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Ethnomedical uses, chemical constituents, and evidence-based pharmacological properties of *Chenopodium ambrosioides* L.: extensive overview

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Abstract

Background: The *Chenopodium* genus is a plant family widely spread worldwide that includes various plant species reputed to possess several medicinal virtues in folk medicines. *Chenopodium ambrosioides* L. is among the most used plants in traditional medicines worldwide. This review aimed to highlight ethnomedicinal uses, phytochemical status, and pharmacological properties of *C. ambrosioides* L.

Main body of the abstract: The analysis of relevant data highlights various ethnomedicinal uses against human and veterinary diseases in forty countries. Most indications consisted of gastrointestinal tract dysfunctioning troubles and worms parasitemia. Around 330 chemical compounds have been identified in different plant parts, especially in its essential oil fractions (59.84%). However, only a few compounds—mainly monoterpenes and glycosides—have been isolated and characterized. Experimental pharmacological studies validated a large scale of significant health benefits. It appeared that many monoterpenes are antioxidant, insecticidal, trypanocidal, analgesic, antifungal, anti-inflammatory, anti-arthritic, acaricidal, amoebicidal, anthelmintic, anticancer, antibacterial, antidiabetic, antidiarrheal, antifertility, antifungal, anti-leishmanial, antimalarial, antipyretic, antisickling, antischistosomal, antiulcer, anxiolytic, immunomodulatory, molluscicidal, and vasorelaxant agents.

Short conclusion: Thus, the *Chenopodium ambrosioides* species necessitates further chemical studies to isolate and characterize new bioactive secondary metabolites and pharmacological investigations to precise the mechanisms of action before clinical trials.

Keywords: *Chenopodium ambrosioides*, Bioactive compound, Therapeutic indications, Pharmacological bioactivity

Background

Ethnomedicine is part of folk medicine practiced by a given population and primarily based on the use of plant or herbal materials presented in various pharmaceutical formulations containing active ingredients [1]. Plants are sources of therapeutically and economically valuable compounds [2]. In recent decades, due to a large amount of research on phytochemistry and pharmacognosy, natural plant products have gained particular importance in treating different diseases [3]. Over 50,000 plants would possess therapeutic virtues.

More than 80% of the population in developing countries depends primarily on plant-based medicines for basic healthcare needs [4, 5]. Since the early 1970s, the WHO keeps stimulating governments in developing countries to benefit from local knowledge on traditional herbal medicaments [6]. Among botanical species of

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great value, the *Chenopodium* genus occupies a vital place. This genus includes about 102 genera and 1400 annual herbaceous species with a pungent smell distributed worldwide, especially in the moderate and subtropical zone [7, 8].

The species *Chenopodium ambrosioides* L. (Amaranthaceae), also well known as Mexican tea, Jesuit's tea or bluebush, Indian goosefoot, Spanish tea, or wormseed in English, is an annual or perennial shrub with a strong aromatic smell. It is widely distributed in West Africa, especially in Nigeria, Senegal, Ghana, and Cameroon [9].

Easy to grow, the plant grows on light (sandy), medium, heavy, acid, neutral, and alkaline soils (pH ranging from 5.2 to 8.3). It prefers moist soil but cannot be growing in the shade. It is mainly found on dry wasteland and cultivated ground. It is a cultivated and cosmopolitan species. The WHO pointed out that *C. ambrosioides* is among the most used plants in traditional medicines worldwide [8] widely used as an edible medicinal plant (especially leaves and seeds). Some recent review studies have reported primary data on conventional uses, phytochemicals, and pharmacological properties of *C. ambrosioides* [10–12].

We designed this review to complement that checks in a more detailed overview of medicinal uses, chemical composition, and evidence-based pharmacological properties that are missing.

Literature review method

The data presented are from full articles in English or French retrieved via Internet search with Google Scholar, PubMed/Medline, Science Direct, Scopus, the Wiley Online Library, Web of Science, and any other helpful search engines using *Chenopodium ambrosioides* OR *Dysphania ambrosioides* as the primary keywords, without time limit restriction. A total of 309 references were cited in this present review retrieved from those scientific engines.

Botanical description of *Chenopodium ambrosioides*

Chenopodium ambrosioides is a perennial tropical herb with a grooved, multi-branched reddish stem and a robust disagreeable scent growing that reaches up to 1 m high (Fig. 1). The leaves are oval (up to 4 cm long and 1 cm wide), sharply toothed, alternate, and a short petiole. The flowers are small and green, and the seeds are very small and green when fresh and black when dry. His inflorescence is the racemose type, presenting small flowers green colored. The sources are numerous, spherical, and have black color [8, 13].

Taxonomical classification of *C. ambrosioides* L

Kingdom: Plantae

Fig. 1 Photo of *Chenopodium ambrosioides* L. (Taken in Bukavu, Democratic Republic of Congo)

Phylum: Tracheophyta
Class: Magnoliopsida
Order: Caryophyllales Juss. ex Bercht. & J.Presl
Family: Amaranthaceae Juss.
Subfamily: Chenopodioideae Burnett
Genus: *Dysphania* R.Br.
Synonym: *Dysphania ambrosioides* (L.) Mosyakin & Clemants.

Ethnomedicinal knowledge

Table 1 describes data collected from ethnopharmacological investigations from forty countries. The information includes vernacular names, parts used, local uses, formulations, voucher numbers, and references for each country. Only 64.33% of voucher numbers have been listed for plant identification and authentification.

As indicated in Fig. 2a, the leaves were the most used parts (50.26%), followed by the whole (entire) plant (11.79%), aerial parts (8.72%), roots (6.15%), flowers, and stems (5.64%), seeds (3.59%), branches (2.05%), twigs (1.54%), bark, and shoots (1.03%). Several studies supported the use of leaves as the most used part of traditional medicines worldwide. According to Moshi and al [161]., the frequent use of leaves is associated with their ease of accessibility among the aboveground parts of plants in natural ecosystems. Overall, decoction has often been found as an adequate formulation of herbal remedies as it is easy to prepare by mixing a drug with boiling water [168].

As indicated in Fig. 2a, the leaves were the most used parts (50.26%), followed by the whole (entire) plant (11.79%), aerial parts (8.72%), roots (6.15%), flowers, and

Table 1 Traditional uses of the different parts of *C. ambrosioides* worldwide

Countries	Vernacular names	Part(s) used	Traditional uses	Formulation/method of administration	References
Angola	Santa Maria, nkavua	Leaf	Abdominal pain, respiratory diseases, backache, rheumatic pain, fever, gynecological, childhood disease (growth disorders), malaria, and diarrhea	Raw, infusion/enema, oral, bathing, steam bathing, and dermal	[14]
Argentina	Caré	Leaf and stem	Intestinal parasites	Infusion/–	[15]
	Huesaxa, Iqo, Davioxon	Aerial part	Intestinal parasites	Infusion and decoction/oral	[16]
	Paico	–	Gastrointestinal/liver diseases	–	[17]
	Paico macho	Leaf	Digestive, stimulative, diaphoretic, and vermifuge	–	[18]
Bangladesh	–	–	Snake, insect, and animal bites	–	[19]
	–	Leaf	Buruli ulcer	Decoction/–	[20]
Benin	Azongbidiwa, gbidiwa	Whole plant	Malaria, and fever	Decoction/oral	[21]
Bolivia	Caré	Leaf	Intestinal disorders and dysentery	Squeeze/embrocation	[22]
	Paico	Leaves, branches, flower, and stem	Stomach pain, swollen stomach, cold, hyperacidity, and diarrhea	Infusion/–	[23]
	Paico, paikko	Aerial part	Stomachic pain (abdominal pain), bile, and vesicular disorders	Decoction, infusion, and juice/oral	[24]
	Paicu	Leaf	Diarrhea, cystitis, intestinal parasites, and infections	Infusion and juice /internal	[25]
	Payco, payqu, p'aki p'aki	Aerial parts and root	Intestinal catarrh, dysmenorrhea, asthma, and gallstone colic	Infusion/internal and external applications	[26]
	Payqu	Leaf	Rheumatism, fever and hepatitis	Infusion/poultice	[27]
Brazil	American wormseed	–	Post-extraction healing (teeth)	–	[28]
	Erva-de-bicho/Erva-Santa-Maria	Leaf and stem	Hemorrhoids	Infusion and decoction/–	[29]
	Erva-de-Santa Maria	Leaf	Wounds	Maceration/transdermic route	[30]
	Erva-de-Santa Maria	Leaf and seed	Infectious diseases, gastrointestinal system diseases, and respiratory system diseases	Infusion, decoction/–	[31]
	Erva de Santa maria	–	Anti-inflammatory, and increasing breathing	–	[32]
	Erva-de-Santa-maria	Aerial part	Vermifuge and soothing	Decoction and juice/oral	[33]
	Erva-de-santa-maria	Leaf	Vermifuge	Infusion/–	[34]
	Erva-de-Santa- Maria, mentruz, mastruz	Leaf	Vermifuge, inflammation, and wounds	Juice/bandage	[35]
	Erva-de-santa- maria, mastruz	Aerial parts, whole plant, and roots	General infection, cold, worms, depurative, tranquilizer, insomnia, flu, sinusitis, stomachache, gastritis, arm pain, inflammation, wound healing, bone fracture, sprain, injury, injury with blood clot (bleeding), and distress	Decoction, infusion, maceration, fresh, cataplasm, and juice/–	[36]
	Erva-de- santa- maria, mastruz	Whole plant	Malaria	Infusion and maceration/oral	[37]
	Mastruço	Whole plant	As vermifuge, stomachic, and expectorant	Juice/oral	[38]
	Mastruço, mastruz	Leaf, stalks, branch, and root	Expectorant, cough, musculoskeletal injury, influenza, tuberculosis, and respiratory disease	Maceration, decoction, juice, and infusion/oral	[39]
	Mastruz	Leaf	Fever, cough, coughing with secretions, and pneumonia	Infusion/–	[40]
	Mastruz	Leaf	Worms, thud, pneumonia, lung, and stomachache	–/oral	[41]
	Mastruz	Leaf	Inflammation, constipation, and flu	Infusion/–	[42]

Table 1 Traditional uses of the different parts of *C. ambrosioides* worldwide *(Continued)*

Countries	Vernacular names	Part(s) used	Traditional uses	Formulation/method of administration	References
	Mastruz	Leaf	Malaise and worms	Infusion/–	[43]
	Mastruz	Leaf, inflorescence (flowers), and twig Leaf and twig	Amoeba, worms Worms (Cattle, goat, chicken, pig, and sheep)[a]	Raw, maceration and trituration/– Trituration in water, maceration, and decoction/–	[44]
	Mastruz	Leaf	Expectorant, for coughing, for worms	Infusion and juice/–	[45]
	Mastruz	Leaf	Diarrhea and dysentery	-	[46]
	Mastruz	Leaf	Worm, flu, cough, and stomach pain	Juice, syrup, and infusion/ oral	[47]
	Mastruz	Leaf	Anthelmintic in canine[a]	Maceration/–	[48]
	Mastruz	Leaf	Wound healing, anti-inflammatory, and diarrhea (veterinary use)[a]	Juice and plaster/–	[49]
	Mastruz	Leaf, seed, and root	Gastritis, factures, ulcer, worm, intestinal problems, stomach, gallbladder problems, hematoma, ulcer, expectorant, inflammation, and colics	Decoction, leave soaking, juice, poultice, maceration, and infusion/oral and topical application	[50]
	Mastruz	Leaf or branch	Worms, gastritis, cancer, flu, congested chest, tonic, cough, congestion, tuberculosis, stomachache, women's problems, fights ulcer, erysipelas, and any swollen	Mixture, syrup, infusion, cataplasm, and compress/–	[51]
	Mastruz	Leaf	Worms, influenza, tuberculosis, and bronchitis	-	[52]
	Mastruz	Leaf	Leishmanial ulcers	Decoction and powder/ bathing	[53]
	Mastruz	Leaf	Cough and vermifuge	Juice and syrup/–	[54]
	Mentruz, erva- de-santa-maria	Aerial part	Muscle pain, lesions in bone, bronchitis, and worms	Decoction, syrup, raw, and infusion/massage, plaster, and oral	[55]
	Mastruz/Santa Maria	Leaf	Worms and bruise	Maceration//topical application	[56]
	(erva de) Santa Maria, mastruz, mentruz		Cough and tuberculosis	Tea, syrup, and juice/–	[57]
	Santa-maria	-	Vermifuge	–	[58]
Cameroon	Elog minsom	Leaf	Intestinal worms	Infusion/oral	[59]
	–	Leaf	Female infertility	–	[60]
	–	Leaf stem	Hypertension	Decoction/oral	[61]
Colombia	Paico	Whole plant	Snake bites	Decoction/ointment and bathing	[62]
	Yerba santa	Leaf	Intestinal parasites	Decoction or infusion/oral	[63]
Congo-Brazzaville	Akwa: awoulouwoussou Soundi : loukaya louamoukouyou	Leaf	Convulsions	Decoction/oral	[64]
	Lari: lukaya luakuyu Akwa: awoulouwoussou	Leaf	Cough, fever, epilepsy, worms, and hemiplegia	Decoction/oral	[65]
Congo-Democratic Republic	Kepamakusu, mudia nioka, Kulamoka, Kivundja homa, Dikanga bakishi	Whole plant	Diabetes mellitus	Decoction/oral	[66]
	Lufwa nyoki	Leaf	Gastrointestinal disorders in livestock[a]	Maceration and crush/–	[67]
	Mugunduzimu, kivunjahoma,	Leaf	Malaria	Decoction/oral	[68]

Table 1 Traditional uses of the different parts of *C. ambrosioides* worldwide *(Continued)*

Countries	Vernacular names	Part(s) used	Traditional uses	Formulation/method of administration	References
	namahuma				
	Nkasa kindongo	Leaf	Helminthiasis	Maceration/oral	[69, 70]
	Nkasi kindongo	Bark	Diabetes mellitus	Maceration/–	
	Timor	Leaf	Low back pain, and roundworm	–/oral and tropical application	[71]
	Zorbeih	–	Stomach discomfort and intestinal worms	Infusion/–	[72]
Cuba	Apazote	Leaf and whole plant	Dysentery	Decoction/oral	[73]
	Apasote	The whole plant, aerial part, and leaf	Parasites, rheumatisms, and arthrosis	Maceration, decoction, and juice/oral and topical application	[74]
Ecuador	Paico	Branch	Culture-bound syndromes and digestive system	–/rubbing	[75]
	Paico	Seed and leaf	Antiparasite, analgesic, lacerations, intestinal inflammation, and stomach pain	Juice/oral	[76]
	Paico-Paycu	Leaf	Bleeding after childbirth	–	[77]
Egypt	Sorbeyh, minatteena	Aerial part	Analgesic, stimulant to decrease fever, emmenagogue, anti-helminthic, carminative, and antiseptic	Infusion/–	[78]
Ethiopia	Etse-farus	Root	Snake bite	Crushed/–	[79]
	–	Whole plant	Internal parasite, abdominal pain, and abdominal swelling[a]	Maceration/oral and nasal application	[80]
France (Guadeloupe)	Simenn kontra	Leaf	Intestinal parasites	Decoction/–	[81]
Ghana	–	Leaf and bark	Cancers (breast, brain, stomach, throat)	Decoction/oral	[82]
	–	Leaf	Tuberculosis	–	[83]
Guatemala	Apazote	Leaf	Diabetes (type-2)	Infusion/oral	[84]
	Pasujt, apazote, epazote	Aerial part, seed, and root	*Empacho*, diarrhea, stomachache, abdominal cramps, and parasitic worms	–	[85]
Honduras	Epazote	–	Parasites in all livestock[a]	–	[86]
India	Chandan Bathua	Aerial part	Anthelmintic	Juice/oral	[87]
	Galisoppu	Leaf	Skin swellings and dysmenorrhea	Paste and infusion/oral and external application	[88]
	Khatua	Leaf	Gynecological disorders (pain during menstruation)	Maceration/–	[89]
	Kirmani	Whole plant	Piles (hemorrhoids)	Paste/ointment	[90]
	Pthoori	Root	Febrifugal affections	–	[91]
	Sonkina gida	Whole plant	Anthelmintic and skin allergy	Juice and crushed/oral and external application	[92]
	Waljuin	Leaf	Nervous tension and skin disease	Decoction, crushed, and paste/oral and topical application	[93]
	Zewa dawda kual, ganhar	The whole plant and aerial part	Dandruff and intestinal worms	Oil and crushed/oral and topical application	[94]
Italy	–	Leaf, and flower (dried)	Worms (helminths)	Decoction/oral	[95]
Jamaica	Semicontract	Whole plant, leaf, and stem	Intestinal worms	Decoction, infusion, and juice/oral	[96]
Jordan	Goose foot	Leaf and root	Diuretic (edema) and bladder	Decoction/–	[97]
	Mirwaha, Fus Elajooz	Leaf	Spasms	Infusion/–	[98]

Table 1 Traditional uses of the different parts of *C. ambrosioides* worldwide *(Continued)*

Countries	Vernacular names	Part(s) used	Traditional uses	Formulation/method of administration	References
Madagascar	Taimborontsiloza	Leaf	Intestinal parasites	Ingestion/internal application	[99]
	Taimboritsiloza	Entire plant	Placental apposition, parasites, and nosebleeds	–	[100]
Mauritius	Bautrisse	Leaf	Intestinal worms (pediatric use)	Decoction/oral	[101]
	Herbe botrice	Leaf	Cough, Scabies, worms, and kill lice	Infusion, decoction, crush, and juice/oral and bathing	[102]
México	Epazote	Leaf	Diarrhea, stomachache vermifuge, and vomiting	Infusion/oral	[103]
	Epazote	Aerial part	Cough, and erysipelas	Infusion and maceration/oral and topical application	[104]
	Epazote	Leaf and stem	Facilitate childbirth and menstrual cramps	–	[105]
	Epazote, Epazotl	Leaf	Abdominal pain, cough, flu, stomachache, and vermifuge	Infusion/oral	[106]
	Epazote, Tijson	Leaf	Vermifuge, arthritis, diarrhea, stomachache, to keep away from bad spirits	Infusion/oral	[107]
	–	Twigs	Infectious bowel diseases	Maceration/–	[108]
	–	Aerial part	Culture bound syndromes (folk diseases), gastrointestinal disorders, and hepatic complaints	–	[109]
Morocco	L'm'khinza	Aerial part	Fever and migraine	–	[110]
	Mhinza	Leaf	Fever, headache, ovarian and menstrual pain	Raw and decoction/poultice and oral	[111]
	Mkhinza	-	Fever	-	[112]
	Mkhinza	Leaf	Diabetes mellitus	Maceration/oral	[113]
	Mkhinza	Leaf	Diabetes mellitus	Infusion/–	[114]
	Mkhinza	Whole plant	Diabetes mellitus	Decoction/–	[115]
	Mkhinza	Leaf	General health, gastrointestinal, pediatric, endocrinological	Infusion/poultice, bathing, and oral ingestion	[116]
	Mkhinza	Leaf, and flower	Diabetes mellitus and hypertension	Decoction and infusion/–	[117]
	Mkhinza	Leaf, and flower	Diabetes mellitus	Infusion/–	[118]
	Mkhinza	Leaf	Diabetes mellitus	Juice/–	[119]
	Mkhinza	Leaf	Diabetes mellitus	Decoction and infusion/–	[120]
	Mkhinza	Leaf and flower	Hypertension	Infusion and juice/–	[121]
	Mkhinza	Leaf and flower	Hypertension and cardiac diseases	–	[122]
	Mkhinza	Leaf and flower	Diabetes	–	[123]
	Mkhinza	Leaf, and flower	Diabetes mellitus	–	[124]
	M'khinza	Leaf and aerial part	Antipyretic, sunstroke, anti-emetic, stomachic, and mouthwash	Decoction/oral and local application	[125]
	M'khinza	Leaf	Fever, headache, heart problems		[126]
	Zarriâat, Mkhinza	Seed	Asthma, cold, labor pain, pains, and helminths, and as an abortifacient	Infusion and as cigarettes/ oral and external application	[127]
	-	Leaf	Pains (abdominal and head pain)	Juice and powder/oral and cataplasm	[128]
	-	-	Fever, cough, vomiting, rheumatism, diarrhea, migraine, nervosity, respiratory and hepatic disorders, gynecological disorders, bladder	Decoction, powder, infusion, and mask/–	[129]

Table 1 Traditional uses of the different parts of *C. ambrosioides* worldwide *(Continued)*

Countries	Vernacular names	Part(s) used	Traditional uses	Formulation/method of administration	References
			diseases, influenza, hematoma, diabetes, hair loss, and gastrointestinal disorders		
	In Arabic	Leaf and stem	Head problems, fever, and pathologies of the digestive systems	Decoction, infusion, and maceration/oral and external application	[130]
Mozambique	Kanunka uncono	–	Intestinal ulcers and stomach-aches	–	[131]
Netherlands	Woronmenti, Tiki menti, Fukufuku menti	Whole plant	–	–	[132]
Nigeria	Arunpale, Akintola	Root	Sickle cell disease	–	[133]
	Arunpale	Leaf	High blood pressure (Hypertension)	Decoction/oral	[134]
	Ebigben-Suigben	Leaf and root	Rheumatism	As food/oral	[135]
	Ewe arunpale	Leaf	Cancer (prostate and breast)	Concoction/oral	[136]
Pakistan	Baagi bethwa	Whole plant	Sexual impotence	Decoction/–	[137]
	Baljawain	Seed	Abdominal problems and headache	–	[138]
	Boi Sarmy	Leaf	Anthelmintic	Decoction/oral	[139]
	Buthu	Whole plant	Various symptoms of malaria	Decoction/oral	[140]
	Chandan bathwa	Whole plant	Anthelmintic and for piles	–	[141]
	Chulai	Whole plant	Intestinal worms	Infusion/–	[142]
	Chulai	-	Cough, pulmonary obstruction, amenorrhea, carminative, diaphoretic, emmenagogue, and expulsion of the dead fetus	Infusion/–	[143]
	Gundi Booti	Leaf and stem	Pile and indigestion problems, especially diarrhea	Decoction/–	[144]
	Skhabotay	Young shoot	Warts	Raw (dried)/oral	[145]
	Surna	Root	Rheumatism	Decoction/–	[146]
Panama	–	Leaf	Stomachache and worms	Decoction and juice/–	[147]
	Paico macho, cashua paico	Leaf, root	Liver problems, with "bilis" (gall bladder trouble), stomach pain, and diarrhea	Decoction/oral	[148]
	Paico	Aerial part	Parasites, stomach pain, colic, gases, skin parasites, and wounds	Infusion, decoction, and as food/oral, topical application, and bathing	[149]
	Paico	–	Stomach ache, abdominal pain with gas, colics, fever, to bathe bodies, and intestinal parasites, and diarrhea		[150]
	Paico	Leaf and seed	Vermifuge for children	Squeezed and juice/oral	[151]
	Paico	Leaf and stem	Endoparasites; and constipation	Infusion/oral	[152]
Perú	Chinche, huacatay, Payco	Leaf, stem, and flower	Digestive, antiparasitic, intestinal worms, colics, upset stomach, and diarrhea	Infusion/oral	[153]
Rwanda	Umwisheke	Stem with leaves	Voluntary depigmentation	Powder/topical application	[154]
South Africa	Imboya	Leaf	Skin disorders (skin itch, eczema, and pimples)	–/tropical application	[155]
	Nsukumbili	Whole plant	Lymphatic filariasis	Infusion/oral	[156]
	Unukani, Ikhambi	Whole plant	Diarrhea (especially for children)	Maceration, decoction, and infusion/anal and oral	[157]
Spain	Te´	Aerial part	Digestive, stomachic and laxative	Infusion/internal	[158]
Tanzania	Akaita malogo	Leaf	HIV/AIDS-related conditions (Herpes simplex, cryptococcal meningitis)	–	[159]
	Injaga-yabekwabi, Nemu ya Masai	Leaf and shoot	Infections (vaginal ulcers and tapeworm)	Infusion and maceration/oral and external application	[160]
	Orwita marago/	Leaf	For making soap and as a lucky charm	–/tropical application	[161]

Table 1 Traditional uses of the different parts of *C. ambrosioides* worldwide *(Continued)*

Countries	Vernacular names	Part(s) used	Traditional uses	Formulation/method of administration	References
	Kaitamarogo				
Trinidad and Tobago	Worm grass	Plant tops	Anthelmintic for backyard chickens[a]	–	[162]
Uganda	Katta dogo	Leaf	Charms/bewitchment, and intestinal worms	Decoction/oral	[163]
	–	Leaf	Headache and epilepsy	Crushed/topical application and oral	[164]
	–	Leaf, stem, fruit, whole plant, and seed pods	Fever in pregnancy women "amakiro," abdominal pain, and cold sores	Infusion and powder/oral and topical application	[165]
Venezuela	Goosefoot	Leaf	Parasites	Decoction/oral	[166]
Vietnam	Sành, Rau mu i, Dầu giun	Leaf	Acne and urticaria	Crushed/topical application	[167]

[a] veterinary use, – not specified

stems (5.64%), seeds (3.59%), branches (2.05%), twigs (1.54%), bark, and shoots (1.03%). Several studies supported the use of leaves as the most used part of traditional medicines worldwide. According to Moshi and al [161]., the frequent use of leaves is associated with ease of accessibility among the aboveground parts of plants in natural ecosystems.

The results in Fig. 2b show that infusion is the most used formulation mode (27.36%), followed by decoction (23.88%). Many reasons can explain infusion as the most mode of preparation of *C. ambrosioides*. Infusion is convenient for soft plant parts, especially those containing volatile compounds, so that the solvent (water) may quickly enter into the tissues in a short preparation time; the plant is very rich in essential oils.

Figure 2c shows that the oral route is the most used (56.36%). This route presents many advantages, including safety, good patient compliance, ease of ingestion, pain avoidance, and versatility to accommodate various drugs. Thus it is preferred over different administration routes of drug delivery [169]. Other ways are also used, such as tropical (10.91%), bathing (5.45%), external (5.45%), paste (4.55%), internal (3.64%), ointment, and anal (1.82%).

Concerning medical uses, *Chenopodium ambrosioides* is indicated in treating several human diseases, disorders, and injuries of different organs/systems, both in human and veterinary medicines. Veterinary indications are limited compared to humans. Seven signs have been listed for veterinary purposes, mainly including worms (parasites) and gastrointestinal disorders (pain, swelling, diarrhea) in livestock. Also, canine and backyard chickens were explicitly cited.

Toxicological studies

A subchronic toxicological investigation of leaf aqueous extract for 15 days has not produced mortality in mice. Overall, at the highest dose (500 mg/kg bw, per os), no alteration in body weight, food, and water consumption has been noted, except in some changes in organ weights and biochemical markers like albumin serum, triglycerides, and in the VLDL values [170]. In the oral acute toxicity test for 24 h, 3 g of aqueous leaf extract/kg bw increased transaminase levels and decreased urea serum level in rats. Results did not note any clinical signs of toxicity, macroscopic lesions, and change in total protein, creatinine, triglycerides, and cholesterol levels. On the other hand, in sub-chronic evaluation for 15 days, the extract significantly reduced ALT serum value at the dose of 1 g/kg bw.

Furthermore, the authors suggested congestion in the kidneys' medullar region at 1 and 3 g/kg bw [171]. Gadano et al. [172] found that preparations (aqueous decoction and infusion) of the aerial part at different concentrations (1, 10, 100, 1000 mg/ml) could provoke genetic damage by elevation of chromosomal aberrations and sister chromatid exchanges subjected to human lymphocyte cell cultures. A reduction of mitotic indexes appeared after treatment. A similar study concluded a possible strong interaction between DNA and active principles of aqueous extracts [173].

Phytochemistry

Table 2 summarizes the compounds isolated and characterized from different extracts, fractions, and plant parts.

Table 3 reports compounds identified in different parts of the plant. Around 330 compounds (including their isomers) have been placed in other extracts/fractions, mainly in essential oil (59.54%). The majority of them were monoterpenes (43.16%) followed by flavonoid

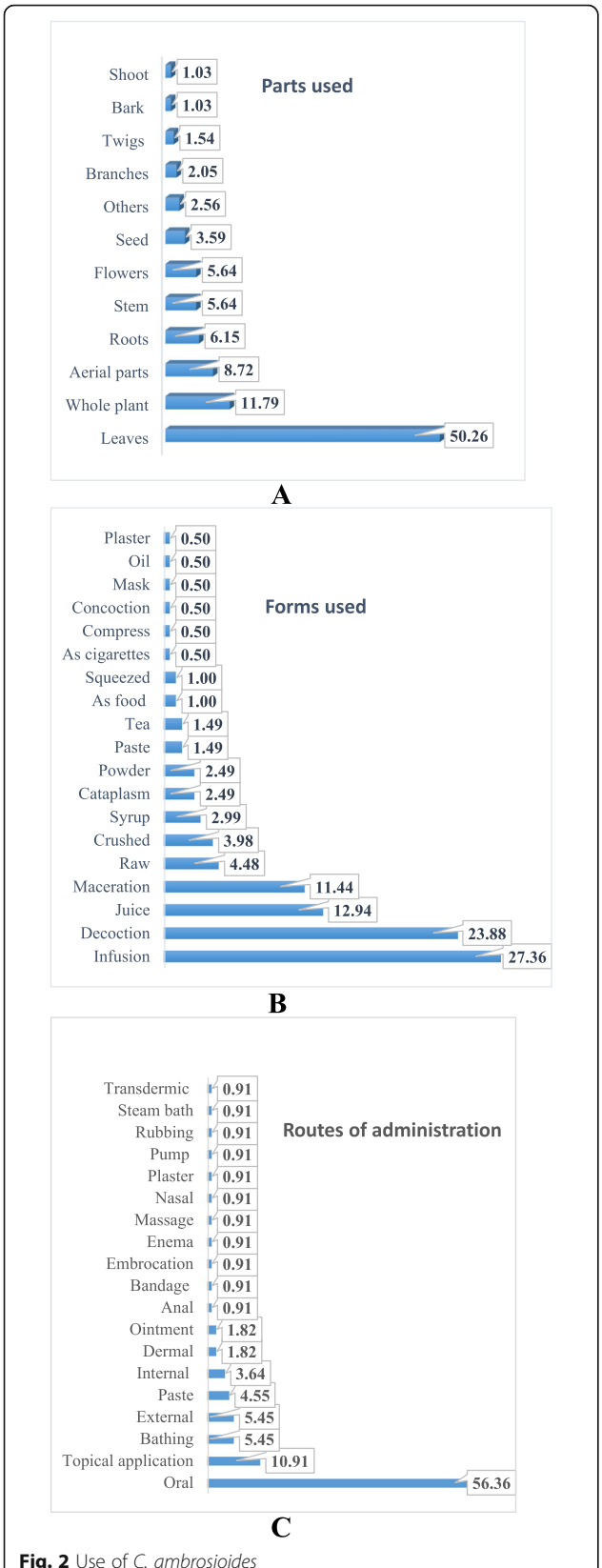

Fig. 2 Use of *C. ambrosioides*

glycosides (10.33%), sesquiterpenes (8.51%), esters (5.78%), aliphatic acids and ketones (4.26%), alcohol (3.65%), aliphatic hydrocarbons and aromatic acids (2.43%), carbohydrates (2.13%), and others. For example, essential oils analyzed from four Kenyan plants (ginger, garlic, tick berry, and Mexican marigold), terpenes constituted the highest composition [191]. Monoterpenes and sesquiterpenes are natural products and essential oils' main constituents [192, 193]. Alcohols, aldehydes, esters, ethers, ketones, and phenols are made up of the six functional groups of organic compounds necessary to aromatherapists, especially in essential oils' terpenoid and nonterpenoid volatile compounds (aliphatic and aromatic hydrocarbons). Terpenes or isoprenoids are the largest single class of compounds found in these essential oils [194]. In the same vein, after monoterpenes, flavonoids glycosides were the majority in the plant (10.33%). Hydroalcoholic extraction (8.33%) and polar fraction obtained from ethanol (8.14%) have been used as the most critical sources of compounds after essential oil, according to Table 2. Flavonoids and flavonoid glycosides are usually extracted in ethanol and hydroalcoholic extracts. Weirong and al [195]. found that the best yield of extraction of the flavonoids from *Opuntia milpa alta* Skin was obtained with 80% ethanol at the temperature of 90 °C. Overall, aqueous alcohol solutions are suitable for extracting flavonoids [196].

Among those 329 compounds, terpinene was the most cited (6.76%). Two isomers of terpinene were found, and β-terpinene (3.82%) has been the most cited than α-terpinene (2.94%). However, from 37 studies on chemical composition essential oil of *C. ambrosioides*, as presented in the above table, α-terpinene was found to be the main constituent (40.5%) of essential oils from different countries include Brazil [197–199], Cameroon [200], China [201], Colombia [202], Egypt [203], India [204–206], Morocco [207], Nigeria [13], and Rwanda [208]. His concentration was variable according to countries and used parts. His highest concentration was 65.4% from essential leaf oil collected and analyzed from India [206]. The terpinenes, both α- and γ-isomers, are natural cyclic monoterpenes naturally largely spread in the plant kingdom. They have been identified in several species. For example, in tea trees, α-terpinene is a major constituent of the essential oil tree [209]. After terpinene, ascaridole with their three isomers [cis-ascaridole/ascaridole (3.24%), isoascaridole (1.76%), and trans-ascaridole (0.88%)] was also cited (5.88%). From those 37 studies, ascaridole (specifically cis-ascaridole) was also the majority monoterpene (35.13%) in the essential oil of *C. ambrosioides*. For example, it was the main secondary metabolites in essential oil collected from Argentina [210, 211], Benin [212], Brazil [213–216], China [188, 217], France [218], Hungary [219], India [220], Mexico

Table 2 Secondary metabolites isolated from *C. ambrosioides*

Compound	Part used/extract (fraction)	References
Alkaloids		
1-Piperoylpiperidine	Whole plant/methanol (n-butanol)	[174]
Coumarins		
1,2-Benzopyrone	Leaves/ethanol 70% (n-butanol)	[175]
Scopoletin	Whole plant/methanol (dichloromethane)	[174]
Cyclohexanones		
4-Hydroxy-4-methyl-2-cyclohexen-1-one	Whole plant/–	[176]
Fatty acids		
Octadecanoic acid	Whole plant/methanol (ethyl acetate)	[174]
Flavonoids		
Kaempferol	Fruits/methanol (ethyl acetate)	[177]
	Leaves/ethanol 70% (n-butanol)	[175]
Isorhamnetin	Fruits/methanol (ethyl acetate)	[177]
Patuletin	Whole plant/–	[176]
Quercetin	Fruits/methanol (ethyl acetate)	[177]
Glycosides		
Benzyl beta-D-glucopyranoside	Whole plant/–	[176]
Chenopodioside A	Roots/methanol (–)	[178]
Chenopodioside B	Roots/methanol (–)	[178]
Dendranthemoside B	Whole plant/–	[176]
Kaempferol 3-*O*-α-L-$^{1}C_{4}$–rhamnopyranoside (afzelin)	Leaves/ethanol 70% (n-butanol)	[175]
Kaempferol 3-*O*-α-L-$^{1}C_{4}$-rhamnosyl-(1‴→2″)-β-D-$^{4}C_{1}$-xylopyranoside	Leaves/ethanol 70% (n-butanol)	[175]
Kaempferol 3-rhamnoside-4′-xyloside	Fruits/methanol (ethyl acetate)	[177]
Kaempferol 3-rhamnoside-7-xyloside	Fruits/methanol (ethyl acetate)	[177]
Kaempferol 7-*O*-α-L-$^{1}C_{4}$–rhamnopyranoside	Leaves/ethanol 70% (n-butanol)	[175]
Kaempferol 7-rhamnoside	Leaves/ethyl acetate (–)	[179]
Kaempferol-3,7-di-O-alpha-L-rhamnopyranoside	Whole plant/–	[176]
Kaempferol-7-O-alpha-L-rhamnopyranoside	Whole plant/–	[176]
Kaempfrol 7-rhamnoside (ambroside)	Leaves/ethyl acetate (–)	[179]
Quercetin-7-O-alpha-L-rhamnopyranoside	Whole plant/–	[176]
Scutellarein-7-*O*-α-rhamnopyranosyl-(1→2)-α-rhamnopyranoside	Aerial parts/ethanol (ethyl acetate)	[180]
Scutellarein-7-*O*-α-rhamnopyranosyl-(1→2)-α-rhamnopyranosyl-(1→2)-α-rhamnopyranoside	Aerial parts/ethanol (ethyl acetate)	[180]
Lignanes		
Syringaresinol	Whole plant/–	[176]
Monoterpenes		
(–) (1R*,2S*,3S*,4S*)-1,2,3,4-Tetrahydroxy-*p*-menthane	Aerial parts/n-hexane-ethyl acetate-methanol (n-hexane-ethyl acetate, 1:1)	[181]
(–) (1R*,4S*)-1,4-Dihydroxy-*p*-menth-2-ene	Aerial parts/ n-hexane-ethyl acetate-methanol (n-hexane-ethyl acetate, 1:1)	[181]
(–)-(1*R*,4*S*)-*p*-Mentha-2,8-dien-1-hydroperoxide	Aerial parts/ethyl acetate (diethyl ether-soluble)	[182]
(–)-(1*S*,4*S*)-*p*-Mentha-2,8-dien-1-hydroperoxide	Aerial parts/ethyl acetate (diethyl ether-soluble)	[182]
(–)-(2*R*,4*S*)-*p*-Mentha-1(7),8-dien-2-hydroperoxide	Aerial parts/ethyl acetate (diethyl ether-soluble)	[182]
(–)-(2*S*,4*S*)-*p*-Mentha-1(7),8-dien-2-hydroperoxide	Aerial parts/ethyl acetate (diethyl ether-soluble)	[182]
(1R,2S)-3-p-Menthen-1,2-diol	Stems/ethanol (ethyl acetate)	[183]

Table 2 Secondary metabolites isolated from *C. ambrosioides (Continued)*

Compound	Part used/extract (fraction)	References
(1R,2S,3S,4S)- 1,2,3,4-Tetrahydroxy-*p*-menthane	Stems/ethanol (ethyl acetate)	[183]
(1R,4S)-*p*-Menth-2-en-1-ol	Stems/ethanol (ethyl acetate)	[183]
(1S,2S,3R,4S)-1-Methyl-4-(propan-2-yl)cyclohexane-1,2,3,4-tetrol	Stems/ethanol (ethyl acetate)	[183]
1,2,3,4-Tetrahydroxy-*p*-menthane	Leaves and stems/ethanol (hexane-ethyl acetate)	[184]
1,2:3,4-Diepoxy-*p*-menthane	Leaves/essential oil (ethyl acetate)	[185]
1,4-Dihydroxy*p*-menth-2-ene	Stems/ethanol (ethyl acetate)	[183]
1,4-Epoxy-*p*-menth-2-ene	Leaves/essential oil (ethyl acetate)	[185]
1-Methyl-4β- isopropyl-1-cyclohexene4α,5α,6α-triol	Stems/ethanol (ethyl acetate)	[183]
4-Hydroxy-4(α or β)-isopropyl-2-methyl-2-cyclohexen-1-one	Stems/ethanol (ethyl acetate)	[183]
Ascaridole	Whole plant/ethanol (hexane-ethyl acetate)	[186]
	Aerial part/methanol (hexane)	[187]
	Aerial parts/ethyl acetate (diethyl ether-soluble)	[182]
	Aerial parts/–	[188]
	Leaves and stems/ethanol (hexane-ethyl acetate)	[184]
Chenopanone	Aerial parts/ n-hexane-ethyl acetate-methanol (n-hexane-ethyl acetate, 1:1)	[181]
Cis-*p*-Menthadiene-l(7),8ol-2	Whole plant/ethanol (hexane-ethyl acetate)	[186]
Isoascaridole	Aerial parts/–	[188]
α-Terpinene	Aerial parts/–	[188]
δ-4-Carene	Aerial parts/–	[188]
p-Cymene	Aerial parts/–	[188]
Phenolic amides		
N-Trans-feruloyl tyramine	Whole plant/–	[176]
Polyphenolic acids		
Caffeic acid	Leaves/ethanol 70% (n-butanol)	[175]
Sterols		
2,2-Dihydro-spinasterol	Whole plant/acetone (methanol-acetonitrile)	[189]
Avenasterol	Whole plant/acetone (methanol-acetonitrile)	[189]
Spinasterol	Whole plant/acetone (methanol-acetonitrile)	[189]
Stigmasterol	Whole plant/methanol (ethyl acetate)	[174]
β-sitosterol	Whole plant/methanol (ethyl acetate)	[174]
Other compounds		
Chenopodiumamine A	Whole plant/ethanol (chloroform)	[190]
Chenopodiumamine B	Whole plant/ethanol (chloroform)	[190]
Chenopodiumamine C	Whole plant/ethanol (chloroform)	[190]
Chenopodiumamine D	Whole plant/ethanol (chloroform)	[190]
Chenopodiumoside A	Whole plant/ethanol (chloroform)	[190]
Grasshopper ketone	Whole plant/–	[176]

[221] and Togo [222]. Besides this α-terpinene and ascaridole, we also found in some rare cases carvacrol (5.4%), *m*-cymene (2.7%), *p*-cymene (2.7%), *o*-cymene (2.7%), α-terpinyl acetate (2.7%), limonene (2.7%), cis-piperitone oxide (2.7%), and trans-pinocarveol (2.7%), as main secondary metabolites of essential oil of *C. ambrosioides*.

Figure 3 shows some most cited chemical structures identified in different studies, including α-pinene, α-terpinene (**1**), limonene (**2**), *p*-cymene (**3**), carvacrol (**4**), *p*-cymen-8-ol (**5**), *p*-mentha-1,3,8-triene (**6**), thymol (**7**), terpinolene (**8**), geraniol (**9**), β-phellandrene (**10**), β-myrcene (**11**), pinene (**12**), camphor (**13**), ascaridole

Table 3 Main secondary metabolites identified in *C. ambrosioides*

Identified secondary metabolites	Part used	Source	References
(2E)-2-Ethylidene-1,1-dimethylcyclopentane	Leaves	Non-polar fraction (pentane)	[223]
(d)-2-Caren	Leaves	Essential oil	[224]
(E)-2-Hexenal	Leaves, whole plant	Essential oil	[208, 224]
(E)-2-Tetradecene	Leaves	Essential oil	[224]
(E)-Ascaridole	Aerial parts, leaves	Hexane fraction, essential oil	[216, 225]
(E)-Carveol	Leaves	Essential oil	[202]
(E)-Caryophyllene	Leaves	Essential oil	[202, 211, 218]
(E)-Phytol	Aerial parts	Essential oil	[226]
(E)-Piperitol acetate	Leaves	Essential oil	[216]
(E)-Piperitone epoxide	Leafy stems	Essential oil	[212]
(E)-*p*-Mentha-2,8-dien-1-ol	Leafy stems	Essential oil	[212]
(E)-β-Ionone	Leafy stems	Essential oil	[198, 212]
(E)-β-Ocimene	Leaves	Essential oil	[185]
(Z)-Ascaridole	Aerial parts, leaves	Hexane fraction, essential oil	[188, 216, 217, 225]
(Z)-β-Ocimene	Whole plant	Essential oil	[205]
(Z)-Carvyl	Leaves	Essential oil	[216]
1,2,3,4-Tetrahydroxy-*p*-menthane	Whole plant	Essential oil	[218]
1,2,3-Menthatriene	Leaves	Essential oil	[202]
1,2:3,4-Diepoxy-*p*-menthane	Leaves	Essential oil	[185]
1,3,8-*p*-Menthatriene	Leaves	Essential oil	[227]
1,4-Dihydroxy-*p*-menth-2-ene	Leaves	Essential oil	[202, 218]
1,4-Cyclohex-2-enedione	Whole plant	Essential oil	[201]
1,4-Epoxy-*p*-menth-2-ene	Leaves	Essential oil	[185]
1,6-Isopropyl-3-methyl-7-oxabicyclo[4.1.0] heptan-2-one	Leaves	Non-polar fraction (pentane)	[223]
1-[2-Methyl-5-(1-methylethenyl)cyclopentyl]-(1α,2α,5β) ethanone	Leaves	Essential oil	[204]
1-Hydroxy-2-heptanone	Aerial parts	Essential oil	[226]
1-Methyl-3-(1-methyl ethyl)-cyclohexene	Leaves	Essential oil	[224]
1-Methyl-4-(1-methylethylidene)cyclohexene	Whole plant	Essential oil	[201]
2(3H)-Furanone, dihydro-3,4-xy	Leaves	Polar fraction (ethanol)	[223]
2,3-Epoxy carvone	Leaves	Essential oil	[227]
2-Carene	Aerial parts	Essential oil	[207]
2-Ethylcyclohexanone	Aerial parts, leaves, aerial parts	Essential oil	[188, 217, 224, 226]
2-Hexenoic acid	Leaves	Polar fraction (ethanol)	[223]
2-Methyl, dodecyl ester	Leaves	Essential oil	[221]
2-Methyl-2-buteonic acid	Leaves	Essential oil	[224]
2-Methyl-4-pentenoic acid	Leaves	Polar fraction (ethanol)	[223]
2-Methyl-5-(1-methyl ethyl)-2-	Leaves	Essential oil	[224]

Table 3 Main secondary metabolites identified in *C. ambrosioides (Continued)*

Identified secondary metabolites	Part used	Source	References
cyclohexen-1-one			
2-Pentadecanone	Leaves	Essential oil	[224]
2-Propenoic acid,	Leaves	Essential oil	[221]
3,4-Dimethylbenzaldehyde	Leaves	Non-polar fraction (pentane)	[223]
3,4-Epoxy-*p*-menthan-2-one	Aerial parts, leaves	Essential oil	[188, 204, 217]
3,7,11,15-Tetramethyl-2-hexadecen-1-ol	Leaves	Non-polar fraction, polar fraction	[223]
3,7-Dimethyl-2,6-octadien-1ol	Aerials parts, leaves	Essential oil	[203, 204]
3-Carene	Aerial parts	Essential oil	[207]
3-Methyl-6-(1-methy-ethyl)	Leaves	Essential oil	[221]
3-Tetradecanone	Leafy stems	Essential oil	[212]
4,7,7-Trimethylbicyclo[4.1.0]hept-4-en-3-ol	Leaves	Non-polar fraction (pentane)	[223]
4,8,12,16-Tetramethylheptadecan-4-olide	Leaves	Non-polar fraction (pentane)	[223]
4-Aminobutyric acid	Leaves	Polar fraction (ethanol)	[223]
4-Carene	Leaves	Essential oil	[202]
4-Isopropenyl-1-methyl-2-cyclohexen-1-ol	Leaves	Non-polar fraction (pentane)	[223]
5-Hydroxyhexanoic acid	Leaves	Non-polar fraction (pentane)	[223]
5-Isopropenyl-2-methylenecyclohexanol	Leaves	Non-polar fraction (pentane)	[223]
6-Methyl-3-(1-methyl ethyl)-7-oxabicyclo [4.1.0]heptan-2-one	Whole plant	Essential oil	[201]
7-Oxabyciclo(4.1.0) heptan 2-one	Leaves	Essential oil	[221]
9,12,15-Octadecatrienoic acid, methyl ester (Z,Z,Z)-	Leaves	Non-polar fraction (pentane)	[223]
9,12-Octadecadienoic acid (Z,Z)	Leaves	Polar fraction (ethanol)	[223]
9,12-Octadecadienoic acid, methyl ester	Leaves	Non-polar fraction (pentane)	[223]
Allo-aromadendrene	Leaves	Essential oil	[228]
Allyl levulinate	Leaves	Essential oil	[228]
Amyl levulinate	Leaves	Essential oil	[228]
Apigenin	Leaves	Methanol extract	[229]
Apiole	Aerial parts	Essential oil	[230, 231]
Aritasone	Leaves	Essential oil	[206]
Ascaridole	Aerial parts, leaves, whole plant	Essential oil	[13, 197, 198, 200, 203, 205–208, 210, 211, 213, 218, 220, 224, 226, 231–236]
Ascaridole epoxide	Leaves	Essential oil	[198, 221]
Benzaldehyde	Leaves	Essential oil	[206]
Benzene, *m*-di-tert-butyl-	Leaves	Non-polar fraction (pentane)	[188, 223]
Benzyl alcohol	Aerial parts, leaves	Hexane fraction, essential oil	[216, 225]
Bicyclo[3.2.1]oct-2-ene, 3-	Leaves	Non-polar fraction (pentane)	[223]

Table 3 Main secondary metabolites identified in *C. ambrosioides (Continued)*

Identified secondary metabolites	Part used	Source	References
methyl-4-methylene-			
Bicyclo[3.3.1]nonan-1-ol	Whole plant	Essential oil	[201]
Bicyclogermacrene	Whole plant	Essential oil	[211]
Borneol	Whole plant	Essential oil	[211]
Camphor	Leaves, aerial parts	Essential oil	[203, 211, 219, 220, 228, 237]
Carvacrol	Leaves, aerial parts, whole plant, inflorescences	Non-polar fraction (pentane), Essential oil, hexane fraction	[188, 197, 198, 200, 202, 203, 207, 208, 210, 216, 217, 222, 223, 225–228, 231, 233, 237]
Carvone	Leaves	Essential oil	[211, 228]
Carvone oxide	Leaves, aerial parts	Essential oil	[207, 226, 228, 237]
Carvotanacetone epoxide	Leaves	Essential oil	[226]
Caryophyllene	Whole plant	Essential oil	[211]
Caryophyllene diepoxide	Leaves	Essential oil	[227]
Caryophyllene oxide	Aerial parts, leaves	Essential oil	[188, 198, 202, 207, 217, 227]
Catechol	Leaves	Methanol extract	[229–231]
Chrysin	Leaves	Chloroform fraction	[238]
Cis-Ascaridole	Aerial parts, leaves	Essential oil	[203, 204, 219, 221, 237]
Cis-Carveol	Leaves	Essential oil	[211, 228]
Cis-Carvyl acetate	Leaves	Essential oil	[237]
Cis-Linalool oxide	Leaves	Essential oil	[228]
Cis-Piperitol	Aerial parts	Essential oil	[188, 217]
Cis-Piperitone epoxide	Leaves	Essential oil	[197, 237]
Cis-p-Mentha-1(7),8-dien-2-ol	Whole plant	Essential oil	[218]
Cis-p-Mentha-2,8-dien-l-ol	Leaves, aerial parts	Essential oil	[218, 226, 228]
Cis-*p*-Mentha-2-1-ol	Whole plant	Essential oil	[219]
Cis-Verbenyl acetate	Whole plant	Essential oil	[211]
Cis-β-Farnesen	Leaves	Essential oil	[239]
Cis-β-Ocimene	Aerial parts, leaves	Essential oil	[203, 204, 206]
Citronellal	Leafy stems	Essential oil	[198, 212]
Citronellyl acetate	Leaves	Essential oil	[204]
Coumaroyl-xylose acid	Aerial parts	Hydro-alcoholic extract	[240]
Cyclobutane carboxylic acid, cyclohexyl ester	Aerial parts	Essential oil	[207]
Cyclobutane carboxylic acid, heptyl ester	Aerial parts	Essential oil	[207]
Cyclohexadecane	Leaves	Essential oil	[224]
Cyclooctanone	Whole plant	Essential oil	[201]
Cyclotetradecane	Leaves	Essential oil	[224]
Dehydro-*p*-cymene	Aerial parts, leaves	Essential oil	[200, 206]
D-Fructose	Leaves	Polar fraction (ethanol)	[223]
D-Glucitol	Leaves	Polar fraction (ethanol)	[223]
D-Glucose	Leaves	Polar fraction (ethanol)	[223]
D-Glucose (isomer 2)	Leaves	Polar fraction (ethanol)	[223]
D-Glucose (isomer 3)	Leaves	Polar fraction (ethanol)	[223]
D-Glucose (isomer 4)	Leaves	Polar fraction (ethanol)	[223]

Table 3 Main secondary metabolites identified in *C. ambrosioides (Continued)*

Identified secondary metabolites	Part used	Source	References
Dihydroactinidiolide	Leaves	Non-polar fraction (pentane)	[223]
Dihydrocarveol	Leaves	Essential oil	[228]
Dihydrocarvyl acetate	Leaves	Essential oil	[206]
dl-Limonene	Leaves	Essential oil	[204, 227]
DL-Malic acid	Leaves	Polar fraction (ethanol)	[223]
Ellagic acid	Leaves	Methanolic extract	[229]
Estragol	Leaves	Essential oil	[202]
Ethanolamine	Leaves	Polar fraction (ethanol)	[223]
Ethyl salicylate	Whole plant	Essential oil	[219]
Eucalyptol	Aerial parts	Essential oil	[235]
Eugenol	Leaves	Essential oil	[202]
Farnesyl acetone	Leaves	Essential oil	[224]
Ferulic acid	Leaves	Methanolic extract	[229]
Ferulic acid derivate	Whole plant	Methanolic extract	[241]
Feruloyl pentoside acid	Leaves	Methanolic extract	[229, 241]
Fraganyl acetate	Aerial parts	Essential oil	[226]
Fumaric acid	Leaves	Polar fraction (ethanol)	[223]
Gallic acid	Leaves	Methanol extract	[229]
ɣ-Curcumene	Aerial parts, leaves	Essential oil	[203, 204]
γ-Elemene	Whole plant	Essential oil	[211]
ɣ-Terpinene	Leafy stems, leaves, aerial parts, whole plant, inflorescences	Essential oil	[13, 200, 201, 203–208, 212, 218, 220, 222, 227, 228, 234, 235, 237]
Geranial	Leaves	Essential oil	[228]
Geranic acid	Leaves	Essential oil	[228]
Geraniol	Leaves, aerial parts, inflorescences, whole plant	Essential oil	[205, 207, 219, 222, 228]
Geranyl acetate	Whole plant	Essential oil	[208]
Geranyl propionate	Aerial parts	Essential oil	[207]
Geranyl tiglate	Aerial parts	Essential oil	[188, 217]
Germacrene	Whole plant	Essential oil	[211]
Germacrene D-4-ol	Whole plant	Essential oil	[211]
Glucuronic acid	Aerial parts	Hydro-alcoholic extract	[240]
Glycerol	Leaves	Polar fraction (ethanol)	[223]
Glycerol phosphate	Leaves	Polar fraction (ethanol)	[223]
Heptyl isobutyrate	Whole plant	Essential oil	[219]
Hesperetin	Aerial parts	Hydro-alcoholic extract	[240]
Hexadecamethyl-cyclooctasioxane	Aerial parts	Essential oil	[207]
Hexadecanoic acid	Aerial parts	Essential oil	[226]
Hexahydrofarnesyl acetone	Aerial parts	Essential oil	[188, 217, 223, 226]
Hexanoic acid	Leaves	Polar fraction (ethanol)	[223]
Hexyl tiglate	Aerial parts, whole plant, leaves	Essential oil	[205, 226, 230, 231, 237]
Isoascaridole	Leafy stems, aerial	Essential oil	[188, 198, 200, 207, 212, 217, 218,

Table 3 Main secondary metabolites identified in *C. ambrosioides (Continued)*

Identified secondary metabolites	Part used	Source	References
	parts, leaves, and inflorescences		220, 222, 231, 235, 236]
Isoborneol	Leaves	Essential oil	[228]
Isobornyl acetate	Leaves, whole plant	Essential oil	[205, 228]
Isobornyl propionate	Leaves	Essential oil	[228]
Isobutyl benzoate	Leaves	Essential oil	[228]
Isobutyric acid, 3-hydroxy	Leaves	Polar fraction (ethanol)	[223]
Isoprenyl tiglate	Aerial parts	Essential oil	[226]
Isopulegol	Leaves	Essential oil	[228]
Isopulegyl acetate	Leaves, whole plant	Essential oil	[205, 228]
Isorhamnetin	Flowers, leaves, and stem	Aqueous infusion, ethanolic extract	[242]
Isorhamnetin dirhamnoside	Whole plant	Methanolic extract	[241]
Isorhamnetin *O*-pentoside	Leaves	Methanol extract	[229]
Isorhamnetin *O*-rhamnoside	Leaves	Methanol extract	[229]
Isorhamnetin *O*-rhamnosyl-pentoside	Whole plant	Methanolic extract	[241]
Isorhamnetin-3-*O*-rutinoside	Aerial parts	Hydro-alcoholic extract	[240]
Kaempferol	Flowers, leaves and stem, aerial parts	Aqueous infusion, ethanolic extract, methanol extract, hydroalcoholic extract	[229, 240, 242]
Kaempferol 3-*O*-alpha-l-rhamnoside	Aerial parts	Hydro-alcoholic extract	[240]
Kaempferol 3-*O*-rutinoside	Flowers, leaves, and stem	Aqueous infusion and ethanolic extract	[229, 241, 242]
Kaempferol dirhamnoside-*O*-hexoside	Flowers, leaves, and stem	Aqueous infusion, ethanolic extract	[241, 242]
Kaempferol *O*-dirhamnoside	Leaves	Methanol extract	[229]
Kaempferol *O*-glucuronside	Leaves	Methanol extract	[229]
Kaempferol *O*-pentosyl-rhamnosyl-hexoside	Whole plant	Methanolic extract	[241]
Kaempferol *O*-rhamnosyl-pentoside	Flowers, leaves and stem	Aqueous infusion, ethanolic extract	[242]
Kaempferol-3,7-dirhamnoside	Whole plant	-	[243]
Kaempferol-3-glucoside-2″-rhamnoside-7-rhamnoside	Aerial parts	Hydro-alcoholic extract	[240]
Kaempferol-3-glucoside-3″-rhamnoside	Aerial parts	Hydro-alcoholic extract	[240]
Kaempferol-*O*-pentoside-2″-rhamnoside-hexoside	Aerial parts	Hydro-alcoholic extract	[240]
Kaempferol-*O*-rhamnoside-pentoside	Aerial parts	Hydro-alcoholic extract	[240]
Lavandulyl acetate	Leaves	Essential oil	[228]
L-Carvacrol	Aerial parts	Essential oil	[200]
Limonene	Leafy stems, leaves, aerial parts, whole plant	Essential oil, the non-polar fraction (pentane)	[13, 185, 198, 200–203, 206–208, 218–220, 223, 224, 228, 234, 237]
Limonene oxide	Aerial parts, leaves	Essential oil	[198, 206, 207]
Linalool	Leaves, aerial parts	Essential oil	[226, 228]
Linalyl acetate	Aerial parts	Essential oil	[226]

Table 3 Main secondary metabolites identified in *C. ambrosioides (Continued)*

Identified secondary metabolites	Part used	Source	References
Luteolin	Flowers, leaves, and stem	Aqueous infusion, ethanolic extract, methanol extract	[229, 242]
Luteolin C-hexoside	Leaves	Methanol extract	[229]
Luteolin C-hexoside-O-pentoside	Whole plant	Methanolic extract	[241]
m-Cresol	Aerial parts	Essential oil	[226]
m-Cresyl acetate	Leaves	Essential oil	[227]
m-Cymen-8-ol	Aerial parts	Essential oil	[226]
m-Cymene	Leaves	Essential oil	[227]
Menthol	Leaves	Essential oil	[228]
Menthone	Whole plant	Essential oil	[205]
Methacrylic acid, tetradecyl ester	Leaves	Essential oil	[221]
Methyl hexanoate	Leaves	Essential oil	[228]
Methyl salicylate	Whole plant	Essential oil	[219]
Myrcene	Aerial parts, leaves, whole plant	Essential oil	[207, 208, 234]
Myrcenol	Whole plant	Essential oil	[219, 220]
Myrtenol	The whole plant, leaves	Essential oil	[211, 227]
Naphthalene	Leafy stems	Essential oil	[198, 212]
Naringin	Aerial parts	Hydro-alcoholic extract	[240]
Neomenthyl acetate	Aerial parts	Essential oil	[230, 231]
Neral	Aerial parts, leaves, and inflorescences, whole plant	Essential oil	[205, 207, 211, 222]
Nerol	Leaves	Essential oil	[219, 228]
Neryl acetate	Leaves	Essential oil	[228]
Neryl formate	Leaves	Essential oil	[228]
Neryl oxide	Whole plant	Essential oil	[208]
Neryl tiglate	Aerial parts	Essential oil	[226]
Nonanal	Leaves	Essential oil	[224]
Norbornyl acetate	Leaves	Essential oil	[228]
o-Cymene	Leaves, whole plant	Essential oil, Non-polar fraction (pentane)	[201, 202, 219, 223]
Oxalic acid	Leaves	Polar fraction (ethanol)	[223]
p,α-di-Menthyl styrene	Aerial parts	Essential oil	[188, 217]
Palmitic acid	Leaves	Polar fraction (ethanol)	[223]
Pantothenic acid	Leaves	Polar fraction (ethanol)	[223]
p-Coumaric acid	Flowers, leaves, and stem	Aqueous infusion, ethanolic extract, polar fraction (ethanol)	[223, 242]
p-Coumaroyl acid derivative	Whole plant	Methanolic extract	[241]
p-Coumaroyl pentoside acid	Leaves	Methanolic extract	[229, 241]
p-Cresol	Leaves	Essential oil	[216, 237]
p-Cymen-7-ol	Whole plant	Essential oil	[208]
p-Cymen-8-ol	Leaves, aerial parts	Essential oil	[202, 216, 218, 226, 234, 237]
p-Cymene	Leaves, aerial parts, whole plant,	Essential oil, hexane fraction	[13, 185, 188, 198, 202, 203, 205–208, 210, 213, 216–218, 220, 222, 224, 225,

Table 3 Main secondary metabolites identified in *C. ambrosioides (Continued)*

Identified secondary metabolites	Part used	Source	References
	inflorescences		227, 228, 231–237]
p-Cymenol	Leaves	Essential oil	[202, 206, 227]
Perillyl alcohol	Leaves, aerial parts	Essential oil	[207, 228]
Phellandral	Aerial parts	Essential oil	[226]
Phosphoric acid	Leaves	Polar fraction (ethanol), essential oil	[223, 224]
Phytol	Leaves, aerial parts	Non-polar fraction (pentane), polar fraction (ethanol), essential oil	[185, 188, 217, 223, 224]
Pinocarvone	Leaves, whole plant	Essential oil	[206, 211, 219, 237]
Piperitone	Leave, aerial parts	Essential oil	[188, 206, 216, 217]
Piperitone oxide	Aerial parts, leaves	Essential oil	[200, 203, 204, 227]
p-Menth-3-en-2,7-diol	Whole plant	Essential oil	[205]
p-Mentha-1,3,8-triene	Leaves, aerial parts, whole plant, inflorescences	Essential oil	[205, 208, 216, 222, 226]
p-Mentha-1,8-diene	Aerial parts	Essential oil	[200]
p-Mentha-6,8-dien-2-one, (R)-(−)-	Leaves	Non-polar fraction (pentane)	[223]
p-Menthan-1,5-diene-8-ol	Whole plant	Essential oil	[219]
p-Methyl-acetophenone	Leaves	Essential oil	[202]
Precocene I	Leaves	Essential oil	[234]
Precocene II	Aerial parts	Essential oil	[188, 217]
Pulegone	Leaves	Essential oil	[224]
Quercetin	Leaves	Chloroform fraction, methanol extract	[229, 238]
Quercetin (acyl)glucuronide-*O*-rhamnoside	Whole plant	Methanolic extract	[241]
Quercetin-3-*O*-arabinoglucoside	Aerial parts	Hydro-alcoholic extract	[240]
Quercetin 3-*O*-glucoside	Flowers, leaves and stem, aerial parts	Aqueous infusion, ethanolic extract, methanol extract, hydroalcoholic extract	[229, 240–242]
Quercetin 3-*O*-neohesperide	Leaves	Methanolic extract	[229, 241]
Quercetin 3-*O*-rutinoside (Rutin)	Flowers, leaves and stem, aerial parts	Aqueous infusion, ethanolic extract, hydroethanolic, ethyl acetate fraction, n-butanol fraction, methanol extract, hydroalcoholic extract	[229, 238, 240, 242]
Quercetin 3-*O*-rutinoside-(1→2)-*O*-rhamnoside	Whole plant	Methanolic extract	[241]
Quercetin dirhamnoside	Flowers, leaves, and stem	Aqueous infusion, ethanolic extract, methanol extract	[229, 242]
Quercetin *O*-glucuronide	Leaves	Methanol extract	[229]
Quercetin *O*-pentosyl-hexoside	Whole plant	Methanolic extract	[241]
Quercetin *O*-pentosyl-rhamnosyl-hexoside	Whole plant	Methanolic extract	[241]
Quercetin-*O*-rhamnoside-pentoside	Aerial parts	Hydro-alcoholic extract	[240]
Quercetin *O*-rhamnosyl-glucuronide	Whole plant	Methanolic extract	[241]
Quercetin *O*-rhamnosyl-pentoside	Flowers, leaves and stem	Aqueous infusion	[242]
Quinic acid	Aerial parts	Hydro-alcoholic extract	[240]

Table 3 Main secondary metabolites identified in *C. ambrosioides (Continued)*

Identified secondary metabolites	Part used	Source	References
Resorcinol	Leaves	Methanol extract	[229]
Sabinene	Whole plant, leaves	Essential oil	[185, 208, 220]
Safrole	Whole plant	Essential oil	[219]
Squalene	Leaves	Non-polar fraction (pentane)	[223]
Stearic acid	Leaves	Polar fraction (ethanol)	[223]
Succinic acid	Leaves	Polar fraction (ethanol)	[223]
Sucrose	Leaves	Polar fraction (ethanol)	[223]
Terpinolene	Leaves and inflorescences, whole plant	Essential oil	[205, 206, 208, 222, 234]
Terpinyl acetate (*cis*-dihydro-alpha)	Whole plant	Essential oil	[219]
Terpinyl acetate (*trans*-dihydro-alpha)	Whole plant	Essential oil	[219]
Thujyl acetate	Whole plant	Essential oil	[208]
Thymol	Leafy stems, aerial parts, leaves, whole plant	Essential oil, polar fraction	[188, 197, 200–202, 207, 208, 212, 217, 223, 224, 226, 234]
Thymol acetate	Leafy stems	Essential oil	[198, 212]
Trans-2-caren-4-ol	Whole plant	Essential oil	[201]
Trans-Ascaridole	Leaves, aerial parts	Essential oil	[202–204, 219, 237]
Trans-Ascaridole glycol	Leaves	Essential oil	[197]
Trans-Carveol	Leaves	Essential oil	[228]
Trans-Carvyl acetate	Leaves	Essential oil	[237]
Trans-Caryophyllene	Whole plant	Essential oil	[13]
Trans-Chrysanthenyl acetate	Whole plant	Essential oil	[220]
Trans-Isoascaridole	Leaves	Essential oil	[237]
Trans-p-2,8-Menthadien-1-ol	Aerial parts	Essential oil	[188, 217]
Trans-p-Coumaric acid	Leaves	Methanolic extract	[229, 241]
Trans-Phytol	Leaves	Essential oil	[202]
Trans-Pinene hydrate	Whole plant	Essential oil	[220]
Trans-Pinocarveol	Leaves, whole plant	Essential oil	[205, 211, 228, 237]
Trans-Pinocarvyl acetate	Whole plant	Essential oil	[219]
Trans-Piperitone epoxide	Leaves	Essential oil	[197]
Trans-Piperitone oxide	Leaves	Essential oil	[226, 237]
Trans-p-Mentha-1(7),8-dien-2-ol	Aerial parts, leaves	Essential oil	[203, 204, 218, 226]
Trans-p-Mentha-2,8-dien-1-ol	Aerial parts, leaves	Essential oil	[204, 217, 218]
Trans-p-Mentha-2,8-dienol	Leaves, aerial parts	Non-polar fraction (pentane)	[188, 223]
Trans-Sabinene hydrate	Leaves	Essential oil	[228]
Trans-Verbenol	Leaves	Essential oil	[228]
Trans-Verbenyl acetate	Aerial parts	Essential oil	[235]
Trans-β-Cymene	Aerial parts, leaves	Essential oil	[203, 204]
Trans-β-Ocimene	Leaves and inflorescences	Essential oil	[206, 222]
Undecanal	Leaves	Essential oil	[228]

Table 3 Main secondary metabolites identified in *C. ambrosioides (Continued)*

Identified secondary metabolites	Part used	Source	References
Uracil	Leaves	Polar fraction (ethanol)	[223]
Urea	Leaves	Polar fraction (ethanol)	[223]
Viridiflorene	Whole plant	Essential oil	[211]
Vitamin E	Leaves	Non-polar fraction (pentane)	[223]
α,*p*-Dimethyl styrene	Aerial parts, leaves	Essential oil	[226, 227]
α,α-4-Trimethylbenzyl	Aerial parts	Essential oil	[217]
α,α-4-Trimethylbenzyl alcohol	Aerial parts	Essential oil	[188]
α-Caryophyllene (humulene)	Leaves	Essential oil	[13, 202, 211]
α-Guaiene	Leaves	Essential oil	[228]
α-Gurjunene	Leaves	Essential oil	[211]
α-Linolenic acid	Leaves	Polar fraction (ethanol)	[223]
α-Methylionol	Aerial parts	Essential oil	[207]
α-Muurolene	Leaves	Essential oil	[211]
α-Patchoulene	Leaves	Essential	[202]
α-Phellandrene	Leaves	Essential oil	[208, 228]
α-Pinene	Leaves, aerial parts	Essential oil	[13, 188, 200, 207, 217, 219, 220, 228]
α-Selinene	Whole plant	Essential oil	[13]
α-Terpinene	Aerial tissues, leaves, whole plant, inflorescences (flowers)	Essential oil, hexane fraction	[13, 185, 197, 198, 200–208, 213, 216–220, 222, 225, 227, 228, 235–237]
α-Terpineol	Leaves	Essential oil	[198, 202, 216]
α-Terpinolene	Leaves, aerial parts	Essential oil	[13, 203, 204, 224]
α-Terpinyl acetate	Leaves, aerial parts	Essential oil	[206, 226, 228, 234]
α-Thujene	Leaves	Essential oil	[227, 228]
α-Thujone	Whole plant	Essential oil	[220]
β-Caryophyllene	Leaves, aerial parts	Essential oil	[204, 226, 228, 234]
β-Copaene	Leaves	Essential oil	[228]
β-Curcumene	Whole plant	Essential oil	[211]
β-Fenchene	Whole plant	Essential oil	[13]
β-Gurjunene	Whole plant	Essential oil	[211]
β-Ionone	Leaves	Non-polar fraction (pentane)	[223]
β-Lactic acid	Leaves	Polar fraction (ethanol)	[223]
β-Myrcene	Aerial parts, leaves	Essential oil	[13, 198, 203, 204, 206, 220, 227]
β-Phellandrene	Aerial part, leaves, whole plant	Essential oil	[200, 201, 203, 204, 206, 208, 234]
β-Pinene	Leaves, aerial parts	Essential oil	[185, 202, 207, 217, 228]
β-Selinene	Whole plant	Essential oil	[13]
δ-3-Carene	Leaves, whole plant	Essential oil	[208, 218, 224, 234]
δ-4-Carene	Aerial parts, leaves	Essential oil	[188, 202, 217, 230]
δ-4-Carene-3,7,7-trimethylbicycle [4.1.0]-4-heptene	Whole plant	Essential oil	[231]
δ-Cadinene	Leaves	Essential oil	[228]

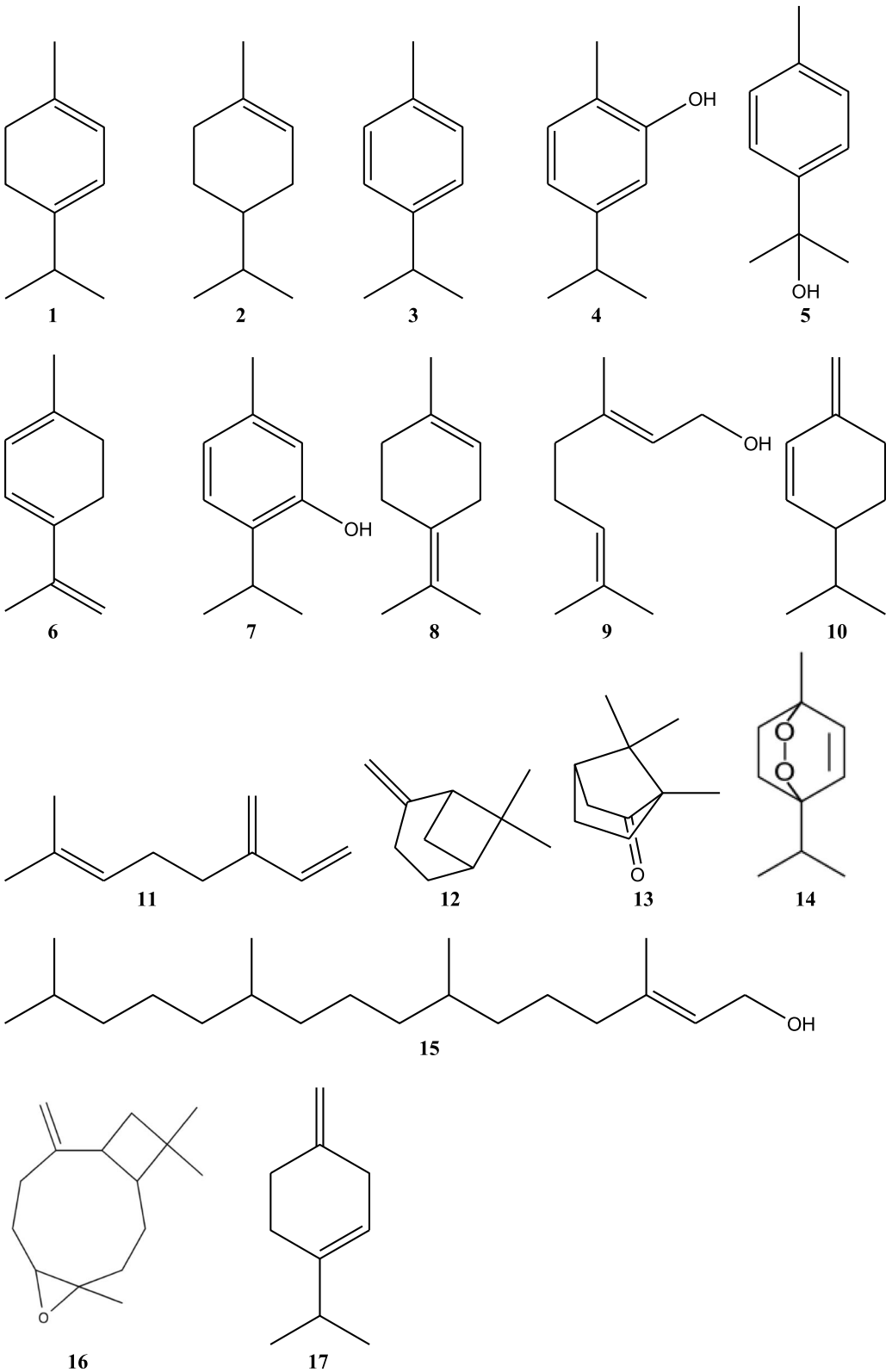

Fig. 3 Structures of a few significant compounds from *C. ambrosioides* (Draw using ChemDraw Ultra 8.0 software)

(**14**), phytol (**15**), β-aryophyllene (**16**), and β-terpinene (**17**).

Pharmacological potential of crude extracts, fractions, and essential oils

Preclinical studies both in vivo and in vitro of crude extracts and essential oils from different parts of *Chenopodium ambrosioides* have been highlighted and outlined below: anti-arthritic, acaricidal, amoebicidal, anthelmintic, anticancer, antibacterial, antidiabetic, antidiarrheal, antifertility, antifungal, anti-inflammatory, anti-leishmanial, antimalarial, anti-nociceptive, antipyretic, antioxidant, antisickling, antischistosomal, antiulcer, anxiolytic, bone regeneration, immunomodulatory, insecticidal, molluscicidal, trypanocidal, and vasorelaxant activities have been documented and reported. Overall, a single extract or essential oil could show several activities in different pharmacological models.

Anti-arthritic potential

It was reported that *C. ambrosioides* graft through a gel from the lyophilized aqueous extract enhanced precociously bone neoformation in rabbits radius fracture the same way as autogenous bone marrow [249]. Recently, a formulation from chitosan and plant extract (20%) showed a potent effect of bone regeneration in rats through a complete alveolar bone reparation after 30 days' treatment and bone fractures. It was also noted to improve osteoblastic activity in the treated group [250]. Leaf hydroalcoholic crude extracts significantly ($p < 0.01$) improved bone density by 34.5% and 34.8% at the knee and heel, respectively. Moreover, the bone architecture appeared completely preserved in collagen-induced arthritis male DBA1/J mice [251].

Acaricidal property

Preparations contained 40% and 60% of leaf hydroalcoholic extract showed the best percentage of death (99.7% and 100%) in females *Rhipicephalus* (*Boophilus*) *microplus* (cattle tick), respectively [252]. Requiem®EC (*Chenopodium*-based biopesticide). Previously, Musa et al. [253] have reported acaricidal and sublethal effects of that formulation on eggs and immatures of spider mite (*Tetranychus urticae*). A foaming soap was containing his essential oil, at different doses (0.03, 0.06, 0.09, and 0.12 μL of essential oil/g of soap) induced mortality in *Rhipicephalus lunulatus*, with the best result obtained at the highest dose (96.29% of mortality) on the eighth day [254].

Amoebicidal activity

In vitro and in vivo studies of oral administration of E.O. to hamsters infected with *Entamoeba histolytica* concluded his efficacy. Trophozoites of parasites exposed to E.O. and metronidazole changed color compared to the control, and E.O. inhibited the growth of serval trophozoites in a dose-dependent manner [221].

Anthelmintic effect

Leaf crude aqueous and hydroalcoholic extracts, at the concentration of 0.5 mg/ml, inhibited 100% of egg hatching of *Haemonchus contortus*. However, the aqueous extract produced significant mortality in adult parasites, dose-dependently [255]. However, E.O. (0.2 ml of oil/kg bw) after 7 days of post-treatment was not effective in terms of reduction of parasite burden both to adults and kids goats with natural mixed-nematode (*Haemonchus contortus*) infections [256]. A nematicidal evaluation in vitro of different concentrations (0.6, 1.25, 2.50, 5, 10, 20, and 40 mg/ml) of aerial part hexane extract on gerbils three months of age (experimentally infected with *Haemonchus contortus* L3), for 24 h and 72 h post confrontation, exhibited exciting activity. Therefore, at concentrations of 20 and 40 mg/ml, it showed lethal activity of 92.8% and 96.3%, respectively. Furthermore, the authors noted a decrease of 27.1% of the parasitic burden [257].

Antibacterial activities

From MIC of 4.29 to 34.37 mg/ml, leaf ethyl acetate fraction inhibited several strains, which showed effectiveness against *Enterococcus faecalis*, *Paenibacillus apiarus*, *Paenibacillus thiaminolyticus*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus* (They exhibited the lowest values of MIC). However, chloroform fraction was the most active against *Mycobacterium* species include *M. avium* (MIC = 625 μg/ml) and *M. smegmatis* (MIC= 156.25 μg/ml)[238]. Oliveira-Tintino et al. [245] obtained essential oil from *C. ambrosioides*, and α-terpinene has potentialized norfloxacin and ethidium bromide against it *Staphylococcus aureus* by significative reduction of their MIC through inhibition of efflux pumps. These results are under a previous study where the essential oil significantly decreased MIC of tetracycline and ethidium bromide against the same strain and the exact mechanism [244]. The fruit methanol extract showed antibacterial potential against three strains, including *Enterococcus faecalis*, *Escherichia coli*, and *Salmonella typhimurium* with MIC values (μg/ml) of 4375, 1094, and 137, respectively. As a standard drug, Chloramphenicol produced the best effect MIC values against those strains (MIC = 6 μg/ml)[258]. Hydroethanolic leaf extract showed a weak antimycobacterial activity on *Mycobacterium tuberculosis subsp. tuberculosis Mycobacterium tuberculosis*; Strain H37Ra with a MIC of 5,000 μg/ml. However, the leaf extract of *Solanum torvum* showed the best effect (MIC= 156.3 μg/ml)[259]. However, a previous study from South Africa confirmed

the antibacterial activity of the acetone extract against *Mycobacterium tuberculosis*. In fact, with a MIC value of 0.1 mg/ml [260]. Essential oils inhibited Gram-positive (*Listeria monocytogenes*) growth and Gram-negative bacteria [199]. Pharmacological screening of medicinal plants from South African used against common skin pathogens reported the efficacy of dichloromethane-methanol extract on *Staphylococcus aureus*, *Staphylococcus epidermidis*, *Pseudomonas aeruginosa*, *Brevibacillus agri*, *Propionibacterium acnes*, and *Trichophyton mentagrophytes* with MIC values of 0.80, 0.50, 0.25, 0.50, 0.40, and 0.25 mg/ml respectively. These MIC values were close to those obtained from standards drugs, including methicin and gentamycin resistants to *Staphylococcus aureus* (0.25 and 0.50 mg/ml)[261].

Anticancer property

Leaf hydroalcoholic extract (5 mg/kg) inhibited the development of ascitic and solid tumor Ehrlich tumors in Swiss mice, on cells implanted on the left footpad, and in the peritoneal cavity. It also extended the life expectancy of tumor-bearing mice [262]. Furthermore, Cruz et al. [263] reported his antitumor effect on macrophage and lymphoid organ cellularity models by increasing nitric oxide production and the number of cells in the peritoneal cavity spleen and lymph node. Also, the activity of the macrophages increased. Leaf and fruit methanol extract produced contradictory results than other plant extracts on the enterocyte cell line Caco-2 demonstrated. Thus, fruit extract was the most cytotoxic with CC_{50}= 45 ± 7 μg/ml; however, leaf extract was the least cytotoxic with IC_{50} = 563 ± 66 μg/ml [258]. However, essential oils from the ethanol extract exhibited a potent anticancer property on RAJI cells. That effect was similar to that obtained with doxorubicin (as a standard) with IC_{50} of 1 mg/ml and 13.2 mg/ml, respectively. Furthermore, the fractions extracted effectively affected myeloid leukemia cells compared to positive control with 34 and 47 mg/ml values, respectively [215]. EO showed antitumor properties on human liver cancer SMMC-7721 cells by inhibiting cell proliferation, stopping cell division in the Go/G1 phase, and inducing caspase-dependent apoptosis [264].

Antidiabetic effect

Crude leaves extract (100–300 mg/kg bw) significantly reduced blood glucose levels in low-dose STZ-treated and high-fat diet-fed mice after 2 weeks of treatment [265]. At a 20 μg/ml concentration, root hexane extract showed an antidiabetic potential by the high level of α-amylase inhibition (50.24 ± 0.9%)[266].

Antidiarrheal activity

The percentage of 43.4 ± 6.5 and 48.7 ± 11.6, respectively, methanolic and aqueous extracts (300 mg/kg) from the aerial parts (green variety) showed suitable antisecretory property on intestinal secretion response in the rat jejunal loops model. That effect was better than that obtained from loperamide, as a standard drug (43.3 ± 13.1%) [267]. Previously, a similar study of the methanol extract from aerial parts at the same concentration showed an inhibition rate of 40.4 ± 1.0% on charcoal–gum acacia-induced hyperperistalsis in rats. That effect was also better than that obtained from loperamide as a standard drug, with a percentage of inhibition of 34.0 ± 3.7 [268].

Antifeedant activity

EO showed high contact toxicity against the DBM, *Plutella xylostella.* His fumigant toxicity was more pronounced to the second-instar than third- and fourth-instar larvae. Either contact or fumigant toxicities, EO showed the best results compared to α-terpinene and *p*-cymene [269].

Antifertility effect

The leaf methanolic extract produced an antifertility effect temporally in male rats (but reversible). It was mainly observed weak spermatozoa in a vaginal smear in female rats and reduced pups born after 60 days of treatment, dose-dependently. Thus, females' fertility rate was 83%, 66%, and 50%, respectively, in groups treated with 50, 100, and 150 mg/kg of plant extracts. After the cessation of treatment, the hormonal status becomes normal in male rats [270].

Antifungal potential

At the concentration of 0.1%, essential of from leaf methanol extract inhibited in range of 90 and 100% *Aspergillus flavus*, *Aspergillus glaucus*, *Aspergillus niger*, *Aspergillus ochraceous*, *Colletotrichum gloespor- ioides*, *Colletotrichum musae*, and *Fusarium semitectum* [216]. It also exhibited the highest antifungal effect on *Colletotrichum* acutatum, *C. fragariae*, and *C. gloeosporioides* compared to essential oils *Zanthoxylum armatum* and *Juniperus communis*. It inhibited growth zones at 80 and 160 μg/spot, from 6.5 to 8.0 mm and 11.0 to 14.5 mm. At the dose of 160 μg/spot, that effect on all three fungal species was closed to that produced by the reference (captan)[232]. At the concentration of 500 μg/ml, EO inhibited all two aflatoxigenic strains of *A. flavus* and the production of aflatoxin B1 production at 10 μg/ml [271]. In the same way, EO was toxic and inhibited the mycelial growth of all fungi, including *Aspergillus flavus*, *A. niger*, *A. ochraceus*, and *A. terreus*. His fungitoxicity was more effective than those obtained from aluminum phosphide and ethylene dibromide, taken as standards fumigants [220]. Previously, after 72 h of exposition, 176.5 μl EO/l has inhibited at 97.3% (mycelial inhibition)

Fusarium oxysporum [202]. At the concentration of 200 μg/ml, leaf hexane extract inhibited the complete growth of *Candida kruse* [272]. Moreover, with GM-MIC = 7.82 μg/ml, EO demonstrated a strong effect against *C. krusei* [273]. However, the EO from aerial parts has been sensible on *Candida glabrata* and *C. guilliermondi* [200]. Brahim et al. [207] demonstrated a complete synergic action of EO's combination from aerial parts with conventional drugs, especially fluconazole against microbial strains like *Candida parapsilosis C. krusei* and *C. glabrata*. The MIC of fluconazole was decreased by 8–16-fold. On the other hand, leaf, stem, root, and inflorescence methanol extracts showed a significant effect against *Macrophomina phaseolina*, with the best result obtained from leaf extract [274].

Anti-*Giardia* activity

Leaf hydroalcoholic extracts obtained from maceration and percolation produced attractive in vitro activity against *Giardia lamblia* trophozoites with the IC_{50} of 214.16 ± 5.02 and 198.18 ± 4.28 μg/ml, respectively [46].

Anti-inflammatory property

Leaf and stem ethanol extract (300 and 500 mg/kg bw) significantly inhibited paw edema and edema induced by carrageenan (56%), prostaglandin-E2 (55%), bradykinin (62%), and BK (60%) in mice [184]. Leaf crude hydroalcoholic extract produced anti-inflammatory and antinociceptive properties in the chronicity of osteoarthritis conditions. In fact, after the tenth day of treatment with different doses of the section, it was observed a decrease of knee edema, intensities of allodynia, synovial inflammation, and other symptoms related to pain [275]. Inhalation of ethanolic extract (nebulized extract) improved lung inflammation by modulating the pulmonary inflammatory response induced following the ischemia-reperfusion method of the mesenteric artery in rats [276]. Topical treatment of leaf and stem ethanol extracts enhanced the cutaneous wound healing caused by wound-induced experimentally in mice. Overall, the extracts repaired tissue, and improved lesion size on days 7, 14, and 19 after injury induction, recovering from the injured area [184].

Anti-leishmanial effect

In vitro study of EO against both *Leishmania amazonensis* and *L. donovani* showed complete inhibition of growth of promastigotes and intracellular amastigotes. Otherwise, in vivo investigation, in BALB/c mice infected with *L. amazonensis*, 30 mg/Kg of EO notably decreased the size of the lesions caused by the disease [277]. Besides, in this condition, EO prevented lesion development of parasite burden compared to pure compounds including ascaridole, carvacrol, and caryophyllene oxide for 14 days of evaluation. Moreover, statistically, EO was more effective than a standard drug (glucantime) [231]. Aqueous extract from the aerial part (100 μg/ml) exhibited a growth inhibition by 87.4% of *Leishmania amazonensis* collected from patients [278].

Antimalarial potential

After 3 days of treatment, leaf crude hydroalcoholic extract (5 mg/kg/day) extended the life expectancy of BALB/c mice infected with *Plasmodium berghei* at the end of the 21st-day evaluation. Furthermore, the extract enhanced the parasitemia evaluated by flow cytometry 3 days after infection. On the other hand, plant extract significantly (1.9- to 4.3-fold) interacted with total proteins of erythrocytes infected by *P. falciparum*, compared to a standard drug (chloroquine). Moreover, at the dose of 25.4 μg/ml (LC_{50}), plant extract completely prevented *Plasmodium falciparum*'s growth [279].

Anti-nociceptive

The results demonstrated that the oral administration of the extract at the dose of 500 mg/kg bw inhibited at 77.39% of neurogenic and 95.06% degrees of inflammation in Algogen-induced nociception male Swiss mice by administering prostaglandin-E2, formalin, capsaicin, and bradykinin. Furthermore, phlogistic substances produced nociceptive responses that were significantly improved 68%, 53%, and 32%, respectively, for prostaglandin-E2, capsaicin, and bradykinin. However, the inhibition of pain induced by the extract's formalin response was comparable to that obtained by indomethacin, taken as standard [184]. Crude alkaloid extract showed a protective effect against writhings induced by acetic acid in mice [280].

Antipyretic effect

At the dose of 40 mg/kg, aqueous bark extract showed a significant ($p < 0.0001$) antipyretic effect by reduction of body temperature in mice from 36.3 to 31.0 °C [281].

Antioxidant activity

Leaf aqueous crude extract at a 250 μg/ml concentration showed the highest superoxide scavenging radicals and hydroxyl properties with the maximum percentage at 44.35% (more remarkable than that produced by BHA 37.46%) and 51.80% (against 54.23% obtained by BHT), respectively. Furthermore, at the same concentration, intracellular ROS, SOD, nitric oxide production, and CAT concentrations were significantly higher in splenocytes than in control [223]. Aqueous infusion and ethanolic extract showed a protective effect against lipid oxidation from raw pork meat and their products by reducing significantly ($p < 0.05$) compared to control values [242]. Essential oils from leaf extract produced

the antioxidant effect by capturing the DPPH radical [199]. On the other hand, *C. ambrosioides* elevated antioxidant enzyme activities in response to Cu-toxicity [282].

Antisickling potential

1.0 and 0.1 mg/ml of the root, leaf, and bark aqueous and methanol extracts exhibited a significant ($p < 0.05$) anti-sickling effect by inhibiting sodium metabisulphite-induced sickling of HbSS erythrocytes. The best percentage of inhibition (64%) was obtained after 30 min of incubation in aqueous and methanol extract at 0.1 mg/ml. The high dose (10.0 mg/ml) provoked erythrocytes' lysis [283].

Anti-schistosomal activity

A treatment (methanol extracts of *Chenopodium ambrosioides*, *Sesbania sesban*, and mefloquine) of *Schistosoma mansoni* in infected male Swiss Albino mice 3 weeks after infection significantly decreased worm burden around 95.5% and overall enhanced biochemical markers after sacrifice [284]. However, oral administration of methanol extract (1250 mg/kg/day) for 7 days after infection of *Schistosoma mansoni* in mice reduced to 53.7% (10 against 22.3 worms) the rates of worm load/mouse. On the other hand, biochemical and parasitological parameters such as serum total protein, and albumin values, and activities of AlT, AsT, AkP, and AcP were improved in animals [285]. In vitro EO from leaves (25 and 12.5 μg/ml) demonstrated a notable schistosomicidal effect producing 100% of mortality of adult *Schistosoma mansoni* within 24 and 72 h [237].

Anti-ulcer property

In *Helicobacter pylori*-infected mice, volatile oil (49.32 mg/kg daily) showed an excellent eradication rate which was comparable to that produced by references such as lansoprazole (12.33 mg/kg), metronidazole (164.40 mg/kg), and clarithromycin (205.54 mg/kg). Their eradication rations through rapid urease tests were closer and represented 60% and 70% for the experimental group and reference groups, respectively. Histological investigation of gastric scores indicated no notable change (inflammation) in the experimental group. On the other hand, in vitro study showed no bacterial growth after an incubation period of 12 h at the dose of 16 mg/l (MIC value against *H. pylori*)[286].

Anxiolytic activity

Bark aqueous extract (120 mg/kg bw) significant ($p < 0.0001$) elevated the percentages of entries into open arms (51%) and of time spent in open arms (31.8%) in the Elevated Plus Maze model. Furthermore, like diazepam, plant extract significantly ($p < 0.0001$) decreased in the percentage of entries (48.9%) and time (24.7%) in closed arms. Moreover, in the stress-induced hyperthermia test in mice, the same plant concentration reduced temperature at 1.1 °C, a value close to that obtained by phenobarbital [281].

Immunomodulatory activity

Rodrigues et al. [240] found leaf hydroalcoholic extract recently elevated the number of B lymphocytes and splenocytes during the young worms and the pulmonary phases in Swiss mice infected with 50 cercariae *Schistosoma mansoni* after 60 days post-infection. Furthermore, it also increased the total number of macrophages, peritoneal cells, and neutrophils during the adult worm phase. The number of macrophages remained unchanged. However, during the cutaneous, lung, young worm, and adult worm phases, the extract reduced cytokines IFN-γ, TNF-α, IL-4, and the liver area granulomas.

Insecticidal effect

Leaf powder (200 g per 100 kg beans) applied on *Acanthoscelides obtectus,* and *Zabrotes subfasciatus* inhibited their growth totally [287]. Leaf ethanolic extraction at a concentration of 5% reduced the number of adult *Bemisia tabaci* 72 h after application by spraying [288]. After 14 days of exposure, aerial parts powder (5 g/kg) caused 100% mortality in adults, *Trogoderma granarium*, and *Tribolium castaneum* [203]. Insecticidal investigation from EO collected in Egypt showed an attractive potential against *Culex pipiens* larvae with a low EC_{50} value of 0.750 ppm [289]. Administrated alone, the essential oil from leaf extract of *C. ambrosioides* has shown high toxicity to darkling beetle *Alphitobius diaperinus* adults after 24 h of exposure, compared to a standard insecticide (cypermethrin). His effectiveness was 50 times more than that of cypermethrin. Moreover, their combination at 11.79 μg/cm^2 showed high inhibition of *Alphitobius diaperinus* with LC_{50} of 603.36 μg/cm^2 [210]. Furthermore, ethanol extract at a concentration of 6% significantly inhibited ($p < 0.05$) *Bemisia tabaci*, a pest of many crops (93%) [290]. Bossou et al. [212] found that after 24 h of exposition, essential oil from leafy stem exhibited inhibition on *A. arabiensis* (LC_{50}= 17.5 ppm and LC_{90}= 33.2 ppm) and *A. aegypti* (LC_{50} = 9.1 ppm and LC_{90} = 14.3 ppm).

Molluscicidal activity

The lowest concentration of hexane extract from the aerial produced a strong molluscicidal effect against *Bulinus truncates* (LC_{50} = 1.41 and LC_{90}= 2.23 mg/l) [291].

Relaxant property

Leaf aqueous, methanol and ethyl acetate extracts showed a relaxant effect on thoracic aortic rings isolated from Wistar rats inhibiting vasoconstriction induced by phenylephrine, dose-dependently manner. Methanol extract appeared most potent at the dose of 1 mg/ml, producing 68.7 ± 8.9% of relaxation [292]. At the concentration of 1000 μg/ml, EO from leaves, the tracheal smooth muscle isolated from rats was wholly relaxed due to a contraction caused by potassium, acetylcholine, serotonin, and barium in the presence of a high potassium concentration [197].

Repellent activity

Results obtained by Soares et al. [293] showed that leaf ethanolic extract induced an attractive repellence index (66%) against *Amblyomma cajennense* (Acari: Ixodidae) when applied in high concentrations (2.200 mg/cm^2). The concentration of 10 μl/ml, EO exhibited 100% mortality of pulse bruchids *Callosobruchus chinensis* and *C. maculatus* of stored pigeon pea seeds [294].

Trypanocidal effect

The leaf dichloromethane extract showed remarkable activity (IC_{50} = 17.1 μg/ml) against *Trypanosoma brucei brucei* among 30 Ethiopian medicinal plants [295].

Bioactivity of the isolated compounds

Table 4 shows that the antioxidant effect was among the most pharmacological investigated tools of compounds isolated from *C. ambrosioides*. Most of them were focused on flavonoids, including their glycosides (75%, 3 of 4 studies). The best described pharmacological potential of flavonoids and their glycosides is their antioxidant capacity, depending on functional groups' arrangement about the nuclear structure. There are three main antioxidant mechanisms of action: upregulation or protection of antioxidant defenses, scavenging of reactive oxygen species, and suppressing their formation through both enzyme inhibition and chelation of trace elements involved in a free radical generation [296]. By the way, other compounds isolated from the plant showed several activities include antioxidant, trypanocidal, analgesic, antifungal, anti-inflammatory, anticancer, antihypertensive, antimalarial, cytotoxic, myorelaxant, and sedative. α-terpinene isolated from different plants (*Umbelliferae labiatae*, *Ferula hermonis*, *Acinos rotundifolius*, *Hyssopus cuspidatus*, and *Salvia officinalis*) showed antimicrobial activities against so many strains [297]. Kaempferol and its glycosides have demonstrated an antihypertensive potential in most cases. For example, kaempferol 3-*O*-alpha-L-rhamnoside has shown antihypertensive effect in both standard and hypertensive rats prolonged diuretic effect by decreasing Ca^{2+} (through his elimination) and increasing of urinary excretion of Cl^- and Na^+ [298].

On the other hand, scutellarein synthesized from scutellarin produced in vivo a more substantial antioxidant effect by scavenging capacities toward DPPH, •O.H., $ABTS^{+\bullet}$, free radicals [299]. Caryophyllene oxide has shown anticancer property MG-63 human osteosarcoma cells via various mechanisms [300]. Moreover, Fidyt et al. [301] supported the cytotoxicity of β-caryophyllene oxide, characterized from different plant resources, on cancer cell lines (human cervical adenocarcinoma, ovarian, lung, gastric, stomach, and leukemia cancer cells). *p*-cymene extracted from the essential oil of *Origanum acutidens* presented lower antifungal activity on the mycelial growth of various phytopathogenic fungi [302].

Insecticidal and antioxidant evaluations were the main pharmacological properties of the compounds isolated from different parts of *Chenopodium ambrosioides*. The main class of secondary metabolites is represented by monoterpenes, the most represented phytochemical found in Tables 2 and 3. Monoterpenes and sesquiterpenes are secondary metabolites of essential oils, which possess significant biological functions among repellant potential [193]. Among natural compounds involved in chemical defense against insects, terpenoids appeared to have a significant insecticidal potential [303] which produce different mechanisms, by attracting pollinators or by deterring herbivores, monoterpenes and sesquiterpenes play a vital role in the relations between organisms on one side and their environment on the other side [304]. Monoterpenes isolated from *C. ambrosioides* (Ascaridole, isoascaridole, and *p*-cymene) have shown significant bioactivities, particularly insecticidal against adults *Blattella germanica* and *Sitophilus zeamais* [188, 217].

Clinical trials

A clinical investigation in 72 patients examined for parasitic intestinal infections, after 8 days of treatment, the plant extract inhibited *Ancylostoma duodenale* and *Trichuris trichiura* completely, against 50 *Ascaris lumbricoides* [305]. Similarly, a clinical trial study in Peru on efficacy comparison between a *C. ambrosioides* juice and Albendazole for 15 days of treatment in 60 children concluded reducing *Ascaris lumbricoides* burden and complete disappearance of *Ascaris* eggs in feces. That juice produced the best eradication rate of parasites than albendazole, 59.5%, and 58.3%, respectively. Moreover, it was also 100% effective against *Hymenolepsis nana* [306].

Nutritional values

Leaves, stems, and roots collected in Nigeria showed macronutrients such as K, Na, and Mg. Other minerals

Table 4 Pharmacological properties of isolated compounds from *C. ambrosioides* L

Secondary metabolite	Activity	Pharmacological mechanism	References
(−)-(2*S*,4*S*)-*p*-Mentha-2,8-dien-1-hydroperoxide	Trypanocidal	Toxicity against epimastigotes of *Trypanosoma cruzi*	[182]
(−)-(1*S*,4*S*)-*p*-Mentha-2,8-dien-1-hydroperoxide	Trypanocidal	Toxicity against epimastigotes of *Trypanosoma cruzi*	[182]
4-Hydroxy-4(α or β)-isopropyl-2-methyl-2-cyclohexen-1-one	Anti-inflammatory	Inhibition of NO production of LPS-stimulated Raw macrophages	[183]
α-Terpinene	Antimicrobial	Reduction of efflux pump in *Staphylococcus aureus*	[244, 245]
	Myorelaxant	Inhibition of contraction induced by potassium, acetylcholine, or serotonin in rats.	[197]
Ascaridole	Antimalarial	Inhibition of the growth and development of *Plasmodium falciparum*	[246]
	Analgesic	Prolongation of anesthesia effect and protection against writhings induced by using acetic acid in mice	[187]
	Sedative	Reduction of locomotor activity in mice	[187]
	Antifungal	Inhibition of the growth of *Sclerotium rolf*	[186]
	Cytotoxic	Inhibition of human lymphoblastic leukemia T, promyelocytic leukemia, and breast cancer cells.	[247]
	Trypanocidal	Toxicity against epimastigotes of *Trypanosoma cruzi*	[182]
	Cytotoxicity	Redox-active iron in mammalian cells and mitochondria	[248]
	Insecticidal	Contact toxicity and fumigation against *Sitophilus zeamais* adults	[188]
	Insecticidal	Toxicity to male *Blattella germanica*	[217]
Caryophyllene oxide	Cytotoxicity	Inhibition of the respiratory chain in mammalian cells and mitochondria	[248]
Chenopodiumamine A and C	Anti-inflammatory	Significant inhibition against LPS induced TNF-α or IL-6 gene expressions	[190]
Chenopodiumamine A and C	Antioxidant	Inhibition against malondialdehyde	[190]
Isoascaridole	Insecticidal	Toxicity to male *Blattella germanica*	[217]
Cis-*p*-Menthadiene-l(7),8ol-2	Antifungal	Inhibition the growth of *Sclerotium rolf*	[186]
Kaempferol-3,7-dirhamnoside	Antihypertensive	Induction of hypotension in genetically prone hypertensive rats	[243]
Kaempferol 3-*O*-α-L-$^{1}C_{4}$-rhamnosyl-(1‴→2″)-β-D-$^{4}C_{1}$-xylopyranoside	Antioxidant	Radical scavenging activity SC_{50}	[175]
Neral	Anticancer	Cytotoxicity on HaCaT cell line	[222]
p-Cymene	Insecticidal	Toxicity to male *Blattella germanica*	[217]
Scutellarein-7-*O*-α-rhamnopyranosyl-(1→2)-α-rhamnopyranosyl-(1→2)-α-rhamnopyranoside	Antioxidant	Radical scavenging activity	[180]
Scutella-rein-7-*O*-α-rhamnopyranosyl-(1→2)-α-rhamnopyranoside	Antioxidant	Radical scavenging activity	[180]

that have been quantified include Fe, Zn, Mn, Pb, Cd, and Cu. Beyond ash, moisture, crude fat, and carbohydrates, amino acids like leucine, isoleucine, methionine, cysteine, phenylalanine, tyrosine, threonine, and valine have been identified and quantified in leaves, stems, and roots [307]. Barros et al. [241] found free sugars (fructose, glucose, sucrose, trehalose) and organic acids (oxalic, quinic, malic, ascorbic, citric, and fumaric acids) in methanolic extract. Fructose was the most represented, with a ratio of 74.4% of total sugars. Furthermore, up to 26 fatty acids (including cis-8,11,14-eicosatrienoic acid; arachidonic acid; cis-11,14,17-eicosatrienoic acid; and cis-5,8,11,14,17-eicosapentaenoic acid) and tocopherols (α, β, ϫ, and δ-tocopherols) have been also quantified. Polyunsaturated were predominant than monounsaturated fatty acids. Among polyunsaturated fatty acids, α-linolenic (48.54%) and linoleic (19.23%) were a majority. In contrast, α-tocopherol represented 98.52% of total tocopherols. A few amino acids have been identified in leaves and aerial parts of ethanol extract and scarcely essential oil. These amino acids are β-and L-alanine, asparagine, isoleucine, leucine, phenylalanine, proline, serine, threonine, tyrosine, valine [223].

Conclusions

Research concerning medicinal herbs' multiple properties in different areas includes Phytomedicine use, Phytochemistry, Pharmacology, and Toxicology, are summarized. These researches arouse more and more interest. Scientific investigations of *Chenopodium ambrosioides* have proved their importance in those areas. Different parts of the plant possess potential as a possible source of interesting bioactive compounds likely to treat several human and animal diseases. Further investigations are necessary to promote this plant due to its possibilities therapeutically exploitable. Future research needs to establish a relationship between phytochemical composition, pharmacological and toxicological aspects and investigate deeply and strictly controlled clinical studies for users' safety and efficacy.

Abbreviations

$ABTS^{+\cdot}$: 2,2′-azinobis(3-ethylbenzothiazoline-6-sulfonic acid) cation radical; ACP: Acyl carrier protein; AIDS: Acquired immunodeficiency syndrome; AkP: Alkaline phosphatase; ALT: Alanine transaminase; AST: Aspartate transaminase; BHA: Butylated hydroxyanisole; BHT: Butylated hydroxytoluene; BK: Bradykinin; bw: Body weight; CAT: Catalase; CC_{50}: The 50% cytotoxic concentration; DBA1: Diamond-Blackfan anemia 1; DBM: Diamondback moth; DNA: Deoxyribonucleic acid; DPPH: 2,2-Diphenyl-1-picrylhydrazyl; EC_{50}: Half maximal effective concentration; H37Ra: *Mycobacterium tuberculosis* (Mtb) strains; HaCaT cell line: Spontaneously immortalized human keratinocyte line; HbSS: Sickle cell; HIV: Human immunodeficiency virus; GM: Geometric mean; IC_{50}: Inhibitory concentration 50%; LC_{90}: Inhibitory concentration 90%; IFN-γ: Gamma interferon; IL-4: Interleukin-4; IL-6: Interleukin-6; MG-63: Human osteosarcoma cell line; MIC: Minimal inhibitory concentration; NO: Nitric oxide; OH: Hydroxyl radical; PS: Polysaccharide; RAJI: Human B lymphoblastoid cell line; ROS: Reactive oxygen species; SC_{50}: Concentration required to inhibit 50% of the free radical-scavenging activity; SOD: Superoxide dismutase; STZ: Streptozotocin; TNF-α: Tumor necrosis factor alpha; VLDL: Very-low-density lipoprotein; WHO: World Health Organization

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Authors' contributions

FMK conceived the manuscript, conducted the review, and wrote the first draft. JNK, JT, and AGA revised and approved the manuscript. All authors read, corrected, and approved the final manuscript.

Availability of data and materials

All data and materials are available on request.

Declarations

Ethics approval and consent to participate

Not applicable

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The authors state that there is no conflict of interest for this review.

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