SHST
Horticulture and Forestry
Society of Transylvania

Ayoka TO and Nnadi CO (2022)
Notulae Scientia Biologicae
Volume 14, Issue 2, Article number 11177
DOI:10.15835/nsb14211177
Research Article

NSB
Notulae Scientia
Biologicae

Lesser-known leafy vegetables of Southeastern Nigeria (*Vitex doniana* and *Zanthoxylum zanthoxyloides*)

Thecla O. AYOKA[1]*, Charles O. NNADI[2]

[1]*University of Nigeria, Nsukka, Faculty of Physical Sciences, Department of Science Laboratory Technology (Biochemistry Unit), 410001, Enugu State, Nigeria; thecla.ayoka@unn.edu.ng (*corresponding author)*

[2]*University of Nigeria, Nsukka, Faculty of Pharmaceutical Sciences, Department of Pharmaceutical and Medicinal Chemistry, 410001, Enugu State, Nigeria; charles.nnadi@unn.edu.ng*

Abstract

Vitex doniana and *Zanthoxylum zanthoxyloides* are plants grown in the Southeastern part of Nigeria. They have been used traditionally as food and in medicine, also in teeth cleaning and as a mouth wash to reduce pain. The availability of these plants has sparked a surge in interest in knowledge about their supplements and contents, including nutrients, mineral components, and bioactive chemicals, which are critical for drug discovery and development. Compounds derived from them have been used as effective pharmaceuticals throughout human history. This review is aimed at providing a comprehensive report on the chemical constituents, traditional uses, biological and pharmacological activities of *Vitex doniana* and *Zanthoxylum zanthoxyloides*. Information was sourced from literatures using search engines such as Google, Google Scholar, Microsoft Academic, ResearchGate, and Semantic Scholar. The plants were found to contain natural products such as alkaloids, phenolics, tannins, saponins, glycosides, steroids, proteins, carbohydrates, anthraquinones, resins, lignans, lipids, allicins, balsams, hydroxycinnamic acid, oleanolic acid, esters, norisoprenoids, anthracene, essential oils and terpenes, which seem to correlate with their antioxidant potentials. They have gained interest recently due to the presence in them of varieties of their bioactive compounds. Biological and pharmacological studies revealed that they possess antioxidant, anti-cancer, antimalarial, anti-inflammatory, antimicrobial activities and hepatoprotective properties. In addition, the alkaloidal content of *V. doniana* and *Z. zanthoxyloides* can enhance serum biochemical parameters, repair cellular damage and fibrosis in the liver, and control hepatocyte activity.

Keywords: antioxidant; hepatoprotective; vegetables; *Vitex doniana*; *Zanthoxylum zanthoxyloides*

Introduction

Southeastern Nigeria is an area that has cultural diversity and traditions. The basic food habits and medical practices of the area are observed. There are a number of traditional medical methods such as folk/tribal medicine practiced in Southeastern Nigeria, and medicinal sources are taken from medicinal plants in these practices (Elekwe *et al.*, 2017; Chinwe, 2018). Nevertheless, the majority of edible foods and their components, such as fruits, seeds, roots and leaves are also found to have substances of medicinal value, such as flavonoids,

Received: 13 Jan 2022. Received in revised form: 23 Feb 2022. Accepted: 09 May 2022. Published online: 30 May 2022.
From Volume 13, Issue 1, 2021, Notulae Scientia Biologicae journal uses article numbers in place of the traditional method of continuous pagination through the volume. The journal will continue to appear quarterly, as before, with four annual numbers.

tannins and other phenolic compounds (Orabueze *et al.*, 2017; Iheanacho *et al.*, 2019). About 2000 plants are estimated to be used in local health traditions in Southeast's mostly rural and tribal villages (Nnamani *et al.*, 2009). Of these, the actual therapeutic value of a small fraction is either little known or unknown to the plant's population mainstream (Ikeyi *et al.*, 2014; Enechi, 2019).

The use of all parts of medicinal plants in the treatment of diseases has been described, and this serves as the basis for the search for and development of novel drugs (Tougoma *et al.*, 2021a). Over the years, man has used many leafy vegetables to fight and control disease and pain. The plant materials that are mostly used for these purposes are leaves, barks and seeds (Wanzala *et al.*, 2012). They are used in the form of concoctions, decoction, or infusions. The use of medicinal plants is found in almost all cultures, in some, many types of plants are used (Osum *et al.*, 2013). Some are efficacious while others are not.

Southeastern Nigeria has different climatic variations, favoring region-specific vegetables and their use (Orabueze *et al.*, 2017; Iheanacho and Ogunwa, 2021). Different studies on fruit and leaf vegetables of *Vitex doniana* and *Zanthoxylum zanthoxyloides* especially consumed in southeastern Nigeria, and their chemical and biological activities by different researchers are reviewed in this study.

This review is aimed at exploring the bioactivity, biological and chemical activities of the two leafy vegetables eaten in southeastern Nigeria and to outline the practical reasons why they are being encouraged to consume these vegetables.

Materials and Methods

Electronic search engines (Google, Google Scholar, Microsoft Academic, ResearchGate, and Semantic Scholar) were used to collect literature using the terms *Vitex doniana, Zanthoxylum zanthoxyloides*, *fagara zanthoxyloides*, bioactivity, toxicity, phytochemistry, proximate composition, hepatocurative and hepatoprotective of the two plants. After being found to be specifically relevant to the main theme of this paper, the details provided in this analysis was chosen.

Results

Vitex doniana

A. Plant profile

Synonyms

Vitex cuneata, *Vitex cienkowskii*, *Vitex pachyphylla.*

Vitex comprises of over 270 species, which are mainly shrubs and trees (Orwa *et al.*, 2009).

B. Taxonomic classification

Kingdom: *Plantae*, Phylum: *Magnoliophyta*, Class: *Magnoliopsida*, Order: *Lamiales,* Family: *Verbenaceae*, Genus: *Vitex*, Epithet: *Doniana* Sweet (Yangora and Bello, 2017).

C. Common names

English: Black plum, West African plum, Amargna: Plem, Ari: Silanri, French: Prunier noir, Koro, Polish: Cetona, Swahili: Mfudu, mfuru, mfuu, Amharic: Plem, Bemba: Mufutu, Luganda: Munyamazi, Nyanja: Mfifya, Igbo: Uchakiri, Fulani: Tunci, Hausa: Dinya, Yoruba: Oori-nla (Orwa *et al.*, 2009).

D. Distribution

Vitex doniana is distributed widely in tropical Africa (Aiyeloja, 2014) Nigeria inclusive, especially South-eastern Nigeria (Lasekan, 2017).

E. Description

A tree 15-20 m high, or to 25 m in good conditions, girth 1-20 m, of the dense forest, wooded savanna, coastal savanna and riverine thickets (Bangou *et al.*, 2019). The bark is light grey. Leaves are made up of 5-7 leaflets, which are wide at the tip, they are also hairless. The fruits are shaped like earth, with a size of 2-5 cm long. They are green in colour, but black when ripe. Flowers are white and numerous (Orwa *et al.*, 2009). The photograph of the plant is represented as shown in Figure 1.

Figure 1. *Vitex doniana*

F. Traditional uses

V. doniana fruits are taken to suppress appetite by farmers and hunters. It is also used to promote soil fertility as a mulch, as food, as medicine and as timber to make dyes and charcoal (Orwa *et al.*, 2009; Dadjo *et al.*, 2012). Leaves are employed to treat oedema, diabetes, ulcer and in diuresis. The twig of *V. doniana* is employed in cleaning teeth (Chinwe, 2018). The leaves' decoction is given to induce labour during child birth. *V. doniana* is used in making smoke. Its extracts are employed to manage infestation by worm in poultry. The leaves can also serve as fodder for cattle (Wanzala *et al.*, 2012). The leaf extract is taken as a therapy for eye and liver problems, releases pain during child birth and enhances milk production in lactating mothers. It serves as a supplement for deficiency of vitamins A and B, and also as a remedy for kidney diseases (Burkill, 2000).

G. Phytochemical studies and chemical constituents

Various phytochemical studies have been carried out over the years on different parts of *V. doniana* (Table 1). According to Sanni *et al.* (2019), forty three (43) different bioactive compounds were found in the methanol extract of *V. doniana* leaves. They are β- Bisabolene, linalool, erucic acid, α-Farnesene, D-Nerolidol, α-Caryophyllene, α-Copaene and Calarene They also identified some trace elements namely Fe, Mn, Se, Cu and Zn in the leaf extract. Sonibare *et al.* (2009) investigated the chemical composition of *V. doniana* using GC-MS. In their report, they identified twelve compounds including phytol, β-phellandrene, β-caryophyllene, caryophyllene oxide, caryophyllene, bicyclogernacrene and α-pinene. Thirty-five (35) aroma constituents were identified in the free fractions of *V. doniana* sweet while Twenty-eight (28) aroma constituents were found in the bound fraction. Those detected in the free fraction are alcohols, esters, and terpenes, while those identified in the bound fraction are ketones, alcohols, terpenes and norisoprenoids (Lasekan, 2017). Ifeanacho *et al.* (2019) carried out characterization of phytoconstituents using Gas chromatography.

Table 1. Phytochemicals present in various parts of *V. doniana*

Plant parts	Extracts/fractions	Phytochemical constituents	References
Root	Ethanol	Flavonoids, glycosides, sterols, proteins.	Agbafor and Nwachukwu, 2011
		Saponins, tannins	Tijani *et al.*, 2017
	Acetone	Flavonoids, glycosides, sterols, proteins.	Agbafor and Nwachukwu, 2011
	Aqueous	Tannins, saponins	Tijani *et al.*, 2017
Leaf	Methanol	Proteins, carbohydrates.	Nnamani *et al.*, 2009
		Flavonoids, terpenes, tannins.	Sanni *et al.*, 2019
		Saponins, tannins, anthraquinones, resin, flavonoids, alkaloids, carbohydrates, balsam.	Nwachukwu and Uzueto, 2010
		Triterpenoids	Mohammed *et al.*, 2016
	Acetone	Glycosides, proteins	Agbafor and Nwachukwu, 2011
	Ethanol	Flavonoids, glycosides, proteins, tannins	Agbafor and Nwachukwu, 2011
	Hydoethanol	Tannins, saponins	Tijani *et al.*,2017
		Terpenes, essential oils, glycosides, anthracene	Lagnika *et al.*, 2012
	Butanol	Alkaloids, flavonoids, lignans, terpenoids, lipids	Ayoka *et al.*, 2020a
Bark	Acetone	Glycosides, steroids, proteins	Agbafor and Nwachukwu, 2011
		Tannins, saponins	Tijani *et al.*, 2017
	Aqueous	Flavonoids	Agbafor and Nwachukwu, 2011
	Ethanol	Flavonoids, Glycosides, steroids, proteins	Agbafor and Nwachukwu, 2011
Fruits	Methanol	Sugars, phytin, tannins	Agbede and Ibitoye, 2007
		Alcohols, terpenes, norisoprenoids, esters, ketones	Lasekan, 2017
		Tannins, saponins, cardiac glycosides, alkaloids, flavonoids, terpenoids, steroids	Imoisi *et al.*, 2021a
	Ethyl acetate	Oleanolic acid	Adjei and Fosu-Mensah, 2021
Seed	Methanol	Alkaloids, flavonoids, phenolics	Amah and Okogeri, 2019

A total of nine (9) saponins, eleven (11) flavonoids, sixty-one (61) terpenoids, three (3) allicins and hydroxycinnamic acid were identified in their study. Several putative compounds were identified in the soluble butanol of *V. doniana* by peak dereplication of LC-MS chromatograms (Ayoka *et al.*, 2020a). Seven alkaloids, four flavonoids, two lignans, four terpenoid and one lipid were identified. Among the compounds tentatively characterized are vitedoin B, quercetin, myricetin, casticin and vitexilactone. According to their report, there was a 10.33%, 0.69%, 0.45%, 0.49% and 0.39% extractive yield of methanol extract, dichloromethane, hexane, ethylacetate and butanol fractions respectively. Olajide *et al.* (2018) reported an 8.25% yield of methanol extract in a similar work. Three compounds 20-hydroxyecdysone, turkesterone and ajugasterone were isolated from the stem bark of *V. doniana* using nuclear magnetic resonance (NMR) spectroscopy (Bunu *et al.*, 2021).

H. Proximate composition

The proximate composition and iron content of *V. doniana* leaves were determined. There was a high mineral content due to high ash, low moisture and high iron contents in the leaves of *V. doniana* (Yangora and Bello, 2017). The moisture, protein and carbohydrate contents of *V. doniana* leaf were set to be 10.8%, 8.74% and 58.94% respectively (Nnamani *et al.*, 2009). The fruits were found to contain good concentrations of useful macro-mineral elements as well as sugars, phytin and tannins, with lower vitamin C levels as compared with other common plants (Agbede and Ibitoye, 2007). Their proximate compositions were determined to be ash (52.7 ± 0.1), moisture (487.7 ± 0.5), fat (30.0 ± 0.4), protein (72.8 ± 0.1), fibre (67.3 ± 0.7), and carbohydrates (289.5 ± 0.8) g/kg. The level of sugar ranged between 474 and 40000 mg/kg. Osum *et al.* (2013) investigated the proximate parameters of the leaves. Protein, fibre, ash, moisture, fat and carbohydrate contents were found to be 0.07 – 17.29%, 1.85 – 6.33%, 0.47 – 6.55%, 10.86 – 95.67%, 0.05 – 1.24% and 3.61 – 58.08% respectively. Micronutrients such as Ca, Fe, Na, vitamin A, vitamin E and vitamin B2 were recorded as 13.38 – 59.50 mg $100g^{-1}$, 3.0 – 18.00 mg $100g^{-1}$, 0.37 – 1.29 mg $100g^{-1}$, 1.5 – 32.98 mg $100g^{-1}$, 54.6 – 3583.26 IU, 3.11 – 53.36 mg $100g^{-1}$ and 0.01 – 9.63 mg $100g^{-1}$ respectively. The nutritional values of black plum were determined to be ash (11.50%), moisture (16.66%), crude proteins (8.24%), crude fat (34.62%), crude fibre (0.58%), and carbohydrate (28.40%). Other parameters measured included vitamin A (0.27), vitamin B1 (18.33), vitamin B2 (4.80) and vitamin C (35.58) mg $100g^{-1}$. K, Na, Ca, Fe, Cu, Mg and P levels were 16.5, 10.40, 30.27, 5.20, 2.70, 20.10 and 16.50 (mg $100g^{-1}$) respectively (Vunchi *et al.*, 2011). According to the report of Aiwonegbe *et al.* (2018), the proximate composition of moisture, crude fibre, ash, crude protein, carbohydrates and crude lipids were as follows 10.00%, 18.00%, 4.50%, 0.60%, 43.20% and 23.70% respectively. Similarly, the result of Bello *et al.* (2014) showed that the moisture, crude protein, crude fibre, crude fat, ash and carbohydrate contents were 8.04%, 8.75%, 15.58%, 11.75%, 5.10%, 7.92% and 70.20% respectively. Also, ascorbic acid, Ca, K, and Fe contents were 24.0 mg $100g^{-1}$, 3.36 g $100g^{-1}$, 1.13 g $100g^{-1}$ and 0.12 mg kg^{-1} respectively. Abdulsalam *et al.* (2019) in their work, processed *V. doniana* fruit into juice, and then estimated their nutritional value. The proximate composition of carbohydrate, crude fat, crude protein, moisture, ash, crude fibre was determined to be 5.22%, 0.30%, 1.93%, 96.36%, 0.94% and 0.60% respectively. *V. doniana* plum was demonstrated to be highly nutritious with moisture, ash, fat, fibre, protein and carbohydrate contents as 77.03%, 1.65%, 2.9%, 2.75%, 8.10% and 7.57% respectively, while Imosis *et al.* (2021b) in their work determined the moisture, ash content, fat, fibre, protein and carbohydrate to be 9.90%, 21.5%, 0.75%, 0.006% and 67.84% respectively. The bioactive and nutritional effects of *V. doniana* leaves were investigated. A high fibre and protein content (14.67-35.39) and (15.46 – 37.30) g $100g^{-1}$ respectively were reported, while the lipid and carbohydrate contents (0.80 – 1.93) and (4.02 – 9.70) g $100g^{-1}$ respectively were moderate (Iheanacho and Ogunwa, 2021). The edible pulp of *V. doniana* were found to be have a pH of 5.20, moisture content of 67.9%, 12.5 % sucrose and 7.3 % reducing sugar, while its syrup contains 51.7% reducing sugar, 25% moisture and 12.9% sucrose contents (Abu, 2007). Fats, proteins, fatty acids, and amino acids were found in the seeds after phytochemical analysis (Amah and Okogeri, 2019).

I. Pharmacological effect

Antioxidant activity

Agbafor and Nwachukwu (2011) desclosed that the stem bark, leaves and root extracts of *V. doniana* have antioxidant properties that can be compared to standard antioxidant drugs. Its antioxidant property was associated to its phenolic contents. The methanol leaf extract exhibits good DPPH radical scavenging effect compared with quercetin (Sanni *et al.*, 2019; Ani *et al.*, 2020). Lagnika *et al.* (2012) reported the antioxidant properties of *V. doniana* on hydroethanol and methanol extracts. Their result was similar with that of Agbafor and Nwachukwu (2011). Ayoka *et al.* (2020a) attributed the antioxidant potentials of *V. doniana* leaves to the presence of phenolics and alkaloids (Njoku *et al.*, 2019). According to them, dichloromethane fraction which contains the bulk alkaloid fraction showed the highest antioxidant activity. They demonstrated its antioxidant properties on the methanol extracts, dichloromethane and butanol fractions of the leaves. The antioxidant activity of aqueous, ethanol and n-hexane fractions of *V. doniana* was evaluated (Yakubu *et al.*, 2014). They demonstrated that the DPPH scavenging activity of *V. doniana* followed the order: ethanol extract > aqueous extract > *n*-Hexane extract. Sanni *et al.* (2019) in their work identified some trace elements and forty-three phytochemicals in the extract, which they claimed may be accountable for its significant antioxidant activity. Adjei and Fosu-Mensah (2021) in their work determined the antioxidant effects of *V. doniana* fruits using the DPPH model, with the ethyl acetate fraction having an IC_{50} 99.35 ± 0.77 μg ml^{-1}. However, its antioxidant activity using DPPH model ranges from 71.0 ± 0.4 to 48.3 ± 0.1 (Charles and Mgina, 2021), while the IC_{50} was found to be 245.8 μg ml^{-1} (Imoisi *et al.*, 2021a).

Antimicrobial activity

V. doniana contains alkaloids, tannins, and flavonoids which accounts for its properties as antifungal and antibacterial agents (Agbafor and Nwachukwu, 2011). Lagnika *et al.* (2012) carried out similar work on the leaves using the hydroethanol and methanol extracts. Kuta *et al.* (2015) looked at the antibacterial effect of the bulk extract and fractions of the leaves and stem bark using *in vitro* methods. They demonstrated that extract of ethanol produced the highest antibacterial potential. The anti-microbial studies on the leaf and stem bark extracts of *V. doniana* were demonstrated by Egharevba *et al.* (2010). Their analysis was carried out using ethylacetate, methanol and hexane extracts of the leaf and stem bark. The extracts impaired *P. aeruginosa*. Anti-microbial potential against *E. Coli* and *S. typhi* followed the order; acetone extract > methanol extract > ethanol extract (Nwachukwu and Uzueto, 2010) . Aiwonegbe *et al.* (2018) reported that *E. coli, Pseudomonas aeruginosa, Staphylococcus aureus,* and *Klebsiella pneumonia* were impaired by acetone and methanol extracts. The zone of inhibition was found to be between 10.50 – 21.00 mm for all concentrations. Sonibare *et al.* (2009) had earlier reported that the essential oils have antibacterial properties against *Proteus mirabilis*, *Bacillus subtilis* and *Candida albicans*. Meanwhile, the bark extract and the three compounds isolated in the work of Bunu *et al.* (2021) were investigated for anti-microbial and anti-protozoan activities. They all inhibited strains of bacterial with less activity (MIC values of 500-1000 μg ml^{-1}) exhibited by the three compounds isolated, with greater activity exhibited by the crude extract (MIC values of 125-250 μg ml^{-1}. They further added that at a concentration of 4.8 g ml-1, it has no action against *P. falciparum*.

Anti-inflammatory activity

Bioactive constituents found in the plant may be accountable for its analgesic and anti-inflammatory roles. Saponins and alkaloids have anti-inflammatory properties, which was reported by Iweke *et al.* (2006). They demonstrated that the formation of paw edema in rats induced by agar were prevented when the rats were administered the extracts of the leaves (Adjei and Fosu-Mensah, 2021).

Hepatoprotective effect

Hepatoprotective study on the dichloromethane fraction (DCM-F) of *V. doniana* leaves was demonstrated. The study measured the activity of enzymic and non-enzymic markers in carbon tetrachloride-induced hepatocellular damage. In CCl_4-induced rats, dichloromethane fractions triggered a substantial elevation ($p < 0.05$) in catalase, superoxide dismutase, glutathione peroxidase, and vitamins C and E relative to usual (Ayoka *et al.*, 2020a). A similar work had earlier reported the ameliorating effect of its ethanol extract following aluminum-induced liver damage, (Yakubu *et al.*, 2016) and kidney (Abdulrahman *et al.*, 2007). The authors indicated that the serum activities of these biochemical markers were remarkably decreased following the intake of the ethanolic extract of *V. doniana*. Yakubu *et al.* (2016) also reported that *V. doniana* administration did not invoke any change in the concentration of serum bilirubin of animal models. Olajide *et al.* (2018) suggested that the hepatocurative effect of *V. doniana* may be due to its anti-inflammatory and antioxidant activities. Similar work by Olajide *et al.* (2018) reported that *V. doniana* decreased serum concentrations of blood urea nitrogen (BUN) and creatinine in cadmium-induced toxicity in rats.

Toxicology

Acute toxicity studies were done on the extracts as well as fractions of *V. doniana* (Ayoka *et al.*, 2020a; Onwukwe *et al.*, 2020). During the duration of the study, the treated mice did not produce lethality (mortality). The mice did not experience any significant weight loss or changes in their food patterns. Skin dryness, hair loss, or general weakening were not observed in the mice. Their results were similar to Sha'a *et al.* (2011), which looked at the toxicity of *V. doniana* extracts. Adjei and Fosu-Mensah (2021) estimated LD_{50} to be greater than 3000 mg kg^{-1}, while there is an increased lymphocyte and red blood cell counts in their subacute studies. Imosis *et al.* (2021b) also determined LD_{50} to be above 5000 mg kg^{-1}.

Zanthoxylum zanthoxyloides

A. Plant Profile

Synonyms

Fagara zanthoxyloides Lam, *Zanthoxylum senegalense* DC, *Zanthoxylum polyganum* Schum (Matu, 2011).

B. Taxonomic Classification

Kingdom: *Plantae*, Order: *Rutales*, Family: *Rutaceae*, Sub-family: *Toddalioideae,* Genus: *Zanthoxylum*, Species: *Zanthoxyloides* (Matu, 2011; Boye *et al.*, 2012).

C. Common names

English: Artar root or candlewood, Igbo: Alga, Hausa: Fasahuari, Moore: Rapeko, Djoula: Wouho, Bambara: Wo, Gozo ngua, Wolof: Guene gui deg, Toucouleur: Dori, Peuhl: Barkeley, Bulabarkele, (Adesina, 2005).

D. Distribution

Z. zanthoxyloides is abundant in West African savannah and dry forest vegetation, coastal areas from Senegal to Nigeria and Cameroon. It occurs abundantly in coastal areas and at low altitudes and well drained soils (Anne *et al.*, 2013).

E. Description

It's a 6-12 m tall tree. The bark is grey and rough, with prickles. The leaves are alternate, garnished with prickles. Flowers are 5-6 cm in diameter, white or green. The fruits contain a black shiny single seed (Ouédraogo *et al.*, 2019). Its photograph is represented in Figure 2.

Figure 2. *Zanthoxylum zanthoxyloides*

F. Traditional uses

In traditional medicine, *Z. zanthoxyloides* is employed extensively in the management of disease (Table 2). Because of the presence of thorns, they are planted as hedges. It has antimicrobial properties and positive effect on oral pathogens (Dofuor *et al.*, 2019). Sheep also browse the leaves. It is a fetish plant with magico-religious uses, such as protection against spirit (Matu, 2011).

G. Phytochemical studies and chemical constituents

Reports on the phytochemicals of *Z. zanthoxyloides* have revealed several compounds with pharmacological potentials. Benzo[C] phenanthridine alkaloid, fagaronine, an active compound isolated from *Z. zanthoxyloides*, has strong antileukemic activity against both L 1210 and P-388 leukemia. Other compounds isolated from its root such as chelerythrine, aporphine (N-methyl-corydine), berberine and canthine-6-one are found to have antimicrobial activity (Anne *et al.*, 2013). Others are dihydrokavain, oxychelerythrin, skimmianine, magnoflorine, tembetarin and 8-methoxydictamine (furoquinolines). It also contains arottianamide, fagaramide, piperlonguminine, rubermamine and N-isopentyl cinnamamide (Nantongo *et al.*, 2018). Pellitorine is the component that is responsible for the hot peppery taste of *Z. zanthoxyloides*, it is regarded as the local anaesthetic component of the roots. Its main component N-isobutyldeca-trans-4-

dieanamide, is very active against house fly, *Musca domestica L.* It also has antibacterial and antimalarial properties (Anne *et al.*, 2013).

Table 2. Traditional uses of various parts of *Z. zanthoxyloides*

Plant parts	Traditional uses	References
Stem and root decoctions	Used ae therapeutics in the management of tuberculosis and general body weakness. Used in the treatment of whooping cough.	Matu, 2011; Guendehou *et al.*, 2018 Boyle *et al.*, 2012
Root extracts	Used as a mouthwash and to treat a sore throat Used to control hypertension and in the management of sickle cell disease.	Matu, 2011; Dofuor *et al.*, 2019 Anne *et al.*, 2013
Pulped stem bark and root bark	Used to stupefy fish when thrown into water, to treat cancer; also applied to the eyes to treat conjunctivitis.	Matu, 2011
Crushed bark	Used to treat scabies	Matu, 2011
Bark macerated in wine	Used as a remedy for venereal diseases as well as intestinal worms and dysentery.	Anne *et al.*, 2013
Shoots, roots and twigs	Employed as a chewing stick.	Koshkomba *et al.*, 2017
Wood/timber	Used to manufacture ceremonial torches as well as for building purposes.	Matu, 2011. Anne *et al.*, 2013
Seeds	Serve as necklace.	Matu, 2011
Leaves	Used as a seasoning, sheep also browse it.	Matu, 2011
Leaf, bark and root extracts	Used to protect stored food against pests.	Matu, 2011

Coumarins such as aesculetin dimethylether (scoparone), 6,7,8-trimethoxy coumarin, scopoletin, umbelliferone, xanthotoxin, impertorin, bergaptenin, marmesin, pimpinellin and furocoumarins were all detected in the stem bark of *Z. zanthoxyloides*. Sesamin and asarinin which are lignans have also been isolated from the root, fruits and stem bark. Other compounds such as zanthoxylol, diosmin, fagarol and hesperidin have been detected and characterized. Lupeol, β-sitosterol and β-amyrin were isolated from different parts of plants (Nantongo *et al.*, 2018). An anti-sickling agent, 2-hydroxymethyl benzoic acid has been isolated from the root. Alkaloids such as chelerythrine dihydroavicine and oxychelerythrine were also isolated from the root and bark. Others are skimmianine, 8-methoxydictamine, 3-dimethylallyl-4-methoxy-2-quinolone, tembetarine, berberine, magnoflorine, 6- canthinone and N-methyl-corydine isolated from the roots (Nantongo *et al.*, 2018). *Z. zanthoxyloides* leaves contain essential oils such as α-pinene, myrcene and trans-β-ocimene. Its fruit has monoterpenoids, linalool, geranial and fairly high proportion of oxygenates. (Adekunle *et al.*, 2012) identified and quantified three flavonoids (quercetin, kaempferol and rutin) from the ethanolic extract of the stem using HPLC-DAD. Hesperidin, neohesperidin and eriocitrin (flavonones) and quercetin, quercetin-3-O-glucopyranoside, datiscin, quercitrin, hyperoside (flavonols) and neodiosmin (flavones) were all identified in all plant extracts. As well as rutin and kaempferol. Other compounds identified from the fruits of the plant are geraniol, citronellol, citronellyl acetate, citronellal, limonene, (E)-β- ocimene, myrcene, and α-pinene. Burkinabines A, B and C were detected in the root bark of the plant (Anne *et al.*, 2013). Thirty (30) important compounds were tentatively characterized in the butanol fractions of *Z. zanthoxyloides* leaves using HPLC-MS dereplication. They detected for the first-time good number of phenolic compounds and alkaloids whose roles are unknown in radical scavenging activity (RSA) (Ayoka *et al.*, 2020b). They reported the extractive yield of the extracts and fractions as methanol extract (12.4%), dichloromethane fraction (0.7%), hexane fraction (0.43%), ethylacetate fraction (0.47%) and butanol fraction (0.41%). Olushola-Sudoks *et al.* (2020) identified forty-six chemical constituents grouped into phytochemicals such as phytosterols, coumarins, terpenes and fatty aldehydes. Misra *et al.* (2013) in their own work identified citronellol and geraniol as the major compositions of the essential oils of *Z. zanthoxyloides.* They also maintained that the fruits exhibited moderate antimicrobial and anticancer activities. Phytochemical results of the aqueous bark of *Z. zanthoxyloides* showed that alkaloids and flavonoids are present (Tougoma *et al.*, 2021). Structures of some compounds isolated from the plants are represented in Figure 3.

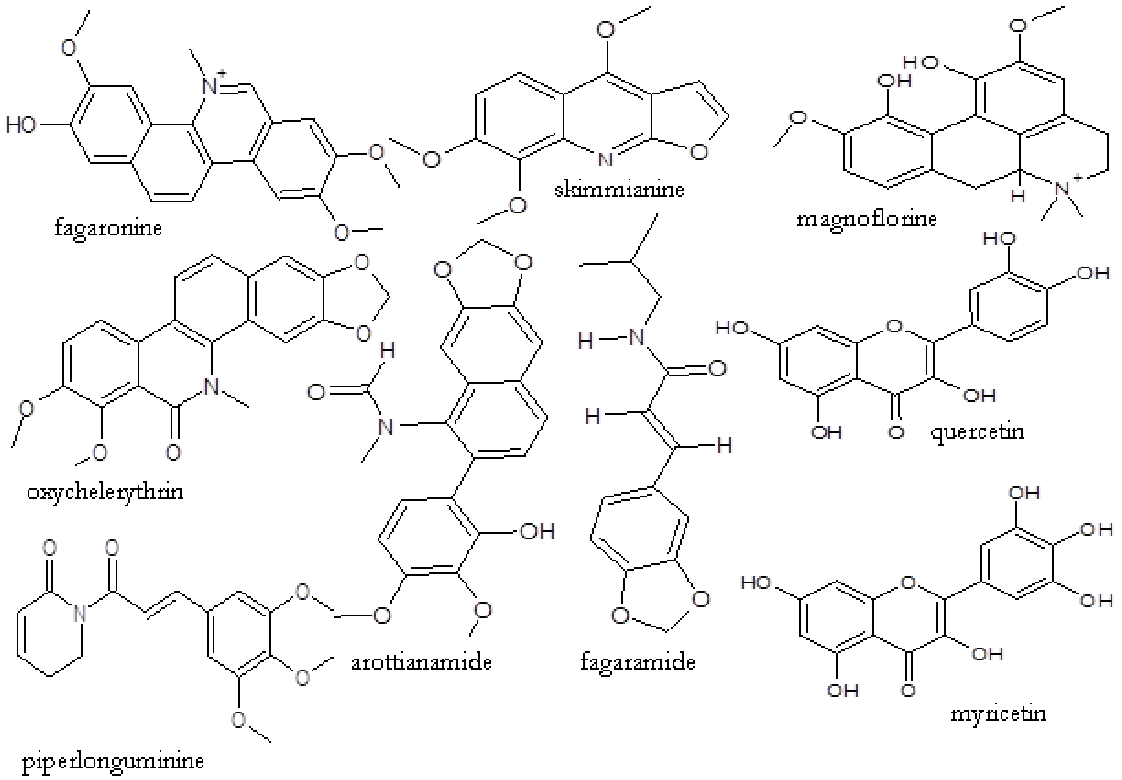

Figure 3. Some compounds isolated from *V. doniana* and *Z. zanthoxyloides*

F. Proximate composition

Proximate composition of the ethanolic stem bark extract was analysed (Olushola-Sudoks *et al.*, 2020). They determined the proximate analysis parameters for moisture 9.47%, crude fat 6.36%, crude protein 11.00%, crude fibre 18 .75%, ash 4.29% and total carbohydrates 50.13%. Other parameters determined were Na 12946.7760 ppm, K 1012.9924 ppm, Ca 6055.5591 ppm, Fe 1093.8837 ppm, Mg 1478.5064 ppm and Zn 216.8516 ppm.

G. Pharmacological Effect

Antioxidant Activity

The methanolic extract of *Z. zanthoxyloides* was showed to possess both antioxidant and acethylcholinesterase inhibitory effect. Tine *et al.* (2017) in his work tested the antioxidant properties of all the extracts using the ABTS model. The activity reduced in the order leaf > stem > root > fruit extracts. The methanol extracts of the fruits, leaves, stems, barks, trunks, and roots of the plant have also been investigated. The extracts from other parts were found to have less antioxidant activities than the leaf and trunk bark extracts (Tine *et al.*, 2017). Different extracts from *Z. zanthoxyloides* stem bark showed considerable reduction of free radicals (Negi *et al.*, 2011). Similar work on antioxidant properties was carried out using the ethanol extract of its stem by Adekunle *et al.* (2012), where they reported that its good antioxidant activity may be due to the presence of the flavonoids quantified. Chaaib *et al.* (2003), investigated the antiradical, antioxidant and antifungal properties of *Z. zanthoxyloides* root bark. It was claimed that they do this by reducing the formation of free radicals, suggesting a function for them in the treatment of disorders as a supporting and supplemental treatment. The methanolic extracts of *Z. zanthoxyloides* have shown both antioxidant (Chaaib *et al.*, 2003) and acetylcholinesterase inhibitory activity (Queiroz *et al.*, 2006). Ayoka *et al.* (2020b) demonstrated the antioxidant effects of the butanol sub-fractions. In DPPH assay, the activity decreased in the order BF2 > BF5 > BF1 > BF3 > BF4. While in the TAC and FRAP models, the antioxidant activity followed the order BF3 > BF5 > BF1 > BF4 > BF2.

Antimicrobial activity

The anti-bacterial potential of the root of *Z zanthoxyloides* has been demonstrated. It was reported that the toothpaste formulated from the root bark and whole root have remarkable activity against organisms that cause dental illness (Orafidiya *et al.*, 2010). This is in agreement to its ethno-medicinal use as a chewing stick. Similar anti-microbial work was done on the aqueous and ethanol extracts of its root, in which the aqueous extracts showed better anti-microbial effect than the ethanol extract (Anne *et al.*, 2013). The activity of light irradiation on the antimicrobial activity of the methanol extract of *Z. zanthoxyloides* was demonstrated by Adegbolagun and Olukemi (2010). According to them, there was a reduction or loss of activity when different sources of radiation were used to cause irradiation on the methanol extracts of *Z. zanthoxyloides*. Ynalvez *et al.* (2012) also evaluated the antimicrobial properties of *Z. zanthoxyloides* on various extracts of the root bark. They measured antimicrobial activities against *E. coli*, *Staphylococcus aureus*. There was no discernible variation in inhibition zone among microorganisms exposed to the extracts.

Anti-inflammatory properties

The anti-inflammatory and antipyretic activities of *Z. zanthoxyloides* were investigated using the hydroethanolic extracts of the roots, leaves and aqueous stem bark. Both extracts significantly inhibited appearance of pain in Wistar rats induced using egg albumin and formalin (Diatta *et al.*, 2014; Tougoma *et al.*, 2021a).

Bioactivity

The biological potentials of the extracts and fractions of *Z. zanthoxyloides* are summarized in Figure 4. The gastroprotective effect of *Z. zanthoxyloides* was investigated by Boye *et al.* (2012). They demonstrated that the ethanol root bark extract significantly decreased in a dose-dependent way, the number of ulcers per stomach, and increased the ulcerative index and the curative ratio. Zahoul *et al.* (2010) demonstrated that the active constituents present in the different extracts of *Z. zanthoxyloides* roots reduced blood pressure. This report demonstrated its anti-hypertensive effects. The anti-malarial effect of the extracts of *Z. zanthoxyloides* bark was demonstrated by Gansane *et al.* (2010), the antimicrobial activity was investigated by Tine *et al.* (2017a). They showed that the extracts inhibited the development of the plasmodium parasite. Similarly, Enechi *et al.* (2019) worked on methanol extracts as antimalarial agents. They maintained that the ethanol extract modified the biochemical status of the infected mice. Dofuor *et al.* (2019) in their work demonstrated that different fractions (methanol, butanol and dichloromethane) of *Z. zanthoxyloides* root inhibited *T. brucei* cell cycle, with dichloromethane and methanol fractions showing higher activity. In addition, the ameliorative effect of *Z. zanthoxyloides* on alloxan-induced diabetic rats was demonstrated by Aloke *et al.* (2012). They noted increase in the activity of the liver enzymes at higher concentrations of *Z. zanthoxyloides*, and also demonstrated that serum albumin and total protein concentrations were increased in diabetic rats treated with feed formulated with *Z. zanthoxyloides*. Alkaloidal extracts of *Z. zanthoxyloides* leaves improved the insulin level of diabetic rats and also restored the histoarchitecture of liver and kidney (Kyei-Barffour and Adokoh, 2021). They also demonstrated anti-tumour and hepatoprotective effects on CCl_4/olive oil induced toxicity on rats. They were also found to improve hepatoprotective damage and body weight/liver ratio (Acheampong *et al.*, 2021). The analgesic effects of the aqueous extract of its bark were also investigated by Tougoma *et al.* (2021b). They maintained that writhing pain was significantly reduced in albino Wistar rats administered the extract.

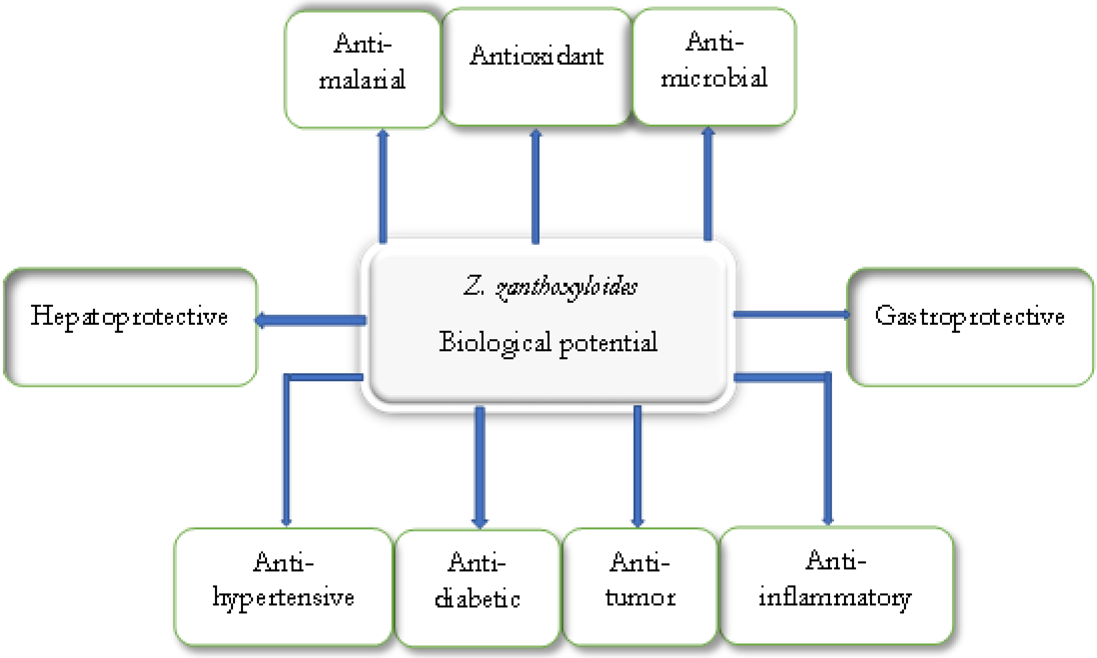

Figure 4. Biological potentials of *Z. zanthoxyloides*

Toxicology

The methanol and aqueous extracts of its root bark were found to be slightly toxic at higher concentrations. Their LD_{50} concentrations were reported to be 4148 ± 467 mg kg^{-1} and 5500 ± 875 mg kg^{-1} body weight respectively (Guendehou *et al.*, 2018). Similarly, Ogwai-Okeng *et al.* (2003) measured LD_{50} to be 5.0 g kg^{-1} body weight. Cerebral irritation was observed in the mice before death. Enechi *et al.* (2019) also reported LD_{50} of 5000 mg kg^{-1} in their work. Gbeta et al. (2021) demonstrated that the root bark extract of *Z. zanthoyloides* are relatively safe. There was no damage on the liver and kidney function after its administration on albino rats.

Prospects of V. doniana and Z. zanthoxyloides in phytomedicine and nutrition

Phytomedicine includes the combination of native medicine practices and numerous therapeutic experiences from many past ages. It provides helpful guidance on the choice, concocting and application of herbal preparations in the management and treatment of diseases (Bhardwaj *et al.*, 2018). The growing demand and suitability of herbal medicine is believed to be healthy, cheaper and readily available for all natural products. However, phytomedicine is often concerned with some questions over its pharmacognosy and optimization relative to prescription medicines. *V. doniana* and *Z. zanthoxyloides* are reported to be effectively used to cure skin problems, malaria, liver disease, conjunctivitis, hypertension, cancer and other infectious diseases (Yakubu *et al.*, 2016; Dofuor *et al.*, 2019; Bunu *et al.*, 2021: Imosis *et al.*, 2021a; Tougoma *et al.*, 2021a; Tougoma *et al.*, 2021b). Their prospects in phytomedicine and nutrition are shown in Figure 5. In the treatment of acute and chronic diseases, constituents of *V. donina* and *Z. zanthoxyloides* have produced many clinically beneficial products, and search for newer therapeutic agents from them is also ongoing (Adesina, 2005; Chinwe, 2018; Olajide *et al*., 2018; Imosis *et al*., 2021b; Charles and Mgina, 2021; Iheanacho and Ogunwa, 2021; Acheampong *et al*., 2021). The study of both plants has increased over the years, to clinically examine their use and to authenticate their herbal products. As a result, we set out to investigate the current state of their use in the treatment of various ailments and associated pharmacological problems, while also considering the increased future potential for herbal medicines.

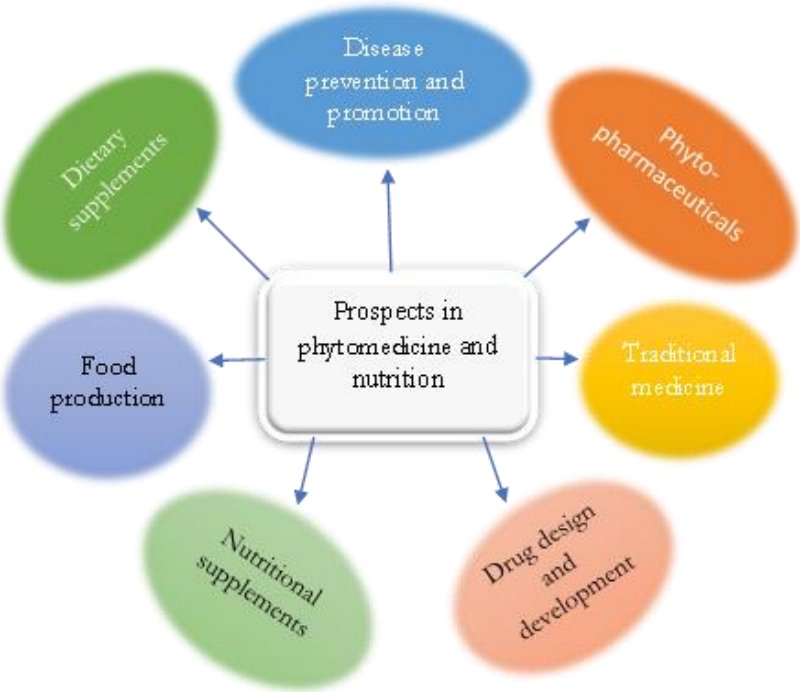

Figure 5. Prospects of *V. doniana* and *Z. zanthoxyloides* in phytomedicine and nutrition

Conclusions

There is an array of secondary metabolites in the leaves of *V. doniana* and *Z. zanthoxyloides*. Such secondary metabolites are alkaloids, flavonoids, tannins, coumarins, terpenes and saponins. It is possible to relate the antioxidant activity found in *V. donina* and *Z. zanthoxyloides* to the significant number of secondary metabolites they produce. Some studies attributed this to the presence of alkaloids and phenolics.

Based on the history and context of the publications and research papers used as the basis for this analysis, it can be proposed that *V. doniana* and *Z. zanthoxyloides* are of great importance for the developments in safety and efficacy medicine, bringing to the fore, chemotherapeutic actions of antioxidant, anti-inflammatory, anti-cancer and anti-microbial activities.

These plants can provide new opportunities for limited diagnostic tools to be considered for future studies in the treatment of diseases or their symptoms. However, there should be further research on the mechanisms of action of these phytochemicals responsible for the biological activities. Studies to isolate and characterize these bioactive alkaloids should be carried out. Meanwhile, the rich antioxidant potentials of the plant's fractions need to be investigated in detail to enable the formulation of liver treating drugs. These additional studies would give an intuition into the mechanisms that lead to the specific bioactivities of *V. doniana* and *Z. zanthoxyloides*.

Authors' Contributions

Conceptualization (TOA and CON); Data curation (TOA); Formal analysis (CON); Methodology (TOA); Resources (TOA and CON); Software (TOA); Supervision (CON); Validation (TOA and CON); Visualization (TOA and CON); Writing - original draft (TOA); Writing - review and editing (CON). All authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

Not applicable.

Acknowledgements

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

References

Abdulrahman FI, Onyeyili PA, Sanni S, Ogugbuaja VO (2007). Toxic effect of aqueous root-bark extract of *Vitex doniana* on liver and kidney functions. International Journal of Biological Chemistry 1(4):184-195. *https://doi.org/10.3923/ijbc.2007.184.195*.

Abdulsalam H, Jibia SA (2019). Cottage processing of black plum (*Vitex doniana*) into juice in Katsina state, North-western part of Nigeria. UMYU Journal of Microbiology Research 4(2):88-95. *https://doi.org/10.47430/ujmr.1942.015*.

Abu JD (2007). Development of a sweetener from black plum (*Vitex doniana)* fruit. International Journal of Food Properties 5:153-159. *https://doi.org/10.1081/JFP-120015598*.

Acheampong DO, Baffour IK, Barku VVA, Addo JK, Essuman MA, Boye A (2021). *Zanthoxylum zanthoxyloides* alkaloidal extract improves CCl_4-induced hepatocellular carcinoma-like phenotypes in rats. Evidenced-Based Complementary and Alternative Medicine 2021:1-16. *https://doi.org/101155/2021/3804379*.

Adegbolagun OM, Olukemi OO (2010). Effect of light irradiation on the antimicrobial activity of *Zanthoxylum zanthoxyloides* (Lam.) methanolic extract. African Journal of Pharmacy and Pharmacology 4(4):145-150. *https://doi.org/10.5897/AJPP.9000115*.

Adejumo AA, Alaye SA, Ayagbe RO, Abi EA, Adedokun FT (2013). Nutritional and anti-nutritional composition of Black plum (*Vitex doniana*). Journal of Natural Sciences Research 3(12):144-148. *https://www.jnsr.8520-10456-1-PB.pdf*.

Adekunle AS, Kamdem J, Rocha JB (2012). Antioxidant activity and HPLC analysis of *Zanthoxylum zanthoxyloides*. Report and Opinion 4:6-13.

Adesina SK (2005). The Nigerian Zanthoxylum; chemical and biological values. African Journal of Traditional, Complementary and Alternative Medicines 2(3):282-301. *https://doi.org/10.4314/ajtcam.v2i3.31128*.

Adjei S, Fosu-Mensah G (2021). Fruits of *Vitex doniana* sweet: toxicity profile, anti-inflammatory and antioxidant activities, and quantification of one of its bioactive constituents oleanolic acid. Heliyon 7(9):e07910. *https://doi.org/10.1016/j.heliyon.2021.e07910*.

Agbafor KN, Nwachukwu N (2011). Phytochemical Analysis and Antioxidant Property of Leaf Extracts of *Vitex doniana* and *Mucuna pruriens*. Biochemical Research International. 2011:1-4. *https://doi.org/10.1155/2011/459839*.

Agbede JO, Ibitoye AA (2007). Chemical composition of black plum (*Vitex doniana*): An under-utilized fruit. Journal of Food, Agriculture and Environment 5:95-96.

Aiwonegbe AE, Iyasele JU, Izevbuwa NO (2018). Proximate composition, phytochemical and antimicrobial screening of the methanol and acetone extracts of *V. doniana* fruit pulp. Ife Journal of Science 20(2):317-325. *https://doi.org/10.4314/ijs.v2012.12*.

Aiyeloja AA (2014). Preference and suitability of Nigerian grown *Gmelina arborea* Linn. Roxb. and *Vitex doniana* sweet woods for beekeeping in Imeko, Nigeria. International Journal of Scientific and Engineering Research 5(5):1484-1493.

Aloke C, Nwachukwu N, Ugwuja EI, Idenyi JN, Nwachi EU, Obasi IO, Oga O (2012). Effects of *Zanthoxylum zanthoxyloides* leaves on blood glucose, lipid profile and some liver enzymes in alloxan induced diabetic rats. International Journal of Science and Nature 3(3):497-501.

Amah UJ, Okogeri O (2019). Nutritional and phytochemical properties of wild black plum (*Vitex Doniana*) seed from Ebonyi state. International journal of horticulture, Agriculture, and Food Science 3(1):32-36. *https://dx.doi.org/10.22161/ijhaf.3.1.5*.

Anne IO, Andrew OO, Idu M (2013). Phytochemistry and antimicrobial activity of *Zanthoxylum zanthoxyloides* root used as chewing stick in Nigeria. The Journal of Phytopharmacology 2(6):1-7.

Ani ON, Udedi SC, Anajekwu BA, Asogwa KK, Ekwealor KU (2020). Inhibitory potential and antidiabetic activity of leaf extracts of *Vitex doniana*. African Journal of Biochemistry Research 14(3):72-80. *https://doi.org/10.5897/AJBR2020.1098*.

Ayoka TO, Nwachukwu N, Nnadi CO (2020a). Identification of potential antioxidant and hepatoprotective constituents of *Vitex doniana* by UHPLC/+ESI-QQTOF-MS/MS analysis. Asian Journal of Pharmaceutical and Clinical Research 13(8):142-148. *http://dx.doi.org/10.22159/ajpcr.2020.v13i8.37956*.

Ayoka TO, Nwachukwu N, Ene AC, Igwe CU, Nnadi CO (2020b). Liquid Chromatography-Mass Spectrometric Analyses of potential antioxidant constituents from *Zanthoxylum zanthoxyloides* leaves: Probing into the role of alkaloids. Tropical Journal of Natural Product Research 4(10):817-823. *https://doi.org/10.26538/tjnpr/v4i10.26*.

Bangou MJ, Meda NTR, Hermann YO (2019). Traditional uses, phytochemistry and pharmacology review of two *Vitex*: *diversifolia and doniana*. International Journal of Research and Development in Pharmacy and Life Science 8(2):29-36. *https://doi.org/10.21276/IJRDPL.2278-0238.2019*.

Bello MO, Asubonteng K, Sodamade A, Adeniyi S (2014). Nutrient potentials of two lesser-known leafy vegetables (*Vitex doniana L.* and *Sesamum indicum* L.). International food Research Journal 21(5):1993-1999.

Bhardwaj S, Verma R, Gupta I (2018). Challenges and future prospects of herbal medicine. International Research in Medical and Health Sciences 1(1):12-15. *https://doi.org/10.36437/irmhs.2018.1.1.D*.

Boye A, Koffuor GA, Boampong JN, Amoateng P, Ameyaw EO, Ansah EO, Addai GM (2012). Gastroprotective effect and safety assessment of *Zanthoxylum zanthoxyloides* (Lam.) Waterm root bark extract. American Journal of Pharmacology and Toxicology 7(2):73-80. *https://doi.org/10.3844/ajptsp.2012.73.80*.

Burkill HM (2000). Useful plants of West Tropical Africa. Royal Botanic Garden (2nd ed), Kewer.

Bunu MI, Ndinteh DT, Macdonald JR, Langat MK, Isyaka SM, Sadgrove NJ, Melnikovova I, Fernandez-Cusimamani E (2021). Ecdysteroids from the stem bark of *Vitex doniana* sweet (*Lamiaceae; ex. Verbenaceae*): A Geographically variable African medicinal species. Antibiotics 10(8):937-945. *https://doi.org/10.3390/antibiotics10080937*.

Chaaib F, Queiroz EF, Ndjoko K, Diallo D, Hostettmann K (2003). Antifungal and antioxidant compounds from the root bark of *Fagara zanthoxyloides*. Planta Medica 69: 316-320. *https://doi.org/10.1055/s-2003-38877*.

Charles D, Mgina C (2021). Antioxidant activities in *Vitex doniana* and *Saba comorensis* fruits from coastal forests of Tanzania. International Journal of Food Properties 24(1):1222-1228. *https://doi.org/10.1080/10942912.2021.1958838*.

Chinwe U (2018). Bitter herbs of eastern Nigeria (*Gongronema latifolium*, *Vernonia amygdalina* and *Vitex doniana*): A Review. African Journal of Traditional, Complementary and Alternative Medicine 15(3):47-56. *https://doi.org/10.21010/ajtcamv15i3.6*.

Dadjo C, Assogbadjo AE, Fandohan B, Kakai RG, Chakeredza S, Sinsin B (2012). Uses and management of black plum (*Vitex doniana* sweet) in Southern Benin. Fruits 67(4):239-248. *https://doi.org/10.1051/fruits/2012017*.

Diatta W, Sy GY, Manga CI, Diatta K, Fall AD, Bassene E (2014). Analgesic and anti-inflammatory of leaf extract of *Zanthoxylum zanthoxyloides* (Lam.) Zepernick and Timler (*Rutaceae*). International Journal of Biological and Chemical Sciences 8:128-133. *http://www.bioline.org.br/pdf?np12024*.

Dofuor AK, Djameh GI, Ayertey F, Bolah P, Amoa-bosompem M, Kyeremeh K, Ohashi, M (2019). Antitrypanosomal effects of *Zanthoxylum zanthoxyloides* (Lam.) Zepern. & Timler extracts on African Trypanosomes. Evidence-Based Complementary and Alternative Medicine 5:1-14. *https://doi.org/10.1155/2019/1730452*.

Egharevba HO, Ocheme OE, Ugbabe G, Abdullahi MS, Iliya I, Okhale ES, Okogun JI (2010). Phytochemical screening and anti-microbial studies of methanol, ethylacetate and hexane extracts of *Vitex doniana* sweet (stem bark and leaf). Nature and Science 8(8):177-185.

Elekwa I, Ugbogu AE, Okereke SC, Okezie E (2017). A review of selected medicinal plants with potential health benefits in South-eastern Nigeria. International Journal of Pharmaceutical and Chemical Sciences 6(4):162-171.

Enechi OC, Amah CC, Okagu IU, Ononiwu CP, Azidiegwu VC, Ugwuoke EO (2019). Methanolic extracts of *Fagara zanthoxyloides* leaves possess antimalarial effects and normalizes haematological and biochemical status of *Plasmodium berghei*-passaged mice. Pharmaceutical Biology 57(1):577-585.

Gansane A, Sanon S, Quattara P, Hutter S, Ollivier E, Azas N, Guissou I (2010). Antiplasmodial activity and cytotoxicity of semi purified fractions from *Zanthoxylum zanthoxyloides* Lam. bark of trunk. International Journal of Pharmacology 6:921-925. *https://doi.org/10.3923/ijp.2010.921.925*.

Gbate M, Ashamo OM, Kayode AL (2021). Toxicological evaluation of *Zanthoxylum zanthoxyloides* (Lim.) Zepernick & Timler root bark used as biopesticide and medicine. Journal of Medicinal Plants Research 15(2):106-117. *https://doi.org/10.5897/JMPR2020.7081*.

Guendehou F, Djossa BA, Kenou C, Assogbadjo AE (2018). Review of Studies on *Zanthoxylum zanthoxyloides* (Lam): Availability and ethnomedical, phytochemical. Scholars Journal of Research in Agriculture and Biology 3(3):244-254. *https://www.scischolars.com/journals/index.php/sjrab*.

Ifeanacho MO, Ogunwa SC, Amadi PU (2019). Phytochemical composition of *Vitex doniana.* Analytical Chemistry Letters 9(6):863-875. *https://doi.org/10.1080/22297928.2020.1722221*.

Iheanacho MO, Ogunwa SC (2021). Nutritional and Bioactive potentials of an underutilized vegetable-*Vitex doniana*. Food and Nutritional Sciences 12:978-995. *https://doi.org/10.1002/jsfa.7006*.

Ikeyi PA, Omeh NY (2014). A review of the ethnotherapeutics of medicinal plants used in traditional/alternative medicinal practice in Eastern Nigeria. International Journal of Current Microbiology and Applied Sciences 3:675-683.

Imosis C, Iyasele JU, Imhontu EE, Orji UR, Okhale S (2021a). Phytochemical and antioxidant capability of *Vitex doniana* (Black plum) fruit. Journal of Chemical Society of Nigeria 46:156-162. *https://doi.org/10.46602/jcsn.v46i1.589*.

Imosis C, Iyasele JU, Okhale S (2021b). Proximate and acute toxicity profile of *Vitex doniana* (Black plum) fruit. Journal of Chemical Society of Nigeria 46:597-603. *https://doi.org/10.46602/jcsn.v46i2.597*.

Iwueke AV, Nwodo OFC, Okoli CO (2006). Evaluation of the anti-inflammatory and analgesic activities of *Vitex doniana* leaves. African Journal of Biotechnology 5(20):1929-1935.

Koshkomba E, Touckia I, Worowounga X, Mololi A, Mukeina G, Semballa S, Akpagana K (2017). Case study and phytochemical investigation of *Zanthoxylum zanthox*yloides and *Zanthoxylum macrophylum (Rutaceae)* in the Central African Republic and Togo: A comparative approach. American Journal of Phytomedicine and Clinical Therapeutics 6(1):1-9. *https://doi.org/10.21767/2321-2748.100337*.

Kuta FA, Onochie I, Garba S, Adedeji AS (2015). An *in vitro* and *in vivo*, anti-bacterial activity of *Vitex doniana* crude extracts on *Salmonella typi*. International Journal of Scientific Research in Science, Engineering and Technology 1:71-79.

Kyei-Barffour I, Adokoh CK (2021). Alkaloidal extract from *Zanthoxylum zanthoxyloides* stimulates insulin secretion in normoglycemic and nicotinamide/streptozotocin-induced diabetic rats. Heliyon 7(7):e07452. *https://doi.org/10.1016/j.heliyon.2021.e07452*.

Lagnika L, Amoussa M, Adjovi Y, Sunni A (2012). Antifungal, antibacterial and antioxidant properties of *Adansonia digitata* and *Vitex doniana* from Benin. Journal of Pharmacognosy and Phytotherapy 4(4):44-52. *https://doi.org/10.5897/JPP12.006*.

Lasekan O (2017). Identification of the aroma compounds in *Vitex doniana* sweet: free and bound odorants. Chemistry Central Journal 11:1-8. *https://doi.org/10.1186/s13065-017-0247-7*.

Matu EN (2011). *Zanthoxylum zanthoxyloides* (Lam.) Zepern. & Timler. In: Schmelzer GH, Gurib-Fakim A (Eds). PROTA (Plant Resources of Tropical Africa) pp 1-10.

Misra LN, Vyry Wouatsa NA, Kumar S, Kumar RV, Tchoumbougnang F (2013). Antibacterial cytotoxic activities and chemical composition of fruits of two Cameroonian *Zanthoxylum* species. Ethnopharmacology 148(1):74-80. *https://doi.org/10.1016/j.jep.2013.03.069*.

Mohammed M, Danmallam A, Jajere UM, Kolo MT, Abubakar A, Babakano JM (2016). Three triterpenoids from the leaf extract of *Vitex doniana* (Verbenaceae). Journal of Pharmaceutical Research International 2016:1-8. *https://doi.org/10.9734/BJPR/2016/24335*.

Nantongo JS, Odoi JB, Abigaba G, Gwali S (2018). Variability of phenolic and alkaloid content in different plant parts of *Carissa edulis Vahl* and *Zanthoxylum chalybeum Engl.* BMC Research Notes 11:1-5. *https://doi.org/10.1186/s13104-018-3238-4*.

Negi J, Bisht V, Bh A, Singh P, Sundriyal R (2011). Chemical constituents and biological activities of the genus Zanthoxylum: A review. Journal of Pure and Applied Chemistry 5:412-416.

Njoku OC, Airaodion AI, Awosanya O, Ekenjoku JA, Okoroukwu VN, Ogbuagu EO, ... Igwe C (2019). Antidiabetic potential of alkaloid extracts from *Vitex doniana* and *Ficus thonningii* leaves on alloxan-induced diabetic rats. International Research Journal of Gastroenterology and Hepatology 2(2):1-12. *https://doi.org/10.9734/irjgh/2019/v5i230084*.

Nnamani CV, Oselebe H, Agbatutu A (2009). Assessment of nutritional values of three underutilized indigenous leafy vegetables of Ebonyi State, Nigeria. African Journal of Biotechnology 8(9):2321-2324. *http://www.academicjournals.org/AJB*.

Nwachukwu E, Uzueto HO (2010). Antimicrobial activities of leaf of *Vitex doniana* and *Cajanus cajan* on some bacteria. Researcher 2:1-11.

Ogwai-Okeng JW, Obua C, Anokbongg WW (2003). Acute toxicity effects of the methanolic extract of *Fagara zanthoxyloides* (Lam.) root-bark. African Health Sciences 3(3):124-126.

Olajide JE, Sanni M, Omattah GO (2018). Effect of methanol leaf extract of *Vitex Doniana* on Cadmium Chloride-Induced toxicity in Kidney and Liver tissues of male Wistar rats. International Journal of Trend in Scientific Research and Development 2(6):1306-1315. *https://doi.org/10.31142/ijtsrd18876*.

Olushola-Sudoks AA, Igbo UE, Asiebo G, Damola IA, Igwe CC (2020). Elemental analysis and phytochemical characterisation of *Zanthoxylum zanthoxyloides* (Lam.) Zepern and Timler stem bark. Journal of Pharmacognosy and Phytochemistry 9(5):41-46. *https://doi.org/10.22271/phyto.2020.v9.i5a.12420*.

Onwukwe OS, Ukwuani JN, Onymelukwe AO, Azubuike NC, Onuba AC, Ogu OC, ... Achukwu PU (2020). Assessment of the sub-acute toxicity profile of *Vitex doniana* (sweet) leaf fractions on albino rats. Annual Research and Review in Biology 35:86-95. *https://doi.org/10.9734/arrb/2020/v35i230192*.

Orabueze CI, Adesegun SA, Nwafor EL, Coker HA (2017). Ethnobotanical survey of medicinal plants and herbal formulations used in management of malaria in Nsukka, South east, Nigeria. Nigerian Journal of Natural Product and Medicine 21:66-81. *https://doi.org/10.4314/njnpm.v21i1.10*.

Orafidiya OL, Akinkunmi OE, Oginni OF, Oluwamakin A (2010). Effectiveness of extracts of the root of *Zanthoxylum zanthoxyloides* (Linn.) Waterman (*Rutaceae)* formulated as toothpastes. Nigerian Journal of Natural Products and Medicine 14(1):21-26. *http://dx.doi.org/10.4314/njnpm.v14i1i.5*.

Orwa C, Mutua A, Kindt R, Jamnadass R, Anthony S (2009). *Vitex doniana*; Agroforestry Database: a tree reference and selection guide version 4.0.

Osum FI, Okonkwo TM, Okafor GI (2013). Effect of processing methods on the chemical composition of *V. doniana* leaf and leaf products. Food Science and Nutrition 1(3):241-245. *https://doi.org/10.1002/fsn3.31*.

Ouédraogo L, Nacoulma AP, Compaoré M, Lagnika L, Kiendrebeogo M (2019). Stem bark of *Zanthoxylum zanthoxyloïdes* a possible substitute of root bark for the conservation of the species in Burkina Faso. African Journal of Biotechnology 18(9):197-205. *https://doi.org/10.5897/AJB2019.16743*.

Queiroz EF, Hay AE, Chaaib F, Van Diemen D, Dialla D, Hostettmann K (2006). New and bioactive aromatic compounds from *Zanthoxylum zanthoxyloides*. Plant Medica 72:746-750. *https://doi.org/10.1055/s-2006-941504*.

Sanni M, Olajide JE, Omattah GO (2019). Chemical constituents and radical scavenging activity of methanol leaf extract of *Vitex doniana*. FUW Trends in Science and Technology Journal 4(1):179-183.

Sha'a KK, Oguche S, Watila IM, Ikpa TF (2011). *In-vitro* antimalarial activity of the extracts of Vernonia amygdalina commonly used in traditional medicine in Nigeria. Science World Journal 6:5-9.

Sonibare OO, Effiong I, Oladosu IA, Ekundayo O (2009). Chemical constituents and antimicrobial activity of the essential oil of *Vitex doniana* sweet (*Verbernacene)*. Journal of Essential Oil-Bearing Plants 12(2):185-188. *https://doi.org/10.1080/0972060X.2009.10643709*.

Tijani A, Shettima YA, Abdulrahman FI, Khan IZ, Tom GM, Cong LI (2017). Isolation and structural elucidation of 20-Hydroxyecdystone from *Vitex doniana* sweet stem bark (black plum). Medicinal Chemistry 7:828-831. *https://doi.org/10.4172/2161-0444.100436*.

Tine Y, Diop A, Diatta W, Desjobert JM, Boyle CSB, Costa J, … Paolini J (2017a). Chemical diversity and antimicrobial activity of volatile compounds from *Zanthoxylum zanthoxyloides* Lam. according to compound classes, plant organs and Senegalese sample locations. Chemistry and Biodiversity 14. *https://doi.org/10.1002/cbdv.201600125*.

Tine Y, Yang Y, Renucci F, Costa J, Wele A, Paolini J (2017b). LC-MS/MS analysis of flavonoid compounds from *Zanthoxylum zanthoxyloides* extracts and their antioxidant activities. Natural Product Communication 12(12):1865-1868. *https://doi.org/10.1177/1934578X1701201213*.

Tougoma A, Atchrimi SK, Denou A, Idah OV, Egesie GU, Odeh SO (2021a). Assessment of the antipyretic and anti-inflammatory effects of *Zanthoxylum zanthoxyloides* stem bark aqueous extract on Wister rats. Issues in Biological Sciences and Pharmaceutical Research 9(3):78-85. *https://doi.org/10.15739/ibspr.21.008*.

Tougoma A, Atchrimi SK, Denou A, Idah OV, Egesie GU, Odeh SO (2021b). Antinociceptive evaluation of the aqueous bark extract of *Zanthoxylum zanthoxyloides* (Lam.) Zepern. And Timler (*Rutaceae)* on albino Wistar rats. Journal of Applied Biosciences 160:16495-16506. *https://doi.org/10.35759/JABs.160.6*.

Vunchi MA, Umar AN, King MA (2011). Proximate, vitamins and mineral composition of *Vitex doniana* (black plum) fruit pulp. Nigeria Journal of Basic and Applied Sciences 19(1):1-9. *https://doi.org/10.4314/njbas.v19i1.69352*.

Wanzala W, Takken W, Mukabana WR, Pala AO, Hassanali A (2012). Ethnoknowledge of Bukusu community on livestock tick prevention and control in Bungoma district, Western Kenya. Journal of Ethnopharmacology 140(2):298-324. *https://doi.org/10.1016/j.jep.2012.01.021*.

Yakubu OE, Nwodo OFC, Imo C, Abdulrahaman M, Uyeh LB (2016). Effects of *Vitex doniana* leaf extract on aluminium-induced toxicity in male Wistar albino rats. Journal of Applied Biology and Biotechnology 4(5):37-40. *https://doi.org/10.7324/JABB.2016.40506*.

Yakubu OE, Nwodo OFC, Joshua PE, Ugwu MN, Odu AD, Okwo F (2014). Fractionation and determination of total antioxidant capacity, total phenolic and total flavonoids contents of aqueous, ethanol and n-hexane extracts of *Vitex doniana* leaves. African Journal of Biotechnology 13(5):693-698. *https://doi.org/10.5897/AJB2013.13225*.

Yangora SM, Bello AA (2017). Determination of moisture, ash and iron content in black plum (*Vitex Doniana*) leaves. Biochemistry Research International 1(1):186-191.

Ynalvez RA, Cardenas C, Addo JK, Adukpo GE, Dadson BA (2012). Evaluation of the antimicrobial activity of *Zanthoxylum zanthoxyloides* root bark extracts. Research Journal of Medicinal Plant 6(2):149-159. *https://doi.org/10.3923/rjmp.2012.149.159*.

Zahoul SO, Zirihi NG, Soro YT, Traore F (2010). Hypotensive effect of an aqueous extract of *Zanthoxylum zanthoxyloides* (Lam.) Waterman (*Rutaceae)*. Phytotherapie 5:359-369.