prevalence of 42.16% [30]. Furthermore, a study among Grade 12 learners in the central Phoenix Region of Kwa-Zulu Natal, South Africa reported 29.7% and 13.7% prevalence of pre-hypertension and hypertension, respectively [31]. Hypertension in Africa is worrisome since it is complicated by not being correctly diagnosed, lack of symptoms and the limited availability of treatments.

Mechanism of blood pressure regulation

The heart is central to the circulation of blood in the body as it pumps oxygenized blood to other parts of the body and receives deoxygenated blood from the body which is then purified to oxygenated blood and redistributed. As the blood is pumped to other parts of the body, it passes through narrow blood vessels while exerting pressure on the vessel walls as it flows through. The lateral pressure that is applied by blood on the vessel walls as it flows through is known as blood pressure. This pressure strongly depends on the nature of the blood vessel, particularly the vessels wall and also on the distance between the heart and the blood vessel. Naturally, the body has several mechanisms in place to regulate the blood pressure. These processes could be rapid or slow depending on the type of mechanism in place.

Nervous regulation of blood pressure

The sympathetic nervous system is involved in the regulation of blood pressure (BP) as the sympathetic tone controls vasoconstriction of the blood vessels [32]. The smooth muscle cells of blood vessels are always in a state of contraction. As a result, blood vessels are in a state of vasoconstriction which depends on the sympathetic tone. When the sympathetic tone increases, the vasoconstriction also increases. This in turn, increases the total peripheral resistance leading to an increase in BP. The increased BP is detected by the baroreceptors located at the aortic arch and carotid sinus. These baroreceptors in response transmit impulses to the vasomotor center of the medulla oblongata responsible for the control of BP [33]. Within the vasomotor center, are the pressor and depressor area for the regulation of BP. The baroreceptor impulses inhibit or suppress the pressor area without affecting the depressor area. The inhibition of the pressor area decreases the sympathetic tone leading to vasodilatation of the blood vessel. As a result, the total peripheral resistance decreases thereby decreasing the BP to normal level.

Conversely, a decrease in BP causes the baroreceptors in the aortic arch and carotid sinuses which are the BP-sensitive neurons to send fewer impulses to cardiovascular centers in the spinal cord. This promptly decreases

parasympathetic output while it increases sympathetic output to the heart and its vasculature, leading to raised cardiac output and vasoconstriction. Thus, causing a rise in BP. The nervous regulation of BP is fast and occurs within few seconds [33].

Hormonal regulation of blood pressure

Blood pressure can also be regulated by important hormones. The various types of hormonal regulation of BP as reviewed by Ashton [34] include renin-angiotensin-aldosterone, vasopressin or anti-diuretic hormone (ADH) and the adrenalin (epinephrine) and noradrenalin (nor epinephrine) systems.

Renin-angiotensin-aldosterone system

When the BP falls, it stimulates the juxta glomerular apparatus of the kidney to secrete renin [35]. Renin acts as an enzyme on angiotensinogen, a plasma protein to converts it into angiotensin I. Angiotensin I is then converted into angiotensin II. Angiotensin II causes the walls of blood vessels to contract thereby decreasing the caliber of resistance of blood vessels. This leads to an increase in total peripheral resistance which in turn increases the BP returning it to normal. More so, angiotensin II can also stimulate the adrenal cortex to increase the secretion of aldosterone to act in the kidney to increase the re-absorption of sodium and water thereby increasing the blood volume [6]. The increase in blood volume increases the BP.

Vasopressin or antidiuretic hormone system

When the BP is low, the hypothalamus is stimulated which in turn stimulates the posterior pituitary to secrete antidiuretic hormone (ADH), also known as vasopressin [36]. Vasopressin acts on the blood vessel wall to raise the degree of constriction thereby causing vasoconstriction. This increases the total peripheral resistance leading to a rise in BP to the normal level. ADH also acts in the kidney by increasing the re-absorption of water leading to a rise in blood volume thereby increasing BP to the normal level [37].

Adrenaline and noradrenaline system

A fall in BP stimulates the hypothalamus which in turn stimulates sympathetic nervous system. The sympathetic nervous system then stimulates the adrenal medulla to release more adrenaline [38]. Adrenaline acts on blood vessel walls and promotes vasoconstriction. This results in an increase in total peripheral resistance which in turn elevates BP to normal level. When the BP is high, the glomerular filtration rate in the kidney increases. This leads to an increment in urine output and water loss from the body. Consequently, the blood volume lowers which in turn deceases the BP. This is usually a long-term process of BP regulation [38].

Treatment of hypertension

Majority of antihypertensive drugs are analogues that are dependent on the various mechanisms of hypertension regulation. The various pharmacological classes of BP lowering medications include beta blockers, diuretics, angiotensin converting enzyme inhibitors, angiotensin II receptor antagonists, calcium channel blockers, renin inhibitors, alpha-adrenergic receptor blockers, centrally acting agents and vasodilators [39].

Beta blockers are the first line choice of therapy for hypertension [40]. They are antihypertensive drugs that block the action of catecholamines on beta-adrenergic receptors in the sympathetic nervous system [41]. However, beta blockers have been associated with adverse effects. Diuretics are the second most prescribed type of BP lowering drugs and are known to reduce BP by inducing vasodilation [42]. Although they are effective, high dose of diuretics in patients with comorbidities such as diabetes, gout, or erectile dysfunction in men should be avoided [43] due to potential side effects including abnormalities in carbohydrate, electrolyte, uric acid and lipid metabolism [44]. Angiotensin converting enzyme inhibitors (ACEIs) are another category of antihypertensive drugs that exert their action in the renin-angiotensin-aldosterone system [45]. They act by inhibiting the conversion of angiotensin I to angiotensin II, thereby preventing vascular smooth muscle contraction and thereby decreasing vasoconstriction. Furthermore, the action of ACEI indirectly decreases the release of aldosterone [46]. This process leads to a decrease in BP. ACEI could be used alone or in combination with other BP lowering medications to treat hypertension [45]. In general, ACEIs and angiotensin II receptor blockers are recommended as the second line treatment due to increased chance of cerebrovascular events in people of the African ancestry [46]. Angiotensin II receptor blockers are another class of antihypertensive agents that

act by blocking the binding of angiotensin II to their receptors [47]. They equally activate angiotensin II type 2 receptors, which dilate the small arteries leading to cardiac and renal protection [48]. The Angiotensin II receptor blockers are prescribed as the first choice of initiation and maintenance of BP lowering treatment, either alone or in conjunction with other antihypertensive medications [47]. Calcium channel blockers are recommended as the first choice of therapy, either in monotherapy or in conjunction therapies [49]. They are well tolerated in lowering BP levels and in reducing high blood pressure related to organ damage [50]. Nifedipine is one of the commonly recommended calcium channel blockers for hypertension treatment due to its effectiveness, but it may possess potentially harmful side effects on heart rate when the short-lasting formulations is used, whereas it may provide long term BP lowering effects when the long-lasting (extended-release) formulations of nifedipine is used [49]. Alpha blockers have been available as antihypertensive drugs for more than 40 years and are commonly prescribed as the first line therapy [50]. They lower BP by blocking postsynaptic α-receptors, thus inhibiting norepinephrine-induced vasoconstriction [51]. Side effects of alpha blockers include dizziness, headache, and tachycardia due to sudden drop in BP [52]. Peripheral adrenergic inhibitors are anti-hypertensive drugs that lower BP by blocking neurotransmitters. Reserpine is a peripherally acting adrenergic drug and lowers BP by depleting sympathetic biogenic amines. As a result, this blocks the smooth muscles from getting the "message'' to constrict [53]. Reserpine has been used as the first line therapy since the 1940s and then changed to be used as the second line therapy recently [54]. It has been reported that the side effects of reserpine include heartburn, diarrhoea, stuffy nose and nightmares [53]. Vasodilators also known as vasorelaxants are a group of anti-hypertensive drugs used to treat systemic hypertension [55]. Vasodilators such as hydralazine hydrochloride and minoxidil reduce BP by exerting peripheral vasodilation effect through a direct relaxation of vascular smooth muscle. The side effects of these drugs include headache, pains in the joints, heart palpitations or aches and swelling around the eye [53]. It has been reported that minoxidil causes water retention, hypertrichosis and pericarditis [55]. Although these anti-hypertensive drugs are effective in treating hypertension, they have notable side effects. As a result, attention has been drawn towards alternative anti-hypertensive therapies with minimal adverse effects. Plants have gained considerable interest as antihypertensive agents due to their therapeutic potentials with minimal adverse effects.

Medicinal plants and hypertension in Africa

The use of medicinal plants in treating diseases has gained substantial attention recently and has been encouraged by the WHO [56]. The wide use of traditional herbs among rural African communities to treat hypertension is believed to be due to the lack or irregular availability of anti-hypertensive drugs and the belief that medicinal plant products are safer and less toxic than synthetic drugs [57,58]. An ethno-botanical survey conducted in Souk Ahras District in Algeria found that the plants most frequently used for the treatment of hypertension were *Allium cepa, Allium sativum, Artemisia herba-alba, Nigella sativa, Oleaeuropea,* and *Rosmarinus officinalis* [59]. The most frequent plants for controlling hypertension by Edo people in Nigeria include *Celosia, Talium triangulare* and *Amaranthus cruentus* [60]. Another study in Maputaland documented most used plants for the management of hypertension. These include, *Momordica balsamina, Aloe marlothii*, *Hypoxis hemerocallidea, Musa acuminate, Strchnos madagascriensis* and *Senecio serratuloides* [61]. Furthermore, another ethno-botanical survey conducted in Nkonkobe Municipality in the Eastern Cape Province of South Africa found that the most frequently used plants for the treatment of high BP belonged to the Asteraceae, Hypoxidaceae and Fabaceae plant families and the species most frequently used in this region was *Tulbaghia violacea* [62]. Several plants in Africa have been reported to possess anti-hypertensive effects as summarised in Table 1. These include the following:

***Dietes iridioides* L.**

Dietes iridioides L. also commonly known as fortnight lily, African iris, "Indawo-Yehlathi*"*, morea iris or wild iris belongs to the plant family Iridaceae [63]. It is found in African countries such as South Africa and Angola. The rhizomes of *Dietes iridioides* are known to reduce pain during childbirth and to treat hypertension. Furthermore, the roots of this plant are known to alleviate menstrual pain [58]. A study conducted

in Gauteng Province of South Africa found that *Dietes iridioides* possesses short- and long-term BP lowering effects in hypertensive rats [63]. Rich in flavonoid, may act as an angiotensin converting enzyme (ACE) inhibitor preventing the conversion of angiotensin I to angiotensin II as it has been reported to possess ACE inhibitory activity *in vitro* [64,65].

Ficus exasperate Vahl

Ficus exasperata Vahl is a member of the plant family Moraceae [66]. It is used in Edo and Delta States of Nigeria to treat hypertension [57]. The plant is also commonly used in some parts of Africa to treat hypertension, epilepsy, arthritis, bleeding, and wounds [66].

Table 1. Medicinal plants in Africa with antihypertensive activities

Scientific name	Local name	Mechanism of action	Overall effect	Ref.
Dietes iridioides L.	"Indawo-yehlathi"	Inhibition of the angiotensin converting enzyme (ACE)	Long term BP lowering effects	[63-65]
Ficus exasperata Vahl	Sand paper tree	Inhibition of ACE Inhibition of the angiotensin II receptors Increasing NO (vasorelaxant)	Reducing BP	[66,67]
Asystasia gangentica L.	"Rumput Israel"	Inhibition of ACE	Reducing BP and heart rate in spontaneously hypertensive rats	[68-70]
Clausena anisata (Willd.) Hook.f. ex Benth.	"Isifudu"	Inhibition of ACE	Reducing SBP, DBP, MAP,	[71-73]
Tulbaghia violacea Harv.	Wild garlic	Inhibition of ACE, Inhibition of β_1 adrenoceptors Reduction of aldosterone Stimulation of muscarinic receptor	Lowering BP parameters including SBP, DBP and heart rate	[74-76]
Bryophyllum pinnatum (Lam.) Oken.	"Odaa opue"	Increasing endothelium-derived relaxation factor (vasorelaxant)	Lowering BP but can be cardio-toxic at high dose	[76-80]
Viscum album L.	Mistletoe	Calcium ion channel blockade in smooth muscle (vasorelaxant)	Reduceing the MAP, heart rate of hypertensive rats.	[81-83]
Musanga cecropioides R.Br. ex Tedlie	Umbrella tree	ACE blockage Inhibition of cholinergic and sympathetic response (vasorelaxant)	Caused a dose dependent fall in the SBP, DBP, MAP and heart rate of the rats.	[84-86]
Mammea africana Sabine	African mammae-aple	Activation of the nitric oxide-cGMP-ATP-dependent potassium channels pathway (vasorelaxant)	Reducing BP and SBP	[87-91]
Cinnamomum zeylanicum Blume	Ceylon cinnamon	Increasing NO Activation of the KATP channels in vascular smooth muscle (vasorelaxant)	Decreasing BP	[92-94]
Picralima nitida (Stapf) T.Durand & H.Durand	"Akuamma"	Increase in acetylcholine-mediated cholinergic response Increasing NO (vasorelaxant)	Reducing BP	[95-97]
Momordica charantia L.	Bitter melon	Inhibition of ACE Increasing NO (vasorelaxant)	Reducing BP and heart rate	[98-101]
Senecio serratuloides DC.	Two-day cure	Inhibition of ACE Increasing NO (vasorelaxant)	Reducing SBP and DBP	[102,103]
Taraxacum officinale (L.) Weber ex F.H.Wigg.	Dandelion	-	Lowering BP	[104-106]
Allium sativum L.	Garlic	Vasodilation Prostaglandin-like effect (vasorelaxant)	Lowering BP	[59]
Momordica balsamina L. *Aloe marlothii* A.Berger	Balsam apple Mountain Aloe	-	Lowering BP	[61]
Agathosma betulina *Cannabis sativa L*	"Ibuchu" "UmYa"	-	Lowering BP	[62]
Talinum triangulare (Jacq.) Willd.	Water leaf	-	Lowering BP	[60]
Adansonia digitata L.	African baobab	Inhibition of ACE	Lowering SBP, DBP, MAP and heart rate	[107-110]
Osteospermum imbricatum L.	"Umashiqolo"	Increasing NO (vasorelaxant)	Reducing SBP, DBP, heart rate	[111-112]
Sclerocarya birrea (A.Rich.) Hochst.	"Marula' or "Mafura"	Vessel endothelium relaxation (vasorelaxant)	Reducing SBP, heart rate and MAP	[113-115]

BP: blood pressure; SBP: systolic blood pressure; DBP: diastolic blood pressure; MAP: mean arterial pressure; NO: nitric Oxide; -: not available

A study conducted in Benin, Nigeria revealed that *Ficus exasperata* leaf extracts possess hypotensive effects [57]. Another study in Nigeria showed *Ficus exasperata* to be rich in flavonoids, alkaloids, tannins, and saponins, and was shown to reduce systemic arterial BP and heart rate. It has been reported that the plant is rich in flavonoids, tannins, catechins, β-sitosterol and polyphenolic compounds which may be responsible for its anti-hypertensive properties [67]. The mode of action of this plant has been through the inhibition of ACE and nitric oxide (NO) as has been previously reported to possess ACE and arginase inhibitory effects [66]. Reducing arginase activity prevents the synthesis of nitric oxide (NO) which regulates blood vessel constriction (vasorelaxant).

***Asystasia gangetica* L.**

Asystasia gangetica belongs to the Acanthaceae plant family. Eight species of this plant are found in Southern Africa, particularly in Kwa-Zulu Natal Province of South Africa [68]. The leaf of the plant is regarded as a potential food source because it possesses high amounts of proteins, amino acids, sugar, minerals, lipids and fiber. It is also used as a remedy for diseases [69]. Leaf extract of *Asystasia gangetica* was shown to lower BP and heart rate as well as inhibiting ACE and angiotensin II receptors in spontaneously hypertensive rats [69]. Thus, its action might be through the inhibition of ACE as has been previously reported [70].

***Clausena anisata* (Willd.) Hook.f. ex Benth.**

Clausena anisata belongs to the plant family Rutaceae [71]. It is native to Southern Africa and it is locally known as *"Isifudu"* [72]. The plant is used as insecticide in Cameroon [71]. Various parts of the plant have been used to treat respiratory ailments, malaria, heart disorders and hypertension [73]. A study carried out in Gauteng, South Africa found that the leaf extract of *Clausena anisata* added to drinking water every day for 40 days decreased BP parameters such as diastolic BP (DBP), systolic BP (SBP) and mean arterial pressure of hypertensive rats which could be through the ACE inhibitory mechanism [72]. Phytochemical studies have reported this plant to be rich in coumarins, alkaloids such as clausenol and clausamine, terpenoid hydrocarbons, and sesquiterpenoids [72].

***Tulbaghia violacea* Harv.**

Tulbaghia violacea belongs to Alliaceae family. It is usually associated with onion and garlic [74]. Belonging to the same family, it smells like garlic. Similarly, it is rich in saponin and bioflavonoids. It is used in South Africa to treat different conditions including fever, asthma, paralysis, tuberculosis, colds, stomach problems. rheumatism, oesophageal cancer and hypertension [75]. Furthermore, this plant has been reported by ethnobonatical survey to be one of the most used plants to treat cardiovascular diseases (CVDs) in Nkonkobe Municipality, South Africa [62]. A study conducted in the Western Cape Province of South Africa found that the methanol leaf extract of *Tulbaghia violacea* significantly decreased BP parameters including SBP, DBP, mean arterial pressure and heart rate in spontaneously hypertensive rats [74]. The mode of action of *Tulbaghia violacea* in this study was found as inhibiting the β_1 adrenoreceptors and the ACE [74]. Another study showed that the anti-hypertensive activity of *Tulbaghia violacea* in male spontaneously hypertensive rats was as a result of the reduction in plasma aldosterone levels and stimulation of muscarinic receptors [76].

***Bryophyllum pinnatum* (Lam.) Oken.**

Also known as *Bryophyllum calycinum* and *Kalanchoe pinnata*, *Bryophyllum pinnatum* is a perennial herb from the Crasullaceae family. It is predominantly distributed in Africa, Madagascar, China and Australia [77]. The plant is reported to possess hypotensive effects by Igbo people in Nigeria [78]. The leaves are used for the treatment of urinary calculi by the Tobago tribe, Nigeria. Furthermore, the leaves of this plant are known to have anti-diabetic, anti-inflammatory, anti-ulcer, muscle relaxant and anti-hypertensive effects [77]. A study showed that the leaf extract could lower arterial BP and heart rate in hypertensive rats. It was shown to decrease the rate and force of contractions of atria in guinea-pig and inhibited contractions induced by electrical field stimulation and drugs [79]. Reports from Cameroon showed this plant to possess anti-hypertensive properties by reducing BP and heart rate and increasing endothelium-derived relaxation factor thereby promoting blood vessel relaxation. This anti-hypertensive property may

be accounted for by the presence of tannins, phenolics, flavonoids and glycosides in the plant [80].

***Viscum album* L.**

Viscum album is a species from the plant family Viscaceae [81]. It is a partial parasitic plant that grows on deciduous plants such as oak, pines, apple, citrus and elms among others [82]. The plant is predominantly distributed throughout Europe, North Africa, Austria and Nigeria [82]. It contains phenolic acids, phenylpropanoids and flavonoids with antioxidant and anti-inflammatory effects which are known to reduce BP [81]. A study conducted in Calabar, Nigeria found that the extract of *Viscum album* significantly reduced BP with no effect on the heart rate of normotensive Albino Wistar rats. The study suggested that this plant might possibly be involved in the sympathetic mechanism [82]. Another study showed that the plant exhibited smooth muscle relaxant activity mediated through voltage-dependent calcium ion channel blockade. This postulated a possible vasorelaxant and spasmolytic activity responsible for its anti-hypertensive property which might have been induced by phytochemicals including tannins, alkaloids, saponins phenols, flavonoids, glycosides and terpenoids [83].

***Musanga cecropioides* R.Br. ex Tedlie**

Musanga cecropioides belongs to the Uricaceae family [84]. It is predominantly found in tropical West Africa [58]. The bark decoction of this plant is used to treat high BP, liver disease, alleviate menstrual pain and high blood sugar levels in Nigeria. Furthermore, the sap is drunk to cure cough and chest pain [58]. Phytochemical screening shows the presence of alkaloids, phlobatannins, saponins, anthraquinones, tannins, reducing sugars, glycosides, and flavonoids [85]. The extract of *Musanga cecropioides* was found to decrease SBP, DBP, mean arterial pressure and heart rate in Sprague-Dawley rats [86]. Its vasorelaxant hypotensive effect may be through ACE blockade as well as inhibition of cholinergic and sympathetic response [86].

***Mammea africana* Sabine**

Mammea Africana is a member of the plant family Guttiferae [87]. It is found in tropical Africa and is used in traditional medicine [88]. The stem-bark of the plant is used by Ibibio people in Nigeria as a remedy for hypertension, cough and scabies. Furthermore, the plant has been reported to possess cardioprotective, antioxidant, anti-inflammatory and vasorelaxant activities [87]. Methanol/methylene chloride extract of the stem-bark prevented the onset of arterial hypertension and significantly decreased the left ventricular hypertrophy in L-N^G-Nitro arginine methyl ester ($_L$-NAME)-induced hypertensive rats [89]. Another study showed *Mammea Africana* to reduce SBP in $_L$-NAME- or glibenclamide-induced hypertension in rats. This plant's anti-hypertensive effects may be due to its vasorelaxant activity which may be mediated via the activation of the nitric oxide-cGMP-ATP-dependent potassium channels pathway [90]. The vasorelaxant activity in reducing BP may be due to xanthones, flavonoids and coumarins including two 4-n-propylcoumarins and one 4-phenylcoumarins as has been previously reported [91].

***Cinnamomum zeylanicum* Blume**

Cinnamomum zeylanicum is another plant used to treat hypertension. It belongs to the plant family Lauraceaue and is widely distributed in Sri-Lanka and South India as well as central Africa [92]. *Cinnamomum zeylanicum* is also known as Ceylon cinnamon which has coumarin content. Coumarin contents possess strong coagulant activity known to potentially cause negative effects on the liver. However, coumarin content in Ceylon cinnamon is insignificant and is not known to cause any toxic effects [93]. The stem bark of the plant is used in Cameroon to treat increased BP, muscular pain and gastrointestinal disorders [92]. A study conducted in Cameroon among $_L$-NAME-induced hypertensive rats found that BP was lowered by 12.5%, 26.6% and 30.6% at intravenous administration doses of 5 mg/kg, 10 mg/kg and 20 mg/kg, respectively [92]. Another study showed this plant to possess anti-hypertensive properties by decreasing mean arterial BP and induction of vasorelaxant activity in $_L$-NAME-induced hypertension in rats. The possible mechanism for BP lowering activity may be as a result of its vasorelaxant effects mediated via increased production of endothelial NO and activation of the KATP channels in vascular smooth muscle [94]. This activity could be attributed to the presence of flavonoids, polyphenols, saponins and alkaloids [94].

***Picralima nitida* (Stapf) T.Durand & H.Durand**

Picralima nitida belongs to the Apocynaceae family [95]. It is commonly found in African forest regions, widely distributed through Ivory Coast to Ghana [96]. The plant is used in traditional medicine to treat various diseases such as malaria, anaemia, tumour, hypertension and menstrual pain because it possesses natural bioactive compounds [97]. A study reported that active principles of this species constitute 10 alkaloids present in different parts of the plant including the bark, root, leaves and fruits, which are implicated in its biological activities such as anti-inflammatory, anti-fever and hypoglycemic control activities [96]. A study carried out in Côte d'Ivoire found that the aqueous seed extract of this plant decreased BP in rabbits [96]. A study showed that the hypotensive effect of this plant was due to the acetylcholine-mediated cholinergic and NO-induced vasodilatory effects attributed to phytochemicals including alkaloids, polyterpenes, sterols, and saponosides [95].

***Momordica charantia* L.**

Momordica charantia also known as bitter melon belongs to the Cucubirtaceae family. It is widely distributed in the tropical and sub-tropical regions of the world including India, China, Singapore, New Zealand, Malaysia, East Africa, Nigeria and Ghana [98]. This plant is rich in phytochemicals including chlorogenic acid, tannin, epicatechin, gallic acid, catechin, alkaloids, carotenoids, sterols and gentisic acid [99]. Morphological parts of the plant such as stems, leaves, fruits and roots are used in Africa to control high BP and diabetes mellitus [100]. A study conducted by Jia and colleagues reported that this plant possesses medical properties including hypoglycemic, anti-tumor, contraceptive, anti-oxidant and anti-inflammatory activities [98]. Another study found that the intravenous administration of the extract of the whole plant reduced systemic arterial BP and heart rate of normal and hypertensive Dahl salt-sensitive rats [100]. This plant has also been shown to lower BP in salt-induced hypertensive rats. The possible mechanism of action was suggested as NO induced-vasorelaxant activity of the plant [101]. A systematic review reported that *Momordica charantia* hypotensive effect could results from its ACE inhibitory activity exerted by its bioactive components including polysaccharides and peptides as well as its phenolic compounds such as flavonoids [99].

***Senecio serratuloides* DC.**

Senecio serratuloides is a member of the plant family Asteraceae. It is widely distributed in parts of South Africa that receive summer rainfall [102]. A study reported that the main limitation with this plant is that the genus possesses pyrolizidine alkaloids which are linked with hepatic and pulmonary disorders [103]. However, the plant also possesses medical properties such as anti-oxidant, anti-inflammatory and wound healing activities [102]. It is rich in alkaloids, polyphenols, steroids, tannins, saponins, flavonoids, terpenes and glycosides [103]. A study conducted in the Eastern Cape Province of South Africa found that the hydroethanol extract of *Senecio serratuloides* had low toxicity (LD_{50} > 5000 mg/kg. Furthermore, the study found that the extract significantly decreased SBP and DBP as well as regulated NO and angiotensin II activity in $_{L}$-NAME-induced hypertensive rats [102]. This may suggest a possible mechanism of hypotensive effect via vasodilatory and ACE inhibitory activities [102].

***Taraxacum officinale* (L.) Weber ex F.H.Wigg.**

Taraxacum officinale, also known as Dandelion belongs to the family Aesteraceae. It has been used as a medicinal plant. It is indigenous to Europe and can now be found in other continents such as Africa, North and South America [104]. Dandelion is sold as a healthy food as it contains medical properties that are beneficial such as anti-inflammatory, antioxidant, anti-carcinogen and anti-hypoglycaemic effects [105]. A study carried out in the Eastern Cape Province of South Africa showed that the leaf and root extracts of *Taraxacum Officinale* prevented lipid peroxidation marked by significant decrease in malondialdehyde (MDA) level in target organs against free radical-mediated oxidative stress in $_{L}$-NAME-induced hypertensive rats [104]. It was further reported that dandelion possessed anti-hypertensive properties by lowering BP and did not exhibit toxicity in animal models [104,106]. These findings suggest that dandelion could prevent the development of hypertension by inhibiting oxidative stress through its antioxidant potential. Although the mechanism of action against hypertension is yet to be established, this plant is rich in phenolics, tannins, alkaloids,

terpenoids, glycosides, steroids, and saponins which may contribute to its hypotensive activity [106].

***Adansonia digitata* L.**

African baobab scientifically known as *Adansonia digitate* L. belongs to the Bombaceae family. It is usually used by traditional healers to treat CVDs [107]. This genus is predominantly found in Africa. The parts of baobab such as leaves, fruits, seeds and bark continue to contribute to the households of many African populations as a source of medicine or food [107]. A study conducted at the University of Ngaoundéré in Cameroon found that the aqueous extract of stem bark of *Adansonia digitata* reduced hemodynamic parameters including DBP and SBP in $_{L}$-NAME-induced hypertensive rats [107]. Another study conducted in Bayero University, Kano, Nigeria found that extracts of baobab significantly decreased lipid indices which are associated with hypertension such as plasma total cholesterol, triglycerides, low density lipoprotein-cholesterol and significantly increased high density lipoprotein-cholesterol in rats fed with a high lipid diet [108]. Another study showed that this plant lowered SBP, DBP, mean arterial pressure and heart rate to normal in $_{L}$-NAME-induced hypertensive rats and also possessed ACE activity [109]. Thus, the anti-hypertensive effect of this plant could be due to its ACE inhibitory activity and the presence of flavonoids, terpenoids, alkaloids, saponins and glycosides [110].

***Osteospermum imbricatum* L.**

Osteospermum imbricatum known as "*Umashiqolo"* in the Eastern Cape Province of South Africa, is a member of the Asteraceae family found in South Africa and Mozambique [111]. This genus is used locally to treat hypertension [112]. A study carried out at Walter Sisulu University, Eastern Cape Province of South Africa found that the leaf extract of *Osteospermum imbricatum* significantly decreased hemodynamic parameters such as DBP and SBP in Wistar rats treated with $_{L}$-NAME [111]. Another study by the same group, confirmed the anti-hypertensive effect of this plant as it reduced SBP, DBP, HR and increased NO in $_{L}$-NAME-induced hypertensive rats. Acute toxicity test showed the plant to be non-toxic and was well tolerated by the animals. The plant is rich in saponins, tannins, flavonoids, cardiac glycosides, alkaloids, terpenoid, steroids and phenolic compounds [112]. The increase in NO suggests potential vasorelaxant activity accountable for its anti-hypertensive property.

***Sclerocarya birrea* (A.Rich.) Hochst.**

Sclerocarya birrea commonly known as "Marula or Mafura" is commonly distributed in Southern Africa. The fruits of the plant are commonly eaten as food but also to prepare traditional alcoholic beverage called "Mukumbi″ as well as a commercial alcoholic beverage called "Amarula". The plant has been demonstrated to possess medicinal properties against obesity and metabolic syndrome [113]. The stem-bark extract has been shown to decreases SBP and heart rate in hypertensive Dahl salt-sensitive rats [114]. Long-term administration of the plant's stem-bark extract (5 weeks) resulted in a reduction in mean arterial BP [115]. Aqueous extract of this plant has been shown to induce aortic vessel endothelium relaxation in noradrenaline-induced contraction in rats [114]. This suggests that the plant's mode of action against hypertension may be due to its vasorelaxant activity. *Sclerocarya birrea* has been reported to be rich in flavonoids, and polyphenols [113] which may be responsible for its anti-hypertensive activity.

Conclusion

Hypertension constitutes a major public health problem in Africa. Several plants have been used locally to treat hypertension in the African continent. Studies have revealed potential anti-hypertensive effects in animals along with the phytochemical constituents and some potential mechanism of action thus providing the scientific basis and validating the ethnopharmacological use of these plants in the treatment of hypertension. While these plants present future prospects in the production of safer and effective anti-hypertensive therapy, a lot of work is needed to further elucidate the mode of action of these plants and the principal active compounds in treating hypertension as this information is not sufficient for most of these studies in Africa. The exploration of the wide array of medicinal plants in the treatment of hypertension in Africa may go a long way in providing more effective drugs for the management of hypertension in this continent.

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Author contributions

Benedicta Ngwenchi Nkeh-Chungag and Godwill Azeh Engwa developed the concept; Godwill Azeh Engwa and Edna Ngoakoana Matjuda; performed literature search and sourced data; Godwill Azeh Engwa and Edna Ngoakoana Matjuda wrote the first draft of the manuscript; Benedicta Ngwenchi Nkeh-Chungag and Godwill Azeh Engwa reviewed and revised the manuscript. All authors proofread and approved the final manuscript.

Declaration of interest

The authors declare that there is no conflict of interest. The authors alone are responsible for the accuracy and integrity of the paper content.

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Abbreviations

ACE: angiotensin converting enzyme; ACEIs: angiotensin converting enzyme inhibitors; ADH: anti-diuretic hormone; BP: blood pressure; CVDs: cardiovascular diseases; DBP: diastolic blood pressure; L-NAME: L-N^G-nitro arginine methyl ester; MAP: mean arterial pressure; NO: nitric oxide; SBP: systolic blood pressure; TPR: total peripheral resistance