Chemical composition and biological activities of the essential oils of genus *Xylopia* L. (Annonaceae). A review

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Xylopia L. includes approximately 180 species and is an important genus of the Annonaceae family due to its production of secondary compounds. It comprises several species that are native to the African region and can serve as valuable medicinal plants thanks to their biological and pharmacological properties. In fact, the local populations often use it for different medicinal purposes, such as for malaria, cough, stomachache, rheumatism, and inflammation. The objective of this study was to carry out a review of essential oils of the genus *Xylopia* and their biological activities. The data were collected from the scientific electronic databases including SciFinder, Scopus, Elsevier, PubMed, and Google Scholar. A total of thirty-seven *Xylopia* species have been reported for their essential oils and biological activities. It can be observed that the major components were germacrene D, bicyclogermacrene, (*E*)-caryophyllene, limonene, α-pinene, and β-pinene. Pharmacological studies indicated that the essential oil exhibited antifungal, antibacterial, antimicrobial, antioxidant, antitumor, anticancer, cytotoxicity, molluscicidal, anti-proliferative, anti-trypanosoma, larvicidal, spasmolytic action, anti-inflammatory, and toxicity. This review is mainly meant to provide relevant information on the phytochemical features of *Xylopia* species, with emphasis on the essential oil, providing guidance for the selection of accessions or species with the best chemical profiles. It was also possible to identify species that have not yet started studies and possible activities of their essential oils. Besides, more preclinical analyses, as well as clinical trials, are required to evaluate the potential of essential oils from *Xylopia* species for drug development.

Keywords: Essential oil, Xylopia, Annonaceae, Biological activity, Germacrene D.

1. INTRODUCTION

It is believed that about 80% of the population worldwide, especially Asian and African countries use plants and herbal medicines as a source of medicinal agents and primary health care. Traditional medicine is an important form of health care for many people and covers a wide variety of therapies and practices, which vary from country to country. Many useful drugs were inspired by plant sources and nature continues to be a major source of new structural leads, and effective drug development [1]. Thus, based on these estimates, the proper identification and classification of plant species is of great importance.

The Annonaceae family is the largest family of the Magnoliales order and consists of about 135 genera and over 2500 species. The family has a source of edible fruit that can be considered to have economic importance [2]. *Xylopia* L. which includes approximately 180 species and is an important genus of the Annonaceae family due to its production of secondary compounds. *Xylopia* is largely in West African countries like Nigeria, Ghana, and Cameroon. The bark, roots, leaves, fruits, and seeds of *Xylopia are* used in medicines throughout western and central Africa. Besides, there are few reports of local users of *Xylopia* wood as a material for building and tools [3]. *Xylopia* is a canopy tree 50 metres tall. Various species of this tree habit form buttresses at the base of the trunk. All *Xylopia* species usually have a spiral arrangement of leaves on the stem of the trees, hence, the branches have a spiral arrangement. Leaf arrangement on the branches is always arranged alternately in two opposite vertical rows, as shown in Figure 1. The bark is usually defined as smooth and light grey to brown in colour, but a small number of the species have rough and scaly bark. Normally, the cut bark will have an aromatic character [4, 5].

Essential oils are important natural sources and are used as raw materials for the production of fragrance compounds in cosmetics, as flavouring additives for food and beverages, as scenting agents in a variety of household products, and as intermediates in the synthesis of other perfume chemicals [6, 7]. Essential oils from aromatic and medicinal plants have been known since antiquity to possess biological activity, most notably antibacterial, antifungal and antioxidant properties [8-11].

The essential oils of the genus *Xylopia* have been broadly studied and investigated. Previous studies have described the biological activities of various *Xylopia* species such as antibacterial, antimicrobial, antifungal, antioxidant, and antitumor activities. The available information on the essential oils of *Xylopia* species was collected via electronic searches such as Pubmed, SciFinder, Scopus, Google Scholar, and Web of Science. The aim of this work is to give an overview of all published studies on the chemical composition and biological activities of *Xylopia* essential oils.

Figure 1 - Leave alternate arrangement of *Xylopia sp.* [62]

2. MEDICINAL USES OF *XYLOPIA*

Medicinal plants have been of prime importance in the folkloric traditional medicine systems for centuries. The remedial properties of these plants are remarkable. Due to the unpleasant side effects and ineffectiveness of many conventional drugs, the search for new drugs of natural origin has gained momentum in recent years. In this regard, different species of the genus *Xylopia* have always been in

Table I - Medicinal uses of *Xylopia spp.*

Species	Part	Traditional, ethnomedicinal properties, prescriptions, and uses
X. aethiopica	Fruits	Used to treat syphilis, boils, malaria, fungal infections, cough, stomachache, hernia, cholera, dizziness, amenorrhea, headache, neuralgia, carminative, rheumatism, hemorrhoids, dysentery, flatulence, bronchitis, uterine fibroid and female infertility [12]
	Roots	Administered orally to expel worms and other parasitic animals from the intestines, or in teeth-rinsing and mouth-wash extracts against toothaches [13]
	Leaves	Decoctions of the leaves are used against rheumatism, headaches and as an emetic [14]
	Seed	Used to treat scabies, asthma, stomach pains, rheumatism, malaria, cough, bronchitis, dysentery, female sterility, and abdominal pains [15]
X. aromatica	Flowers	Use in folk medicine as a carminative, stimulant, diuretic, treatment of digestive diseases and spice for seasoning meat [16]
X. frutescens	Seeds	Used to treat rheumatism halitosis, tooth decay, intestinal diseases, inflammation treatment, antidiarrheal, to improve digestion, as a bladder stimulant and to trigger menstruation [17]
	Leaves	Used to treat fever [18]
X. ferruginea	Bark	Used to stop vomiting [19]
X. laevigata	Leaves	To treat heart diseases, treating tumors and inflammatory conditions [20]
X. malayana	Leaves	Traditionally used for treatment after childbirth [21]
X. parviflora	Roots	Used as a chewing stick and possess antibacterial components which keep the teeth healthy [22]
X. sericea	Seeds	Used as an analgesic, anti-inflammatory and to treat gastrointestinal disorders [23]
	Fruits	Used as a carminative remedy and as a condiment in cuisine as a replacement for black pepper [24]

Table II - Major components of *Xylopia* essential oils

Species	Locality	Parts	Total components	Major components
X. hypolampra	Cameroon	Stem bark	28 (90.5%)	Verbenone (20.2%) **(1)**, borneol (7.8%), myrtenol (6.8%), eucalyptol (5.9%), nopinone (5.5%) [25]
X. ochrantha	Brazil	Leaves	27 (96.6%)	Bicyclogermacrene (25.1%) **(2)**, germacrene D (20.9%), β-pinene (8.0%), sylvestrene (6.5%), (*E*)-caryophyllene (6.2%) [26]
X. laevigata	Brazil	Leaves	27 (98.6%)	Germacrene D (43.6%) **(3)**, bicyclogermacrene (14.6%), (*E*)-caryophyllene (7.9%), germacrene B (7.3%) [27]
			32 (96.6%)	Germacrene D (27.0%) **(3)**, bicyclogermacrene (12.8%), (*E*)-caryophyllene (8.6%), γ-muurolene (8.6%), δ-cadinene (6.8%) [28]
			36 (96.6%)	γ-Muurolene (17.7%) **(4)**, δ-cadinene (12.2%), bicyclogermacrene (7.7%), α-copaene (7.1%) [20]
			33 (97.3%)	Germacrene D (18.9%) **(3)**, bicyclogermacrene (18.4%), β-elemene (9.5%), δ-selinene (9.2%), (*E*)-caryophyllene (8.5%) [29]
			33 (97.6%)	Germacrene D (27.0%) **(3)**, bicyclogermacrene (12.8%), (*E*)-caryophyllene (8.6%), γ-muurolene (8.6%) [29]
			44 (99.7%)	Germacrene D (60.4%) **(3)**, γ-muurolene (17.9%), bicyclogermacrene (14.6%), δ-cadinene (13.4%), (*E*)-caryophyllene (7.9%), germacrene B (7.3%) [30]
			36 (97.4%)	γ-Muurolene (17.9%) **(4)**, δ-cadinene (13.4%), germacrene D (9.0%), bicyclogermacrene (7.0%) [31]
		Fruits	10 (99.6%)	Limonene (56.2%) **(5)**, α-pinene (28.0%) [32]
X. aromatica	Brazil	Flower	28 (99.9%)	Pentadecan-2-one (16.3%) **(6)**, bicyclogermacrene (9.7%), 7-*epi*-α-eudesmol (7.7%), khusinol (7.2%), *n*-tricosane (6.1%) [16]
			10 (13.7%)	Limonene (44.6%) **(5)**, α-pinene (24.8%), β-pinene (16.7%).[33]
		Leaves	47 (97.9%)	Spathulenol (27.1%) **(7)**, khusinol (13.0%), bicyclogermacrene (8.5%), globulol (6.4%), *cis*-guaia-3,9-dien-11-ol (5.9%) [16]
			19 (75.1%)	Bicyclogermacrene (36.5%) **(2)**, spathulenol (20.5%) [33]
		Fruit	21 (21.5%)	Limonene (36.4%) **(5)**, α-pinene (19.2%), β-pinene (13.3%) [33]
X. frutescens	Brazil	Leaves	23 (91.2%)	Bicyclogermacrene (23.2%) **(2)**, germacrene D (21.1%), (*E*)-caryophyllene (17.2%), β-elemene (6.3%) [28]
			20 (90.2%)	(*E*)-Caryophyllene (23.9%) **(8)**, γ-cadinene (12.4%), β-ocimene (8.1%), cadin-4-en-10-ol (5.7%) [17]
			34 (96.5%)	(*E*)-Caryophyllene (31.4%) **(8)**, bicyclogermacrene (15.1%), germacrene D (9.6%), δ-cadinene (5.4%), viridiflorene (5.0%) [34]
			24 (91.0%)	(*E*)-Caryophyllene (24.8%) **(8)**, bicyclogermacrene (20.8%), germacrene D (17.0%), β-elemene (7.9%), (*E*)-β-ocimene (6.8%) [29]
X. sericea	Brazil	Fruits	84 (99.0%)	Spathulenol (16.4%) **(7)**, guaiol (13.9%), germacrene D (8.1%) [23]
			83 (92.6%)	1,8-Cineole (22.3%) **(9)**, *p*-cymene (17.9%), α-pinene (6.3%), β-pinene (6.8%), limonene (6.4%) [35]
X. langsdorffiana	Brazil	Fruits	9 (99.0%)	α-Pinene (34.5%) **(10)**, limonene (31.7%), camphene (11.5%), sclarene (10.3%) [36]
		Leaves	19 (91.6%)	Germacrene D (22.9%) **(3)**, *trans*-β-guaiene (22.6%), (*E*)-caryophyllene (15.7%) [37]
X. parviflora	Cameroon	Fruits	34 (99.0%)	β-Pinene (35.7%) **(11)**, α-pinene (11.1%), myrtenol (6.5%), (*E*)-β-ocimene (5.4%) [38]
			34 (98.6%)	β-Pinene (32.9%) **(11)**, α-pinene (10.8%), (*E*)-β-ocimene (8.0%), myrtenol (5.20%) [38]
			28 (90.8%)	β-Pinene (40.0%) **(11)**, α-pinene (14.0%), *trans*-ocimene (5.4%), camphene (4.0%) [5]
X. malayana	Malaysia	Leaves	29 (94.4%)	β-Pinene (42.0%) **(11)**, α-pinene (15.2%), elemol (11.6%), bicyclogermacrene (5.2%) [39]
X. fusca	Malaysia	Leaves	22 (78.8%)	Germacrene D (17.0%) **(3)**, bicyclogermacrene (12.0%), β-elemene (11.5%), β-pinene (10.1%) [39]
X. elliptica	Malaysia	Leaves	34 (80.7%)	Bicyclogermacrene (11.5%) **(2)**, sabinene (10.6%), α-pinene (9.0%), elemol (8.1%) [39]

Continua Tabella II

Species	Locality	Parts	Total components	Major components
X. maccraea	Australia	Leaves	58 (94.3%)	Bicyclogermacrene (34.0%) **(2),** germacrene D (6.1%), δ-3-carene (5.6%), β-caryophyllene (5.3%) [40]
Xylopia sp.	Australia	Leaves	33 (75.9%)	Spathulenol (30.9%) **(7)**, globulol (9.2%), viridiflorol (4.8%), caryophyllene oxide (4.6%) [40]
X. longifolia	France	Roots	38 (88.3%)	*trans*-Pinocarveol (10.8%) **(12)**, myrtenal (9.6%), α-pinene (6.9%), *p*-cymene (5.8%), verbenone (5.4%) [41]
		Bark	16 (94.1%)	δ-Cadinol (33.8%) **(13)**, bornyl acetate (17.7%) [41]
		Leaves	24 (91.8%)	α-Pinene (10.1%) **(10)**, *trans*-pinocarveol (10.1%), spathulenol (6.6%), myrtenal (6.3%) [41]
		Flowers	26 (98.2%)	Spathulenol (36.1%) **(7)**, *p*-cymene (26.9%) [41]
		Seeds	33 (96.9%)	*p*-Cymene (21.1%) **(14)**, limonene (13.9%), α-phellandrene (10.2%), γ-muurolene (8.1%), β-phellandrene (6.2%) [41]
		Seedless fruits	40 (92.2%)	α-Phellandrene (19.2%) **(15)**, *p*-cymene (18.7%), limonene (12.2%), pinocarveol ester (7.7%), β-phellandrene (7.6%) [41]

the focus, specifically in Africa including Nigeria, Ghana, Cameroon, Sudan the Ivory Coast, and others. *Xylopia* was usually used to treat fever, cough, and various skin infections. Various parts of the plant such as leaves, stems, roots, flowers, and seeds were found to be beneficial to humans and can be used as traditional medicine. Table I shows several *Xylopia* species and their medicinal uses [12-24].

3. CHEMICAL COMPOSITIONS OF *XYLOPIA* ESSENTIAL OILS

The major components in the chemical profiles of essential oils and volatiles of the *Xylopia* plants from 1989 to December 2019 are listed in Table II [25-41]. In addition, the chemical structures of several major components identified from the *Xylopia* essential oil are shown in Figure 2.

In earlier reports, there are fifteen *Xylopia* species were described on the essential oil composition. They were *X. aethiopica*, *X. aromatica*, *X. elliptica, X. fusca*, *X. frutescens*, *X. hypolampra*, *X. laevigata, X. langsdorffiana*, *X. longifolia, X. malayana*, *X. maccraea*, *X. ochrantha*, *X. parviflora*, *X. sericea* and *Xylopia sp.* Most of the species are reported from Brazil. Besides, three species are reported, each from Malaysia and Africa, two species from Australia, and one from France. The extraction of the essential oils was done mostly from the leaf part. Along with, fruit, flower, stem, and root were also studied. *X. maccraea* has the highest total components which found fifty-eight components, while *X. aromatica* has the highest percentage that contributed for about 99.8% of the total oils.

Monoterpenes hydrocarbons, oxygenated monoterpenes, sesquiterpene hydrocarbons, and oxygenated sesquiterpenes were dominated as the main group components of the *Xylopia* essential oils, together with esters, aldehydes, ketones, and

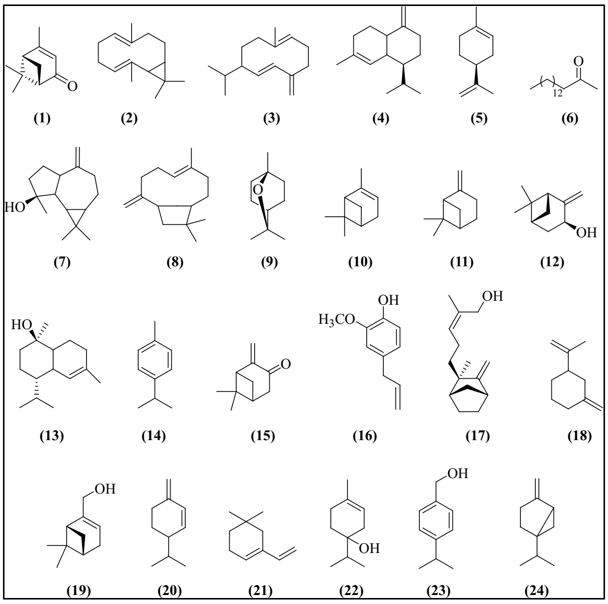

Figure 2 - Chemical structures of major components identified from *Xylopia* essential oils

phenylpropanoids. Germacrene D was characterised as the main component in the leaf oil of *X. aethiopica, X. fusca X. laevigata*, *X. langsdorffiana,* and *X. aethiopica* fruit oil. Besides, bicyclogermacrene was reported to be the major component of the leaf oil of *X. aromatica*, *X. elliptica, X. frutescens*, *X. maccraea,* and *X. ochrantha.* In addition, β-pinene has been reported from the fruit oil of *X. aethiopica*, the leaf oil of *X. malayana*, and the fruit oil of *X. parviflora.* Spathulenol was also identified as a major component from the leaf oil of *X. aromatica, Xylopia sp.,* the flower oil of *X. longifolia*, and the fruit oil of *X. sericea.*

Meanwhile, *X. aethiopica* is one of the species from the genus *Xylopia* that has received the most attention and has been widely studied. It is commonly known as *African pepper* and widely distributed in Africa [42]. Most of the studies are from Cameroon

Table III - Major components of *Xylopia aethiopica* essential oils

	Part	Total components	Major components
Nigeria	Fruits	37 (98.7%)	Eugenol (12.2%) **(16)**, acetyl eugenol (7.0%), 1,8-cineole (6.8%), sabinene (6.7%), *cis*-ocimene (6.2%) [43]
		36 (92.9%)	β-Santalol (14.5%) **(17)**, α-cadinol (13.0%), benzyl benzoate (10.1%), dodecanoic acid (10.1%), elemol (9.2%) [44]
		18 (50.6%)	1,8-Cineole (15.1%) **(9)**, sabinene (6.6%), terpinen-4-ol (4.1%) [45]
	Leaves	15 (88.5%)	1,8-Cineole (26.6%) **(9)**, β-pinene (15.3%), myrtenal (6.6%), pinanol (6.0%), 4-terpinenol (5.2%), α-pinene (5.1%) [46]
Ghana	Leaves	42 (87.7%)	Germacrene D (24.5%) **(3)**, β-pinene (17.3%), α-pPinene (5.3%), *trans*-caryophyllene (5.2%) [47]
	Root	40 (84.6%)	*trans*-Mentha-1(7),8-diene (30.4%) **(18)**, β-copaen-4-α-ol (13.3%), β-pinene (7.1%), bornyl-acetate (5.3%) [47]
	Stem	47 (93.3%)	*trans*-Mentha- (7),8-diene (30.7%) **(18)**, germacrene D (8.8%) cyperene (7.6%), α-pinene (7.3%), β-pinene (5.8%) [47]
	Fresh fruit	41 (98.4%)	β-Pinene (25.5%) **(11)**, germacrene D (19.4%), β-phellandrene (9.7%), (+)-α-pinene (7.9%), (-)-α-pinene (6.4%), *trans*-m-mentha-1(7),8-diene (5.8%), δ-elemene (5.7%) [47]
	Dried fruit	40 (96.6%)	Germacrene D (25.1%) **(3)**, β-pinene (21.6%), 1,8-cineole (7.4%), δ-elemene (6.9%), α-pinene (5.0%) [47]
Cameroon	Fruits	70 (97.1%)	β-Pinene (32.1%) **(11)**, β-phellandrene (10.7%), (*Z*)-γ-bisabolene (10.0%), α-pinene (7.3%), α-phellandrene (6.8%) [48]
		4 (72.5%)	β-Pinene (37.8%) **(11)**, α-pinene (18.4%), limonene (8.6%), β-cubebene (7.7%) [49]
		32 (98.0%)	β-Pinene (28.2%) **(11)**, terpinen-4-ol (15.1%), α-pinene (10.8%), β-phellandrene (5.8%), γ-terpinene (5.7%) [38]
		68 (80.2%)	Myrtenol (12.0%) **(19)**, β-pinene (9.0%), *trans*-sabinol (7.0%), limonene (6.0%) [50]
		9 (95.7%)	β-Pinene (27.9%) **(11)**, sabinene (23.9%), β-phellandrene (15.9%), α-pinene (11.1%), 4-terpinenol (5.1%) [51]
		9 (95.1%)	β-Pinene (27.9%) **(11)**, sabinene (23.9%), β-phellandrene (15.9%), α-pinene (11.1%), 4-terpinenol (5.1%) [51]
		54 (96.1%)	β-Pinene (39.3%) **(11)**, β-phellandrene (17.2%), α-pinene (13.6%), germacrene D (5.0%) [52]
		55 (95.3%)	β-Pinene (38.1%) **(11)**, α-pinene (10.2%), β-phellandrene (8.7%) [52]
		47 (96.4%)	β-Pinene (44.1%) **(11)**, β-phellandrene (13.8%), α-pinene (12.4%) [52]
		59 (86.1%)	β-Phellandrene (31.4%) **(20)**, β-pinene (8.2%), germacrene D (5.3%) [52]
Ivory Coast	Leaves	23 (96.1%)	β-Pinene (43.3%) **(11), g**ermacrene D (24.0%), α-pinene (14.0%), (*E*)-β-caryophyllene (5.7%) [14]
		12 (56.5%)	β-Pinene (16.0%) **(11)**, β-eudesmol (12.6%), α-pinene (10.3%) [53]
	Root	27 (95.6%)	4,4-Dimethyl-2-vinylcyclohex-1-ene (43.7%) **(21)**, 3,3-dimethyl-1-vinylcyclohex-1-ene (22.4%), camphene (8.8%) [14]
	Fruit	9 (65.9%)	β-Pinene (20.5%) **(11)**, α-pinene (17.7%), 1,8-cineole (7.4%), α-phellandrene (5.6%) [53]
Sudan	Fruit	63 (94.0%)	Terpinen-4-ol (11.3%) **(22)**, β-pinene (6.1%), α-terpineol (6.0%), 1,8-cineole (5.4%) [54]
		45 (97.4%)	4-Isopropylbenzyl alcohol (16.6%) **(23)**, α-pinene (11.3%), γ-cadinene (11.1%), α-phellandrene (10.5%), β-phellandrene (8.9%) [55]
Belgium	Fruits	68 (99.0%)	β-Pinene (38.1%) **(11)**, α-pinene (10.2%), β-phellandrene (8.7%) [56]
		68 (97.3%)	β-Pinene (16.7%) **(11)**, 4-terpinenenol (16.7%), β-phellandrene (9.3%) [56]
Mali	Fruit	31 (90.8%)	β-Pinene (19.1%) **(11)**, γ-terpinene (14.7%), *trans*-pinocarveol (8.6%), *p*-cymene (7.3%) [57]
	Powder	42 (70.1%)	β-Pinene (9.9%) **(11)**, α-cadinol (6.9%), *trans*-pinocarveol (4.6%), α-pinene (4.1%), 1,8-cineole (4.0%) [57]
Benin	Leaves	29 (95.0%)	β-Pinene (34.9%) **(11)**, elemol (14.9%), α-pinene (11.6%) [58]
	Fruit	39 (95.0%)	β-Pinene (41.9%) **(11)**, sabinene (34.4%), α-pinene (16.4%), terpinene-4-ol (7.1%), germacrene D (6.6%) [58]
		41 (82.3%)	Sabinene (36.0%) **(24)**, 1,8-cineole (12.7%), terpinen-4-ol (6.9%), β-pinene (5.7%) [59]
Cairo	Fruit	21 (94.2%)	Terpinen-4-ol (23.4%) **(22)**, 1,8-cineole (16.3%), β-pinene (14.6%), α-terpineol (11.1%), cuminic aldehyde (6.5%) [60]
Chad	Fruits	33 (98.3%)	β-Pinene (24.6%) **(11)**, sabinene (14.5%), β-phellandrene (10.4%), terpinen-4-ol (10.0%), α-pinene (8.3%) [38]

Continua Tabella III

	Part	Total components	Major components
France	Fruits	71 (92.0%)	1,8-Cineole (13.3%) **(9)**, β-pinene (11.5%), sabinene (9.9%), *trans*-pinocarveol (8.2%), myrtenal (6.3%) [15]
Togo	Fruits	35 (89.9%)	β-Pinene (23.6%) **(11)**, α-pinene (11.0%), sabinene (9.8%), germacrene D (8.3%), 1,8-cineole (8.2%) [61]

Table IV - Biological activities of *Xylopia* essential oils

Bioactivities	Essential oils	Description
Antifungal	*X. aethiopica*	The fruits oil showed weak activity against *Aspergillus niger* and *Fusarium oxysporium* with MIC values 3000 and 4000 ppm, respectively [48]
	X. aromatica	The leaves oil showed weak activity against *Candida albicans* with MIC value 500 µg/mL [16]
Antibacterial	*X. aethiopica*	The fruits oil possessed activity against *Staphylococcus aureus*, *Bacillus licheniformis*, *Escherichia coli* and *Klebsiella pneumoniae* with MIC values of 0.5-32 µg/mL at low cell density and 8-64 µg/mL at high cell density [3]
	X. aethiopica	The fruits oil showed various degree of inhibitory effect against *Streptococcus pyogenes, Staphylococcus aureus, Bacillus subtilis, Enterobacter aerogenes, Klebsiella pneumonia, Escherichia coli,* and *Serratia marcescens* with the activity index value (vs. gentamicin) 73%, 68%, 71%, 83%, 87%, 63%, and 164%, respectively [43]
	X. laevigata	The leaves oil exhibited activity against *Staphylococcus aureus*, *Staphylococcus epidermidis*, and *Candida tropicalis* all with a MIC value of 100 µg/mL, each [31]
	X. sericea	The fruits oil demonstrated high bacteriostatic effect against *Staphylococcus aureus*, *Enterobacter cloacae*, *Bacillus cereus,* and *Klebsiella Pneumonia* with MIC values 7.8, 7.8, 15.63 and 62.5 µg/mL, respectively [23]
Antimicrobial	*X. aethiopica*	The fruits oil was inactive against *Stellocapella maydis*, *Aspergillus flavus*, *Aspergillus ocheraceus,* and *Fusarium oxysporum* at 5 mg/mL concentration [45]
	X. aromatica	The flower and leaves oils exhibited the lowest MIC against *Streptococcus pyogenes* with the value of 200 and 100 µg/mL, respectively [16]
	X. hypolampra	The stem bark oil was inactive against *Staphylococcus aureus, Streptococcus pyogenes,* and *Escherichia coli* [25]
	X. laevigata	The leaves oil exhibited significant activity against *Staphylococcus aureus*, *Staphylococcus epidermidis*, and *Candida tropicalis* with MIC value 100 µg/mL each [31]
Antioxidant	*X. aethiopica*	The fruits and leaves oil showed weak activity in DPPH radical with IC_{50} values 4.1 and 4.9 mg/mL, respectively [53]
	X. aethiopica	The fruits oil is found to be significant in scavenging superoxide anion radical, 57.2-86.8% (conc. 0.033-0.048 g/mL) [47]
	X. laevigata	The leaves oil gave inhibition of DPPH radical was 98.15% (conc. 10 mg/mL) [20].
	X. laevigata	The leaves oil gave 1468.96 µmol TE/g in the oxygen radical absorbance capacity (ORAC) assay [31]
	X. sericea	The fruits oil showed 80% of oxidation inhibition in the thiobarbituric acid-reactive substance (TBARS) assay (conc. 200 µg/mL) [23]
Antitumor	*X. frutescens*	The leaves oil was able to inhibit tumor growth in mice in a dose-dependent manner with inhibition rates were 31.0-37.5% [34]
	X. langsdorffiana	The fruits oil showed selectivity in its antiproliferative action against Leukaemia and NCI/ADR-RES cells, with total growth inhibition (TGI) values of 1.8 and 45.4 µg/mL, respectively [36]
Anticancer	*X. laevigata*	The leaves oil displayed activity against SF-295 glioblastoma cell and HL-60 promyelocytic leukemia cell lines, with IC_{50} values 14.4 and 17.5 µg/mL, respectively [30]
Cytotoxicity	*X. aethiopica*	The fruits oil was toxic to *Artemia salina* at a concentration ranging from 1.09 mg to 69.5 mg/mL [45]
	X. frutescens	The leaves oil displayed cytotoxicity on tumor cell lines and showed IC_{50} values ranging from 24.6 to 40.0 µg/mL for the bronchoalveolar lung carcinoma (NCI-H358M) and metastatic prostate carcinoma (PC-3M) cell lines, respectively [34]
	X. parviflora	The fruits oil oils exerted cytotoxic activity against MCF-7 and normal cell line (ARPE-19) with IC_{50} values of 0.155 µL/mL and 0.166 µL/mL, respectively [38]
Molluscicidal	*X. langsdorffiana*	The leaves oil showed significant molluscicidal activity against *Biomphalaria glabrata*, with an LC_{90} value of 5.6 µg/mL [37]
	X. ochrantha	The nanoemulsion of the leaves oil caused the mortality in *Biomphalaria tenagophila*, *Biomphalaria straminea* and *Biomphalaria glabarata* of different sizes at levels ranging from 50 to 100% (conc. 100 ppm) [26]
Anti-proliferative	*X. laevigata*	The leaves oil exhibited potent activity UACC-62 (melanoma), NCI-ADR/RES (ovarian-resistant) and NCI-H460 (lung) cell lines, with total growth inhibition (TGI) values of 4.03, 4.26, and 8.37 µg/mL, respectively [31]

Continua Tabella IV

Bioactivities	Essential oils	Description
Anti-trypanosoma	*X. frutescens*	The leaves oil showed trypanocidal activity against epimastigote and trypomastigote forms of *Trypanosoma cruzi* with IC_{50} values of 20.2 and 11.9 μg/mL, respectively [29]
	X. laevigata	The leaves oil showed trypanocidal activity against epimastigote and trypomastigote forms of *Trypanosoma cruzi* with IC_{50} values of 20.2 and 11.9 μg/mL, respectively [29]
	X. laevigata	The leaves oil has a strong trypanocidal activity against *Trypanosoma cruzi* with an IC_{50} value of 93.9±2.6 μg/mL [31]
Larvicidal	*X. laevigata*	The leaves oil showed weak activity against *Aedes aegypti* with LC_{50} value of 632.36 μg/mL [31]
Spasmolytic action	*X. frutescens*	Spasmolytic action mechanism of the leaves oil on guinea pig ileum can involve histaminergic receptor antagonism and Ca^{2+} influx blockade, which results in $[Ca^{2+}]_c$ reduction leading to smooth muscle relaxation [17]
Anti-inflammatory	*X. laevigata*	The leaves oil showed activity on carrageenan-induced leukocyte migration and carrageenan-induced hind paw edema in mice with percentage inhibition of 59.2 and 65.6%, respectively [20]
Toxicity	*X. aethiopica*	In a minimum dose of 1.74 $mgcm^{-2}$ of filter paper, the leaves oil caused 100% mortality of *Sitophilus zeamais* [46]
	X. parviflora	The root bark oil was toxic against *Callosobruchus maculatus*, LT_{50} at a dose of 6.25 mL/mL air was significantly lower than 11.94 (10.92-12.68) h, 11.67 (9.98-12.24) h and 10.11 (9.21–11.28) h obtained at 0.78, 1.56 and 3.15 mL/mL air, respectively [22]

and based on the fruit. Table III shows the chemical compositions of *X. aethiopica* essential oils from a different region [43-62]. The essential oils of *X. aethiopica* are mainly dominated by monoterpenes hydrocarbons. They were sabinene, *cis*-ocimene, β-pinene, α-pinene, and *trans-m*-mentha-1(7),8-diene. In addition, oxygenated monoterpenes that were found in the oil were 1,8-cineole, pinanol, and 4-terpinenol. Eugenol, a phenylpropanoid was also identified from the fruit oil, collected from Nigeria. Previous investigations on the chemistry of the essential oil of *X. aethiopica* have shown the presence of several chemotypes, namely β-pinene-rich [11, 14, 47-53], 1,8-cineole-rich [15, 45, 46], terpinen-4-ol-rich [38, 54, 60], sabinene-rich [51, 58, 59], and germacrene D-rich [14, 47, 61].

4. BIOLOGICAL ACTIVITIES

The literature study reveals that *Xylopia* essential oils have been reported in various biological activities. They were antifungal, antibacterial, antimicrobial, antioxidant, antitumor, anticancer, cytotoxicity, molluscicidal, anti-proliferative, anti-trypanosoma, larvicidal, spasmolytic action, anti-inflammatory, and toxicity. Table IV describes the details of these activities.

5. CONCLUSIONS

In this article we reviewed the relevant literature to congregate the medicinal uses, chemical composition, and bioactivities information on the *Xylopia* essential oils. According to the study, analysis of the essential oil of *Xylopia* species revealed a high content of germacrene D, bicyclogermacrene, (*E*)-caryophyllene, limonene, α-pinene, and β-pinene. It is evident that there are variations between different species and between the same species with a different origin. To unravel the full therapeutic potential of *Xylopia* species, more pharmacological investigations into other pharmacological activities should be performed. Furthermore, preclinical analyses, as well as clinical trials as conducted for essential oils from other species, are required to evaluate the potential of essential oils from *Xylopia* species for drug development.

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