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 ethnomedical uses, phytochemical status, and pharmacological properties of *C. ambrosioides* L.

**Main body of the abstract:** The analysis of relevant data highlights various ethnomedical uses against human and veterinary diseases in forty countries. Most indications consisted of gastrointestinal 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-arithmetic, acaricidal, amoebicidal, anthelmintic, anticaner, antibacterial, antidiabetic, antidiarrheal, antifertility, antifungal, anti-leishmanial, antimalarial, antipyretic, antischistosomal, antilucier, 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
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

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
| 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, lqo, 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-maría, 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] |
| 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 | Ameoba, worms             | Raw, maceration and trituratin/--                      | [44]         |
|                    |                  | Worms (Cattle, goat, chicken, pig, and sheep) | Trituration in water, maceration, and decoction/--   |              |
| 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             | Wound healing, anti-inflammatory, and diarrhea (veterinary use) | Maceration/--                                           | [48]         |
| Mastruz            | Leaf, seed, and root | Gastritis, facts, 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, tonsil, 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 | Decoction and powder/bathing                    | [52] |
| Mastruz            | Leaf             | Leishmanial ulcers         | -                                                     | [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]         |
|                    |                  |                           | Tea, syrup, and juice/--                              | [57]         |
| Cameroon           | Leaf             | Cough and tuberculosis     | Teais, syrups, and juice/--                           | [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] |
| Congo-Brazzaville  | Leaf             | Intestinal parasites       | Decoction or infusion/oral                            | [63]         |
| Congo-Democratic Republic | Leaf | Convulsions           | Decoction/oral                                         | [64]         |
|                    | Leaf             | Cough, fever, epilepsy, worms, and hemiplegia | Decoction/oral | [65] |
|                    | Leaf             | Diabetes mellitus          | Decoction/oral                                         | [66]         |
|                    | Leaf             | Gastrointestinal disorders in livestock | Maceration and crush/--                               | [67]         |
|                    | Leaf             | Malaria                    | Decoction/oral                                         | [68]         |
| 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/oral                       |            |
|           | 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  | Ets-farus     | Root        | Snake bite       | Crushed/–                             | [79]       |
|           | –             | Whole plant | Internal parasite, abdominal pain, and abdominal swelling* | Maceration/oral and nasal application | [80]       |
| France    | 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]       |
|           | Pasu$t$, apazote, epazote | Aerial part, seed, and root | Empacho, diarrhea, stomachache, abdominal cramps, and parasitic worms | – | [85]       |
| Honduras  | Epa$zote$    | –           | Parasites in all livestock* | – | [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   | Semicontact  | Whole plant, leaf, and stern | Intestinal worms | Decoction, infusion, and juice/oral | [96]       |
| Jordan    | Goose foot   | Leaf and root | Diuretic (edema) and bladder | Decoction/– | [97]       |
|           | Minwaha, Fus Elajooz | Leaf | Spasms | Infusion/– | [98]       |
| 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, Epazotl     | Leaf and stem | Facilitate childbirth and menstrual cramps                                       |                                                                              | [105]      |
|               | Epazote, Tijon       | 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’mikhinza           | Aerial part   | Fever and migraine                                                               |                                                                              | [110]      |
|               | -                    | Leaf         | Fever, headache, ovarian and menstrual pain                                     | Raw and decoction/poultice and oral                                          | [111]      |
|               | Mikhinza             | -            | Fever                                                                            |                                                                              | [112]      |
|               | Mikhinza             | Leaf         | Diabetes mellitus                                                                | Maceration/oral                                                              | [113]      |
|               | Mikhinza             | Leaf         | Diabetes mellitus                                                                | Infusion/–                                                                   | [114]      |
|               | Mikhinza             | Whole plant  | Diabetes mellitus                                                                | Decoction/–                                                                  | [115]      |
|               | Mikhinza             | Leaf         | General health, gastrointestinal, pediatric, endocrinological                     | Infusion/poultice, bathing, and oral ingestion                               | [116]      |
|               | Mikhinza             | Leaf, and flower | Diabetes mellitus and hypertension                                           | Decoction and infusion/–                                                  | [117]      |
|               | Mikhinza             | Leaf, and flower | Diabetes mellitus                                                                | Infusion/–                                                                  | [118]      |
|               | Mikhinza             | Leaf         | Diabetes mellitus                                                                | Juice/–                                                                      | [119]      |
|               | Mikhinza             | Leaf         | Diabetes mellitus                                                                | Decoction and infusion/–                                                      | [120]      |
|               | Mikhinza             | Leaf and flower | Hypertension                                                                     | Infusion and juice/–                                                         | [121]      |
|               | Mikhinza             | Leaf and flower | Hypertension and cardiac diseases                                               |                                                                              | [122]      |
|               | Mikhinza             | Leaf and flower | Diabetes                                                                        |                                                                              | [123]      |
|               | Mikhinza             | Leaf and flower | Diabetes mellitus                                                                |                                                                              | [124]      |
|               | M’kikhinza           | Leaf and aerial part | Antipyretic, sunstroke, anti-emetic, stomachic, and mouthwash | Decoction/oral and local application                                         | [125]      |
|               | M’kikhinza           | Leaf         | Fever, headache, heart problems                                                  |                                                                              | [126]      |
| Zamiâat, Mikhinza | 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, rhematism, diarrhea, migraine, nervosity, respiratory and hepatic disorders, gynecological disorders, bladder | Decoction, powder, infusion, and mask/–                                    | [129]      |
| Countries          | Vernacular names        | Part(s) used | Traditional uses                                                                 | Formulation/method of administration                      | References |
|--------------------|-------------------------|--------------|-----------------------------------------------------------------------------------|-------------------------------------------------------------|------------|
| 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                                                               | Decoction/oral                                              | [133]      |
|                    | Arunpale                | Leaf         | High blood pressure (Hypertension)                                               | Decoction/oral                                              | [134]      |
|                    | Ebibgen-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]      |
|                    |                         | -            | Cough, pulmonary obstruction, amenorrhoea, 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]      |
|                    | Sumna                   | 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               | Chiche, 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/–                                                  | [158]      |
| Tanzania           | Akaita malogo           | Leaf         | HA/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]      |
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
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]. Monoterprenes 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 monoterprenes, 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 monoterpene 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/ascari
dole (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
| 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-cyclohex-1-one | Whole plant/–                                          | [176]      |
| **Fatty acids**               |                                                           |            |
| Octadecanoic acid             | Whole plant/methanol (ethyl acetate)                      | [174]      |
| **Flavonoids**                |                                                           |            |
| Kaempferol                    | Fruits/methanol (ethyl acetate)                           | [177]      |
| Isorhamnetin                  | Leaves/ethanol 70% (n-butanol)                            | [175]      |
| 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,1′-C4-rhamnopyranoside (afzelin) | Leaves/ethanol 70% (n-butanol) | [175] |
| Kaempferol 3-O-α,1′-C4-rhamnopyranyl-(1″→2″)-β-o-4-C1-xylopyranoside | Leaves/ethanol 70% (n-butanol) | [175] |
| Kaempferol 3-harmnioside-4″-xyloside | Fruits/methanol (ethyl acetate) | [177] |
| Kaempferol 3-harmnioside-7″-xyloside | Fruits/methanol (ethyl acetate) | [177] |
| Kaempferol 7-O-α,1′-C4-rhamnopyranoside | Leaves/ethanol 70% (n-butanol) | [175] |
| Kaempferol 7-harmnioside      | Leaves/ethyl acetate (–)                                  | [179]      |
| Kaempferol 3,7-di-O-alpha-1″-rhamnopyranoside | Whole plant/– | [176] |
| Kaempferol-7-O-alpha-1″-rhamnopyranoside | Whole plant/– | [176] |
| Kaempfl 7-harmnioside (ambroside) | Leaves/ethyl acetate (–) | [179] |
| Quercetin-7-O-alpha-1″-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] |
| (–),(1R,4S)-p-Mentha-2,8-dien-1-hydroperoxide | Aerial parts/ethyl acetate (diethyl ether-soluble) | [182] |
| (–),(1R,4S)-p-Mentha-2,8-dien-1-hydroperoxide | Aerial parts/ethyl acetate (diethyl ether-soluble) | [182] |
| (–),(2R,4S)-p-Mentha-1(7),8-dien-2-hydroperoxide | Aerial parts/ethyl acetate (diethyl ether-soluble) | [182] |
| (–),(2S,4S)-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] |
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 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-4α 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] |
| β,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] |
| 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]-1q,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] |
| 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-1-ol   | 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-methylene cyclohexanol | 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-Oxabicyclo[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]                                                                 |
| Antasone                         | 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-              | Whole plant | Essential oil | [201] |
| Bicycle[3.3.1]nonan-1-ol         | Whole plant | Essential oil | [211] |
| Bicyclogermacrene                | Whole plant | Essential oil | [211] |
| Borneol                          | Whole plant | Essential oil | [203, 211, 219, 220, 228, 237] |
| Camphor                          | Leaves, aerial parts | Essential oil | [211] |
| 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-Carduel                      | 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-1-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-Farnesien                  | 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] |
| Cyclo tetradecane                | 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]                               |
| γ-Curcumene                      | Aerial parts, leaves       | Essential oil                   | [203, 204]                          |
| γ-Elemene                        | Whole plant                | Essential oil                   | [211]                               |
| γ-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, 221] |
Table 3 Main secondary metabolites identified in *C. ambrosioides* (Continued)

| Identified secondary metabolites | Part used | Source | References |
|----------------------------------|-----------|--------|------------|
| parts, leaves, and inflorescences |           | Essential oil | 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, hydro-alcoholic 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 di-rhamnoside-O-hexoside | Flowers, leaves, and stem | Aqueous infusion, ethanolic extract | [241, 242] |
| Kaempferol O-dirhamnoside | Leaves | Methanol extract | [229] |
| Kaempferol O-glucuronoside | 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] |
| α-Cymene                         | Leaves, whole plant | Essential oil, Non-polar fraction (pentane) | [201, 202, 219, 223] |
| Oxalic acid                      | Leaves | Polar fraction (ethanol) | [223] |
| p,a-Di-Methyl styrene            | Aerial parts | Essential oil | [188, 217] |
| Palmitic acid                    | Leaves | Polar fraction (ethanol) | [223] |
| Pantotenic 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                                      |
|---------------------------------|------------------------------------|---------------------------------------------|------------------------------------------------|
| p-Cymenol                       | Inflorescences                     | Essential oil                               | [227, 228, 231–237]                            |
| 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-arabinogluconoside | 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 dithamnoside          | Flowers, leaves, and stem          | Aqueous infusion, ethanolic extract, methanol extract | [229, 242]                                     |
| Quercetin O-glucuronoside       | 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]                                          |
| 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-Caryl acetate              | Leaves    | Essential oil | [237] |
| Trans-Caryophyllene               | Whole plant | Essential oil | [13] |
| Trans-Chrysanthenyl acetate       | Whole plant | Essential oil | [220] |
| Trans-Isoscaridole                | 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] |
| 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,α-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-Patchouline                                   | Leaves                        | Essential oil                 | [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)
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, anthelminthic, anticancer, antibacterial, antidiabetic, anti-diarrheal, antifertility, antifungal, anti-inflammatory, anti-leishmanial, antimalarial, anti-nociceptive, antipyretic, antioxidant, antiscicking, 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 neof ormation 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 repair 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-m’EC (Chenopodium-based biopesticide). Previously, Musa et al. [253] have reported acaricidal and sub-lethal 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 nematocidal 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 apiarius, 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 norfloxacain 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 methicillin and gentamycin resistant 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 CC50 = 45 ± 7 μg/ml; however, leaf extract was the least cytotoxic with IC50 = 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 IC50 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 antisecretery potential 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

The leaf methanolic extract produced an antifeedant 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 gloeosporioides*, *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 phoshide 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 krusei [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 fluczoneol against microbial strains like Candida parapsilosis C. krusei and C. glabrata. The MIC of fluczoneol 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 IC₅₀ 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 carvophyline 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 (LC₅₀), 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 Allogen-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 AIT, 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]. Administered 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/cm²). 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 (IC50 = 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 defense, 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 Ca²⁺ (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⁺⁺, free radicals [299]. Caryophyllene oxide has shown anticytotoxic property MG-63 human osteosarcoma cells via various mechanisms [300]. Moreover, Fidy 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 repellent 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 Hymenolepis nana [306].

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

| Secondary metabolite                          | Activity          | Pharmacological mechanism                                                                 | References |
|-----------------------------------------------|-------------------|------------------------------------------------------------------------------------------|------------|
| (−)-(25,45)-p-Mentha-2,8-dien-1-hydroperoxide | Trypanocidal      | Toxicity against epimastigotes of Trypanosoma cruzi                                     | [182]      |
| (−)-(15,45)-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]|
| Ascaridole                                    | Antimicrobial     | Inhibition of toxicity induced by potassium, acetylcholine, or serotonin in rats.        | [197]      |
|                                                               | 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]      |
|                                                               | Cytotoxicity      | 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]      |
|                                                                 | Cytotoxicity      | Inhibition of the respiratory chain in mammalian cells and mitochondria                 | [248]      |
|                                                                 | Anti-inflammatory | Significant inhibition against LPS induced TNF-α or IL-6 gene expressions                | [190]      |
|                                                                 | Antioxidant       | Inhibition against malondialdehyde                                                      | [190]      |
|                                                                 | Insecticidal      | Toxicity to male Blattella germanica                                                     | [217]      |
|                                                                 | Antifungal        | Inhibition the growth of Sclerotium rolf                                                 | [186]      |
|                                                                 | Antihypertensive  | Induction of hypotension in genetically prone hypertensive rats                          | [243]      |
|                                                                 | Antioxidant       | Radical scavenging activity SC_{50}                                                     | [175]      |
|                                                                 | Antioxidant       | Radical scavenging activity                                                            | [180]      |
|                                                                 | Antioxidant       | Radical scavenging activity                                                            | [180]      |
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.

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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.

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