


Article

Chemistry and Bioactivity of *Croton* Essential Oils: Literature Survey and *Croton hirtus* from Vietnam

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Abstract: Using essential oils to control vectors, intermediate hosts, and disease-causing microorganisms is a promising approach. The genus *Croton* in the family Euphorbiaceae is a large genus, with many species containing large amounts of essential oils, however, essential oil studies are limited in terms of the number of *Croton* species investigated. In this work, the aerial parts of *C. hirtus* growing wild in Vietnam were collected and analyzed by gas chromatography/mass spectrometry (GC/MS). A total of 141 compounds were identified in *C. hirtus* essential oil, in which sesquiterpenoids dominated, comprising 95.4%, including the main components β -caryophyllene (32.8%), germacrene D (11.6%), β -elemene (9.1%), α -humulene (8.5%), and caryophyllene oxide (5.0%). The essential oil of *C. hirtus* showed very strong biological activities against the larvae of four mosquito species with 24 h LC₅₀ values in the range of 15.38–78.27 μ g/mL, against *Physella acuta* adults with a 48 h LC₅₀ value of 10.09 μ g/mL, and against ATCC microorganisms with MIC values in the range of 8–16 μ g/mL. In order to provide a comparison with previous works, a literature survey on the chemical composition, mosquito larvicidal, molluscicidal, antiparasitic, and antimicrobial activities of essential oils of *Croton* species was conducted. Seventy-two references (seventy articles and one book) out of a total of two hundred and forty-four references related to the chemical composition and bioactivity of essential oils of *Croton* species were used for this paper. The essential oils of some *Croton* species were characterized by their phenylpropanoid compounds. The experimental results of this research and the survey of the literature showed that *Croton* essential oils have the potential to be used to control mosquito-borne and mollusk-borne diseases, as well as microbial infections. Research on unstudied *Croton* species is needed to search for species with high essential oil contents and excellent biological activities.

Keywords: *Croton*; antimicrobial; antiparasitic; larvicidal; molluscicidal



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1. Introduction

In the family Euphorbiaceae, the genus *Croton* has the largest number of species with about 13,000 species, which are distributed mainly in tropical and subtropical areas [1]. Secondary metabolites in this genus include terpenoids, alkaloids, phenolic compounds, and phenylpropanoids [2]. The volatile compounds (essential oils) in *Croton* species are important products with many biological activities such as antioxidant [3–7], antibacterial,

antifungal [8–10], anti-inflammatory [2,11–13], cytotoxic [6,11,14–17], antitumor [16,17], insecticidal, amebicidal [18], anti-parasitic, anti-ulcerogenic [19–21], antinociceptive [22,23], modulation of antibiotic and antifungal activities [24], myorelaxant [25], antispasmodic [26], anxiolytic, [2,27], anthelmintic [28], vasorelaxant [29], and pharmacological effects.

Mosquito-borne diseases are a global health problem, particularly diseases with a high number of annual infections such as human malaria (148–304 million), dengue (67–136 million), yellow fever (84,000–170,000 in Africa), chikungunya (693,000 in the Americas), Zika (500,000 in the Americas), lymphatic filariasis (31.3–46.7 million), Japanese encephalitis (35,000–50,000), and West Nile fever (2588) [30].

Parasitic diseases transmitted by snails are a serious health problem in addition to mosquito-borne diseases. In 2021, 136 million school-aged children and 115.4 million adults in 51 countries required preventive chemotherapy for schistosomiasis, which represents a slight increase over that in 2020 (239.6 million) [31]. It is estimated that the acute and chronic symptoms of this disease result in a loss of 4.5 million disability-adjusted life years (DALY) [32]. Food-borne trematodiasis are most prevalent in east Asia and South America and can result in severe liver and lung disease. Estimates from the WHO show that food-borne trematodes are important causes of disability with an estimated annual total of 200,000 illnesses and more than 7000 deaths per year, resulting in more than 2 million disability-adjusted life years globally [33].

Antibiotic-resistant bacteria are the biggest global health threat today, affecting anyone of any age in any country. The overuse of antibiotics in humans and animals is accelerating this process. Antibiotic resistance leads to an increasing number of infections, less effective treatment with traditional antibiotics, longer hospital stays, higher medical costs, and increased mortality [34]. Overuse and frequent repeated use of traditional insecticides have created resistant mosquito populations [35]. Although resistance to schistosomiasis has not been formally reported, it is a persistent and probable concern [36–39]. Disease control measures based on a small number of traditional medicines are unsustainable and present risks.

Essential oils, characterized by a complex chemical composition of volatile compounds, are emerging as potential candidates for the control of vectors, intermediate hosts, parasites, and bacteria. The synergistic and antagonistic effects of the complex chemical constituents of essential oils determine the expression of the bioactivity of the essential oil. Many authors believe that it is the complex nature of their chemical composition and the interactions between the components that make it difficult for the target organisms to develop resistance to essential oils [32,40,41]. The trend of synergistic combinations of essential oils with antibiotics [42,43] and pesticides [44–48] to reduce drug use, increase control efficiency, and limit resistance may be an effective solution.

The aim of this study was to obtain and characterize the essential oil from *Croton hirtus* L'Hér from Vietnam and to screen the essential oil for its larvicidal activity against four species of mosquitoes, molluscicidal activity against *Physella acuta*, and antimicrobial activity against a panel of pathogenic microorganisms. In addition, a literature survey of essential oils from *Croton* spp. for the potential control of mosquitoes, snails, parasitic species, and microorganisms was carried out.

2. Results and Discussion

2.1. Chemical Composition

The extraction yield of the essential oil was 0.62% (*w/w*), which was consistent with the range of 0.3–0.6% mentioned in previous reports. Yields of essential oils from *Croton* spp. species range from 0.02 to 6.41% [49,50].

The chemical composition of *C. hirtus* was dominated by sesquiterpenoids (95.4%). The main chemical components included β -caryophyllene (32.8%), germacrene D (11.6%), β -elemene (9.1%), α -humulene (8.5%), and caryophyllene oxide (5.0%). The full analytical results are available in the Supplementary Materials, Table S1.

Previous studies have shown that the main chemical composition of this plant's essential oil varies by season and geographical location. The essential oil samples collected in

the study by Simões included spathulenol (26.7%), β -caryophyllene (10.0%), bicyclogermacrene (9.5%), α -cadinol (7.7%), and cubenol (7.0%) [51]. The essential oil samples collected in Teresina showed seasonal variations in the content of major components, namely β -caryophyllene (27.9–37.3%), germacrene D (6.3–33.7%), α -cadinene (7.0–16.1%), δ -cadinene (1.8–13.5%), and α -humulene (3.6–4.6%) [51]. Essential oil samples collected in the Ivory Coast showed main components that included β -caryophyllene (31.75%), germacrene-D (22.57%), and α -humulene (7.42%) [8].

Essential oils from *Croton* species, in addition to being characterized by monoterpenoids and sesquiterpenoids, are particularly characterized by phenylpropanoids [15,28,52–56]. Essential oils of several species are dominated by a major component such as (E)-anethole [52], linalool [57], guaiol, estragole [54], and methyl eugenol [55].

2.2. Larvicidal Activity

The *C. hirtus* essential oil showed good larvicidal activity against mosquitoes with LC₅₀ values in the range of 15.38–78.27 $\mu\text{g}/\text{mL}$ (Table 1). The compounds β -caryophyllene, α -humulene, and caryophyllene oxide were active against the larvae of *Aedes albopictus* with LC₅₀ values at 24 h of exposure of 56.87, 43.86, and 20.61 $\mu\text{g}/\text{mL}$, respectively [58]. The compounds germacrene D and β -elemene showed very strong toxicity against the larvae of *Ae. aegypti*, *Ae. albopictus*, and *Cx. quinquefasciatus* [59–64].

Table 1. Mosquito larvicidal activity of *Croton hirtus* essential oil ($\mu\text{g}/\text{mL}$).

Test Organism	24-h LC ₅₀ (95% Limits)	24-h LC ₉₀ (95% Limits)	48-h LC ₅₀ (95% Limits)	48-h LC ₉₀ (95% Limits)
<i>Aedes aegypti</i> (third–fourth instar)	29.71 (28.04–31.85)	39.55 (36.11–45.53)	25.67 (24.08–27.82)	34.59 (31.57–39.82)
<i>Aedes albopictus</i> (third–fourth instar)	15.38 (14.51–16.53)	20.10 (18.38–22.99)	14.29 (13.31–15.55)	19.36 (17.61–22.31)
<i>Aedes albopictus</i> (fourth instar, wild)	78.27 (71.15–86.89)	128.37 (115.56–146.48)	60.0 (53.17–67.73)	155.80 (129.95–197.41)
<i>Culex quinquefasciatus</i> (third instar)	50.84 (45.90–56.15)	100.87 (88.39–119.70)	30.42 (28.37–33.78)	38.98 (34.82–48.06)
<i>Culex fuscocephala</i> (third–fourth instar)	65.84 (62.24–69.56)	95.15 (89.61–102.41)	38.21 (33.34–43.62)	156.96 (123.03–220.31)

β -Caryophyllene and its mixtures with caryophyllene oxide and α -humulene (ratio tested relative to the percentage in the essential oil) (Tables 2 and 3) exhibited distinctly different toxicities against *Ae. aegypti* and *Ae. albopictus*. This mixture played a major role in the larvicidal activity against *Ae. aegypti*, but conversely it did not play a role in the larvicidal activity against *Ae. albopictus*.

Table 2. Larvicidal activity of major compounds against *Aedes aegypti* ($\mu\text{g}/\text{mL}$).

Compounds	LC ₅₀ (95% Limits)	LC ₉₀ (95% Limits)	χ^2	<i>p</i>
	24 h			
Caryophyllene oxide	39.65 (35.83–42.53)	49.41 (46.31–53.36)	0.011	1.00
α -Humulene	48.19 (44.33–52.29)	87.64 (78.81–100.02)	1.890	0.596
β -Caryophyllene	111.66 (105.55–118.0)	160.10 (151.39–170.85)	3.782	0.436
Caryophyllene oxide/ α -Humulene/ β -Caryophyllene: 7:2:1	9.54 (8.06–11.00)	23.08 (20.48–26.83)	11.905	0.018
	48 h			
Caryophyllene oxide	37.92 (34.73–40.82)	47.94 (44.58–52.34)	0.015	1.00
α -Humulene	36.22 (33.15–39.51)	70.58 (62.82–81.67)	5.124	0.163

Table 2. Cont.

Compounds	LC ₅₀ (95% Limits)	LC ₉₀ (95% Limits)	χ ²	p
β-Caryophyllene	94.43 (88.37–100.84)	145.91 (136.85–157.04)	1.821	0.769
Caryophyllene oxide/α-Humulene/β-Caryophyllene: 7:2:1	8.97 (7.48–10.40)	22.30 (19.78–25.93)	9.252	0.055

Table 3. Larvicidal activity of major compounds against *Aedes albopictus* (µg/mL).

Compounds	LC ₅₀ (95% Limits)	LC ₉₀ (95% Limits)	χ ²	p
		24 h		
Caryophyllene oxide	38.68 (35.84–41.44)	53.28 (49.31–58.93)	0.212	0.976
α-Humulene	31.49 (28.62–34.67)	65.14 (56.73–78.08)	8.186	0.042
β-Caryophyllene	30.11 (27.65–32.81)	53.88 (47.80–63.20)	1.865	0.601
Caryophyllene oxide/α-Humulene/β-Caryophyllene: 7:2:1	>50	>50	Nd	Nd
		48 h		
Caryophyllene oxide	33.95 (31.55–36.61)	49.37 (44.93–56.02)	2.136	0.545
α-Humulene	26.44 (24.0–29.13)	55.80 (48.53–66.95)	5.662	0.129
β-Caryophyllene	25.70 (23.46–28.17)	50.26 (44.15–59.60)	3.258	0.354
Caryophyllene oxide/α-Humulene/β-Caryophyllene: 7:2:1	>50	>50	Nd	Nd

Nd: not determined.

2.3. Literature Survey

In order to put this current investigation into context, a survey of the literature on *Croton* essential oils and their biological activities was carried out. A total of two hundred and forty-four references were collected, which included one hundred and seven species of *Croton*. The distribution of the study samples collected was as follows: Brazil (one hundred and seventy-six), Venezuela (six), South Africa (six), Cuba (five), Colombia (five), Ecuador (five), Madagascar (four), Nigeria (three), Costa Rica (three), Vietnam (two, not included in this study), Kenya (two), India (two), Cameroon (two), Kenya (two), Peru (two), Ethiopia (two), Mexico (two), Korea (one), Laos (one), Central African Republic (one), Gabon (one), Curacao (one), Benin (one), Argentina (one), Ivory Coast (one), Congo-Brazzaville (one), Sudan (one), Guadeloupe (one), China (one), Thailand (one), Island (one) and Malaysia (one). After reviewing the articles based on the set criteria, seventy-one articles and one book satisfied the criteria and were included herein. Most of the studies collected plant material and were conducted in Brazil.

The previously reported larvicidal activities of *Croton* species against mosquitoes are summarized in Table 4. Most of the essential oils of *Croton* spp. showed good activity (LC₅₀ < 100 µg/mL). It is worth noting that *C. zehntneri* essential oil has been characterized by its main component (*E*)-anethole, which has shown very good larvicidal activity against *Ae. aegypti* [52,65]. Furthermore, studies have reported that the yield of essential oil from the leaves of this species is greater than 1%, and it is non-toxic to mice (LD₅₀: 3464 mg/kg) [65], so this essential oil may be considered for potential use as a biological pesticide. However, since this essential oil has shown geographical variation in terms of its chemical composition [66], an evaluation of the larvicidal activity of all of its chemotypes has not been performed.

Table 4. Summary of *Aedes aegypti* larvicidal activity of essential oils of *Croton* spp.

Species	Yield (%)	Main Components ^a	24-h LC ₅₀ (µg/mL)	24-h LC ₉₀ (µg/mL)	Ref.
<i>Croton argyrophylloides</i> Muell	Aerial parts: Nd	<i>trans</i> -β-Guaiene, α-pinene, β-elemene, 1,8-cineole.	94.6	Nd	[65]
<i>Croton argyrophyllus</i> Kunth	Dried leaves: 0.48	Spathulenol, β-caryophyllene, α-pinene, bicyclogermacrene.	310	700	[67]
<i>Croton heliotropifolius</i> Kunth	Dried leaves: 0.2	β-Caryophyllene, bicyclogermacrene, germacrene D.	544	Nd	[68]
<i>Croton jacobinensis</i> Baill.	Leaves: 0.80	1,8-Cineole, β-caryophyllene, viridiflorene, α-pinene, β-pinene.	79.3	Nd	[69]
	Stalks: 0.70	γ-murolene, γ-cadinene, 6,9-guaiadiene, viridiflorene, 1,8-Cineole, β-caryophyllene, viridiflorene, α-pinene.	117.2	Nd	[69]
	Inflorescences: 0.05	1,8-Cineole, sabinene, 10- <i>epi</i> -γ-eudesmol, hinesol	65.8	Nd	[69]
<i>Croton linearis</i> Jacq	Fresh leaves: 1.50	Methyleugenol, α-copaene, croweacin, caryophyllene oxide.	64.24	143.85	[70]
<i>Croton nepetaefolius</i> Bail	Aerial parts: Nd	β-Caryophyllene, bicyclogermacrene, germacrene D.	66.4	154	[65]
<i>Croton pulegioidorus</i> Baill.	Dried leaves: 5.0	<i>p</i> -Cymene, ascaridole, camphor, α-phellandrene.	159	Nd	[68]
<i>Croton regelianus</i> Müll. Arg.	Fresh leaves: 1.3	Ascaridole, <i>p</i> -cymene, α-terpinene, γ-terpinene.	66.74	Nd	[71]
	Fresh leaves: 0.5	Sesquicineole, α-phellandrene, β-caryophyllene, 1,8-cineole, 1,8-Cineole, <i>o</i> -cymene, α-pinene, α-phellandrene, sabinene.	24.22	Nd	[71]
<i>Croton rhamnifolioides</i> Pax and K. Hoffm.	Fresh leaves: Nd	Spathulenol, β-caryophyllene, caryophyllene oxide, 1,8-cineole	122.3	Nd	[72]
	Dried leaves: 0.80%	β-Phellandrene, <i>trans</i> -β-guaiene, α-pinene, β-caryophyllene, γ-murolene.	89.0	Nd	[72]
<i>Croton sonderianus</i> Muell	Aerial parts: Nd	Camphor, γ-terpineol, α-terpinene, <i>p</i> -cymene, γ-terpinene.	54.5	Nd	[65]
	Leaves: Nd	Camphor, isopinocampheol, β-caryophyllene, spathulenol.	104	119	[73]
<i>Croton tetradenius</i> Baill.	2.73		152	297	[74]
Blend (1:1, <i>w/w</i>) of <i>Croton argyrophyllus</i> Kunth. and <i>Croton tetradenius</i> Baill.	Nd		160	400	[75]
<i>Croton zehntneri</i> Pax et Hoffm	Aerial parts: Nd	(<i>E</i>)-Anethole	26.2	Nd	[65]
	Aerial parts: Nd	(<i>E</i>)-Anethole	28	32	[73]
<i>Croton zehntneri</i> Pax et Hoffm	Leaves: 1.04	(<i>E</i>)-Anethole	56.2	Nd	[52]
	Stalks: 0.46	(<i>E</i>)-Anethole, <i>p</i> -anisaldehyde, anisyl acetate, estragole.	51.3	Nd	[52]
	Inflorescences: 0.30	(<i>E</i>)-Anethole	57.5	Nd	[52]
	Leaves: Nd	α-Pinene, <i>trans</i> -β-guaiene, β-pinene, β-gurjunene, β-elemene.	102	129	[73]
	Leaves: Nd	Methyleugenol, α-copaene, β-caryophyllene	84	Nd	[73]

^a: The order of the compounds is sorted by percentage from high to low and greater than 5.0%. Nd = not determined.

The main constituents of the essential oils of *Croton* spp. were evaluated for their larvicidal activity against mosquito species (Table 5). There were differences between different authors when reporting the activities of the compounds β-caryophyllene, α-pinene, β-pinene, α-terpineol, α-humulene, and α-phellandrene. This difference may have been due to the different health or developmental stages of the larvae between the

groups. The larvicidal activity of (*E*)-anethole was weaker than that of *C. zehntneri* essential oil [52,65], which demonstrated the important role of components in small concentrations, such as anisyl-acetate and dihydroaromadendrene. Bicyclogermacrene did not have synergistic effects with the compounds spathulenol, β -caryophyllene, camphor, or germacrene D in the larvicidal activity of the essential oils of *C. argyrophyllus*, *C. heliotropiifolius*, and *C. pulegioidorus*. This trend was also observed in the larvicidal activity of *Eugenia calycina* essential oil [76].

Table 5. Summary of mosquito larvicidal activity of main components in *Croton* spp. essential oils (24 h or 48 h exposure).

Compound	LC ₅₀ , $\mu\text{g/mL}$	LC ₉₀ $\mu\text{g/mL}$	Mosquito	Ref.
(E)-Anethole	69.2	Nd	<i>Aedes aegypti</i>	[52]
	50.19	65.21	<i>Aedes aegypti</i>	[77]
	34.41–38.98	71.03–82.72	<i>Aedes aegypti</i>	[78]
	67.1–85.5	Nd	<i>Aedes aegypti</i>	[79]
	42	>50	<i>Aedes aegypti</i>	[80]
	50 < LC ₅₀ < 100	Nd	<i>Aedes albopictus</i>	[81]
	73.99	109.86	<i>Ochlerotatus caspius</i>	[82]
	24.8 $\mu\text{L/L}$	32.1 $\mu\text{L/L}$	<i>Culex quinquefasciatus</i>	[83]
	21	34	<i>Culex quinquefasciatus</i>	[84]
	16.56	25.29	<i>Culex pipiens</i>	[85]
Ascaridole (89.5%)	41.85	74.45	<i>Culex quinquefasciatus</i>	[86]
	9.60	Nd	<i>Aedes aegypti</i>	[71]
α -Asarone	22.38–23.82	Nd	<i>Culex pipiens pallens</i>	[87]
Bicyclogermacrene	11.1	22.14	<i>Aedes albopictus</i>	[62]
	12.5	24.2	<i>Culex tritaeniorhynchus</i>	[62]
	10.3	20.9	<i>Anopheles subpictus</i>	[62]
Borneol	>500	>500	<i>Aedes aegypti</i>	[79]
(+)-Borneol	>100	Nd	<i>Culex pipiens pallens</i>	[88]
(-)-Borneol	>100	Nd	<i>Culex pipiens pallens</i>	[88]
δ -Cadinene	8.23	Nd	<i>Anopheles stephensi</i>	[60]
	9.03	Nd	<i>Aedes aegypti</i>	[60]
	9.86	Nd	<i>Culex quinquefasciatus</i>	[60]
Camphor	>250	>250	<i>Culex quinquefasciatus</i>	[84]
	129.17	192.42	<i>Anopheles anthropophagus</i>	[89]
	>500	Nd	<i>Aedes aegypti</i>	[79]
	>50	>50	<i>Aedes aegypti</i>	[80]
1,8-Cineole	>100	Nd	<i>Aedes aegypti</i>	[72]
	57.2	Nd	<i>Aedes aegypti</i>	[90]
	1381	Nd	<i>Aedes aegypti</i>	[91]
	53.63	Nd	<i>Aedes aegypti</i>	[92]
	>100	Nd	<i>Aedes aegypti</i>	[93]
	>100	>100	<i>Culex pipiens pallens</i>	[88]
	191	207	<i>Culex pipiens molestus</i>	[94]
	>200	Nd	<i>Culex pipiens</i>	[95]
	>50.0	>50.0	<i>Aedes aegypti</i>	[96]
	>50.0	>50.0	<i>Aedes albopictus</i>	[96]
	>100	Nd	<i>Aedes albopictus</i>	[81]
>200	>200	<i>Aedes albopictus</i>	[97]	
>250	>250	<i>Culex quinquefasciatus</i>	[84]	
β -Caryophyllene	1038	Nd	<i>Aedes aegypti</i>	[68]
	136.85	280.86	<i>Aedes aegypti</i>	[98]
	298.4	1227.3	<i>Aedes aegypti</i>	[99]
	1202	Nd	<i>Aedes aegypti</i>	[91]
	>50	>50	<i>Aedes aegypti</i>	[80]
	>50	>50	<i>Aedes aegypti</i>	[100]

Table 5. Cont.

Compound	LC ₅₀ , µg/mL	LC ₉₀ µg/mL	Mosquito	Ref.
	29.97	48.34	<i>Aedes aegypti</i>	[61]
	>100	Nd	<i>Aedes aegypti</i>	[93]
	54.95	Nd	<i>Aedes aegypti</i>	[101]
	73.4	434.22	<i>Aedes albopictus</i>	[99]
	44.8	Nd	<i>Aedes albopictus</i>	[102]
	53.14	Nd	<i>Aedes albopictus</i>	[101]
	>200	>200	<i>Aedes albopictus</i>	[97]
	>100	Nd	<i>Aedes albopictus</i>	[81]
	31.09	54.92	<i>Aedes albopictus</i>	[61]
	>50	>50	<i>Aedes albopictus</i>	[100]
	69.60	164.59	<i>Culex quinquefasciatus</i>	[98]
	165.4	220.6	<i>Culex quinquefasciatus</i>	[103]
	44.99	Nd	<i>Culex pipiens pallens</i>	[101]
	48.2	Nd	<i>Culex tritaeniorhynchus</i>	[102]
	>200	Nd	<i>Anopheles anthropophagus</i>	[89]
	134.77	Nd	<i>Anopheles sinensis</i>	[104]
	41.7	Nd	<i>Anopheles subpictus</i>	[102]
	28.86	51.82	<i>Anopheles nuneztovari</i>	[61]
	26.52	46.51	<i>Anopheles triannulatus</i>	[61]
	25.14	54.73	<i>Anopheles darlingi</i>	[61]
	26.36	53.92	<i>Anopheles albitarsis</i>	[61]
	60.17	Nd	<i>Anopheles sinensis</i>	[101]
Caryophyllene oxide	49.46	115.38	<i>Anopheles anthropophagus</i>	[89]
	39.09	Nd	<i>Anopheles sinensis</i>	[104]
	125	Nd	<i>Aedes aegypti</i>	[91]
	>50	>50	<i>Aedes aegypti</i>	[80]
	>50	>50	<i>Aedes aegypti</i>	[100]
	29.8 (1 day old)	74.1 (1 day old)	<i>Aedes aegypti</i>	[105]
	20.61	27.56	<i>Aedes albopictus</i>	[58]
	>50	>50	<i>Aedes albopictus</i>	[100]
	98.52	144.5	<i>Culex quinquefasciatus</i>	[58]
p-Cymene	19.2	41.3	<i>Aedes aegypti</i>	[96]
	21.86–49.25	55.02–115.51	<i>Aedes aegypti</i>	[78]
	17.05	27.30	<i>Aedes aegypti</i>	[98]
	43.3	>50.0	<i>Aedes aegypti</i>	[100]
	69.4	95.2	<i>Aedes aegypti</i>	[106]
	37.1	>100.0	<i>Aedes aegypti</i>	[107]
	12.49	Nd	<i>Aedes aegypti</i>	[92]
	36.9 (1 day old larvae)	54.4 (1 day old larvae)	<i>Aedes aegypti</i>	[108]
	23.3 (1 day old larvae)	46.7 (1 day old larvae)	<i>Aedes aegypti</i>	[109]
	>500	Nd	<i>Aedes aegypti</i>	[79]
	25 < LC ₅₀ < 50	<50	<i>Aedes aegypti</i>	[93]
	33.93	Nd	<i>Aedes aegypti</i>	[101]
	46.7	>50.0	<i>Aedes albopictus</i>	[96]
	34.9	>50.0	<i>Aedes albopictus</i>	[100]
	25.9	66.3	<i>Aedes albopictus</i>	[107]
	35.10	Nd	<i>Aedes albopictus</i>	[101]
	68.3	95.0	<i>Aedes albopictus</i>	[106]
	19.4	28.8	<i>Aedes albopictus</i>	[97]
	50 < LC ₅₀ < 100	Nd	<i>Aedes albopictus</i>	[81]
	21	30	<i>Culex quinquefasciatus</i>	[84]
	15.13	25.41	<i>Culex quinquefasciatus</i>	[98]
	29.34	Nd	<i>Culex pipiens pallens</i>	[101]
	38.07	Nd	<i>Anopheles sinensis</i>	[101]
β-Elemene	10.26	20.02	<i>Anopheles subpictus</i>	[63]
	11.15	21.32	<i>Aedes albopictus</i>	[63]
	12.05	22.40	<i>Culex tritaeniorhynchus</i>	[63]
Elemicin	>100	Nd	<i>Aedes albopictus</i>	[81]

Table 5. Cont.

Compound	LC ₅₀ , µg/mL	LC ₉₀ µg/mL	Mosquito	Ref.	
Estragole	14.01	24.41	<i>Culex quinquefasciatus</i>	[60]	
	12.70	22.32	<i>Aedes aegypti</i>	[60]	
	11.01	19.79	<i>Anopheles stephensi</i>	[60]	
	38.56	95.90	<i>Anopheles anthropophagus</i>	[110]	
	41.67	107.89	<i>Anopheles sinensis</i>	[110]	
Eugenol	7.53	12.35	<i>Ochlerotatus caspius</i>	[82]	
	117	180	<i>Culex quinquefasciatus</i>	[84]	
	82.2–142.9	Nd	<i>Aedes aegypti</i>	[79]	
	12.5 < LC ₅₀ < 25	50 < LC ₉₀ < 100	<i>Aedes albopictus</i>	[81]	
Eugenol (74.0%)	18.28	43.11	<i>Culex pipiens</i>	[85]	
Germacrene D	49.81	106.19	<i>Anopheles anthropophagus</i>	[89]	
	59.5	96.4	<i>Anopheles stephensi</i>	[59]	
	63.6	100.7	<i>Aedes aegypti</i>	[59]	
	21.28	37.04	<i>Culex quinquefasciatus</i>	[60]	
	18.76	33.37	<i>Aedes aegypti</i>	[60]	
	35.96	61.46	<i>Aedes aegypti</i>	[61]	
	33.51	66.43	<i>Aedes albopictus</i>	[61]	
	16.95	30.95	<i>Anopheles stephensi</i>	[60]	
	32.36	58.68	<i>Anopheles nuneztovari</i>	[61]	
	30.31	58.53	<i>Anopheles triannulatus</i>	[61]	
	24.49	45.11	<i>Anopheles darlingi</i>	[61]	
	31.22	55.46	<i>Anopheles albitarsis</i>	[61]	
	α-Humulene	37.89	83.95	<i>Aedes aegypti</i>	[58]
		53.05	82.78	<i>Aedes aegypti</i>	[103]
		28.11	51.1	<i>Aedes aegypti</i>	[61]
		>100	Nd	<i>Aedes aegypti</i>	[93]
		108.06	Nd	<i>Aedes aegypti</i>	[101]
		38.72	63.40	<i>Aedes albopictus</i>	[58]
		106.25	Nd	<i>Aedes albopictus</i>	[101]
		6.86	12.98	<i>Aedes albopictus</i>	[63]
28.89		48.28	<i>Aedes albopictus</i>	[61]	
87.81		140.0	<i>Culex quinquefasciatus</i>	[58]	
108.3		158.2	<i>Culex quinquefasciatus</i>	[103]	
96.35		Nd	<i>Culex pipiens pallens</i>	[101]	
7.39		13.68	<i>Culex tritaeniorhynchus</i>	[63]	
107.35		Nd	<i>Anopheles sinensis</i>	[101]	
6.19		12.03	<i>Anopheles subpictus</i>	[63]	
26.63		49.56	<i>Anopheles nuneztovari</i>	[61]	
33.08		61.41	<i>Anopheles triannulatus</i>	[61]	
30.36		68.88	<i>Anopheles darlingi</i>	[61]	
37.42	82.58	<i>Anopheles albitarsis</i>	[61]		
R-(+)-limonene	11.88	17.78	<i>Aedes aegypti</i>	[77]	
	37	Nd	<i>Aedes aegypti</i>	[91]	
	25 < LC ₅₀ < 50	LC ₉₀ < 100	<i>Aedes albopictus</i>	[81]	
	71.9	96.9	<i>Aedes aegypti</i>	[106]	
	25 < LC ₅₀ < 50	50 < LC ₉₀ < 100	<i>Aedes aegypti</i>	[93]	
	41.2	88.2	<i>Aedes albopictus</i>	[106]	
	(±)-Limonene	17.04	Nd	<i>Aedes aegypti</i>	[101]
14.05		Nd	<i>Culex pipiens pallens</i>	[101]	
S-(−)-Limonene	25 < LC ₅₀ < 50	LC ₉₀ < 100	<i>Aedes albopictus</i>	[81]	
	25 < LC ₅₀ < 50	25 < LC ₉₀ < 50	<i>Aedes aegypti</i>	[93]	
	29.1 (1 day old larvae)	81.3 (1 day old larvae)	<i>Aedes aegypti</i>	[105]	
Limonene	18.1	41.0	<i>Aedes aegypti</i>	[96]	
	19.4	>50.0	<i>Aedes aegypti</i>	[100]	
	32.7	50.0	<i>Aedes albopictus</i>	[96]	
	31.63	41.51	<i>Culex quinquefasciatus</i>	[103]	
	15.0	34.0	<i>Aedes albopictus</i>	[100]	
Linalool	155.73	237.29	<i>Ochlerotatus caspius</i>	[82]	
	>50.0	>50.0	<i>Aedes aegypti</i>	[100]	
	>50.0	>50.0	<i>Aedes albopictus</i>	[100]	

Table 5. Cont.

Compound	LC ₅₀ , µg/mL	LC ₉₀ µg/mL	Mosquito	Ref.
	>500	Nd	<i>Aedes aegypti</i>	[79]
	>100	Nd	<i>Aedes aegypti</i>	[93]
	38.64	69.08	<i>Aedes aegypti</i>	[60]
	35.17	63.45	<i>Anopheles stephensi</i>	[60]
	42.28	73.13	<i>Culex quinquefasciatus</i>	[60]
(-)-Linalool	169.6	220.5	<i>Aedes albopictus</i>	[97]
Methyleugenol	36.5 (1 day old larvae)	99.2 (1 day old larvae)	<i>Aedes aegypti</i>	[109]
	12.5 < LC ₅₀ < 25	Nd	<i>Aedes albopictus</i>	[111]
	53.30–67.02	Nd	<i>Culex pipiens pallens</i>	[87]
β-Myrcene	>100	Nd	<i>Aedes albopictus</i>	[81]
	167	218	<i>Culex quinquefasciatus</i>	[84]
	27.9	Nd	<i>Aedes aegypti</i>	[102]
	>500	Nd	<i>Aedes aegypti</i>	[79]
	23.5	Nd	<i>Aedes albopictus</i>	[102]
β-Myrcene	35.8	>100.0	<i>Aedes aegypti</i>	[107]
	27.0	75.4	<i>Aedes albopictus</i>	[107]
	35.8	>100.0	<i>Aedes aegypti</i>	[106]
	>100.0	Nd	<i>Aedes aegypti</i>	[93]
	27.0	75.5	<i>Aedes albopictus</i>	[106]
α-Phellandrene	39.3	Nd	<i>Aedes aegypti</i>	[72]
	16.6	36.9	<i>Aedes aegypti</i>	[96]
	39.9	>50.0	<i>Aedes albopictus</i>	[96]
	25 < LC ₅₀ < 50	<100	<i>Aedes albopictus</i>	[81]
	>100	Nd	<i>Aedes aegypti</i>	[93]
	39.3	Nd	<i>Aedes aegypti</i>	[72]
α-Pinene	>50.0	>50.0	<i>Aedes aegypti</i>	[96]
	79.1	>100.0	<i>Aedes aegypti</i>	[107]
	45.17–45.70	92.52–96.49	<i>Aedes aegypti</i>	[78]
	15.4	Nd	<i>Aedes aegypti</i>	[90]
	>100.0	>100.0	<i>Aedes aegypti</i>	[106]
	15.87	Nd	<i>Aedes aegypti</i>	[92]
	>500	Nd	<i>Aedes aegypti</i>	[79]
	>100	Nd	<i>Aedes aegypti</i>	[93]
	>50.0	>50.0	<i>Aedes albopictus</i>	[96]
	74.0	>100.0	<i>Aedes albopictus</i>	[107]
	80.6	>100.0	<i>Aedes albopictus</i>	[106]
	74.0	>100.0	<i>Aedes albopictus</i>	[106]
	>100.0	Nd	<i>Aedes albopictus</i>	[81]
	68.68–72.30	113.88–114.43	<i>Aedes albopictus</i>	[112]
	95	581	<i>Culex quinquefasciatus</i>	[84]
	58.44–61.46	124.2–144.56	<i>Culex pipiens</i>	[113]
(1R)-(+)-α-Pinene	47	62	<i>Culex pipiens molestus</i>	[94]
	>100	Nd	<i>Aedes albopictus</i>	[111]
(1S)-(–)-α-Pinene	49	85	<i>Culex pipiens molestus</i>	[94]
	>100	Nd	<i>Aedes albopictus</i>	[111]
β-Pinene	65	359	<i>Culex quinquefasciatus</i>	[84]
	32.97–35.13	93.11–105.59	<i>Aedes aegypti</i>	[78]
	12.1	Nd	<i>Aedes aegypti</i>	[90]
	23.63	32.12	<i>Aedes aegypti</i>	[103]
	>500	Nd	<i>Aedes aegypti</i>	[79]
	27.69	49.91	<i>Aedes aegypti</i>	[60]
	50 < LC ₅₀ < 100	Nd	<i>Aedes aegypti</i>	[93]
	>100	Nd	<i>Aedes albopictus</i>	[81]
	42.39–47.33	63.10–73.11	<i>Aedes albopictus</i>	[112]
	30.46	41.58	<i>Culex quinquefasciatus</i>	[103]
	32.23	56.58	<i>Culex quinquefasciatus</i>	[60]
	36.53–66.52	76.27–109.53	<i>Culex pipiens</i>	[113]
	32.2	Nd	<i>Anopheles stephensi</i>	[102]

Table 5. Cont.

Compound	LC ₅₀ , µg/mL	LC ₉₀ µg/mL	Mosquito	Ref.
Sabinene	23.17	43.39	<i>Anopheles stephensi</i>	[60]
	74.1	>100.0	<i>Aedes aegypti</i>	[106]
	21.20	39.22	<i>Aedes aegypti</i>	[60]
	39.5	71.4	<i>Aedes albopictus</i>	[106]
	6.25 < LC ₅₀ < 12.5	25 < LC ₉₀ < 50	<i>Aedes albopictus</i>	[81]
	25.01	45.15	<i>Culex quinquefasciatus</i>	[60]
Spathulenol	19.67	36.45	<i>Anopheles stephensi</i>	[60]
	>100	Nd	<i>Aedes aegypti</i>	[76]
γ-Terpinene	30.7	>50.0	<i>Aedes aegypti</i>	[96]
	26.8	68.7	<i>Aedes aegypti</i>	[107]
	9.76	16.99	<i>Aedes aegypti</i>	[77]
	11.25	21.55	<i>Aedes aegypti</i>	[98]
	24.58–44.80	72.55–100.71	<i>Aedes aegypti</i>	[78]
	95	Nd	<i>Aedes aegypti</i>	[91]
	26.8	>50.0	<i>Aedes aegypti</i>	[100]
	27.2 (1 day old larvae)	52.4 (1 day old larvae)	<i>Aedes aegypti</i>	[108]
	25 < LC ₅₀ < 50	50 < LC ₉₀ < 100	<i>Aedes aegypti</i>	[93]
	27.53	Nd	<i>Aedes aegypti</i>	[101]
	26	48	<i>Culex quinquefasciatus</i>	[84]
	13.44	23.52	<i>Culex quinquefasciatus</i>	[98]
	24.70	Nd	<i>Culex pipiens pallens</i>	[101]
	29.8	47.5	<i>Aedes albopictus</i>	[96]
	22.8	57.4	<i>Aedes albopictus</i>	[107]
	22.8	>50.0	<i>Aedes albopictus</i>	[100]
	30.03	Nd	<i>Aedes albopictus</i>	[101]
	25 < LC ₅₀ < 50	50 < LC ₉₀ < 100	<i>Aedes albopictus</i>	[81]
	20.21	32.31	<i>Aedes albopictus</i>	[112]
	α-Terpinene	36.42	Nd	<i>Anopheles sinensis</i>
20.2		32.3	<i>Aedes albopictus</i>	[97]
14.7		39.3	<i>Aedes aegypti</i>	[96]
28.1		76.4	<i>Aedes aegypti</i>	[107]
0.4		Nd	<i>Aedes aegypti</i>	[92]
12.5 < LC ₅₀ < 25		12.5 < LC ₉₀ < 25	<i>Aedes aegypti</i>	[93]
21.30		Nd	<i>Aedes aegypti</i>	[101]
25.2		>50.0	<i>Aedes albopictus</i>	[96]
22.4		58.8	<i>Aedes albopictus</i>	[107]
25 < LC ₅₀ < 50		<100	<i>Aedes albopictus</i>	[81]
α-Terpineol	>250	>250	<i>Culex quinquefasciatus</i>	[84]
	>50.0	>50.0	<i>Aedes aegypti</i>	[96]
	76.68	Nd	<i>Aedes aegypti</i>	[92]
	>100	Nd	<i>Aedes aegypti</i>	[93]
	23.49	Nd	<i>Aedes aegypti</i>	[101]
	>50.0	>50.0	<i>Aedes albopictus</i>	[96]
	21.26	Nd	<i>Aedes albopictus</i>	[101]
	>250	>250	<i>Culex quinquefasciatus</i>	[84]
	>100	>100	<i>Culex pipiens pallens</i>	[88]
	21.30	Nd	<i>Culex pipiens pallens</i>	[101]
	194	216	<i>Culex pipiens molestus</i>	[94]
	27.16	Nd	<i>Anopheles sinensis</i>	[101]
	>500	Nd	<i>Aedes aegypti</i>	[79]

Nd: not determined.

2.4. Molluscicidal and Antiparasitic Activities

The essential oil of *C. hirtus* demonstrated molluscicidal activity against adult *P. acuta* with a 48 h LC₅₀ value of 10.09 µg/mL (Table 6). Based on the classification by the World Health Organization (WHO) [114], this essential oil is considered as an active plant molluscicide (LC₅₀ < 20 µg/mL). *Croton rudolphianus* essential oil, which is characterized

by the main components β -caryophyllene, bicyclogermacrene, δ -cadinene, and germacrene D, was active against *Biomphalaria glabrata* with a 48 h LC₅₀ of 47.89 μ g/mL [115].

Table 6. Molluscicidal activity of *Croton hirtus* essential oil and its major components against *Physella acuta* adults (μ g/mL).

Material	LC ₅₀ (95% Limits)	LC ₉₀ (95% Limits)	χ^2	<i>p</i>
Essential oil	10.09 (8.37–12.21)	17.12 (13.80–25.81)	0.68	0.877
Caryophyllene oxide	5.78 (4.86–6.92)	8.96 (7.38–13.42)	0.50	0.921
α -Humulene	7.24 (6.00–8.67)	11.88 (9.71–17.50)	0.62	0.887
β -Caryophyllene	9.58 (7.79–11.72)	18.08 (14.32–27.14)	0.88	0.829

Although only a few studies have been carried out evaluating the toxicity of *Croton* essential oils against snails as disease vectors, a number of essential oil components have been evaluated for their molluscicidal activity [32]. β -Caryophyllene exhibited strong toxicity against *Bulinus truncatus* with an LC₅₀ value of 1.66 μ g/mL [116].

In contrast to the molluscicidal activity, the antiparasitic activities of essential oils and single components have been extensively studied and have also been studied at the in-vivo level [117,118] (Tables 7 and 8). Tables 7 and 8 show that essential oils with high concentrations of β -caryophyllene and/or caryophyllene oxide showed a trend of stronger activity than other essential oils.

Table 7. Summary of antiparasitic activities of *Croton* spp. essential oils.

Species	Yield (%)	Main Components ^a	M/S/P	IC ₅₀ (μ g/mL)	SI ^b	Organisms	Ref.
<i>Croton argyro-phylloides</i> Müll. Arg.	0.2 to 3	Spathulenol, caryophyllene oxide, β -elemene	M: 0 S: 95.17	15.50 16.71 16.41	>6.45 >6.0 >6.1	Promastigotes of <i>Leishmania</i> (V.) <i>braziliensis</i> Promastigotes of <i>Leishmania</i> (L.) <i>amazonensis</i> Promastigotes of <i>Leishmania</i> (L.) <i>chagasi</i>	[119]
<i>Croton cajucara</i> Benth.	Nd	Linalool	Nd	0.0083	Nd	Promastigotes of <i>Leishmania amazonensis</i>	[57]
	Nd	Linalool	Nd	0.022	Nd	Amastigotes of <i>Leishmania amazonensis</i>	[57]
		Linalool		Essential oil at 15.0 ng/mL was able to kill 100% of the parasites in 60 min.	Nd	Adults of <i>Leishmania amazonensis</i> .	[57]
<i>Croton cajucara</i> Benth. (white morphotype)	Nd	Linalool, β -caryophyllene, Germacrene D	Nd	1490	Nd	Adults of <i>Neoechinorhynchus buttnerae</i>	[120]
<i>Croton cajucara</i> Benth. (red morphotype)	Nd	Germacrene D, germacrene A, β -elemene	Nd	1030	Nd	Adults of <i>Neoechinorhynchus buttnerae</i>	[120]

Table 7. Cont.

Species	Yield (%)	Main Components ^a	M/S/P	IC ₅₀ (µg/mL)	SI ^b	Organisms	Ref.
<i>Croton jacobinensis</i> Müll. Arg.	0.2 to 3	Caryophyllene oxide, spathulenol, germacrene B	M: 0 S: 91.64	23.79 22.06 17.69	>4.2 >4.53 >5.65	Promastigotes of <i>Leishmania</i> (V.) <i>braziliensis</i> Promastigotes of <i>Leishmania</i> (L.) <i>amazonensis</i> Promastigotes of <i>Leishmania</i> (L.) <i>chagasi</i>	[119]
<i>Croton linearis</i> Jacq.	1.6	Guaiol	M: 4.89 S: 90.06	20.0 13.8 197.26	4 6.46 1.55	Promastigotes of <i>Leishmania amazonensis</i> Amastigotes of <i>Leishmania amazonensis</i> Promastigotes of <i>Trypanosoma cruzi</i>	[121] [121] [121]
				% Inhibition infection (10 µg/mL): 13.32	Nd	Amastigotes of <i>Trypanosoma cruzi</i>	[121]
<i>Croton linearis</i> Jacq.	0.9% (v/w)	1,8-Cineole, α-pinene, sabinene	M: 75.89 S: 24.11	21.4 18.9	2 3	Promastigotes of <i>Leishmania amazonensis</i> Amastigotes of <i>Leishmania amazonensis</i>	[122] [122]
<i>Croton macrostachyus</i> Hochst. ex Delile	0.038	Benzyl benzoate, linalool, γ-muurolene	Ar: 52.5 M: 11.6 S: 34.9	MIC = 0.08 µL/mL 20.00 nL/mL MIC = 0.16 µL/mL 6.66 nL/mL	Nd 0.5 Nd 1.5	Promastigotes of <i>Leishmania donovani</i> Amastigotes of <i>Leishmania donovani</i> Promastigotes of <i>Leishmania aethiopica</i> Amastigotes of <i>Leishmania aethiopica</i>	[123] [123] [123] [123]
<i>Croton nepetifolius</i> Baill.	0.2 to 3	Methyl eugenol, β-caryophyllene, 1,8-cineole, germacrene B, 3,5-dimethoxytoluene β-	M: 14.02 S: 29.18 P: 39.63	9.87 9.08 14.80	>10.13 >11.01 >6.76	Promastigotes of <i>Leishmania</i> (V.) <i>braziliensis</i> Promastigotes of <i>Leishmania</i> (L.) <i>amazonensis</i> Promastigotes of <i>Leishmania</i> (L.) <i>chagasi</i>	[119]
<i>Croton piauhiensis</i> Mull. Arg.	0.04	Caryophyllene, caryophyllene oxide, limonene, τ-muurolol, p-cymene, bicyclogermacrene	M:39.57 S: 58.85	1.70 13.79	Nd Nd	Promastigotes of <i>Leishmania infantum</i> Axenic amastigotes of <i>Leishmania infantum</i>	[124] [124]
<i>Croton pulegioidorus</i> Baill.	0.27	Ascaridole, p-cymene, camphor, isoascaridole	M: 92.9 S: 0	0.05 2.33	Nd Nd	Promastigotes of <i>Leishmania infantum</i> Axenic amastigotes of <i>Leishmania infantum</i>	[124] [124]
<i>Croton rudolphianus</i> Müll. Arg.	0.96	β-Caryophyllene, bicyclogermacrene, δ-cadinene, germacrene D	M: 8.98 S: 50.94	14.81	Nd	<i>Schistosoma mansoni</i> cercariae	[115]

Table 7. Cont.

Species	Yield (%)	Main Components ^a	M/S/P	IC ₅₀ (µg/mL)	SI ^b	Organisms	Ref.
		7-hydroxycalamenene ^S		IC ₅₀ : 66.7. MIC: 250	>7.5	Promastigote forms <i>Leishmania chagasi</i>	[125]
<i>Croton sincorensis</i> Mart. ex Müll. Arg.	0.2 to 3	Caryophyllene oxide, β-eudesmol, spathulenol, hedycaryol, globulol, humulene epoxide II, viridiflorol, 1,8-cineole	M: 8.24 S: 77.92	27.03 14.16 13.05	>3.7 >7.06 >7.66	Promastigotes of <i>Leishmania (V.) braziliensis</i> Promastigotes of <i>Leishmania (L.) amazonensis</i> Promastigotes of <i>Leishmania (L.) chagasi</i>	[119]
<i>Croton zehntneri</i> Pax and K. Hoffm.	Nd	(<i>E</i>)-Anethole, anisaldehyde, estragole, anisyl acetate	Nd	550 (Ovicidal)	Nd	<i>Haemonchus contortus</i>	[28]
	Nd	(<i>Eanisaldehyde, estragole, anisyl acetate</i>	Nd	1170 (Larvicidal)	Nd	<i>Haemonchus contortus</i>	[28]
<i>Croton zehntneri</i> Pax and K. Hoffm.	Nd	(<i>E</i> -Anethole, estragole, germacrene B		740 (Ovicidal)	Nd	<i>Haemonchus contortus</i>	[28]
	Nd			1370 (Larvicidal)	Nd	<i>Haemonchus contortus</i>	[28]

^a: The order of the compounds is sorted by percentage from high to low and greater than 5.0%. ^b: SI: LC₅₀ cytotoxicity/LC₅₀ parasitic toxicity. Ar: aromatic, M: monoterpenoids, S: sesquiterpenoids, P: phenylpropanoids. Nd = not determined.

Table 8. Summary of antiparasitic activities of essential oil components.

Compound	IC ₅₀ /EC ₅₀ /LC ₅₀ (µg/mL)	Parasites	SI ^a	Ref.
<i>(E)</i> -Anethole	690	Eggs of <i>Haemonchus contortus</i>	Nd	[28]
	2110	Larvae of <i>Haemonchus contortus</i>	Nd	[28]
Ascaridole	0.1 ± 0.01	Promastigotes of <i>Leishmania amazonensis</i>	4	[126]
	0.3 ± 0.05	Amastigotes of <i>Leishmania amazonensis</i>	11	[126]
	0.1 ± 0.01	Promastigotes of <i>Leishmania amazonensis</i>	4	[127]
	Combination 20:80 mg/kg of ascaridole—carvacrol showed lower (<i>p</i> < 0.05) lesion size and parasite burden compared with control groups in in vivo testing on BALB/c mice.	<i>Leishmania amazonensis</i>	Nd	[127]
α-Asarone	20.19	Bloodstream forms of <i>Trypanosoma brucei brucei</i>	5.21	[128]
Camphor	>100	Bloodstream forms of <i>Trypanosoma brucei brucei</i>	Nd	[129]
	IC ₅₀ > 100	Promastigotes of <i>Phytomonas davidi</i>	Nd	[130]
	37.39	Bloodstream forms of <i>Trypanosoma brucei brucei</i>	>6.69	[128]
	5.55	Promastigotes of <i>Leishmania infantum</i>	4.56	[131]
	7.90	Promastigotes of <i>Leishmania major</i>	3.20	[131]

Table 8. Cont.

Compound	IC ₅₀ /EC ₅₀ /LC ₅₀ (µg/mL)	Parasites	SI ^a	Ref.
β-Caryophyllene	12.8	Erythrocytic stages <i>Plasmodium falciparum</i>	4.86	[132]
	28.9	Bloodstream forms of <i>Trypanosoma brucei rhodesiense</i>	2.15	[132]
	50.1	Trypomastigote forms (mammalian stage) of <i>Trypanosoma cruzi</i>	1.24	[132]
	52.4	Amastigotes (the clinically relevant form) of <i>Leishmania donovani</i>	1.19	[132]
	96 µM	Promastigotes of <i>Leishmania amazonensis</i>	Nd	[133]
	13.78	Bloodstream forms of <i>Trypanosoma brucei brucei</i>	1.40	[128]
	1.06	Promastigotes of <i>Leishmania infantum</i>	20.82	[131]
	1.33	Promastigotes of <i>Leishmania major</i>	16.59	[131]
	2.89	Epimastigotes of <i>Trypanosoma cruzi</i>	12.93	[134]
	24.54	Intracellular amastigotes infecting Vero cells of <i>Trypanosoma cruzi</i>	Nd	[134]
	24.02	Promastigotes of <i>Leishmania (Leishmania) infantum</i>	143.85	[134]
	53.39	Intracellular amastigotes infecting THP-1 cells of <i>Leishmania (Leishmania) infantum</i>	Nd	[134]
	Caryophyllene oxide	4.9	Promastigotes of <i>Leishmania amazonensis</i>	0.92
4.4		Amastigotes of <i>Leishmania amazonensis</i>	1.0	[126]
IC ₅₀ > 100		Promastigotes of <i>Phytomonas davidi</i>	Nd	[130]
17.70		Bloodstream forms of <i>Trypanosoma brucei brucei</i>	2.14	[128]
1,8-Cineole	4.9	Promastigotes of <i>Leishmania amazonensis</i>	Nd	[127]
	At 200 µg/mL it killed 100% of protoscoleces after 30 min.	Protoscoleces of <i>Echinococcus granulosus</i>	Nd	[135]
	568.1	Promastigotes of <i>Leishmania amazonensis</i>	>0.18	[136]
	>100	Bloodstream forms of <i>Trypanosoma brucei brucei</i>	Nd	[129]
	IC ₅₀ > 100	Promastigotes of <i>Phytomonas davidi</i>	Nd	[130]
	83.15	Bloodstream forms of <i>Trypanosoma brucei brucei</i>	>3.00	[128]
	Inactive	Promastigotes of <i>Leishmania infantum</i>	Nd	[137]
	Inactive	Promastigotes of <i>Leishmania tropica</i>	Nd	[137]
	Inactive	Promastigotes of <i>Leishmania major</i>	Nd	[137]
	53.40	Promastigotes of <i>Leishmania infantum</i>	5.74	[131]
	74.80	Promastigotes of <i>Leishmania major</i>	4.10	[131]
	0.63	Epimastigotes of <i>Trypanosoma cruzi</i>	63.49	[134]
	>100	Intracellular amastigotes infecting Vero cells of <i>Trypanosoma cruzi</i>	Nd	[134]
>100	Promastigotes of <i>Leishmania (Leishmania) infantum</i>	Nd	[134]	
>100	Intracellular amastigotes infecting THP-1 cells of <i>Leishmania (Leishmania) infantum</i>	Nd	[134]	
p-Cymene	>20	Erythrocytic stages <i>Plasmodium falciparum</i>	4.5	[132]
	45.0	Bloodstream forms of <i>Trypanosoma brucei rhodesiense</i>	2.0	[132]
	>90	Trypomastigote forms (mammalian stage) of <i>Trypanosoma cruzi</i>	Nd	[132]
	>90	Amastigotes (the clinically relevant form) of <i>Leishmania donovani</i>	Nd	[132]
	>1000	Promastigotes of <i>Leishmania amazonensis</i>	Nd	[136]
	76.32	Bloodstream of <i>Trypanosoma brucei brucei</i>	>0.66	[138]
	IC ₅₀ > 100	Promastigotes of <i>Phytomonas davidi</i>	Nd	[130]
	156.17	Promastigotes of <i>Leishmania infantum</i>	Nd	[131]
	219.17	Promastigotes of <i>Leishmania major</i>	Nd	[131]

Table 8. Cont.

Compound	IC ₅₀ /EC ₅₀ /LC ₅₀ (µg/mL)	Parasites	SI ^a	Ref.	
(–)-α-Bisabolol	20 µM	Promastigotes of <i>Trypanosoma cruzi</i>	26.5	[139]	
	285 µM	Epimastigote of <i>Trypanosoma cruzi</i>	2.05	[139]	
	Topical treatment at 2.5% reduced lesion thickness to 56% and had a higher efficacy than the reference control, meglumine antimoniate.	<i>Leishmania tropica</i>	Nd	[117]	
Borneol	5.9	Amastigotes of <i>Leishmania amazonensis</i>	5.41	[140]	
	4.8	Amastigotes of <i>Leishmania infantum</i>	6.65	[140]	
	>20	Erythrocytic stages <i>Plasmodium falciparum</i>	4.5	[132]	
	24.3	Bloodstream forms of <i>Trypanosoma brucei rhodesiense</i>	3.70	[132]	
	>90	Trypomastigote forms (mammalian stage) of <i>Trypanosoma cruzi</i>	Nd	[132]	
	52.1	Amastigotes (the clinically relevant form) of <i>Leishmania donovani</i>	1.73	[132]	
	>100	Bloodstream forms of <i>Trypanosoma brucei brucei</i>	Nd	[129]	
	Inactive	Promastigotes of <i>Leishmania infantum</i>	Nd	[137]	
	Inactive	Promastigotes of <i>Leishmania tropica</i>	Nd	[137]	
	Inactive	Promastigotes of <i>Leishmania major</i>	Nd	[137]	
Eugenol	82.9	Promastigotes of <i>Leishmania amazonensis</i>	Nd	[136]	
	>100	Bloodstream forms of <i>Trypanosoma brucei brucei</i>	Nd	[129]	
	60.4	Amastigotes of <i>Leishmania braziliensis</i>	1.3	[141]	
	43.8	Amastigotes of <i>Trypanosoma cruzi</i>	1.8	[141]	
	665.6	Amastigotes of <i>Plasmodium falciparum</i>	0.12	[141]	
	37.20	Bloodstream forms of <i>Trypanosoma brucei brucei</i>	2.50	[128]	
	80	Promastigote forms of <i>Leishmania amazonensis</i>	Nd	[142]	
	Estragole	32.08	Bloodstream forms of <i>Trypanosoma brucei brucei</i>	>7.80	[128]
		α-Humulene	<i>Leishmania donovani</i>	Nd	[143]
	R-(+)-Limonene	4.24	Bloodstream of <i>Trypanosoma brucei brucei</i>	>11.79	[138]
35.55		Bloodstream forms of <i>Trypanosoma brucei brucei</i>	4.50	[128]	
14.1		Trypomastigote forms of <i>Trypanosoma cruzi</i>	Nd	[144]	
33.7		Epimastigotes of <i>Trypanosoma cruzi</i>	Nd	[144]	
At a concentration of 43.75 µg/mL it produced decreased motility.		Adult worms of <i>Schistosoma mansoni</i>	Nd	[145]	
Limonene	278 µM	Promastigotes of <i>Leishmania amazonensis</i>	Nd	[133]	
	252.0 µM.	Promastigotes of <i>Leishmania amazonensis</i>			
	147.0 µM	Amastigote of <i>Leishmania amazonensis</i>			
	354.0 µM	Promastigotes of <i>Leishmania major</i>			
	185.0 µM	Promastigotes of <i>Leishmania braziliensis</i>			
	201.0 µM	Promastigotes of <i>chagasi</i>			
	38.71	Epimastigotes of <i>Trypanosoma cruzi</i>	>100	[134]	
	145.94	Intracellular amastigotes infecting Vero cells of <i>Trypanosoma cruzi</i>	Nd	[134]	
	>100	Promastigotes of <i>Leishmania (Leishmania) infantum</i>	Nd	[134]	
	>100	Intracellular amastigotes infecting THP-1 cells of <i>Leishmania (Leishmania) infantum</i>	Nd	[134]	
(–)-Linalool	>20	Erythrocytic stages <i>Plasmodium falciparum</i>	4.5	[132]	
	3.6	Bloodstream forms of <i>Trypanosoma brucei rhodesiense</i>	25	[132]	

Table 8. Cont.

Compound	IC ₅₀ /EC ₅₀ /LC ₅₀ (µg/mL)	Parasites	SI ^a	Ref.	
(±)-Linalool	>90	Trypomastigote forms (mammalian stage) of <i>Trypanosoma cruzi</i>	Nd	[132]	
	86.3	Amastigotes (the clinically relevant form) of <i>Leishmania donovani</i>	1.04	[132]	
	276.2	Promastigotes of <i>Leishmania amazonensis</i>	Nd	[136]	
	39.32	Bloodstream forms of <i>Trypanosoma brucei brucei</i>	5.20	[128]	
	Linalool	430	Promastigotes of <i>Leishmania braziliensis</i>	16.93	[146]
		Nd	Amastigote of <i>Leishmania braziliensis</i>	Nd	[146]
	Myrcene	>100	Bloodstream forms of <i>Trypanosoma brucei brucei</i>	Nd	[129]
		198.6	Epimastigote of <i>Trypanosoma cruzi</i>	>5	[147]
		249.6	Intracellular amastigote of <i>Trypanosoma cruzi</i>	>4	[147]
		IC ₅₀ > 100	Promastigotes of <i>Phytomonas davidi</i>	Nd	[130]
		30.16	Epimastigotes of <i>Trypanosoma cruzi</i>	26.33	[134]
		>100	Intracellular amastigotes infecting Vero cells of <i>Trypanosoma cruzi</i>	Nd	[134]
		>100	Promastigotes of <i>Leishmania (Leishmania) infantum</i>	Nd	[134]
		>100	Intracellular amastigotes infecting THP-1 cells of <i>Leishmania (Leishmania) infantum</i>	Nd	[134]
0.31		Trypomastigote forms of <i>Trypanosoma cruzi</i>	2.7	[148]	
0.0043		Promastigotes of <i>Leishmania amazonensis</i>	Nd	[57]	
Nerolidol	0.0155	Amastigote of <i>Leishmania amazonensis</i>	Nd	[57]	
	>20	Erythrocytic stages <i>Plasmodium falciparum</i>	4.5	[132]	
	22	Bloodstream forms of <i>Trypanosoma brucei rhodesiense</i>	4.10	[132]	
	>90	Trypomastigote forms (mammalian stage) of <i>Trypanosoma cruzi</i>	Nd	[132]	
	48.2	Amastigotes (the clinically relevant form) of <i>Leishmania donovani</i>	1.87	[132]	
	2.24	Bloodstream of <i>Trypanosoma brucei brucei</i>	>22.32	[138]	
	74.3	Promastigotes of <i>Leishmania braziliensis</i>	20.19	[146]	
	47.5	Amastigote of <i>Leishmania braziliensis</i>	2.20	[146]	
(Z)-Nerolidol	85	Promastigotes of <i>Leishmania amazonensis</i>	Nd	[118]	
	67	Amastigote of <i>Leishmania amazonensis</i>	Nd	[118]	
	74	Promastigotes of <i>Leishmania braziliensis</i>	Nd	[118]	
	75	Promastigotes of <i>Leishmania chagasi</i>	Nd	[118]	
		<i>Leishmania-amazonensis</i> -infected BALB/c mice were treated with intraperitoneal doses of 100 mg/kg/day for 12 days or topically with 5 or 10% ointments for 4 weeks, and both resulted in significant reductions in lesion sizes.	<i>Leishmania amazonensis</i>	Nd	[118]
	15.78	Bloodstream forms of <i>Trypanosoma brucei brucei</i>	1.87	[128]	
	α-Phellandrene	9.2	Bloodstream of <i>Trypanosoma brucei</i>	2.9	[149]
		32.8	Promastigotes of <i>Leishmania major</i>	0.8	[149]
	α-Pinene	10.7	Erythrocytic stages <i>Plasmodium falciparum</i>	8.21	[132]
		0.42	Bloodstream forms of <i>Trypanosoma brucei rhodesiense</i>	209.05	[132]
	>90	Trypomastigote forms (mammalian stage) of <i>Trypanosoma cruzi</i>	Nd	[132]	
	81.9	Amastigotes (the clinically relevant form) of <i>Leishmania donovani</i>	1.07	[132]	
	4.1	Bloodstream form of <i>Trypanosoma brucei</i>	0.6	[149]	
	55.3	Promastigotes of <i>Leishmania major</i>	<0.1	[149]	

Table 8. Cont.

Compound	IC ₅₀ /EC ₅₀ /LC ₅₀ (µg/mL)	Parasites	SI ^a	Ref.
β-Pinene	2.9	Bloodstream forms of <i>Trypanosoma brucei brucei</i>	>34.5	[129]
	1.145	Tachyzoites of <i>Toxoplasma gondii</i> RH strain	126	[150]
	17.60	Promastigotes of <i>Leishmania infantum</i>	13.08	[131]
	19.80	Promastigotes of <i>Leishmania major</i>	11.63	[131]
	2.74	Epimastigotes of <i>Trypanosoma cruzi</i>	11.57	[134]
	1.92	Intracellular amastigotes infecting Vero cells of <i>Trypanosoma cruzi</i>	Nd	[134]
	45.94	Promastigotes of <i>Leishmania (Leishmania) infantum</i>	57.25	[134]
	>100	Intracellular amastigotes infecting THP-1 cells of <i>Leishmania (Leishmania) infantum</i>	Nd	[134]
	47.37	Bloodstream form of <i>Trypanosoma brucei brucei</i>	>1.06	[138]
	54.8	Bloodstream form of <i>Trypanosoma brucei</i>	0.5	[149]
Sabinene	200.1	Promastigotes of <i>Leishmania major</i>	0.1	[149]
	0.326	Tachyzoites of <i>Toxoplasma gondii</i> RH strain	61	[150]
	50 < IC ₅₀ < 100	Promastigotes of <i>Phytomonas davidi</i>	Nd	[130]
	17.7	Bloodstream of <i>Trypanosoma brucei</i>	1.3	[149]
α-Terpinene	126.6	Promastigotes of <i>Leishmania major</i>	0.2	[149]
	3.7	Erythrocytic stages <i>Plasmodium falciparum</i>	22.89	[132]
γ-Terpinene	3.1	Bloodstream forms of <i>Trypanosoma brucei rhodesiense</i>	27.32	[132]
	49.1	Trypomastigote forms (mammalian stage) of <i>Trypanosoma cruzi</i>	1.73	[132]
	10.5	Amastigotes (the clinically relevant form) of <i>Leishmania donovani</i>	8.07	[132]
	IC ₅₀ > 100	Promastigotes of <i>Phytomonas davidi</i>	Nd	[130]
	>20	Erythrocytic stages <i>Plasmodium falciparum</i>	4.5	[132]
	32.9	Bloodstream forms of <i>Trypanosoma brucei rhodesiense</i>	2.74	[132]
	>90	Trypomastigote forms (mammalian stage) of <i>Trypanosoma cruzi</i>	Nd	[132]
Terpinen-4-ol	>90	Amastigotes (the clinically relevant form) of <i>Leishmania donovani</i>	Nd	[132]
	>20	Erythrocytic stages <i>Plasmodium falciparum</i>	2.17	[132]
	0.66	Bloodstream forms of <i>Trypanosoma brucei rhodesiense</i>	65.61	[132]
	46.8	Trypomastigote forms (mammalian stage) of <i>Trypanosoma cruzi</i>	0.93	[132]
	68.7	Amastigotes (the clinically relevant form) of <i>Leishmania donovani</i>	0.66	[132]
(–)-Terpinen-4-ol	0.02	Bloodstream form of <i>Trypanosoma brucei</i>	1025.0	[149]
	335.9	Promastigotes of <i>Leishmania major</i>	0.1	[149]
	39.51	Bloodstream forms of <i>Trypanosoma brucei brucei</i>	2.64	[128]
	α-Terpineol	>20	Erythrocytic stages <i>Plasmodium falciparum</i>	1.62
0.56		Bloodstream forms of <i>Trypanosoma brucei rhodesiense</i>	57.68	[132]
61.0		Trypomastigote forms (mammalian stage) of <i>Trypanosoma cruzi</i>	0.53	[132]
	75.9	Amastigotes (the clinically relevant form) of <i>Leishmania donovani</i>	0.43	[132]

^a: SI: LC₅₀ cytotoxicity/LC₅₀ parasitic. Nd: not determined.

2.5. Antimicrobial Activity

The essential oil *C. hirtus* exhibited strong antimicrobial activity with MIC values for *E. faecalis* of 8.0 and 16.0 µg/mL for *S. aureus*, *B. cereus*, *E. coli*, and *S. enterica* (Table 9). The compound β-caryophyllene showed strong antimicrobial activity [151], whereas

β -elemene in contrast showed weak antimicrobial activity (MIC > 1000 $\mu\text{g}/\text{mL}$) [151]. The essential oils from the leaves and stems of *Orthosiphon stamineus*, which are characterized by the main components β -caryophyllene (24.0–35.1%), α -humulene (14.2–18.4%), and β -elemene (11.1–8.5%), showed strong antimicrobial activity [152]. *Stachys officinalis* essential oil, which is characterized by the main components germacrene D (19.9%), β -caryophyllene (14.1%), and α -humulene (7.5%), exhibited very strong antimicrobial activity [153]. The main components showed weaker antimicrobial activity than essential oils themselves, which suggests synergistic effects between them.

Table 9. Antimicrobial activity of *Croton hirtus* essential oil and major compounds (MIC, IC₅₀, and $\mu\text{g}/\text{mL}$).

Material	Gram-Positive				Gram-Negative		Yeast
	<i>E. faecalis</i> ATCC29212	<i>S. aureus</i> ATCC25923	<i>B. cereus</i> ATCC13245	<i>E. coli</i> ATCC25922	<i>P. aeruginosa</i> ATCC27853	<i>S. enterica</i> ATCC13076	<i>C. albicans</i> ATCC10231
	MIC ($\mu\text{g}/\text{mL}$)						
Essential oil	8	16	16	16	Na	16	Na
β -Caryophyllene	32	64	64	64	Na	64	Na
α -Humulene	8	16	32	32	Na	16	Na
Caryophyllene oxide	8	32	32	32	Na	32	Na
Streptomycin	256	256	128	32	256	128	Nt
Kanamycin	128	4	8	128	64	16	Nt
Tetracycline	4	16	64	8	256	64	Nt
Nystatin	Nt	Nt	Nt	Nt	Nt	Nt	4
Cyclohexamide	Nt	Nt	Nt	Nt	Nt	Nt	32
	IC ₅₀ ($\mu\text{g}/\text{mL}$)						
Essential oil	3.12 \pm 1.36	5.34 \pm 0.98	5.23 \pm 0.21	5.67 \pm 1.45	Na	5.98 \pm 0.09	Na
β -Caryophyllene	9.35 \pm 2.34	21.23 \pm 1.35	18.56 \pm 1.32	21.46 \pm 1.34	Na	20.15 \pm 1.48	Na
α -Humulene	3.24 \pm 2.12	5.34 \pm 1.34	9.35 \pm 0.36	10.45 \pm 1.56	Na	5.23 \pm 0.08	Na
Caryophyllene oxide	2.67 \pm 2.00	9.56 \pm 1.43	9.32 \pm 0.21	12.56 \pm 2.56	Na	9.34 \pm 0.91	Na
Streptomycin	50.34 \pm 2.32	45.24 \pm 1.36	20.45 \pm 0.39	9.45 \pm 0.35	68.67 \pm 1.89	45.67 \pm 2.30	Nt
Cyclohexamide	Nt	Nt	Nt	Nt	Nt	Nt	10.46 \pm 0.32

Na: Not active; Nt: not tested.

The antimicrobial activities of the essential oils of *Croton* species are summarized in Table 10. It is noteworthy that there are reports on the synergism of essential oils and antibiotics, although essential oils alone or antibiotics alone have shown weakness.

Table 10. Summary of antimicrobial activity of *Croton* spp. essential oils.

Species	Yield (%)	Main Components ^a	M/S/P/B or Other (%)	MIC or IC ₅₀ ($\mu\text{g}/\text{mL}$)	Organisms	Ref.
<i>Croton adamantinus</i> Müll. Arg.	0.6	Methyl eugenol, 1,8-cineole, bicyclgermacrene, β -caryophyllene.	M: 27.66 S: 32.42 P: 14.81	Synergistic effect with gentamicin.	<i>Enterobacter aerogenes</i> , <i>Pseudomonas aeruginosa</i> , Methicillin-resistant <i>Staphylococcus aureus</i> .	[154]
				Synergistic effect with amoxicillin + clavulanate.	Methicillin-resistant <i>Staphylococcus aureus</i> .	[154]
				Synergistic effect with cefepime.	<i>Enterobacter aerogenes</i> , Methicillin-resistant <i>Staphylococcus aureus</i> .	[154]

Table 10. Cont.

Species	Yield (%)	Main Components ^a	M/S/P/B or Other (%)	MIC or IC ₅₀ (µg/mL)	Organisms	Ref.
<i>Croton adipatus</i> Kunth	0.47 ± 0.01	β-Myrcene; α-thujene; limonene; α-phellandrene, β-elemene.	M: 72.73 S: 18.82	>1000	<i>Staphylococcus aureus</i>	[155]
				286.4	<i>Bacillus subtilis</i>	
				>1000	<i>Escherichia coli</i>	
				>1000	<i>Pseudomonas aeruginosa</i>	
				572.8	<i>Candida albicans</i>	
<i>Croton argyrophyllus</i> Kunth	Nd	Bicyclogermacrene, β-pinene, spathulenol, β-caryophyllene, β-phellandrene.	M: 27.94 S: 62.14	10	<i>Bacillus cereus</i>	[156]
				25	<i>Bacillus subtilis</i>	
				25	<i>Staphylococcus aureus</i>	
				25	<i>Escherichia coli</i>	
				25	<i>Pseudomonas aeruginosa</i>	
				Nd	<i>Candida albicans</i>	
				Nd	<i>Candida glabrata</i>	
				Nd	<i>Candida parapsilosis</i>	
<i>Croton argyrophyllus</i> Kunth	0.1 to 0.7	Bicyclogermacrene, <i>epi</i> -longipinanol, spathulenol.	M: 0 S: 99.17–100	312	<i>Staphylococcus aureus</i>	[157]
				NI	<i>Escherichia coli</i>	
				0.1 to 0.7	<i>Staphylococcus aureus</i>	[157]
				0.1 to 0.7	<i>Staphylococcus aureus</i>	[157]
<i>Croton argyrophyllus</i> Kunth	0.38	α-Pinene, bicyclogermacrene	M: 68.5 S: 29.87	≥1024	<i>Escherichia coli</i>	
				156	<i>Staphylococcus aureus</i>	[157]
				NI	<i>Escherichia coli</i>	
				Synergistic effect with chlorhexidine.	<i>Streptococcus mutans</i> <i>Streptococcus salivarius</i> <i>Streptococcus sanguinis</i>	[158]
<i>Croton argyrophyllodes</i> Müll. Arg. (syn <i>Croton tricolor</i> Baill.)	Nd	Spathulenol, bicyclogermacrene, 1,8-cineole, β-elemene, β-caryophyllene, α-pinene.		NI	<i>Candida albicans</i>	[56]
				NI	<i>Candida tropicalis</i>	
				9–19	<i>Microsporium canis</i>	
<i>Croton argyrophyllodes</i> Müll. Arg	0.5	Bicyclogermacrene, spathulenol, β-caryophyllene, myrcene, α-pinene, β-phellandrene, 1,8-cineole.	M: 48.22 S: 47.7	97–195	Forty-nine clinical strains of <i>Mycobacteria tuberculosis</i>	[159]
				97	Standard strain H ₃₇ RV of <i>Mycobacteria tuberculosis</i>	[159]

Table 10. Cont.

Species	Yield (%)	Main Components ^a	M/S/P/B or Other (%)	MIC or IC ₅₀ (µg/mL)	Organisms	Ref.
<i>Croton blanchetianus</i> Baill.	Nd	Caryophyllene oxide, δ-amorphene, τ-muurolol, 1,8-cineole.	M: 10.05 S: 38.84	Inhibition of planktonic cells growth at 50 µg/mL: 78%. Inhibition of planktonic cells growth at 50 µg/mL: 75%.	<i>Candida albicans</i> <i>Candida parapsilosis</i>	[160]
<i>Croton blanchetianus</i> Baill.	7.5	α-Pinene, eucalyptol, sativene, β-caryophyllene, bicyclogermacrene, spathulenol.	M: 35.55–38.07 S: 55.45–55.95	Inactivated at a concentration of 900 µg/mL	<i>Listeria monocytogenes</i> <i>Staphylococcus aureus</i> <i>Leuconostoc mesenteroides</i> <i>Weissella viridescens</i>	[161]
<i>Croton cajucara</i> Benth.	0.4	Linalool	Nd	22.3 13.8 40.1 31.2 33.4 13.4	<i>Lactobacillus casei</i> <i>Streptococcus sobrinus</i> <i>Streptococcus mutans</i> <i>Porphyromonas gingivalis</i> <i>Staphylococcus aureus</i> <i>Candida albicans</i>	[162]
<i>Croton cajucara</i> Benth.	Nd	7-Hydroxycalamenene, δ-cadinene, γ-cadinene, germacrene B, τ-cadinol, caryophyllene oxide.	M: 0 S: 97.59	12.21	<i>Absidia cylindospora</i>	[163]
<i>Croton cajucara</i> Benth.	0.8	Linalool, 7-hydroxycalamenene, β-caryophyllene, germacrene D.	Dominated by Sesquiterpenes	Inhibition growth zones (in cm): 0.9–1.3.	<i>Candida albicans</i>	[164]
			Dominated by Sesquiterpenes	Inhibition growth zones (in cm): 0.5–1.6.	<i>Staphylococcus aureus</i>	[164]
	1.0	Linalool, nerolidol, β-caryophyllene, bicyclogermacrene germacrene D.	Dominated by Sesquiterpenes	Inhibition growth zones (in cm): 0.9–1.3	<i>Candida albicans</i>	[164]
		Linalool, nerolidol, β-caryophyllene, bicyclogermacrene germacrene D.	Dominated by Sesquiterpenes	Inhibition growth zones (in cm): 0.2–1.0	<i>Staphylococcus aureus</i>	[164]
<i>Croton cajucara</i> Benth.	0.65	7-Hydroxycalamenene, α-pinene, linalool.	Nd	39.06 4.88 0.019 1.22 Nd Nd	<i>Mycobacterium smegmatis</i> <i>Mycobacterium tuberculosis</i> Methicillin-resistant <i>Staphylococcus aureus</i> <i>Candida albicans</i> <i>Mucor circinelloides</i> <i>Rhizopus oryzae</i>	[165]
		α-Pinene, linalool, β-caryophyllene.	Nd	5000	<i>Mycobacterium smegmatis</i>	[165]

Table 10. Cont.

Species	Yield (%)	Main Components ^a	M/S/P/B or Other (%)	MIC or IC ₅₀ (μg/mL)	Organisms	Ref.
				4.88	<i>Mycobacterium tuberculosis</i>	
				Na	Methicillin-resistant <i>Staphylococcus aureus</i>	
				1250	<i>Candida albicans</i>	
				Nd	<i>Mucor circinelloides</i>	
				Nd	<i>Rhizopus oryzae</i>	
		7-Hydroxycalamenene (28.4%), linalool (11.0%).	Nd	78.12	<i>Mycobacterium smegmatis</i>	[165]
				4.88	<i>Mycobacterium tuberculosis</i>	
				0.019	Methicillin-resistant <i>Staphylococcus aureus</i>	
				156.25	<i>Candida albicans</i>	
				Nd	<i>Mucor circinelloides</i>	
				Nd	<i>Rhizopus oryzae</i>	
		7-Hydroxycalamenene (30.9%), linalool (9.9%).	Nd	156.25	<i>Mycobacterium smegmatis</i>	[165]
				4.88	<i>Mycobacterium tuberculosis</i>	
				0.004	Methicillin-resistant <i>Staphylococcus aureus</i>	
				0.001	<i>Candida albicans</i>	
				Nd	<i>Mucor circinelloides</i>	
				Nd	<i>Rhizopus oryzae</i>	
		7-Hydroxycalamenene (32.9%), linalool (13.2%).	Nd	156.25	<i>Mycobacterium smegmatis</i>	[165]
				4.88	<i>Mycobacterium tuberculosis</i>	
				0.001	Methicillin-resistant <i>Staphylococcus aureus</i>	
				0.38	<i>Candida albicans</i>	
				3.63×10^{-8}	<i>Mucor circinelloides</i>	
				0.152	<i>Rhizopus oryzae</i>	
		7-Hydroxycalamenene.	S	39.06	<i>Mycobacterium smegmatis</i>	[165]
				312.5	<i>Mycobacterium tuberculosis</i>	
				39.06	Methicillin-resistant <i>Staphylococcus aureus</i>	
				78.125	<i>Candida albicans</i>	
				19.53	<i>Mucor circinelloides</i>	
				39.06	<i>Rhizopus oryzae</i>	
<i>Croton campestris</i> A. St.Hil.	0.04 (leaves)	β-Caryophyllene, bicyclogermacrene, limonene, τ-cadinol.	M: 28.1 S: 67.6	≥512	<i>Escherichia coli</i>	[9]

Table 10. Cont.

Species	Yield (%)	Main Components ^a	M/S/P/B or Other (%)	MIC or IC ₅₀ (µg/mL)	Organisms	Ref.
				≥512	<i>Staphylococcus aureus</i>	
				≥1024	<i>Shigella flexneri</i>	
				≥1024	<i>Pseudomonas aeruginosa</i>	
				≥1024	<i>Bacillus cereus</i>	
	0.02 (branches)	Spathulenol, bicyclogermacrene, β-caryophyllene, terpinen-4-ol, murolo-4,10(14)-dien-1-ol.	M: 25.1 S: 67.8	≥512	<i>Escherichia coli</i>	[9]
				≥128	<i>Staphylococcus aureus</i>	
				≥512	<i>Shigella flexneri</i>	
				≥512	<i>Pseudomonas aeruginosa</i>	
				≥256	<i>Bacillus cereus</i>	
				Synergistic effect with gentamicin	<i>Staphylococcus aureus</i> , <i>Shigella flexneri</i> .	
				Synergistic effect with neomycin.	<i>Pseudomonas aeruginosa</i> , <i>Bacillus cereus</i>	
				Synergistic effect with kanamycin.	<i>Staphylococcus aureus</i> , <i>Bacillus cereus</i>	
<i>Croton campestris</i> St. Hilaire.	0.40	Caryophyllene oxide, humulene oxide II.	M: 16.9 S: 75.2	1.56	<i>Staphylococcus aureus</i>	[166]
				6.25	<i>Enterococcus hirae</i>	
				6.25	<i>Candida albicans</i>	
<i>Croton ceanothifolius</i> Baill.	0.23	Bicyclogermacrene, germacrene D, β-caryophyllene, 1,10-di- <i>epi</i> -cubebol.	M: 8.7 S: 91.3	Synergistic effect with norfloxacin, gentamicin, penicillin.	<i>Staphylococcus aureus</i> , <i>Pseudomonas aeruginosa</i> , <i>Escherichia coli</i> .	[10]
<i>Croton ciliatoglandulifer</i> Ortega.	Nd	Caryophyllene oxide, cubenol, β-caryophyllene.	M: 3.5 S: 91.3	500	<i>Candida albicans</i>	[167]
<i>Croton conduplicatus</i> Kunth.		1,8-Cineole, <i>p</i> -cymene, β-caryophyllene, spathulenol.	M: 51.31 S: 44.42	256 512	Methicillin-sensitive <i>Staphylococcus aureus</i> Methicillin-resistant <i>Staphylococcus aureus</i> Methicillin-sensitive <i>Staphylococcus aureus</i> Methicillin-resistant <i>Staphylococcus aureus</i>	[168]
				Synergistic effect with ampicillin.		
<i>Croton doctoris</i> S. Moore.	0.4	β-Caryophyllene; caryophyllene oxide; α-humulene; α-selinene. β-Caryophyllene, limonene +	M: 0 S: 83.32	0.625 (<i>v/v</i>)	Streptococci group	[169]
<i>Croton ferrugineus</i> Kunth.	0.06 ± 0.02	β-phellandrene, myrcene, germacrene D, linalool, α-humulene.	M: 47.03 S: 47.63	>2000	<i>Escherichia coli</i>	[170]
				>2000	<i>Enterococcus faecalis</i>	
				2000	<i>Micrococcus luteus</i>	
				>2500	<i>Staphylococcus aureus</i>	
				1000	<i>Cándida albicans</i>	
<i>Croton ferrugineus</i> Kunth.	0.06 ± 0.001	β-Caryophyllene, limonene, β-thujene, β-myrcene, β-elemene.	M: 28.03 S: 70.26	>1000	<i>Staphylococcus aureus</i>	[155]
				72	<i>Bacillus subtilis</i>	

Table 10. Cont.

Species	Yield (%)	Main Components ^a	M/S/P/B or Other (%)	MIC or IC ₅₀ (µg/mL)	Organisms	Ref.
				>1000	<i>Escherichia coli</i>	
				>1000	<i>Pseudomonas aeruginosa</i>	
				576.2	<i>Candida albicans</i>	
<i>Croton gratissimus</i> Burch.		Sabinene, α-phellandrene, β-phellandrene, α-pinene, germacrene D.	M: 64.8 S: 27.3	1300	<i>Bacillus cereus</i>	[171]
				600	<i>Staphylococcus aureus</i>	
				200	<i>Staphylococcus faecalis</i>	
				1300	<i>Escherichia coli</i>	
				2500	<i>Proteus vulgaris</i>	
				5000	<i>Pseudomonas aeruginosa</i>	
				5000	<i>Klebsiella pneumoniae</i>	
				>10,000	<i>Proteus vulgaris</i>	
				>10,000	<i>Enterobacter cloacae</i>	
<i>Croton grewoides</i> Baill.	0.1	α-Pinene, sabinene, limonene, bicyclogermacrene, β-caryophyllene.	M: 55.56 S: 44.44	Synergistic effect with norfloxacin, tetracycline.	<i>Staphylococcus aureus</i>	[172]
<i>Croton heliotropiifolius</i> Kunth.	Nd	Limonene, α-pinene, β-caryophyllene, bicyclogermacrene, γ-terpinene.	M: 62.23 S: 35.27	NI	<i>Bacillus cereus</i>	[156]
				NI	<i>Bacillus subtilis</i>	
				NI	<i>Staphylococcus aureus</i>	
				NI	<i>Escherichia coli</i>	
				NI	<i>Pseudomonas aeruginosa</i>	
				NI	<i>Candida albicans</i>	
				NI	<i>Candida glabrata</i>	
				NI	<i>Candida parapsilosis</i>	
<i>Croton heliotropiifolius</i> Kunth (Summer, February).	0.36	β-Caryophyllene, bicyclogermacrene, 1,8-cineole, limonene.	M: 31.72 S: 64.86	500	<i>Bacillus cereus</i>	[173]
				6.25	<i>Enterococcus faecalis</i>	
				500	<i>Escherichia coli</i>	
				Nd	<i>Klebsiella pneumoniae</i>	
				500	<i>Salmonella enterica</i>	
				500	<i>Serratia marcescens</i>	
				500	<i>Shigella flexneri</i>	
				Nd	<i>Staphylococcus aureus</i>	
<i>Croton heliotropiifolius</i> Kunth (Autumn, May).	0.16	β-Caryophyllene, 1,8-cineole, limonene, bicyclogermacrene.	M: 41.12 S: 50.96	Nd	<i>Bacillus cereus</i>	[173]
				125	<i>Enterococcus faecalis</i>	
				Nd	<i>Escherichia coli</i>	
				Nd	<i>Klebsiella pneumoniae</i>	
				Nd	<i>Salmonella enterica</i>	
				500	<i>Serratia marcescens</i>	
				500	<i>Shigella flexneri</i>	
				Nd	<i>Staphylococcus aureus</i>	
<i>Croton heliotropiifolius</i> Kunth (Winter, August).	0.60	β-Caryophyllene, bicyclogermacrene, germacrene D.	M: 16.05 S: 82.39	Nd	<i>Bacillus cereus</i>	[173]

Table 10. Cont.

Species	Yield (%)	Main Components ^a	M/S/P/B or Other (%)	MIC or IC ₅₀ (µg/mL)	Organisms	Ref.
<i>Croton heliotropiifolius</i> Kunth (Spring, November).	0.24	β-Caryophyllene, bicyclogermacrene, germacrene D.	M: 6.04 S: 84.74	500	<i>Enterococcus faecalis</i>	[173]
				500	<i>Escherichia coli</i>	
				Nd	<i>Klebsiella pneumoniae</i>	
				Nd	<i>Salmonella enterica</i>	
				500	<i>Serratia marcescens</i>	
				Nd	<i>Shigella flexneri</i>	
				Nd	<i>Staphylococcus aureus</i>	
<i>Croton heliotropiifolius</i> Kunth.		β-Caryophyllene, γ-muurolene, viridiflorene.	M: 2.01 S: 77.14	Nd	<i>Bacillus cereus</i>	[174]
				500	<i>Enterococcus faecalis</i>	
				500	<i>Escherichia coli</i>	
				Nd	<i>Klebsiella pneumoniae</i>	
				500	<i>Salmonella enterica</i>	
				500	<i>Serratia marcescens</i>	
				Nd	<i>Shigella flexneri</i>	
Nd	<i>Staphylococcus aureus</i>					
<i>Croton heterocalyx</i> Baill.	0.45	Germacrene D, bicyclogermacrene, δ-elemene, β-elemene, spathulenol, linalool.	M: 13.9 S: 84.8	500	<i>Staphylococcus aureus</i>	[174]
				62.5	<i>Bacillus subtilis</i>	[174]
				>500	<i>Escherichia coli</i>	[174]
				>500	<i>Pseudomonas aeruginosa</i>	[174]
				>500	<i>Salmonella choleraesuis</i>	[174]
				>500	<i>Aspergillus niger</i> <i>Candida albicans</i> <i>Pseudomonas aeruginosa</i> <i>Escherichia coli</i> <i>Staphylococcus aureus</i>	[175]
<i>Croton hieronymi</i> Griseb.	0.07	γ-Asarone, (E)-asarone, borneol, camphor.	M: 35.4 S: 9.9 P: 37.1	Percentage of living microorganism: 0% at 100 µg/mL.	<i>Escherichia coli</i> <i>Candida albicans</i>	[176]
				Percentage of living microorganism: 50% at 1000 µg/mL.	<i>Salmonella typhimurium</i>	
				Percentage of living microorganism: 50% at 100 µg/mL.	<i>Klebsiella pneumoniae</i>	
<i>Croton hirtus</i> L' Hér.	0.60	β-caryophyllene, germacrene D, α-humulene, β-elemene.	M: 15.55 S: 77.94	>512	<i>Escherichia coli</i>	[8]
				512	<i>Staphylococcus aureus</i>	
<i>Croton limae</i> A.P. Gomes.	0.36	Cedrol, 1,8-cineole, α-pinene.	M: 42.4 S: 41	Synergistic effect with gentamicin, ceftazidime.	<i>Staphylococcus aureus</i>	[24]
				512	<i>Staphylococcus aureus</i>	
				≥1024	<i>Escherichia coli</i>	

Table 10. Cont.

Species	Yield (%)	Main Components ^a	M/S/P/B or Other (%)	MIC or IC ₅₀ (µg/mL)	Organisms	Ref.
<i>Croton lechleri</i> Müll. Arg.	0.061	Sesquicineole, α-calacorene.	M: 18.84 S: 76.82	≥1024	<i>Pseudomonas aeruginosa</i>	[177]
				≥1024	<i>Klebsiella pneumoniae</i>	
				≥1024	<i>Candida tropicalis</i>	
				≥1024	<i>C. krusei</i>	
				≥1024	<i>C. albicans</i>	
				10,100	<i>Pseudomonas aeruginosa</i>	
<i>Croton malambo</i> H. Karst.	Nd	Methyl eugenol.	M: 0.8 S: 3.3 P: 95.1	1010	<i>Klebsiella oxytoca</i>	[55]
				100	<i>Escherichia coli</i>	
				10,100	<i>Staphylococcus aureus</i> subsp. <i>aureus</i>	
				10,100	<i>Enterococcus faecalis</i>	
				10,100	<i>Micrococcus luteus</i>	
				Inhibition zones in mm from 7.0–8.0 at 10 mg/mL.	<i>Staphylococcus aureus</i> <i>Candida tropicalis</i>	
<i>Croton monteverdensis</i> Huft.	0.03	α-Pinene, β-pinene, linalool.	M: 47.9 S: 51.0	625	<i>Bacillus cereus</i>	[178,
				156	<i>Staphylococcus aureus</i>	179]
<i>Croton niveus</i> Jacq.	0.10	α-Pinene, 1,8-cineole, borneol. Methyl eugenol, bicyclogermacrene, β-caryophyllene, <i>trans</i> -α-bergamotene, 1,8-cineole, α-humulene, <i>ortho</i> -vanillin.	M: 78.3 S: 19.1	625	<i>Bacillus cereus</i>	[178,
				78	<i>Staphylococcus aureus</i>	179]
<i>Croton nepetifolius</i> Baill.				NI	<i>Candida albicans</i>	[56]
				NI >5000	<i>Candida tropicalis</i> <i>Microsporium canis</i>	
<i>Croton oblongifolius</i> Roxb.	0.9	Terpinen-4-ol; α-guaiene; α-bulnesene; β-caryophyllene; myrcene; cyclosativene. β-caryophyllene, limonene, γ-terpinene, germacrene D.	M: 40.3 S: 47.2	0.125%, <i>v/v</i>	<i>Propionibacterium acnes</i>	[180]
<i>Croton piauhiensis</i> Müll. Arg.	0.02		Nd	0.15 (<i>v/v</i>)	<i>Staphylococcus aureus</i>	[49]
				1.25 (<i>v/v</i>)	<i>Staphylococcus aureus</i> (methicillin-resistant)	
				5.0 (<i>v/v</i>)	<i>Staphylococcus epidermidis</i>	
				>5.0 (<i>v/v</i>) 5.0 (<i>v/v</i>)	<i>Pseudomonas aeruginosa</i> <i>Escherichia coli</i>	
<i>Croton pluriglandulosus</i> .	0.46	1,8-Cineole, methyleugenol, elemicin, β-caryophyllene, bicyclogermacrene, 1,3,5-trimethoxybenzene, 3,5-dimethoxytoluene.	M: 6.57 S: 24.83 B: 48.98	Synergistic effect with chlorhexidine.	<i>Streptococcus mutans</i> <i>Streptococcus salivarius</i> <i>Streptococcus sanguinis</i>	[158]

Table 10. Cont.

Species	Yield (%)	Main Components ^a	M/S/P/B or Other (%)	MIC or IC ₅₀ (µg/mL)	Organisms	Ref.
<i>Croton rhamnifolioides</i> .	Nd	Spathulenol, 1,8-cineole, <i>o</i> -cymene, α -terpineol, <i>trans</i> -caryophyllene.	M: 45.65 S: 51.06	1024 Synergistic with antibiotics aminoglycoside and β -lactam, and the antifungal polyene.	<i>Escherichia coli</i> <i>Staphylococcus aureus</i> <i>Pseudomonas aeruginosa</i> <i>Candida albicans</i> <i>Candida krusei</i> <i>Candida tropicalis</i>	[181]
<i>Croton stellulifer</i> B.L. Burt.	0.25–0.44	α -Phellandrene, <i>p</i> -cymene, linalool, α -pinene.	M: 73.5–77.4 S: 5.1–5.4	Inhibition zones in mm from 9.3–17.3.	<i>Escherichia coli</i> <i>Staphylococcus aureus</i> <i>Staphylococcus faecalis</i> <i>Staphylococcus epidermidis</i> <i>Proteus vulgaris</i> <i>Cryptococcus neoformans</i> <i>Cladosporium cladosporioides</i> <i>Aspergillus fumigatus</i>	[182]
<i>Croton tetradenius</i> Baill.	2.4–4.9	<i>p</i> -Cymene, camphor, 1,8-cineole, γ -terpinene, <i>trans</i> -ascaridole, <i>cis</i> -ascaridole.	M: 94.05 S: 2.52	125	<i>Staphylococcus aureus</i>	[183]
<i>Croton tetradenius</i> Baill.	2.4–4.9	Camphor, <i>p</i> -cymene, <i>trans</i> -ascaridole, <i>trans</i> -pinocarveol, 1,8-cineole, α -pinene, pinocarvone.	M: 93.22 S: 1.34	31.5 250 62.5 125	<i>Bacillus cereus</i> <i>Escherichia coli</i> <i>Listeria monocytogenes</i> <i>Salmonella typhimurium</i>	[183]
<i>Croton tetradenius</i> Baill. (CTE101)	4.0	Camphor, <i>p</i> -cymene, <i>trans</i> -ascaridole.	M: 93.22 S: 1.34	5600 11,300 11,300	<i>Escherichia coli</i> <i>Staphylococcus aureus</i> <i>Klebsiella pneumoniae</i>	[184]
<i>Croton tetradenius</i> Baill. (CTE407)	4.0	<i>p</i> -Cymene, <i>trans</i> -ascaridole, 1,8-cineole, camphor, α -terpinene, γ -terpinene, <i>cis</i> -ascaridole.	M: 95.94 S: 1.39	2800	<i>Escherichia coli</i>	[184]
<i>Croton tetradenius</i> Baill.	0.47	<i>p</i> -Cymene, camphor, α -phellandrene, γ -terpinene, α -terpinene, <i>trans</i> -chrysanthenyl acetate.	M: 99.34 S: 0.66	2800 5600 4000	<i>Staphylococcus aureus</i> <i>Klebsiella pneumoniae</i> <i>Staphylococcus aureus</i>	[185]

Table 10. Cont.

Species	Yield (%)	Main Components ^a	M/S/P/B or Other (%)	MIC or IC ₅₀ (µg/mL)	Organisms	Ref.
<i>Croton tetradenius</i> Baill.	0.27	<i>trans</i> -Chrysanthenyl acetate, α -terpinene, <i>p</i> -cymene, γ -terpinene.	M: 87.49 S: 1.28	8000	<i>Staphylococcus aureus</i>	[185]
<i>Croton thurifer</i> Kunth.	0.07 \pm 0.005	β -Elemene, germacrene D.	M: 35.39 S: 62.26	296.1 148 >1000 >1000 >1000	<i>Staphylococcus aureus</i> <i>Bacillus subtilis</i> <i>Escherichia coli</i> <i>Pseudomonas aeruginosa</i> <i>Candida albicans</i>	[155]
<i>Croton tricolor</i> Baill.	Nd	Epiglobulol, α -bisabolol, <i>trans</i> - α -bergamotol, β -caryophyllene, α -acorenol. Bicyclogermacrene, germacrene D, germacrene D-4-ol, α -cadinol.	M: 3.4 S: 88.6	1.0 to 1024	<i>Candida</i> strains	[186]
<i>Croton urucurana</i> Baillon.(Leaves)	0.35	Borneol, cadina-4,10(14)-dien-1 α -ol, sesquicineole, bornyl acetate, γ -gurjunene epoxide.	S: 85.9 Other: 2.8	10 10 10 10 10 10 5 >20	<i>Staphylococcus aureus</i> <i>Staphylococcus epidermidis</i> <i>Pseudomonas aeruginosa</i> <i>Bacillus subtilis</i> <i>Klebsiella pneumoniae</i> <i>Escherichia coli</i> <i>Salmonella setubal</i> <i>Saccharomyces cerevisiae</i> <i>Candida albicans</i>	[6]
<i>Croton urucurana</i> Baillon. (Stem bark)	0.05	Borneol, cadina-4,10(14)-dien-1 α -ol, sesquicineole, bornyl acetate, γ -gurjunene epoxide.	M: 34 S: 57.3	2500 1250 2500 10,000 5000 1250 2500 5000 5000 10,000 16.0	<i>Staphylococcus aureus</i> <i>Staphylococcus epidermidis</i> <i>Pseudomonas aeruginosa</i> <i>Bacillus subtilis</i> <i>Klebsiella pneumoniae</i> <i>Escherichia coli</i> <i>Salmonella setubal</i> <i>Saccharomyces cerevisiae</i> <i>Cryptococcus neoformans</i> <i>Candida albicans</i> <i>Escherichia coli</i>	[6], [187]
<i>Croton zambesicus</i> Mull-Arg.	0.28	1,8-Cineole, cymene, α -terpineol, L-linalool.	M: 69.84 S: 15.62	250.0 16.0 16.0	<i>Pseudomonas aeruginosa</i> <i>Bacillus subtilis</i> <i>Staphylococcus aureus</i>	[188]
<i>Croton zehntneri</i> Pax and K. Hoffm.		Estragole, (<i>E</i>)-anethole, bicyclogermacrene.		>5000 2500 620–1250	<i>Candida albicans</i> <i>Candida tropicalis</i> <i>Microsporium canis</i>	[56]
<i>Croton zehntneri</i> Pax and Hoffm.	Nd	Estragole, 1,8-cineole, eugenol.	M: 13.61 S: 1.7 P: 82.1	Synergistic effect with norfloxacin.	<i>Staphylococcus aureus</i>	[53]

Table 10. Cont.

Species	Yield (%)	Main Components ^a	M/S/P/B or Other (%)	MIC or IC ₅₀ (µg/mL)	Organisms	Ref.
<i>Croton zehntneri</i> Pax and Hoffm.	Bark	Estragole, (E)-anethole.	M: 1.92 S: 0.47 P: 95.96	Inhibition zone diameter (mm): 8.0 at 10 mL.	<i>Staphylococcus aureus</i>	[54]
				Inhibition zone diameter (mm): 19.3 at 10 mL.	<i>Candida parapsilosis</i>	
	Leaves	Estragole.	M: 0 S: 4.5 P: 93.94	Inhibition zone diameter (mm): 8.3 at 10 mL.	<i>Staphylococcus aureus</i>	[54]
				Inhibition zone diameter (mm): 19.0 at 10 mL.	<i>Candida parapsilosis</i>	
<i>Croton zehntneri</i> Pax and Hoffm.		Estragole, 1,8-cineol, eugenol.	M: 13.61 S: 1.7 P: 82.1	25	<i>Shigella fl exneri</i>	[15]
				Nd	<i>Salmonella typhimurium</i>	
				500	<i>Escherichia coli</i>	
				500	<i>Staphylococcus aureus</i>	
<i>Croton zehntneri</i> Pax and K. Hoffm. (Fresh leaves)	1.8	Estragole, spathulenol.	M: 85.0 S: 12.0	58.75	<i>Bacillus subtilis</i>	[14]
				63.15	<i>Bacillus megaterium</i>	
				145.0	<i>Staphylococcus aureus</i>	
				63.43	<i>Shigella sonnei</i>	
				38.52	<i>Salmonella paratyphi</i>	
				131.2	<i>Blastomyces dermatitidis</i>	
				58.75	<i>Candida albicans</i>	
				61.54	<i>Pityrosporum ovale</i>	
				88.51	<i>Cryptococcus neoformans</i>	

^a: The order of the compounds is sorted by percentage from high to low and greater than 5.0%. Nd: Not defined; NI: not inhibited; M: monoterpenoids, S: sesquiterpenoids, B: benzenoids, P: phenylpropanoids.

3. Materials and Methods

3.1. Plant Material and Isolation of Essential Oil

The specimens of *Croton hirtus* L'Hér. were collected at Phong Dien Nature Reserve, Thua Thien Hue Province (16°24'15,84" N 107°12'00,01" E, 415 m elevation) in July 2022. The specimen (label: NCXS-H 110) of this species was identified by Van Huong Bui and was deposited in the Vietnam National Museum of Nature (VNMN) herbarium. The fresh aerial parts were chopped and hydrodistilled with a Clevenger apparatus (Witeg Labortechnik, Wertheim, Germany) for 6 h. The EO was dried over anhydrous Na₂SO₄ and stored at 4 °C until use.

3.2. Gas Chromatographic Analysis

Gas chromatography–mass spectral analyses (GC–MS) of *C. hirtus* essential oil were carried out using previously published instrumentation and protocols [58,114]. A Shimadzu GCMS-QP2010 Ultra (Shimadzu Scientific Instruments, Columbia, MD, USA) with a ZB-5 ms fused silica capillary column (60 m length, 0.25 mm diameter, and 0.25 µm film thickness) (Phenomenex, Torrance, CA, USA), He carrier gas, 2.0 mL/min flow rate, injection and ion source temperatures of 260 °C, and a GC oven program of 50 to 260 °C at 2.0 °C/min was used. A 0.1 µL amount of a 5% (w/v) sample of essential oil in CH₂Cl₂ was injected in split mode with a 24.5:1 split ratio. Identification of the essential oil components was carried out with a comparison of MS fragmentation and retention indices (RI) with those available

in the databases [189–192]. Quantification was performed using external standards of representative compounds from each compound class.

3.3. Screening for Larvicidal Activity

Two species of *Aedes* mosquitoes were maintained continuously at Duy Tan University [193]. Egg rafts of *Cx. fuscocephala* were collected from rice fields in Hoa Vang district, Da Nang (GPS: 16°00'49" N, 108°06'12" E). Egg rafts of *Cx. quinquefasciatus* were collected from car tires containing decomposing organic matter in Da Nang City. Each *Culex* egg raft was hatched separately in plastic trays with tap water overnight to facilitate the precise examination of the species. The larvae were fed a mixture of dog food and yeast (ratio 3:1, *w/w*).

Essential oil and purified compounds were dissolved with ethanol (Sigma–Aldrich, Ho Chi Minh, Vietnam) to obtain a 1% stock solution. Twenty-five larvae of each mosquito species were transferred into 250 mL beakers containing 150 mL of distilled water. Different volumes of each the stock solution were transferred into the beakers containing larvae to obtain exposure concentrations of 100, 75, 50, 25, 12.5, and 6.25 µg/mL. Each concentration was cloned 4 times, and permethrin (Sigma–Aldrich) was used as a positive control. After 24 h and 48 h of exposure, the larvae were determined for mortality.

3.4. Screening for Molluscicidal Activity

Adult snails about 1.0 cm in size were collected in the wild (GPS: 16°01'08" N, 108°07'44" E), and they were acclimated to laboratory conditions 24 h prior to testing. The five snail adults were transferred into 200 mL plastic beakers, which were then filled with 195 mL of distilled water. The adults were exposed to concentrations of 50, 25, 12.5, 6.25, and 3.125 µg/mL. After 24 h of exposure, the snails were recovered by transferring them to plastic beakers containing only distilled water. After 24 h of recovery, the number of dead snails at the exposure concentrations was recorded. Copper sulfate (Xilong Chemicals, Shantou, China) was used as a positive control.

3.5. Screening for Antimicrobial Activity

The ATCC international standard for control of microorganisms include three Gram-negative bacteria strains (*E. coli* ATCC25922, *P. aeruginosa* ATCC27853, and *S. enterica* ATCC13076), three Gram-positive strains (*E. faecalis* ATCC299212, *S. aureus* ATCC25923, and *B. cereus* ATCC 14579), and a strain of *C. albicans* ATCC10231, which were provided by the National Institute for Food Control, Vietnam.

The antimicrobial activity was analyzed based on the multi-concentration dilution method. Samples of essential oils or pure compounds were diluted in DMSO at a decreasing concentration range of 256, 128, 64, 32, 16, 4, and 2 µg/mL, with three replicates for each concentration. Microbial solutions were prepared at a concentration of 2×10^5 CFU/mL, and antimicrobial assays were carried out in 96-well microtiter plates. A 5.12 µL sample solution with a 10 mg/ml concentration was aspirated into the first row containing 100 µL of LB medium and then diluted successively by concentration into rows containing 50 µL until reaching a concentration of 2 µg/mL. Then, 50 µL of microbial solution was added at a concentration of 2×10^5 CFU/ml and incubated at 37 °C. After incubation for 24 hours at 37 °C, the absorbance at 650 nm was measured using a microplate reader (Epoch, BioTek Instruments Inc., Winooski, VT, USA) [194]. Streptomycin, kanamycin, tetracycline, nystatin, and cycloheximide (all compounds were purchased from Sigma–Aldrich) were used as positive controls.

3.6. Data Analysis

Mortality data were analyzed by log-probit analysis [195] to acquire LC₅₀ and LC₉₀ values as well as 95% confidence limits using Minitab® version 19.2020.1 (Minitab, LLC, State College, PA, USA).

3.7. Literature Survey

The materials used in this literature survey were searched on the databases <https://scholar.google.com>, <https://pubmed.ncbi.nlm.nih.gov>, and <https://www.researchgate.net> (accessed on 1 January 2023) with a keyword structure including “essential oil” and *Croton*; bioactive keywords that were searched for included antimicrobial, antifungal, antibacterial, antiparasitic, and “mosquito larvicidal”. There were no language restrictions for the selection of articles. The following criteria were included when considering articles:

- (1) The articles fully reported the chemical composition and mosquito larvicidal activity of the essential oils.
- (2) The articles fully reported the chemical composition and the molluscicidal and antiparasitic activities of the essential oils.
- (3) The articles fully reported the chemical composition and antibacterial activity of the essential oils.
- (4) Articles that reported unreliable GC/MS analysis results, such as chemical compositions that did not match the elution order, retention time, and retention index, were not considered.

4. Conclusions

This work presented a literature survey of the volatile phytochemistry and biological activities of *Croton* species and illustrated the potential utility of these essential oils. Furthermore, the essential oil composition, mosquito larvicidal, molluscicidal, and antimicrobial activities of *Croton hirtus* from Vietnam was included, which adds to our knowledge of the genus *Croton*. β -Caryophyllene occurred abundantly in the essential oils [196], and it was present in most of the essential oils of the *Croton* species. Mixtures of β -caryophyllene, α -humulene, and caryophyllene oxide showed synergistic or antagonistic effects against various organisms. Investigations into the bioactivity of combinations of β -caryophyllene with other major compounds in their respective percentages in the essential oils will help in the development of β -caryophyllene-based products. Based on the results of the antiparasitic activity of β -caryophyllene, caryophyllene oxide, and the *Croton* essential oils containing these two compounds, we suggest that an investigation into the antiparasitic activity of *C. hirtus* essential oil may provide interesting results.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/molecules28052361/s1>. Table S1: Chemical composition of *Croton hirtus* essential oil.

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Sample Availability: Samples of *C. hirtus* essential oil are available from the corresponding author H.H.N.

References

1. Pimentel, B.S.; Negri, G.; Cordeiro, I.; Motta, L.B.; Salatino, A. Taxonomic significance of the distribution of constituents of leaf cuticular waxes of *Croton* species (Euphorbiaceae). *Biochem. Syst. Ecol.* **2020**, *92*, 104106. [\[CrossRef\]](#)
2. Bezerra, F.W.; Bezerra, P.D.N.; de Oliveira, M.S.; da Costa, W.A.; Ferreira, G.C.; de Carvalho, R.N. Bioactive compounds and biological activity of *Croton* species (Euphorbiaceae): An overview. *Curr. Bioact. Compd.* **2020**, *16*, 383–393. [\[CrossRef\]](#)
3. Da Costa, L.S.; de Moraes, Á.A.B.; Cruz, J.N.; Mali, S.N.; Almeida, L.Q.; do Nascimento, L.D.; Ferreira, O.O.; Varela, E.L.P.; Percário, S.; de Oliveira, M.S.; et al. First report on the chemical composition, antioxidant capacity, and preliminary toxicity to *Artemia salina* L. of *Croton campinarenis* Secco, A. Rosário & PE Berry (Euphorbiaceae) essential oil, and in silico study. *Antioxidants* **2022**, *11*, 2410. [\[CrossRef\]](#)
4. De Moraes, S.M.; Catunda Júnior, F.E.A.; da Silva, A.R.A.; Neto, J.S.M.; Rondina, D.; Cardoso, J.H.L. Antioxidant activity of essential oils from Northeastern Brazilian *Croton* species. *Química Nova* **2006**, *29*, 907–910. [\[CrossRef\]](#)
5. Oliveira, S.D.D.S.; Silva, A.M.D.O.E.S.; Blank, A.F.; Nogueira, P.C.D.L.; Nizio, D.A.D.C.; Almeida-Pereira, C.S.; Pereira, R.O.; Menezes-Sá, T.S.A.; Santana, M.H.D.S.; Arrigoni-Blank, M.D.F. Radical scavenging activity of the essential oils from *Croton greviioides* Baill accessions and the major compounds eugenol, methyl eugenol and methyl chavicol. *J. Essent. Oil Res.* **2021**, *33*, 94–103. [\[CrossRef\]](#)
6. Simionatto, E.; Bonani, V.F.L.; Peres, M.T.L.P.; Hess, S.C.; Candido, A.C.S.; Diraimo, D.L.; Poppi, N.R.; Matos, M.D.F.C.; Santos, E.C.S.; Oguma, P.M.; et al. Bioactivity and chemical composition of the essential oils of *Croton urucurana* Baillon (Euphorbiaceae). *J. Essent. Oil Bear. Plants* **2009**, *12*, 250–261. [\[CrossRef\]](#)
7. Sousa, A.; Oliveira, G.; Fonseca, L.; Rocha, M.; Rai, M.; Santos, F.; de Lima, S. Antioxidant properties of *Croton zehntneri* Pax et Hoffm. Essential oil and its inclusion complex with β -cyclodextrin prepared by spray drying. *J. Braz. Chem. Soc.* **2022**, *33*, 1244–1253. [\[CrossRef\]](#)
8. Daouda, T.; Prevost, K.; Gustave, B.; Joseph, D.A.; Nathalie, G.; Raphaël, O.; Rubens, D.; Claude, C.J.; Mireille, D.; Felix, T. Terpenes, antibacterial and modulatory antibiotic activity of essential oils from *Croton hirtus* L' Hér. (Euphorbiaceae) from Ivory Coast. *J. Essent. Oil Bear. Plants* **2014**, *17*, 607–616. [\[CrossRef\]](#)
9. de Almeida, T.S.; Rocha, J.B.T.; Rodrigues, F.F.G.; Campos, A.R.; da Costa, J.G.M. Chemical composition, antibacterial and antibiotic modulatory effect of *Croton campestris* essential oils. *Ind. Crops Prod.* **2013**, *44*, 630–633. [\[CrossRef\]](#)
10. De Araújo, A.C.J.; Freitas, P.R.; Rodrigues dos Santos Barbosa, C.; Muniz, D.F.; Rocha, J.E.; Neto, J.B.d.A.; da Silva, M.M.C.; Moura, T.F.; Pereira, R.L.S.; Ribeiro-Filho, J.; et al. Essential oil of *Croton ceanothifolius* Baill. potentiates the effect of antibiotics against multiresistant bacteria. *Antibiotics* **2020**, *9*, 27. [\[CrossRef\]](#) [\[PubMed\]](#)
11. Abreu, L.S.; do Nascimento, Y.M.; do Espírito-Santo, R.F.; Meira, C.S.; Santos, I.P.; Brandão, R.B.; Souto, A.L.; Guedes, M.L.S.; Soares, M.B.P.; Villarreal, C.F.; et al. Phenylpropanoids from *Croton velutinus* with cytotoxic, trypanocidal and anti-inflammatory activities. *Fitoterapia* **2020**, *145*, 104632. [\[CrossRef\]](#) [\[PubMed\]](#)
12. Martins, A.O.B.P.B.; Rodrigues, L.B.; Cesário, F.R.A.S.; de Oliveira, M.R.C.; Tintino, C.D.M.; Castro, F.F.E.; Alcântara, I.S.; Fernandes, M.N.M.; de Albuquerque, T.R.; da Silva, M.S.A.; et al. Anti-edematogenic and anti-inflammatory activity of the essential oil from *Croton rhamnifolioides* leaves and its major constituent 1,8-cineole (eucalyptol). *Biomed. Pharmacother.* **2017**, *96*, 384–395. [\[CrossRef\]](#) [\[PubMed\]](#)
13. Oliveira Brito Pereira Bezzra Martins, A.; Wanderley, A.G.; Alcântara, I.S.; Rodrigues, L.B.; Cesário, F.R.A.S.; Correia de Oliveira, M.R.; e Castro, F.F.; de Albuquerque, T.R.; da Silva, M.S.A.; Ribeiro-Filho, J.; et al. Anti-inflammatory and physicochemical characterization of the *Croton rhamnifolioides* essential oil inclusion complex in β -cyclodextrin. *Biology* **2020**, *9*, 114. [\[CrossRef\]](#) [\[PubMed\]](#)
14. Andrade, T.C.B.; de Lima, S.G.; Freitas, R.M.; Rocha, M.S.; Islam, T.; da Silva, T.G.; Militão, G.C.G. Isolation, characterization and evaluation of antimicrobial and cytotoxic activity of estragole, obtained from the essential oil of *Croton zehntneri* (Euphorbiaceae). *An. Acad. Bras. Cienc.* **2015**, *87*, 173–182. [\[CrossRef\]](#) [\[PubMed\]](#)
15. Da Costa, J.G.M.; Rodrigues, F.F.G.; Angélico, E.C.; Pereira, C.K.B.; De Souza, E.O.; Caldas, G.F.R.; Silva, M.R.; Santos, N.K.A.; Mota, M.L.; Santos, P.F. Chemical composition and evaluation of the antibacterial activity and toxicity of the essential oil of *Croton zehntneri* (variety estragol). *Rev. Bras. Farmacogn.* **2008**, *18*, 583–586. [\[CrossRef\]](#)
16. Lima, E.; Alves, R.; D'Elia, G.; Anunciação, T.; Silva, V.; Santos, L.; Soares, M.; Cardozo, N.; Costa, E.; Silva, F.; et al. Antitumor effect of the essential oil from the leaves of *Croton matourensis* Aubl. (Euphorbiaceae). *Molecules* **2018**, *23*, 2974. [\[CrossRef\]](#) [\[PubMed\]](#)
17. Meireles, D.R.P.; Fernandes, H.M.B.; Rolim, T.L.; Batista, T.M.; Mangueira, V.M.; de Sousa, T.K.G.; Pita, J.C.L.R.; Xavier, A.L.; Beltrão, D.M.; Tavares, J.F.; et al. Toxicity and antitumor efficacy of *Croton polyandrus* oil against ehrlich ascites carcinoma cells. *Rev. Bras. Farm.* **2016**, *26*, 751–758. [\[CrossRef\]](#)
18. Vunda, S.L.L.; Sauter, I.P.; Cibulski, S.P.; Roehe, P.M.; Bordignon, S.A.L.; Rott, M.B.; Apel, M.A.; von Poser, G.L. Chemical composition and amoebicidal activity of *Croton pallidulus*, *Croton ericoides*, and *Croton isabelli* (Euphorbiaceae) essential oils. *Parasitol. Res.* **2012**, *111*, 961–966. [\[CrossRef\]](#)
19. Hiruma-Lima, C.A.; Gracioso, J.S.; Nunes, D.S.; Brito, A.S. Effects of an essential oil from the bark of *Croton cajucara* Benth. on experimental gastric ulcer models in rats and mice. *J. Pharm. Pharmacol.* **2010**, *51*, 341–346. [\[CrossRef\]](#)

20. Hiruma-Lima, C.A.; Gracioso, J.S.; Bighetti, E.J.B.; Grassi-Kassisse, D.M.; Nunes, D.S.; Souza Brito, A.R.M. Effect of essential oil obtained from *Croton cajucara* Benth. on gastric ulcer healing and protective factors of the gastric mucosa. *Phytomedicine* **2002**, *9*, 523–529. [[CrossRef](#)]
21. Paula, A.C.B.; Toma, W.; Gracioso, J.S.; Hiruma-Lima, C.A.; Carneiro, E.M.; Souza Brito, A.R.M. The gastroprotective effect of the essential oil of *Croton cajucara* is different in normal rats than in malnourished rats. *Br. J. Nutr.* **2006**, *96*, 310–315. [[CrossRef](#)] [[PubMed](#)]
22. De Oliveira Ramos, J.M.; dos Santos, C.A.; Santana, D.G.; Antonioli, A.R.; de Alexandria Santos, D.; Alves, P.B.; Thomazzi, S.M. Impact of *Croton argyrophyllus* essential oil on behavioural models of nociception. *Flavour Fragr. J.* **2017**, *32*, 40–45. [[CrossRef](#)]
23. Santos, F.A.; Jeferson, F.A.; Santos, C.C.; Silveira, E.R.; Rao, V.S.N. Antinociceptive effect of leaf essential oil from *Croton sonderianus* in mice. *Life Sci.* **2005**, *77*, 2953–2963. [[CrossRef](#)] [[PubMed](#)]
24. Leite, T.R.; da Silva, M.A.P.; Dos Santos, A.C.B.; Coutinho, H.D.M.; Duarte, A.E.; da Costa, J.G.M. Antimicrobial, modulatory and chemical analysis of the oil of *Croton limae*. *Pharm. Biol.* **2017**, *55*, 2015–2019. [[CrossRef](#)]
25. Pinho-da-Silva, L.; Mendes-Maia, P.V.; do Nascimento Garcia, T.M.; Cruz, J.S.; de Moraes, S.M.; Coelho-de-Souza, A.N.; Lahlou, S.; Leal-Cardoso, J.H. *Croton sonderianus* essential oil samples distinctly affect rat airway smooth muscle. *Phytomedicine* **2010**, *17*, 721–725. [[CrossRef](#)] [[PubMed](#)]
26. Lima, C.C.; de Holanda-Angelin-Alves, C.M.; Pereira-Gonçalves, Á.; Kennedy-Feitosa, E.; Evangelista-Costa, E.; Bezerra, M.A.C.; Coelho-de-Souza, A.N.; Leal-Cardoso, J.H. Antispasmodic effects of the essential oil of *Croton zehntneri*, anethole, and estragole, on tracheal smooth muscle. *Heliyon* **2020**, *6*, e05445. [[CrossRef](#)]
27. de Oliveira Júnior, R.G.; Ferraz, C.A.A.; Silva, J.C.; de Andrade Teles, R.B.; Silva, M.G.; Diniz, T.C.; dos Santos, U.S.; de Souza, A.V.V.; Nunes, C.E.P.; Salvador, M.J.; et al. Neuropharmacological effects of essential oil from the leaves of *Croton conduplicatus* Kunth and possible mechanisms of action involved. *J. Ethnopharmacol.* **2018**, *221*, 65–76. [[CrossRef](#)]
28. Camurça-Vasconcelos, A.L.F.; Bevilaqua, C.M.L.; Moraes, S.M.; Maciel, M.V.; Costa, C.T.C.; Macedo, I.T.F.; Oliveira, L.M.B.; Braga, R.R.; Silva, R.A.; Vieira, L.S. Anthelmintic activity of *Croton zehntneri* and *Lippia sidoides* essential oils. *Vet. Parasitol.* **2007**, *148*, 288–294. [[CrossRef](#)]
29. Baccelli, C.; Martinsen, A.; Morel, N.; Quetin-Leclercq, J. Vasorelaxant activity of essential oils from *Croton zambesicus* and some of their constituents. *Planta Med.* **2010**, *76*, 1506–1511. [[CrossRef](#)]
30. Franklins, L.H.V.; Jones, K.E.; Redding, D.W.; Abubakar, I. The effect of global change on mosquito-borne disease. *Lancet Infect. Dis.* **2019**, *19*, e302–e312. [[CrossRef](#)]
31. World Health Organization. *Schistosomiasis and Soil—Transmitted Helminthiasis: Progress Report, 2021*; World Health Organization: Geneva, Switzerland, 2022.
32. Pereira, L.P.L.A.; Ribeiro, E.C.G.; Brito, M.C.A.; Silveira, D.P.B.; Araruna, F.O.S.; Araruna, F.B.; Leite, J.A.C.; Dias, A.A.S.; da Cunha Araujo Firmo, W.; Oliveira da Rocha Borges, M.; et al. Essential oils as molluscicidal agents against Schistosomiasis transmitting snails—A review. *Acta Trop.* **2020**, *209*, 105489. [[CrossRef](#)] [[PubMed](#)]
33. World Health Organization. Foodborne Trematode Infections. Available online: <https://www.who.int/news-room/fact-sheets/detail/foodborne-trematode-infections> (accessed on 1 January 2023).
34. World Health Organization. Antibiotic Resistance. Available online: <http://www.who.in/news-room/fact-sheets/detail/antibiotic-resistance> (accessed on 1 January 2023).
35. World Health Organization. The “World Malaria Report 2019” at A Glance. Available online: <https://www.who.int/news-room/feature-stories/detail/world-malaria-report-2019> (accessed on 1 January 2023).
36. Sanchez, M.C.; Cupit, P.M.; Bu, L.; Cunningham, C. Transcriptomic analysis of reduced sensitivity to praziquantel in *Schistosoma mansoni*. *Mol. Biochem. Parasitol.* **2019**, *228*, 6–15. [[CrossRef](#)] [[PubMed](#)]
37. McManus, D.P.; Bergquist, R.; Cai, P.; Ranasinghe, S.; Tebeje, B.M.; You, H. Schistosomiasis—From immunopathology to vaccines. *Semin. Immunopathol.* **2020**, *42*, 355–371. [[CrossRef](#)]
38. Chevalier, F.D.; Le Clec’h, W.; McDew-White, M.; Menon, V.; Guzman, M.A.; Holloway, S.P.; Cao, X.; Taylor, A.B.; Kinung’hi, S.; Gouvras, A.N.; et al. Oxamniquine resistance alleles are widespread in old world *Schistosoma mansoni* and predate drug deployment. *PLOS Pathog.* **2019**, *15*, e1007881. [[CrossRef](#)]
39. Wilson, R.A. Schistosomiasis then and now: What has changed in the last 100 years? *Parasitology* **2020**, *147*, 507–515. [[CrossRef](#)] [[PubMed](#)]
40. Lisboa, F.P.; Silvestre, W.P.; Castro, J.O.; Martins, G.V.; Segabinazzi, L.G.T.M.; Pauletti, G.F.; Dell’Aqua, J.A. In vitro antimicrobial activity of selected essential oils against endometritis-causing microorganisms in mares. *J. Equine Vet. Sci.* **2022**, *110*, 103840. [[CrossRef](#)]
41. Pavela, R. Essential oils for the development of eco-friendly mosquito larvicides: A review. *Ind. Crops Prod.* **2015**, *76*, 174–187. [[CrossRef](#)]
42. Ju, J.; Xie, Y.; Yu, H.; Guo, Y.; Cheng, Y.; Qian, H.; Yao, W. Synergistic interactions of plant essential oils with antimicrobial agents: A new antimicrobial therapy. *Crit. Rev. Food Sci. Nutr.* **2022**, *62*, 1740–1751. [[CrossRef](#)]
43. Langeveld, W.T.; Veldhuizen, E.J.A.; Burt, S.A. Synergy between essential oil components and antibiotics: A review. *Crit. Rev. Microbiol.* **2014**, *40*, 76–94. [[CrossRef](#)]

44. Chansang, A.; Champakaew, D.; Junkum, A.; Jitpakdi, A.; Amornlerdpison, D.; Aldred, A.K.; Riyong, D.; Wannasan, A.; Intirach, J.; Muangmoon, R.; et al. Synergy in the adulticidal efficacy of essential oils for the improvement of permethrin toxicity against *Aedes aegypti* L. (Diptera: Culicidae). *Parasit. Vectors* **2018**, *11*, 417. [[CrossRef](#)]
45. Dassanayake, M.K.; Chong, C.H.; Khoo, T.-J.; Figiel, A.; Szumny, A.; Choo, C.M. Synergistic field crop pest management properties of plant-derived essential oils in combination with synthetic pesticides and bioactive molecules: A review. *Foods* **2021**, *10*, 2016. [[CrossRef](#)]
46. Gross, A.D.; Norris, E.J.; Kimber, M.J.; Bartholomay, L.C.; Coats, J.R. Essential oils enhance the toxicity of permethrin against *Aedes aegypti* and *Anopheles gambiae*. *Med. Vet. Entomol.* **2017**, *31*, 55–62. [[CrossRef](#)] [[PubMed](#)]
47. Suwannayod, S.; Sukontason, K.L.; Pitasawat, B.; Junkum, A.; Limsopatham, K.; Jones, M.K.; Somboon, P.; Leksomboon, R.; Chareonviriyaphap, T.; Tawatsin, A.; et al. Synergistic toxicity of plant essential oils combined with pyrethroid insecticides against blow flies and the house fly. *Insects* **2019**, *10*, 178. [[CrossRef](#)]
48. Tak, J.-H.; Coquerel, Q.R.R.; Tsikolia, M.; Bernier, U.R.; Linthicum, K.; Bloomquist, J.R. Screening for enhancement of permethrin toxicity by plant essential oils against adult females of the yellow fever mosquito (Diptera: Culicidae). *J. Med. Entomol.* **2020**, *57*, 1149–1156. [[CrossRef](#)]
49. Do Vale, J.P.C.; Vasconcelos, M.A.; Arruda, F.V.S.; Firmino, N.C.S.; Pereira, A.L.; Andrade, A.L.; Saker-Sampaio, S.; Sampaio, A.H.; Marinho, E.S.; Teixeira, A.M.R.; et al. Evaluation of antimicrobial and antioxidant potential of essential oil from *Croton piauhiensis* Müll. Arg. *Curr. Microbiol.* **2021**, *78*, 1926–1938. [[CrossRef](#)] [[PubMed](#)]
50. Van Vuuren, S.F.; Viljoen, A.M. In vitro evidence of phyto-synergy for plant part combinations of *Croton gratissimus* (Euphorbiaceae) used in african traditional healing. *J. Ethnopharmacol.* **2008**, *119*, 700–704. [[CrossRef](#)]
51. De Lima, S.G.; Medeiros, L.B.P.; Cunha, C.N.L.C.; da Silva, D.; de Andrade, N.C.; Neto, J.M.M.; Lopes, J.A.D.; Steffen, R.A.; Araújo, B.Q.; Reis, F.D.A. Chemical composition of essential oils of *Croton hirtus* L'Her from Piauí (Brazil). *J. Essent. Oil Res.* **2012**, *24*, 371–376. [[CrossRef](#)]
52. Santos, H.S.; Santiago, G.M.P.; de Oliveira, J.P.P.; Arriaga, A.M.C.; Marques, D.D.; Lemos, T.L.G. Chemical composition and larvicidal activity against *Aedes aegypti* of essential oils from *Croton zehntneri*. *Nat. Prod. Commun.* **2007**, *2*, 1934578X0700201. [[CrossRef](#)]
53. Coutinho, H.D.M.; Matias, E.F.F.; Santos, K.K.A.; Tintino, S.R.; Souza, C.E.S.; Guedes, G.M.M.; Santos, F.A.D.; Costa, J.G.M.; Falcão-Silva, V.S.; Siqueira-Júnior, J.P. Enhancement of the norfloxacin antibiotic activity by gaseous contact with the essential oil of *Croton zehntneri*. *J. Young Pharm.* **2010**, *2*, 362–364. [[CrossRef](#)]
54. Donati, M.; Mondin, A.; Chen, Z.; Miranda, F.M.; do Nascimento, B.B.; Schirato, G.; Pastore, P.; Frolidi, G. Radical scavenging and antimicrobial activities of *Croton zehntneri*, *Pterodon emarginatus* and *Schinopsis brasiliensis* essential oils and their major constituents: Estragole, trans-anethole, β -caryophyllene and Myrcene. *Nat. Prod. Res.* **2015**, *29*, 939–946. [[CrossRef](#)] [[PubMed](#)]
55. Suárez, A.I.; Vásquez, L.J.; Taddei, A.; Arvelo, F.; Compagnone, R.S. Antibacterial and cytotoxic activity of leaf essential oil of *Croton malambo*. *J. Essent. Oil Bear. Plants* **2008**, *11*, 208–213. [[CrossRef](#)]
56. Fontenelle, R.O.S.; Moraes, S.M.; Brito, E.H.S.; Brilhante, R.S.N.; Cordeiro, R.A.; Nascimento, N.R.F.; Kerntopf, M.R.; Sidrim, J.J.C.; Rocha, M.F.G. Antifungal activity of essential oils of *Croton* species from the Brazilian Caatinga Biome. *J. Appl. Microbiol.* **2008**, *104*, 1383–1390. [[CrossRef](#)] [[PubMed](#)]
57. Rosa, M.D.S.S.; Mendonça-Filho, R.R.; Bizzo, H.R.; de Almeida Rodrigues, I.; Soares, R.M.A.; Souto-Padron, T.; Alviano, C.S.; Lopes, A.H.C.S. Antileishmanial activity of a linalool-rich essential oil from *Croton cajucara*. *Antimicrob. Agents Chemother.* **2003**, *47*, 1895–1901. [[CrossRef](#)] [[PubMed](#)]
58. Huy Hung, N.; Ngoc Dai, D.; Satyal, P.; Thi Huong, L.; Thi Chinh, B.; Quang Hung, D.; Anh Tai, T.; Setzer, W.N. *Lantana camara* essential oils from Vietnam: Chemical composition, molluscicidal, and mosquito larvicidal activity. *Chem. Biodivers.* **2021**, *18*, e2100145. [[CrossRef](#)]
59. Ravi Kiran, S.; Bhavani, K.; Sita Devi, P.; Rajeswara Rao, B.R.; Janardhan Reddy, K. Composition and larvicidal activity of leaves and stem essential oils of *Chloroxylon swietenia* DC against *Aedes aegypti* and *Anopheles stephensi*. *Bioresour. Technol.* **2006**, *97*, 2481–2484. [[CrossRef](#)]
60. Govindarajan, M. Chemical composition and larvicidal activity of leaf essential oil from *Clausena anisata* (Willd.) Hook. f. Ex Benth (Rutaceae) against three mosquito species. *Asian Pac. J. Trop. Med.* **2010**, *3*, 874–877. [[CrossRef](#)]
61. De Oliveira, A.C.; Simões, R.C.; Lima, C.A.P.; da Silva, F.M.A.; Nunomura, S.M.; Roque, R.A.; Tadei, W.P.; Nunomura, R.C.S. Essential oil of *Piper purusianum* C.DC (Piperaceae) and its main sesquiterpenes: Biodefensives against malaria and dengue vectors, without lethal effect on non-target aquatic fauna. *Environ. Sci. Pollut. Res.* **2022**, *29*, 47242–47253. [[CrossRef](#)]
62. Govindarajan, M.; Benelli, G. Eco-friendly larvicides from Indian plants: Effectiveness of lavandulyl acetate and bicyclogermacrene on malaria, dengue and Japanese encephalitis mosquito vectors. *Ecotoxicol. Environ. Saf.* **2016**, *133*, 395–402. [[CrossRef](#)]
63. Govindarajan, M.; Benelli, G. α -Humulene and β -elemene from *Syzygium zeylanicum* (Myrtaceae) essential oil: Highly effective and eco-friendly larvicides against *Anopheles subpictus*, *Aedes albopictus*, and *Culex tritaeniorhynchus* (Diptera: Culicidae). *Parasitol. Res.* **2016**, *115*, 2771–2778. [[CrossRef](#)]
64. Govindarajan, M.; Rajeswary, M.; Senthilmurugan, S.; Vijayan, P.; Alharbi, N.S.; Kadaikunnan, S.; Khaled, J.M.; Benelli, G. Curzerene, trans- β -elemenone, and γ -elemene as effective larvicides against *Anopheles subpictus*, *Aedes albopictus*, and *Culex tritaeniorhynchus*: Toxicity on non-target aquatic predators. *Environ. Sci. Pollut. Res.* **2018**, *25*, 10272–10282. [[CrossRef](#)]

65. De Lima, G.P.G.; de Souza, T.M.; de Paula Freire, G.; Farias, D.F.; Cunha, A.P.; Ricardo, N.M.P.S.; de Morais, S.M.; Carvalho, A.F.U. Further insecticidal activities of essential oils from *Lippia sidoides* and *Croton* species against *Aedes aegypti* L. *Parasitol. Res.* **2013**, *112*, 1953–1958. [[CrossRef](#)]
66. Périco, L.L.; Rodrigues, V.P.; Fernando, L.; De Almeida, R.; Fortuna-Perez, A.P. *Medicinal and Aromatic Plants of South America*; Albuquerque, U.P., Patil, U., Máthé, Á., Eds.; Medicinal and Aromatic Plants of the World; Springer: Dordrecht, The Netherlands, 2018; Volume 5, ISBN 978-94-024-1550-6.
67. Cruz, R.C.D.; Silva, S.L.C.E.; Souza, I.A.; Gualberto, S.A.; Carvalho, K.S.; Santos, F.R.; Carvalho, M.G. Toxicological evaluation of essential oil from the leaves of *Croton argyrophyllus* (Euphorbiaceae) on *Aedes aegypti* (Diptera: Culicidae) and *Mus musculus* (Rodentia: Muridae). *J. Med. Entomol.* **2017**, *54*, 985–993. [[CrossRef](#)] [[PubMed](#)]
68. Dória, G.A.A.; Silva, W.J.; Carvalho, G.A.; Alves, P.B.; Cavalcanti, S.C.H. A study of the larvicidal activity of two *Croton* species from Northeastern Brazil against *Aedes aegypti*. *Pharm. Biol.* **2010**, *48*, 615–620. [[CrossRef](#)] [[PubMed](#)]
69. Pino, C.C.C.; de Menezes, J.E.S.A.; Siqueira, S.M.C.; Melo, D.S.; Feitosa, C.R.S.; Santos, H.S. Chemical composition and larvicidal activity against *Aedes aegypti* of essential oils from *Croton jacobinensis* Baill. *Bol. Latinoam. y del Caribe Plantas Med. y Aromat.* **2016**, *15*, 122–127.
70. Amado, J.R.R.; Prada, A.L.; Diaz, J.G.; Souto, R.N.P.; Arranz, J.C.E.; de Souza, T.P. Development, larvicide activity, and toxicity in nontarget species of the *Croton linearis* Jacq essential oil nanoemulsion. *Environ. Sci. Pollut. Res.* **2020**, *27*, 9410–9423. [[CrossRef](#)]
71. Torres, M.C.M.; Assunção, J.C.; Santiago, G.M.P.; Andrade-Neto, M.; Silveira, E.R.; Costa-Lotufo, L.V.; Bezerra, D.P.; Filho, J.D.B.M.; Viana, F.A.; Pessoa, O.D.L. Larvicidal and nematicidal activities of the leaf essential oil of *Croton regelianus*. *Chem. Biodivers.* **2008**, *5*, 2724–2728. [[CrossRef](#)]
72. Santos, G.; Dutra, K.; Lira, C.; Lima, B.; Napoleão, T.; Paiva, P.; Maranhão, C.; Brandão, S.; Navarro, D. Effects of *Croton rhamnifolioides* essential oil on *Aedes aegypti* oviposition, larval toxicity and trypsin activity. *Molecules* **2014**, *19*, 16573–16587. [[CrossRef](#)]
73. Morais, S.M.; Cavalcanti, E.S.B.; Bertini, L.M.; Oliveira, C.L.L.; Rodrigues, J.R.B.; Cardoso, J.H.L. Larvicidal activity of essential oils from Brazilian *Croton* species against *Aedes aegypti* L. *J. Am. Mosq. Control Assoc.* **2006**, *22*, 161–164. [[CrossRef](#)]
74. Da Silva Carvalho, K.; da Cunha e Silva, S.L.; de Souza, I.A.; Gualberto, S.A.; da Cruz, R.C.D.; dos Santos, F.R.; de Carvalho, M.G. Toxicological evaluation of essential oil from the leaves of *Croton tetradenius* (Euphorbiaceae) on *Aedes aegypti* and *Mus musculus*. *Parasitol. Res.* **2016**, *115*, 3441–3448. [[CrossRef](#)]
75. Da Cruz, R.C.D.; da Silva Carvalho, K.; Costa, R.J.O.; da Silva, P.A.; da Cunha e Silva, S.L.; Gualberto, S.A.; de Gusmão, N.B.; de Souza, I.A. Phytochemical and toxicological evaluation of a blend of essential oils of *Croton* species on *Aedes aegypti* and *Mus musculus*. *S. Afr. J. Bot.* **2020**, *132*, 188–195. [[CrossRef](#)]
76. Silva, M.V.; Silva, S.A.; Teixeira, T.L.; De Oliveira, A.; Al Morais, S.; Da Silva, C.V.; Espindola, L.S.; Sousa, R.M. Essential Oil from leaves of *Eugenia calycina* Cambes: Natural larvicidal against *Aedes aegypti*. *J. Sci. Food Agric.* **2021**, *101*, 1202–1208. [[CrossRef](#)]
77. Dhinakaran, S.R.; Mathew, N.; Munusamy, S. Synergistic terpene combinations as larvicides against the dengue vector *Aedes aegypti* Linn. *Drug Dev. Res.* **2019**, *80*, 791–799. [[CrossRef](#)]
78. Pereira Filho, A.A.; Pessoa, G.C.D.; Yamaguchi, L.F.; Stanton, M.A.; Serravite, A.M.; Pereira, R.H.M.; Neves, W.S.; Kato, M.J. Larvicidal activity of essential oils from *Piper* species against strains of *Aedes aegypti* (Diptera: Culicidae) resistant to pyrethroids. *Front. Plant Sci.* **2021**, *12*, 685864. [[CrossRef](#)] [[PubMed](#)]
79. Waliwitiya, R.; Kennedy, C.J.; Lowenberger, C.A. Larvicidal and oviposition-altering activity of monoterpenoids, *trans*-anethole and rosemary oil to the yellow fever mosquito *Aedes aegypti* (Diptera: Culicidae). *Pest Manag. Sci.* **2009**, *65*, 241–248. [[CrossRef](#)] [[PubMed](#)]
80. Cheng, S.-S.; Liu, J.-Y.; Tsai, K.-H.; Chen, W.-J.; Chang, S.-T. Chemical composition and mosquito larvicidal activity of essential oils from leaves of different *Cinnamomum osmophloeum* Provenances. *J. Agric. Food Chem.* **2004**, *52*, 4395–4400. [[CrossRef](#)]
81. Seo, S.-M.; Jung, C.-S.; Kang, J.; Lee, H.-R.; Kim, S.-W.; Hyun, J.; Park, I.-K. Larvicidal and acetylcholinesterase inhibitory activities of Apiaceae plant essential oils and their constituents against *Aedes albopictus* and formulation development. *J. Agric. Food Chem.* **2015**, *63*, 9977–9986. [[CrossRef](#)]
82. Knio, K.M.; Usta, J.; Dagher, S.; Zournajian, H.; Kreydiyyeh, S. Larvicidal activity of essential oils extracted from commonly used herbs in Lebanon against the seaside mosquito, *Ochlerotatus caspius*. *Bioresour. Technol.* **2008**, *99*, 763–768. [[CrossRef](#)]
83. Benelli, G.; Pavela, R.; Iannarelli, R.; Petrelli, R.; Cappellacci, L.; Cianfaglione, K.; Afshar, F.H.; Nicoletti, M.; Canale, A.; Maggi, F. Synergized mixtures of Apiaceae essential oils and related plant-borne compounds: Larvicidal effectiveness on the filariasis vector *Culex quinquefasciatus* Say. *Ind. Crops Prod.* **2017**, *96*, 186–195. [[CrossRef](#)]
84. Pavela, R. Acute toxicity and synergistic and antagonistic effects of the aromatic compounds of some essential oils against *Culex quinquefasciatus* Say larvae. *Parasitol. Res.* **2015**, *114*, 3835–3853. [[CrossRef](#)]
85. Kimbaris, A.C.; Koliopoulos, G.; Michaelakis, A.; Konstantopoulou, M.A. Bioactivity of *Dianthus caryophyllus*, *Lepidium sativum*, *Pimpinella anisum*, and *Illicium verum* essential oils and their major components against the West Nile vector *Culex pipiens*. *Parasitol. Res.* **2012**, *111*, 2403–2410. [[CrossRef](#)] [[PubMed](#)]
86. De Castro, D.S.B.; da Silva, D.B.; Tibúrcio, J.D.; Sobral, M.E.G.; Ferraz, V.; Taranto, A.G.; Serrão, J.E.; de Siqueira, J.M.; Alves, S.N. Larvicidal activity of essential oil of *Peumus boldus* Molina and its ascaridole-enriched fraction against *Culex quinquefasciatus*. *Exp. Parasitol.* **2016**, *171*, 84–90. [[CrossRef](#)] [[PubMed](#)]

87. Perumalsamy, H.; Chang, K.S.; Park, C.; Ahn, Y.J. Larvicidal activity of *Asarum heterotropoides* root constituents against insecticide-susceptible and-resistant *Culex pipiens* Pallens and *Aedes aegypti* and *Ochlerotatus togoi*. *J. Agric. Food Chem.* **2010**, *58*, 10001–10006. [[CrossRef](#)]
88. Ahn, Y.; Kim, N.; Byun, S.; Cho, J.; Chung, K. Larvicidal activity of *Kaempferia galanga* rhizome phenylpropanoids towards three mosquito species. *Pest Manag. Sci.* **2008**, *64*, 857–862. [[CrossRef](#)]
89. Zhu, L.; Tian, Y. Chemical composition and larvicidal activity of essential oil of *Artemisia gilvescens* against *Anopheles anthropophagus*. *Parasitol. Res.* **2013**, *112*, 1137–1142. [[CrossRef](#)]
90. Lucia, A.; Audino, P.G.; Seccacini, E.; Licastro, S.; Zerba, E.; Masuh, H. Larvicidal effect of *Eucalyptus grandis* essential oil and turpentine and their major components on *Aedes aegypti* larvae. *J. Am. Mosq. Control Assoc.* **2007**, *23*, 299–303. [[CrossRef](#)] [[PubMed](#)]
91. Silva, W.J.; Dória, G.A.A.; Maia, R.T.; Nunes, R.S.; Carvalho, G.A.; Blank, A.F.; Alves, P.B.; Marçal, R.M.; Cavalcanti, S.C.H. Effects of essential oils on *Aedes aegypti* larvae: Alternatives to environmentally safe insecticides. *Bioresour. Technol.* **2008**, *99*, 3251–3255. [[CrossRef](#)] [[PubMed](#)]
92. Lucia, A.; Zerba, E.; Masuh, H. Knockdown and larvicidal activity of six monoterpenes against *Aedes aegypti* (Diptera: Culicidae) and their structure-activity relationships. *Parasitol. Res.* **2013**, *112*, 4267–4272. [[CrossRef](#)]
93. Park, H.-M.; Kim, J.; Chang, K.-S.; Kim, B.-S.; Yang, Y.-J.; Kim, G.-H.; Shin, S.-C.; Park, I.-K. Larvicidal activity of Myrtaceae essential oils and their components against *Aedes aegypti*, acute toxicity on *Daphnia magna*, and aqueous residue. *J. Med. Entomol.* **2011**, *48*, 405–410. [[CrossRef](#)]
94. Traboulsi, A.F.; Taoubi, K.; El-Haj, S.; Bessiere, J.; Rammal, S. Insecticidal properties of essential plant oils against the mosquito *Culex pipiens* Molestus (Diptera: Culicidae). *Pest Manag. Sci.* **2002**, *58*, 491–495. [[CrossRef](#)]
95. Koliopoulos, G.; Pitarokili, D.; Kioulos, E.; Michaelakis, A.; Tzakou, O. Chemical composition and larvicidal evaluation of *Mentha*, *Salvia*, and *Melissa* essential oils against the West Nile virus mosquito *Culex pipiens*. *Parasitol. Res.* **2010**, *107*, 327–335. [[CrossRef](#)]
96. Cheng, S.-S.; Huang, C.-G.; Chen, Y.-J.; Yu, J.-J.; Chen, W.-J.; Chang, S.-T. Chemical compositions and larvicidal activities of leaf essential oils from two *Eucalyptus* species. *Bioresour. Technol.* **2009**, *100*, 452–456. [[CrossRef](#)] [[PubMed](#)]
97. Giatropoulos, A.; Kimbaris, A.; Michaelakis, A.; Papachristos, D.P.; Polissiou, M.G.; Emmanouel, N. Chemical composition and assessment of larvicidal and repellent capacity of 14 lamiaceae essential oils against *Aedes albopictus*. *Parasitol. Res.* **2018**, *117*, 1953–1964. [[CrossRef](#)]
98. Huang, H.-T.; Lin, C.-C.; Kuo, T.-C.; Chen, S.-J.; Huang, R.-N. Phytochemical composition and larvicidal activity of essential oils from herbal plants. *Planta* **2019**, *250*, 59–68. [[CrossRef](#)] [[PubMed](#)]
99. Nogueira Sobrinho, A.C.; de Morais, S.M.; Marinho, M.M.; de Souza, N.V.; Lima, D.M. Antiviral activity on the Zika virus and larvicidal activity on the *Aedes* spp. of *Lippia alba* essential oil and β -caryophyllene. *Ind. Crops Prod.* **2021**, *162*, 113281. [[CrossRef](#)]
100. Cheng, S.-S.; Chang, H.-T.; Lin, C.-Y.; Chen, P.-S.; Huang, C.-G.; Chen, W.-J.; Chang, S.-T. Insecticidal activities of leaf and twig essential oils from *Clausena excavata* against *Aedes aegypti* and *Aedes albopictus* larvae. *Pest Manag. Sci.* **2009**, *65*, 339–343. [[CrossRef](#)]
101. Wang, Z.; Perumalsamy, H.; Wang, M.; Shu, S.; Ahn, Y.-J. Larvicidal activity of *Magnolia denudata* seed hydrodistillate constituents and related compounds and liquid formulations towards two susceptible and two wild mosquito species. *Pest Manag. Sci.* **2016**, *72*, 897–906. [[CrossRef](#)]
102. Benelli, G.; Pavela, R.; Drenaggi, E.; Maggi, F. Insecticidal efficacy of the essential oil of Jambú (*Acmella oleracea* (L.) R.K. Jansen) cultivated in Central Italy against filariasis mosquito vectors, houseflies and moth pests. *J. Ethnopharmacol.* **2019**, *229*, 272–279. [[CrossRef](#)]
103. Hoi, T.M.; Huong, L.T.; Van Chinh, H.; Hau, D.V.; Satyal, P.; Tai, T.A.; Dai, D.N.; Hung, N.H.; Hien, V.T.; Setzer, W.N. Essential oil compositions of three invasive *Conyza* species collected in Vietnam and their larvicidal activities against *Aedes aegypti*, *Aedes albopictus*, and *Culex quinquefasciatus*. *Molecules* **2020**, *25*, 4576. [[CrossRef](#)]
104. Luo, D.-Y.; Yan, Z.-T.; Che, L.-R.; Zhu, J.J.; Chen, B. Repellency and insecticidal activity of seven Mugwort (*Artemisia argyi*) essential oils against the malaria vector *Anopheles sinensis*. *Sci. Rep.* **2022**, *12*, 5337. [[CrossRef](#)]
105. Tabanca, N.; Demirci, B.; Ali, A.; Ali, Z.; Blythe, E.K.; Khan, I.A. Essential oils of green and red *Perilla frutescens* as potential sources of compounds for mosquito management. *Ind. Crops Prod.* **2015**, *65*, 36–44. [[CrossRef](#)]
106. Cheng, S.S.; Lin, C.Y.; Chung, M.J.; Liu, Y.H.; Huang, C.G.; Chang, S.T. Larvicidal activities of wood and leaf essential oils and ethanolic extracts from *Cunninghamia konishii* Hayata against the dengue mosquitoes. *Ind. Crops Prod.* **2013**, *47*, 310. [[CrossRef](#)]
107. Cheng, S.-S.; Chua, M.-T.; Chang, E.-H.; Huang, C.-G.; Chen, W.-J.; Chang, S.-T. Variations in insecticidal activity and chemical compositions of leaf essential oils from *Cryptomeria japonica* at different ages. *Bioresour. Technol.* **2009**, *100*, 465–470. [[CrossRef](#)] [[PubMed](#)]
108. Semerdjieva, I.B.; Zheljazkov, V.; Cantrell, C.L.; Astatkie, T.; Ali, A. Essential oil yield and composition of the Balkan endemic *Satureja pilosa* Velen. (Lamiaceae). *Molecules* **2020**, *25*, 827. [[CrossRef](#)] [[PubMed](#)]
109. Tabanca, N.; Avonto, C.; Wang, M.; Parcher, J.F.; Ali, A.; Demirci, B.; Raman, V.; Khan, I.A. Comparative investigation of *Umbellularia californica* and *Laurus nobilis* leaf essential oils and identification of constituents active against *Aedes aegypti*. *J. Agric. Food Chem.* **2013**, *61*, 12283–12291. [[CrossRef](#)]
110. He, Q.; Wang, W.; Zhu, L. Larvicidal activity of *Zanthoxylum acanthopodium* essential oil against the malaria mosquitoes, *Anopheles anthropophagus* and *Anopheles sinensis*. *Malar. J.* **2018**, *17*, 194. [[CrossRef](#)]

111. Seo, S.M.; Lee, J.W.; Shin, J.; Tak, J.H.; Hyun, J.; Park, I.K. Development of cellulose nanocrystal-stabilized Pickering emulsions of massoia and nutmeg essential oils for the control of *Aedes albopictus*. *Sci. Rep.* **2021**, *11*, 12038. [[CrossRef](#)] [[PubMed](#)]
112. Giatropoulos, A.; Papachristos, D.P.; Kimbaris, A.; Koliopoulos, G.; Polissiou, M.G.; Emmanouel, N.; Michaelakis, A. Evaluation of bioefficacy of three *Citrus* essential oils against the dengue vector *Aedes albopictus* (Diptera: Culicidae) in correlation to their components enantiomeric distribution. *Parasitol. Res.* **2012**, *111*, 2253–2263. [[CrossRef](#)] [[PubMed](#)]
113. Michaelakis, A.; Papachristos, D.; Kimbaris, A.; Koliopoulos, G.; Giatropoulos, A.; Polissiou, M.G. *Citrus* essential oils and four enantiomeric pinenes against *Culex pipiens* (Diptera: Culicidae). *Parasitol. Res.* **2009**, *105*, 769–773. [[CrossRef](#)]
114. Hung, N.H.; Dai, D.N.; Cong, T.N.; Dung, N.A.; Linh, L.D.; Van Hoa, V.; Hien, T.T.; Chuong, N.T.H.; Hien, V.T.; Van Nguyen, B.; et al. Pesticidal activities of *Callicarpa* and *Premna* essential oils from Vietnam. *Nat. Prod. Commun.* **2022**, *17*, 1934578X2211106. [[CrossRef](#)]
115. Ribeiro, I.A.T.A.; Sá, J.L.F.; Lima, M.V.; Veras, S.T.S.; Aguiar, J.C.R.O.F.; Aires, A.L.; Albuquerque, M.C.P.A.; da Silva, M.V.; Melo, A.M.M.A.; Navarro, D.M.A.F.; et al. Toxic effect of *Croton rudolphianus* leaf essential oil against *Biomphalaria glabrata*, *Schistosoma mansoni* Cercariae and *Artemia salina*. *Acta Trop.* **2021**, *223*, 106102. [[CrossRef](#)]
116. Lahlou, M. Composition and molluscicidal properties of essential oils of five Moroccan Pinaceae. *Pharm. Biol.* **2003**, *41*, 207–210. [[CrossRef](#)]
117. Corpas-López, V.; Merino-Espinosa, G.; López-Viota, M.; Gijón-Robles, P.; Morillas-Mancilla, M.J.; López-Viota, J.; Díaz-Sáez, V.; Morillas-Márquez, F.; Navarro Moll, M.C.; Martín-Sánchez, J. Topical treatment of *Leishmania tropica* infection using (–)- α -bisabolol ointment in a hamster model: Effectiveness and safety assessment. *J. Nat. Prod.* **2016**, *79*, 2403–2407. [[CrossRef](#)] [[PubMed](#)]
118. Arruda, D.C.; D’Alexandri, F.L.; Katzin, A.M.; Uliana, S.R.B. Antileishmanial activity of the terpene nerolidol. *Antimicrob. Agents Chemother.* **2005**, *49*, 1679–1687. [[CrossRef](#)]
119. Morais, S.; Cossolosso, D.; Silva, A.; de Moraes, M.; Teixeira, M.; Campello, C.; Bonilla, O.; de Paula, V.; Vila-Nova, N. Essential oils from *Croton* species: Chemical composition, in vitro and in silico antileishmanial evaluation, antioxidant and cytotoxicity activities. *J. Braz. Chem. Soc.* **2019**, *5*, 49–52. [[CrossRef](#)]
120. Braga de Oliveira, M.I.; Rodrigues Brandão, F.; Rocha da Silva, M.J.; Carvalho Rosa, M.; Santana Farias, C.F.; Silva dos Santos, D.; Majolo, C.; de Oliveira, M.R.; Chaves, F.C.M.; Bizzo, H.R.; et al. In vitro anthelmintic efficacy of essential oils in the control of *Neoechinorhynchus buttnerae*, an endoparasite of *Colossoma macropomum*. *J. Essent. Oil Res.* **2021**, *33*, 509–522. [[CrossRef](#)]
121. Diaz, J.G.; Arranz, J.C.E.; Da Gama Jaen Batista, D.; Fidalgo, L.M.; De La Vega Acosta, J.; de Macedo, M.B.; Cos, P. Antileishmanial potentialities of *Croton linearis* leaf essential oil. *Nat. Prod. Commun.* **2018**, *13*, 1934578X1801300. [[CrossRef](#)]
122. García-Díaz, J.; Escalona-Arranz, J.C.; Ochoa-Pacheco, A.; Dos Santos, S.G.; González-Fernández, R.; Rojas-Vargas, J.A.; Monzote, L.; Setzer, W.N. Chemical composition and in vitro and in silico antileishmanial evaluation of the essential oil from *Croton linearis* Jacq. stems. *Antibiotics* **2022**, *11*, 1712. [[CrossRef](#)] [[PubMed](#)]
123. Tariku, Y.; Hymete, A.; Hailu, A.; Rohloff, J. Constituents, antileishmanial activity and toxicity profile of volatile oil from berries of *Croton macrostachyus*. *Nat. Prod. Commun.* **2010**, *5*, 975–980. [[CrossRef](#)]
124. De Carvalho, M.G.; Rondon, F.C.M.; Carneiro-Torres, D.S.; Fampa, P.; Bevilaqua, C.M.L.; Nogueira Bandeira, P.; Amorim Gomes, G. *Croton pulegioidorus* Baill and *Croton piuihiensis* Mull. Arg. (Euphorbiaceae) essential oils: Chemical composition and anti-Leishmania activity. *Rev. Virtual Química* **2022**, *14*, 938–946. [[CrossRef](#)]
125. Rodrigues, I.A.; Azevedo, M.M.B.; Chaves, F.C.M.; Bizzo, H.R.; Corte-Real, S.; Alviano, D.S.; Alviano, C.S.; Rosa, M.S.S.; Vermelho, A.B. In vitro cytotoxic effects of the essential oil from *Croton cajucara* (Red Sacaca) and its major constituent 7-hydroxycalamenene against *Leishmania chagasi*. *BMC Complement. Altern. Med.* **2013**, *13*, 249. [[CrossRef](#)]
126. Monzote, L.; García, M.; Pastor, J.; Gil, L.; Scull, R.; Maes, L.; Cos, P.; Gille, L. Essential oil from *Chenopodium ambrosioides* and main components: Activity against Leishmania, their mitochondria and other microorganisms. *Exp. Parasitol.* **2014**, *136*, 20–26. [[CrossRef](#)]
127. Pastor, J.; García, M.; Steinbauer, S.; Setzer, W.N.; Scull, R.; Gille, L.; Monzote, L. Combinations of ascaridole, carvacrol, and caryophyllene oxide against Leishmania. *Acta Trop.* **2015**, *145*, 31–38. [[CrossRef](#)] [[PubMed](#)]
128. Nibret, E.; Wink, M. Trypanocidal and antileukaemic effects of the essential oils of *Hagenia abyssinica*, *Leonotis ocyimifolia*, *Moringa stenopetala*, and their main individual constituents. *Phytomedicine* **2010**, *17*, 911–920. [[CrossRef](#)] [[PubMed](#)]
129. Costa, S.; Cavadas, C.; Cavaleiro, C.; Salgueiro, L.; do Céu Sousa, M. In vitro susceptibility of *Trypanosoma brucei brucei* to selected essential oils and their major components. *Exp. Parasitol.* **2018**, *190*, 34–40. [[CrossRef](#)] [[PubMed](#)]
130. Guzmán, M.; González-Coloma, A.; Fe Andrés, M.; Navarro-Rocha, J.; Martínez-Díaz, R.A. Biological evaluation of essential oils from selected medicinal plants and their main components against *Phytomonas davidi* (Kinetoplastea: Trypanosomatidae). *Chem. Biodivers.* **2020**, *17*, e2000521. [[CrossRef](#)]
131. Essid, R.; Rahali, F.Z.; Msaada, K.; Sghair, I.; Hammami, M.; Bouratbine, A.; Aoun, K.; Limam, F. Antileishmanial and cytotoxic potential of essential oils from medicinal plants in Northern Tunisia. *Ind. Crops Prod.* **2015**, *77*, 795–802. [[CrossRef](#)]
132. Tasdemir, D.; Kaiser, M.; Demirci, B.; Demirci, F.; Baser, K.H.C. Antiprotozoal activity of Turkish *Origanum onites* essential oil and its components. *Molecules* **2019**, *24*, 4421. [[CrossRef](#)]
133. Do Carmo, D.F.M.; Amaral, A.C.F.; MacHado, G.M.C.; Leon, L.L.; De Andrade Silva, J.R. Chemical and biological analyses of the essential oils and main constituents of *Piper* species. *Molecules* **2012**, *17*, 1819–1829. [[CrossRef](#)]

134. Leal, S.M.; Pino, N.; Stashenko, E.E.; Martínez, J.R.; Escobar, P. Antiprotozoal activity of essential oils derived from *Piper* spp. grown in Colombia. *J. Essent. Oil Res.* **2013**, *25*, 512–519. [[CrossRef](#)]
135. Almohammed, H.I.; Alkhaibari, A.M.; Alanazi, A.D. Antiparasitic effects of *Elettaria cardamomum* L. essential oil and its main compounds, 1,8-cineole alone and in combination with albendazole against *Echinococcus granulosus* Protoscoleces. *Saudi J. Biol. Sci.* **2022**, *29*, 2811–2818. [[CrossRef](#)]
136. Silva, A.; Scher, R.; Santos, F.; Ferreira, S.; Cavalcanti, S.; Correa, C.; Bueno, L.; Alves, R.; Souza, D.; Fujiwara, R.; et al. Leishmanicidal activity and structure-activity relationships of essential oil constituents. *Molecules* **2017**, *22*, 815. [[CrossRef](#)]
137. Machado, M.; Dinis, A.M.; Santos-Rosa, M.; Alves, V.; Salgueiro, L.; Cavaleiro, C.; Sousa, M.C. Activity of *Thymus capitellatus* volatile extract, 1,8-cineole and borneol against *Leishmania* species. *Vet. Parasitol.* **2014**, *200*, 39–49. [[CrossRef](#)]
138. Kpadonou Kpoviessi, B.G.H.; Kpoviessi, S.D.S.; Yayi Ladekan, E.; Gbaguidi, F.; Frédérick, M.; Moudachirou, M.; Quetin-Leclercq, J.; Accrombessi, G.C.; Bero, J. In vitro antitrypanosomal and antiplasmodial activities of crude extracts and essential oils of *Ocimum gratissimum* Linn from Benin and influence of vegetative stage. *J. Ethnopharmacol.* **2014**, *155*, 1417–1423. [[CrossRef](#)] [[PubMed](#)]
139. De Menezes, R.R.P.P.B.; Sampaio, T.L.; Lima, D.B.; Sousa, P.L.; de Azevedo, I.E.P.; Magalhães, E.P.; Tessarolo, L.D.; Marinho, M.M.; dos Santos, R.P.; Martins, A.M.C. Antiparasitic effect of (–)- α -bisabolol against *Trypanosoma cruzi* Y strain forms. *Diagn. Microbiol. Infect. Dis.* **2019**, *95*, 114860. [[CrossRef](#)] [[PubMed](#)]
140. Hajaji, S.; Sifaoui, I.; López-Arencibia, A.; Reyes-Batlle, M.; Jiménez, I.A.; Bazzocchi, I.L.; Valladares, B.; Akkari, H.; Lorenzo-Morales, J.; Piñero, J.E. Leishmanicidal activity of α -bisabolol from Tunisian chamomile essential oil. *Parasitol. Res.* **2018**, *117*, 2855–2867. [[CrossRef](#)] [[PubMed](#)]
141. Clemente, C.M.; Pineda, T.; Yepes, L.M.; Upegui, Y.; Allemandi, D.A.; Robledo, S.M.; Ravetti, S. Eugenol carbonate activity against *Plasmodium falciparum*, *Leishmania braziliensis*, and *Trypanosoma cruzi*. *Arch. Pharm.* **2022**, *355*, 2100432. [[CrossRef](#)]
142. Ueda-Nakamura, T.; Mendonça-Filho, R.R.; Morgado-Díaz, J.A.; Korehisa Maza, P.; Prado Dias Filho, B.; Aparício Garcia Cortez, D.; Alviano, D.S.; Rosa, M.D.S.S.; Lopes, A.H.C.S.; Alviano, C.S.; et al. Antileishmanial activity of eugenol-rich essential oil from *Ocimum gratissimum*. *Parasitol. Int.* **2006**, *55*, 99–105. [[CrossRef](#)]
143. Wanas, A.S.; Radwan, M.M.; Mehmedic, Z.; Jacob, M.; Khan, I.A.; Elsohly, M.A. Antifungal activity of the volatiles of high potency *Cannabis sativa* L. against *Cryptococcus neoformans*. *Rec. Nat. Prod.* **2015**, *10*, 214–220.
144. Menezes, L.R.A.; Santos, N.N.; Meira, C.S.; dos Santos, J.A.F.; Guimarães, E.T.; Soares, M.B.P.; Nepel, A.; Barison, A.; Costa, E.V. A new source of (R)-limonene and rotundifolone from leaves of *Lippia pedunculosa* (Verbenaceae) and their trypanocidal properties. *Nat. Prod. Commun.* **2014**, *9*, 1934578X1400900. [[CrossRef](#)]
145. Matos-Rocha, T.; dos Santos Cavalcanti, M.; Barbosa-Filho, J.; Lúcio, A.; Veras, D.; Feitosa, A.; de Siqueira Júnior, J.; de Almeida, R.; Marques, M.; Alves, L.; et al. In vitro evaluation of schistosomicidal activity of essential oil of *Mentha x villosa* and some of its chemical constituents in adult worms of *Schistosoma mansoni*. *Planta Med.* **2013**, *79*, 1307–1312. [[CrossRef](#)]
146. Ceole, L.F.; Cardoso, M.D.G.; Soares, M.J. Nerolidol, the main constituent of *Piper aduncum* essential oil, has anti-*Leishmania braziliensis* activity. *Parasitology* **2017**, *144*, 1179–1190. [[CrossRef](#)] [[PubMed](#)]
147. Teles, A.M.; Silva-Silva, J.V.; Fernandes, J.M.P.; da Silva Calabrese, K.; Abreu-Silva, A.L.; Marinho, S.C.; Mouchrek, A.N.; Filho, V.E.M.; Almeida-Souza, F. *Aniba rosaeodora* (var. *amazonica* Ducke) essential oil: Chemical composition, antibacterial, antioxidant and antitrypanosomal activity. *Antibiotics* **2020**, *10*, 24. [[CrossRef](#)] [[PubMed](#)]
148. Villamizar, L.H.; das Graças Cardoso, M.; de Andrade, J.; Teixeira, M.L.; Soares, M.J. Linalool, a *Piper aduncum* essential oil component, has selective activity against *Trypanosoma cruzi* trypomastigote forms at 4 °C. *Mem. Inst. Oswaldo Cruz* **2017**, *112*, 131–139. [[CrossRef](#)] [[PubMed](#)]
149. Mikus, J.; Harkenthal, M.; Steverding, D.; Reichling, J. In vitro effect of essential oils and isolated mono- and sesquiterpenes on *Leishmania major* and *Trypanosoma brucei*. *Planta Med.* **2000**, *66*, 366–368. [[CrossRef](#)]
150. Pereira Filho, A.A.; Cunha, M.M.; Alves Stanton, M.; Fumiko Yamaguchi, L.; Jorge Kato, M.; Martins-Duarte, É.S. In vitro activity of essential oils from *Piper* species (Piperaceae) against tachyzoites of *Toxoplasma gondii*. *Metabolites* **2023**, *13*, 95. [[CrossRef](#)]
151. Dahham, S.; Tabana, Y.; Iqbal, M.; Ahamed, M.; Ezzat, M.; Majid, A.; Majid, A. The anticancer, antioxidant and antimicrobial properties of the sesquiterpene β -caryophyllene from the essential oil of *Aquilaria crassna*. *Molecules* **2015**, *20*, 11808–11829. [[CrossRef](#)]
152. Hossain, M.A.; Ismail, Z.; Rahman, A.; Kang, S.C. Chemical composition and anti-fungal properties of the essential oils and crude extracts of *Orthosiphon stamineus* Benth. *Ind. Crops Prod.* **2008**, *27*, 328–334. [[CrossRef](#)]
153. Lazarević, J.S.; Dorđević, A.S.; Kitić, D.V.; Zlatković, B.K.; Stojanović, G.S. Chemical composition and antimicrobial activity of the essential oil of *Stachys officinalis* (L.) Trevis. (Lamiaceae). *Chem. Biodivers.* **2013**, *10*, 1335–1349. [[CrossRef](#)]
154. Ximenes, R.M.; de Morais Nogueira, L.; Cassundé, N.M.R.; Jorge, R.J.B.; dos Santos, S.M.; Magalhães, L.P.M.; Silva, M.R.; de Barros Viana, G.S.; Araújo, R.M.; de Sena, K.X. da F.R.; et al. Antinociceptive and wound healing activities of *Croton adamantinus* Müll. Arg. essential oil. *J. Nat. Med.* **2013**, *67*, 758–764. [[CrossRef](#)]
155. Cucho-Medrano, J.L.L.; Mendoza-Beingolea, S.W.; Fuertes-Ruitón, C.M.; Salazar-Salvatierra, M.E.; Herrera-Calderon, O. Chemical profile of the volatile constituents and antimicrobial activity of the essential oils from *Croton adipatus*, *Croton thurifer*, and *Croton collinus*. *Antibiotics* **2021**, *10*, 1387. [[CrossRef](#)]
156. Da Silva Brito, S.S.; Silva, F.; Malheiro, R.; Baptista, P.; Pereira, J.A. *Croton argyrophyllus* Kunth and *Croton heliotropiifolius* Kunth: Phytochemical characterization and bioactive properties. *Ind. Crops Prod.* **2018**, *113*, 308–315. [[CrossRef](#)]

157. Araújo, L.G.; Veras, G.; Oliveira Alves, J.V.; Oliveira de Veras, B.; Silva, M.V.; Bacalhau Rodrigues, J.F.; Lia Fook, M.V.; Sagoe Amoah, S.K.; Conceição de Menezes Torres, M. Chemodiversity and antibacterial activity of the essential oil of leaves of *Croton argyrophyllus*. *Chem. Biodivers.* **2020**, *17*, e2000575. [[CrossRef](#)] [[PubMed](#)]
158. Vasconcelos, B.M.; Pereira, A.M.G.; Coelho, P.A.T.; Cavalcante, R.M.B.; Carneiro-Torres, D.S.; Bandeira, P.N.; da Silva, F.F.; Rodrigues, T.H.S.; Gomes, G.A.; Carneiro, V.A. Enhancement of chlorhexidine activity against planktonic and biofilm forms of oral streptococci by two *Croton* spp. essential oils from the caatinga biome. *Biofouling* **2022**, *38*, 984–993. [[CrossRef](#)] [[PubMed](#)]
159. Barreto Alves, J.A.; da Silva Nunes, M.; Fakhouri, R.; Saquete Martins-Filho, P.R.; do Carmo de Oliveira Ribeiro, M.; Correa de Vasconcelos, A.; Oliveira Santos, P.; Marchioro, M.; de Cassia Trindade, R.; Santos Frazão, G.G.; et al. Inhibition of drug-sensitive and drug-resistant mycobacterium tuberculosis strains by essential oil from *Croton argyrophylloides* Mull. Arg. *Int. Arch. Med.* **2016**, *9*, 1–7. [[CrossRef](#)]
160. Malveira, E.A.; Souza, P.F.N.; Neto, N.A.S.; Aguiar, T.K.B.; Rodrigues, N.S.; Henrique, C.W.B.; Silva, A.F.B.; Lima, L.B.; Albuquerque, C.C.; Freitas, C.D.T. Essential oil from *Croton blanchetianus* leaves: Anticandidal potential and mechanisms of action. *J. Fungi* **2022**, *8*, 1147. [[CrossRef](#)]
161. De Vasconcelos, E.C.; Longhi, D.A.; Paganini, C.C.; Severo, D.d.S.; Canuto, K.M.; de Queiroz Souza, A.S.; de Figueiredo, E.A.T.; de Aragão, G.M.F. Modeling the effect of *Croton blanchetianus* Baill essential oil on pathogenic and spoilage bacteria. *Arch. Microbiol.* **2022**, *204*, 618. [[CrossRef](#)]
162. Alviano, W.S.; Mendonça-Filho, R.R.; Alviano, D.S.; Bizzo, H.R.; Souto-Padron, T.; Rodrigues, M.L.; Bolognese, A.M.; Alviano, C.S.; Souza, M.M.G. Antimicrobial activity of *Croton cajucara* Benth linalool-rich essential oil on artificial biofilms and planktonic microorganisms. *Oral Microbiol. Immunol.* **2005**, *20*, 101–105. [[CrossRef](#)]
163. Azevedo, M.M.B.; Almeida, C.A.; Chaves, F.C.M.; Ricci-Júnior, E.; Garcia, A.R.; Rodrigues, I.A.; Alviano, C.S.; Alviano, D.S. *Croton cajucara* essential oil nanoemulsion and its antifungal activities. *Processes* **2021**, *9*, 1872. [[CrossRef](#)]
164. Azevedo, M.M.B.; Pereira, A.Q.; Chaves, F.C.M.; Bizzo, H.R.; Alviano, C.S.; Alviano, D.S. Antimicrobial activity of the essential oils from the leaves of two morphotypes of *Croton cajucara* Benth. *J. Essent. Oil Res.* **2012**, *24*, 351–357. [[CrossRef](#)]
165. Azevedo, M.; Chaves, F.; Almeida, C.; Bizzo, H.; Duarte, R.; Campos-Takaki, G.; Alviano, C.; Alviano, D. Antioxidant and antimicrobial activities of 7-hydroxy-calamenene-rich essential oils from *Croton cajucara* Benth. *Molecules* **2013**, *18*, 1128–1137. [[CrossRef](#)]
166. El Babili, F.; Fouraste, I.; Moulis, C.; Bessiere, J.M.; Roques, C.; Haddioui, L. Essential oil of leaves of *Croton campestris* St. Hilaire, its secretory elements, and its biological activity. *J. Essent. Oil Res.* **2009**, *21*, 272–275. [[CrossRef](#)]
167. Sánchez-Hernández, G.R.; Villa-Ruano, N.; Rubio-Rosas, E.; Zarate-Reyes, J.A.; Cruz-Durán, R.; Lozoya-Gloria, E. Chemical constituents and anti-fungal activity of the essential oils from *Lantana hirta* and *Croton ciliatoglandulifer*. *Rev. Latinoam. Quim.* **2018**, *46*, 17–24.
168. De Oliveira, G.D.; da Rocha, W.R.V.; Rodrigues, J.F.B.; da Silva Alves, H. Synergistic and antibiofilm effects of the essential oil from *Croton conduplicatus* (Euphorbiaceae) against methicillin-resistant *Staphylococcus aureus*. *Pharmaceuticals* **2022**, *16*, 55. [[CrossRef](#)] [[PubMed](#)]
169. Albuquerque, Y.E.; Danelon, M.; Salvador, M.J.; Koga-Ito, C.Y.; Botazzo Delbem, A.C.; Ramirez-Rueda, R.Y.; Lacerda Gontijo, A.V.; Brighenti, F.L. Mouthwash containing *Croton doctoris* essential oil: In vitro study using a validated model of caries induction. *Future Microbiol.* **2018**, *13*, 631–643. [[CrossRef](#)] [[PubMed](#)]
170. Valarezo, E.; Gaona-Granda, G.; Morocho, V.; Cartuche, L.; Calva, J.; Meneses, M.A. Chemical constituents of the essential oil from Ecuadorian endemic species *Croton ferrugineus* and its antimicrobial, antioxidant and α -glucosidase inhibitory activity. *Molecules* **2021**, *26*, 4608. [[CrossRef](#)]
171. Lawal, O.A.; Ogunwande, I.A.; Osunsanmi, F.O.; Opoku, A.R.; Oyediji, A.O. *Croton gratissimus* leaf essential oil composition, antibacterial, antiplatelet aggregation, and cytotoxic activities. *J. Herbs. Spices Med. Plants* **2017**, *23*, 77–87. [[CrossRef](#)]
172. De Medeiros, V.M.; do Nascimento, Y.M.; Souto, A.L.; Madeiro, S.A.L.; Costa, V.C.d.O.; Silva, S.M.P.M.; Falcão Silva, V.d.S.; Agra, M.d.F.; de Siqueira-Júnior, J.P.; Tavares, J.F. Chemical composition and modulation of bacterial drug resistance of the essential oil from leaves of *Croton grewioides*. *Microb. Pathog.* **2017**, *111*, 468–471. [[CrossRef](#)]
173. De Alencar Filho, J.M.T.; Araújo, L.D.C.; Oliveira, A.P.; Guimarães, A.L.; Pacheco, A.G.M.; Silva, F.S.; Cavalcanti, L.S.; Lucchese, A.M.; Almeida, J.R.G.D.S.; Araújo, E.C.D.C. Chemical composition and antibacterial activity of essential oil from leaves of *Croton heliotropiifolius* in different seasons of the year. *Rev. Bras. Farmacogn.* **2017**, *27*, 440–444. [[CrossRef](#)]
174. Araújo, F.M.; Dantas, M.C.S.M.; e Silva, L.S.; Aona, L.Y.S.; Tavares, I.F.; de Souza-Neta, L.C. Antibacterial activity and chemical composition of the essential oil of *Croton heliotropiifolius* Kunth from Amargosa, Bahia, Brazil. *Ind. Crops Prod.* **2017**, *105*, 203–206. [[CrossRef](#)]
175. Moreno, P.R.H.; Lima, M.E.L.; Caruzo, M.B.R.; Torres, D.S.C.; Cordeiro, I.; Young, M.C.M. Chemical composition and antimicrobial activity of the essential oil from *Croton heterocalyx* Baill. (Euphorbiaceae s.s.) leaves. *J. Essent. Oil Res.* **2009**, *21*, 190–192. [[CrossRef](#)]
176. De Heluani, C.S.; de Lampasona, M.P.; Vega, M.I.; Catalan, C.A.N. Antimicrobial activity and chemical composition of the leaf and root oils from *Croton hieronymi* Griseb. *J. Essent. Oil Res.* **2005**, *17*, 351–353. [[CrossRef](#)]
177. Rossi, D.; Guerrini, A.; Maietti, S.; Bruni, R.; Paganetto, G.; Poli, F.; Scalvenzi, L.; Radice, M.; Saro, K.; Sacchetti, G. Chemical fingerprinting and bioactivity of Amazonian Ecuador *Croton lechleri* Müll. Arg. (Euphorbiaceae) stem bark essential oil: A new functional food ingredient? *Food Chem.* **2011**, *126*, 837–848. [[CrossRef](#)]

178. Werka, J.S.; Boehme, A.K.; Setzer, W.N. Biological activities of essential oils from Monteverde, Costa Rica. *Nat. Prod. Commun.* **2007**, *2*, 1215–1219. [[CrossRef](#)]
179. Setzer, W.N. Chemical compositions of the bark essential oils of *Croton monteverdensis* and *Croton niveus* from Monteverde, Costa Rica. *Nat. Prod. Commun.* **2006**, *1*, 567–572. [[CrossRef](#)]
180. Athikomkulchai, S.; Tadtong, S.; Ruangrunsi, N.; Hongratanaworakit, T. Chemical composition of the essential oil from *Croton oblongifolius* and its antibacterial activity against *Propionibacterium acnes*. *Nat. Prod. Commun.* **2015**, *10*, 1934578X1501000. [[CrossRef](#)]
181. Vidal, C.S.; Oliveira-Tintino, C.D.M.; Tintino, S.R.; Galvão, H.B.F.; da Costa, J.G.M.; Coutinho, H.D.M.; de Menezes, I.R.A. Chemical composition, antibacterial and modulatory action of the essential oil of *Croton rhamnifolioides* Pax and Hoffman leaves. *Biosci. J.* **2016**, *32*, 1632–1643. [[CrossRef](#)]
182. Martins, A.P.; Salgueiro, L.R.; Gonçalves, M.J.; Vila, R.; Tomi, F.; Adzet, T.; Proença da Cunha, A.; Cañigueral, S.; Casanova, J. Antimicrobial activity and chemical composition of the bark oil of *Croton stellulifer*, an endemic species from S. Tomé e Príncipe. *Planta Med.* **2000**, *66*, 647–650. [[CrossRef](#)]
183. Almeida-Pereira, C.S.; de Lima Nogueira, P.C.; Barbosa, A.A.T.; Aparecida de Castro Nizio, D.; de Fatima Arrigoni-Blank, M.; Sampaio, T.S.; Alves, R.P.; de Araujo-Couto, H.G.S.; Feitosa-Alcantara, R.B.; de Melo, J.O.; et al. Chemical composition and antimicrobial activity of essential oils of a *Croton tetradenius* Baill. Germplasm. *J. Essent. Oil Res.* **2019**, *31*, 379–389. [[CrossRef](#)]
184. Siqueira, I.B.; Teixeira Barbosa, A.A.; Jain, S.; Miranda Fernandes, R.P.; Tavares Silva, A.R.S.; Ferreira Barbosa, F.H.; Schimieguel, D.M.; Blank, A.F.; Sacramento, A.G.; de Castro Nizio, D.A.; et al. In vitro antibacterial activity of essential oils of *Croton tetradenius* Baill. from the Brazilian Caatinga Biome and its synergistic effect with ciprofloxacin and meropenem. *J. Essent. Oil Bear. Plants* **2021**, *24*, 12–21. [[CrossRef](#)]
185. Rocha, R.R.; Matos, M.N.C.; Guerrero, J.A.P.; Cavalcante, R.M.B.; Melo, R.S.; Azevedo, Á.M.A.; Pereira, A.M.G.; Lopes, P.H.R.; Rodrigues, T.H.S.; Bandeira, P.N.; et al. Comparative study of the chemical composition, antibacterial activity and synergic effects of the essential oils of *Croton tetradenius* Baill. and *C. Pulegiodorus* Baill. against *Staphylococcus aureus* isolates. *Microb. Pathog.* **2021**, *156*, 104934. [[CrossRef](#)]
186. Miranda, F.M.; Braga do Nascimento Junior, B.; Aguiar, R.M.; Pereira, R.S.; De Oliveira Teixeira, A.; Menzes De Oliveira, D.; de Oliveira Lima, E.; Oigman, S.S.; Moraes de Rezende, C.; Frolidi, G. Promising antifungal activity of *Croton tricolor* stem essential oil against *Candida* yeasts. *J. Essent. Oil Res.* **2019**, *31*, 223–227. [[CrossRef](#)]
187. Simionatto, E.; Bonani, V.F.L.; Morel, A.F.; Poppi, N.R.; Raposo Júnior, J.L.; Stuker, C.Z.; Peruzzo, G.M.; Peres, M.T.L.P.; Hess, S.C. Chemical composition and evaluation of antibacterial and antioxidant activities of the essential oil of *Croton urucurana* Baillon (Euphorbiaceae) stem bark. *J. Braz. Chem. Soc.* **2007**, *18*, 879–885. [[CrossRef](#)]
188. Yagi, S.; Babiker, R.; Tzanova, T.; Schohn, H. Chemical composition, antiproliferative, antioxidant and antibacterial activities of essential oils from aromatic plants growing in Sudan. *Asian Pac. J. Trop. Med.* **2016**, *9*, 763–770. [[CrossRef](#)] [[PubMed](#)]
189. Adams, R.P. *Identification of Essential Oil Components by Gas Chromatography/Mass Spectrometry*, 5th ed.; Texensis Publishing: Gruver, TX, USA, 2017; ISBN 9780998155722.
190. Mondello, L. *FFNSC 3*; Shimadzu Scientific Instruments: Columbia, MD, USA, 2016.
191. NIST17. *NIST17*; National Institute of Standards and Technology: Gaithersburg, MD, USA, 2017.
192. Satyal, P. Development of GC-MS Database of Essential Oil Components by the Analysis of Natural Essential Oils and Synthetic Compounds and Discovery of Biologically Active Novel Chemotypes in Essential Oils. Ph.D. Thesis, University of Alabama in Huntsville, Huntsville, AL, USA, 2015.
193. Huong, L.T.; Hung, N.H.; Dai, D.N.; Tai, T.A.; Hien, V.T.; Satyal, P.; Setzer, W.N. Chemical compositions and mosquito larvicidal activities of essential oils from *Piper* species growing wild in Central Vietnam. *Molecules* **2019**, *24*, 3871. [[CrossRef](#)] [[PubMed](#)]
194. Hadacek, F.; Greger, H. Testing of antifungal natural products: Methodologies, comparability of results and assay choice. *Phytochem. Anal.* **2000**, *11*, 137–147. [[CrossRef](#)]
195. Finney, D. *Probit Analysis*, Reissue, ed.; Cambridge University Press: Cambridge, UK, 2009; ISBN 978-0521135900.
196. Scandiffio, R.; Geddo, F.; Cottone, E.; Querio, G.; Antoniotti, S.; Gallo, M.P.; Maffei, M.E.; Bovolín, P. Protective effects of (*E*)- β -caryophyllene (bcp) in chronic inflammation. *Nutrients* **2020**, *12*, 3273. [[CrossRef](#)]

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