In this brief review, an updated version of the bioactivities of the EOs obtained from numerous species of the genus Curcuma has been provided. Over the last five years, many studies have been reported for the biological effects of the EOs isolated from Curcuma plants such as antimicrobial, antioxidant, anti-inflammatory, anti-trypanosomal, antileishmanial, anti-acetylcholinesterase, antiproliferative, cytotoxic, larvicidal, and insecticidal activities. In this brief review, an updated version of the bioactivities of EOs from different species belonging to Curcuma genus are presented.

**Keywords**
Curcuma, essential oil, bioactivity

**Introduction**
Curcuma L., one of the largest genera (about 108 species) belonging to Zingiberaceae family, includes perennial rhizomatous herbs. Most of the members of this genus are native to subtropical and tropical localities such as Northern Australia, New Guinea, Southern China, Southeast Asia, India, Africa and Central America. The habitat, the flowers, and the shapes of leaves among Curcuma species are analogous. The height of them is ranging from 0.5 to 2.0 meters. The members of this genus are characterized by their inflorescence, which has a compound spike with outstanding bracts each subtending a cincinnus of 2–10 flowers, and they are connected with each other forming pouches at the base.

A large number of Curcuma species have been used for many purposes, including possessing preservatives (3), flavoring (4), and medicinal properties (5). Notably, many species of this genus are known for their traditional medicine to treat many diseases like infectious wounds, pneumonia, abscesses, leucorrhrea, insect bites, diarrhea, and bronchial complaints (6). The chemical compositions and biological activities of numerous Curcuma plants have been reported by prior studies (7-10). In addition, Curcuma plants are a prominent material for extracting essential oils, and they have been reported to have various biological effects such as anti-inflammatory, antimicrobial, antioxidant, antithrombotic, anticancerous, insecticidal, larvicidal effects, etc. (11). In 2018, Dosoky et al. provided an overview of the chemical profiles and bioactivities of EOs obtained from various species of Curcuma genus. Over the last five years, more and more
studies have been reported for the biological properties of the EOs isolated from Curcuma species. Thus, an updated version of the bioactivity of EOs from different species belonging to Curcuma genus is presented in this brief review.

**Biological activity of EOs from Curcuma genus**

**Curcuma longa L.**

*Curcuma longa* L., commonly known as “turmeric”, is a native of Southeast Asia (12). It is also found in other Asian countries such as China, India, Nepal (13). A turmeric rhizome powder is considered as one of the major products from this species. It is broadly used as a spice, flavoring or traditional medicine (13). Furthermore, *Curcuma longa* has been reported to possess some bioactivities effects, including antifungal, antioxidant (14), antimicrobial (12), and antileishmanial (15) activities.

The EO obtained from the *C. longa* leaf collected from Thirssur, India was found to be effective against four pathogenic strains such as *Escherichia coli*, *Pseudomonas aeruginosa*, *Salmonella enterica* with a MIC values of 0.625, 0.625, and 0.500 mg/mL, respectively (16). Teles et al. provided that the EO of *C. longa* aerial part grown in Sao Luis, Brazil displayed effects against *Staphylococcus aureus* with MIC value of 83.3µg/mL (17). Moreover, the rhizome EO of *C. longa* from Morona-Santiago province, Ecuador showed strong antimicrobial activities against *Listeria grayi* and *Saccharomyces cerevisiae* with MIC values of 8.98 mg/mL, followed by *S. aureus* (48.75 mg/mL), *Enterococcus foecalis* (89.5 mg/mL), *Micrococcus luteus* (89.5 mg/mL), *Klebsiella oxytoca* (89.75 mg/mL), *Proteus vulgaris* (89.75 mg/mL), *E. coli* (44.88 mg/mL), *P. aeruginosa* (89.5 mg/mL), and *Candida albicans* (89.75 mg/mL) (18).

*C. longa* leaf EO from Thirssur, India showed cytotoxic activities against MCF-7 and MDA-MB-231 cells with IC$_{50}$ values of 40.74 and 45.17 µg/mL, respectively (16). Le et al. provided that the rhizome EO and its major compounds such as ar-Curcumene, currone, β-sesquiphellandrene of *C. longa* collected from Vietnam showed cytotoxicity and anti-trypanosomal activity. Accordingly, the rhizome EO and its components possessed cytotoxic activities against WI38 and J774 with IC$_{50}$ values of 46.00 and 44.11 nM/mL, 23.15 and 24.03 µg/mL, 43.64 and 25.06 µg/mL, 19.11 and 21.02 µg/mL, respectively (19). Furthermore, they also possessed anti-trypanosomal effect against *Trypanosoma brucei* with IC$_{50}$ values of 3.17 nM/mL, 13.38, 1.38, and 9.89 µg/mL, respectively (19).

The EO isolated from *C. longa* leaf grown in Thirssur, India showed potent DPPH, ABTS, and H$_2$O$_2$. Radical scavenging activities with IC$_{50}$ values of 8.62, 9.21, and 4.35 µg/mL, respectively (16). Meanwhile, the rhizome EO of *C. longa* from Morona-Santiago province, Ecuador also possessed ABTS and DPPH radical scavenging activities with IC$_{50}$ values of 0.871 and 16.512 mg/mL (18). Teles et al. showed that the EOs of *C. longa* aerial part from Sao Luis, Brazil possessed antileishmanial activity against *Leishmania amazonensis* by inhibiting intracellular amastigote and antipromastigote. Accordingly, this EO showed antipromastigote effect with IC$_{50}$ value of 405.5 µg/mL, while IC$_{50}$ of 63.3 µg/mL was intracellular amastigote activity towards the same parasite (17).

**Curcuma aromatica Salisb.**

*C. aromatica* is widely known as “wild turmeric”. This species has been used as a medicinal plant to treat skin eruptions, sprains, bronchitis, hiccough, cough and leukoderma. The EOs isolated from this species have been reported to have various bioactivities, including antibacterial, antifungal, and antioxidant activities (20).

Albaqami et al. provided that the leaf EOs of *C. aromatica* from Thirssur, India has been reported to exhibit cytotoxic activities against MCF-7 and MDA-MB-231 with IC$_{50}$ value of 55.75 and 67.11µg/mL (16). In addition, the EO of *C. aromatic* leaves possessed DPPH, ABTS, and H$_2$O$_2$ radical scavenging effects with IC$_{50}$ values of 15.23, 13.28, and 8.38 µg/mL, respectively (16). This sample EO was also found to be effective against *P. aeruginosa*, *E. coli*, *S. aureus* and *S. enterica* with MIC values of 0.62, 1.00, 0.75, and 1.25 mg/mL, respectively (16). Xiang et al. provided that the rhizome EO of *C. aromatica* from China had an inhibitory effect on some bacterial and fungal strains, including *E. coli*, *P. aeruginosa*, *S. aureus*, *C. albicans*, and *C. cerevisiae* with MIC values of 593.25, 598.75, 595.46, 176.92, and 183.18 µg/mL, respectively (21). Moreover, the anti-inflammatory inhibition of EOs from this plant on TPA-induced mice ear edema has also been reported. Accordingly, at dose of 25, 50, and 100 mg/kg, the anti-inflammation of this EO was 21.65, 44.04, and 68.26%, respectively (21). In addition, EO also possessed cytotoxic activities against LNCaP and HepG2 cells with IC$_{50}$ values of 1.14 and 168.94 µg/mL, respectively (21). Meanwhile, Parida et al. provided that the EO of *C. aromatica* rhizome from forest areas of Eastern Ghats, India showed cytotoxic effect against MCF-7 cell with IC$_{50}$ value of 42.6µL/mL (20).

**Curcuma aeruginosa Roxb.**

*C. aeruginosa* is a perennial herb widely found in Southeast Asia (22). The *C. aeruginosarthizome* has been used extensively in traditional to cure stomachache, diarrhea, uterine pain, tumours, bronchitis, and fungal infections, etc. (20-22).

Fitia et al. demonstrated the cytotoxic effects of the rhizome EO of *C. aeruginosa* from Bogor, Indonesia using brine shrimp (Artemiasalina) lethality test and against MCF-7. Accordingly, this EO possessed cytotoxic activities against *A. saline* and MCF-7 cell with LC$_{50}$ values of 78.2 and 161.0 µg/mL, respectively (23). The rhizome EO of *C. aeruginosa* grown in Malaysia had an inhibitory effect on *S. typhimurium*, *E. coli*, *S. aureus*, *B. cereus* with the inhibition zones of 6.33, 9.00, 9.67, 10.00 mm, respectively (24). In addition, the rhizome EOs from twenty genotypes of *C. aeruginosa* from Tropical Biopharmacare Research Center, Indonesia were found to be effective against *S. mutans*, *S. aureus* and *E. coli*. The results showed that the sixteen out of twenty genotypes displayed activity against *S. aureus* with inhibition zones ranging from 0.52 to 4.79 mm. The five out of twenty genotypes possessed antibacterial effects against *S. mutans* with inhibition zones ranging
from 1.44 to 4.45 mm whereas *E. coli* were inhibited by the only one out of twenty genotypes with inhibition zone of 3.32 mm (25).

**Curcuma zedoaria** (Christm.) Roscoe

*C. zedoaria* is a medicinal plant and is widely found in Asia regions. This species was also used as food and spices (26). In Asia traditional medicine, the plant parts of *C. zedoaria* commonly used to treat tuberculosis, stomach diseases, blood stagnation, enlargement of spleen, toothache, and leukoderm (27). Furthermore, studies demonstrated that the rhizome of this plant possessed various biological effects, including antitumour (28), antimicrobial (29), and anti-inflammatory (30) activities.

The rhizome EO of *C. zedoaria* from Vietnam possessed anti-trypanosomosal effect against *Trypanosoma brucei* with *IC*₅₀ values of 2.51 nL/mL while this EO had also cytotoxic activities against WI38 and J774 with *IC*₅₀ values of 46.64 and 26.81 µg/mL, respectively (19). In addition, the EO of *C. zedoaria* rhizome from Odisha, India has been reported to possess antibacterial and antioxidant effects (31). Accordingly, this EO was active against various microbial strains, including *B. subtilis*, *S. aureus*, *E. coli*, *E. faecalis*, *A. niger*, *P. aeruginosa*, *C. albicans*, *A. flavus* and *F. oxysporum* with MIC values ranging from 6.25 to 50 µg/mL (31). Meanwhile, this EO possessed ABTS and DPPH radical scavenging activities with *IC*₅₀ values of 1.28 and 2.58 µg/mL, respectively (31). In addition, Bressan et al. demonstrated that the EO from *C. zedoaria* showed acaricidal effects against *Rhipicephalus microplus* larvae and engorged females. At dose of 15 mg/mL, this EO exhibited a larvae mortality of 100% *R. microplus* larvae while 98.6% efficacy on engorged females at dose of 80 mg/mL (32). Meanwhile, Junior et al. provided that the EO isolated from *C. zedoaria* rhizome possessed low acaricidal effect on Dermacentornitens with the control percentage of 4.9% (33).

**Curcuma caesia** Roxb.

*C. caesia* is a medicinal herb, native to Central and North East India (34) and also found in South east Asia (35). The rhizome extracts of this species has been reported to use in the treatment of antihelmentic, epilepsy, leprosy, hemorrhoids, cancer, and disorder (36).

The rhizome EO of *C. caesia* from Malaysia showed potent DPPH radical scavenging and anti-inflammatory effects with *IC*₅₀ values of 48.08 and 121.7 µg/mL, respectively. Furthermore, this EO was also found to be effective against *B. subtilis* and *B. cereus* with MIC value of 7.5 µg/mL while *S. cereviaceae* was sensitive to this EO with MIC value of 2.5 µg/mL (37). Borah et al. provided that the leaf EO of *C. caesia* from Assam, India possessed anti-inflammatory, antioxidant, and antimicrobial activities. Accordingly, this EO showed DPPH radical scavenging and anti-inflammatory effects with *IC*₅₀ values of 1.487 and 182.5 µg/mL. Moreover, this EO also had an inhibitory effect on *B. subtilis*, *S. aureus*, *B. cereus* and *S. typhimurium* with MIC values of 10.0, 2.5, 5.0, and 10.0 µg/mL (35). In addition, the EO of *C. caesia* rhizome from Prades, India has been reported to have anti-acetylcholinesterase and free radical scavenging effects. The results showed that the rhizome EO possessed the DPPH, ABTS, hydrogen peroxide, and nitric oxide radical scavenging with *IC*₅₀ values of 186.33, 109.41, 103.45, and 190.55 µg/mL, respectively (38) while this EO had anti-acetylcholinesterase activity with *IC*₅₀ values of 156.33 µg/mL (38).

**Curcuma zanthorrhiza** Roxb.

*C. xanthorrhiza* is an endemic species to Indonesia and also distributed in Thailand, Malaysia, Sri Lanka, and Philippines. In traditional medicine, this plant is used to treat heart disorders, diabetes, anticancer, hepatitis, hypertension, liver complaints, and rheumatism. Furthermore, the extracts from *C. xanthorrhiza* were also reported to possess some bioactivities, such as anti-inflammatory, antihypertensive, antihepatotoxic, antiplatelet, antioxidant, antifungal, and antibacterial activities (39).

Septama et al. provided that the essential obtained from *C. xanthorrhiza* was found to be effective against *S. aureus* and *Bacillus subtilis* with MIC values of 31.2 and 7.8 µg/mL, respectively. Furthermore, this EO has increased the ability to the antibacterial effects of ampicillin when combined with this antibiotic, as a result, the biofilm formation of *B. subtilis* and *S. aureus* were inhibited by this synergistic effect (40). Fitria et al. demonstrated the cytotoxic activities of the rhizome EO of *C. zanthorrhiza* from Bogor, Indonesia using brine shrimp (*Artemiasalina*) lethality test and against MCF-7. Accordingly, this EO possessed cytotoxic activities against A. *salina* and MCF-7 cells with *IC*₅₀ values of 83.6 and 139.8 µg/mL, respectively (23). In addition, the leaf EO of *C. zanthorrhiza* showed DPPH and ABTS radical scavenging activities with *IC*₅₀ values 55.57 and 24.42 µg/mL, respectively (41).

**Curcuma angustifolia** Roxb.

*C. angustifolia* is an endemic species to India and it is a medicinal plant. The rhizomes of this species were used to cure inflammation, intestinal disorders, and bone fracture; the extract from leaves have been reported to have antifungal and antibacterial activities. Moreover, *C. angustifolia* was also known as sources of starch and nutritious plant (42).

The rhizome EO of *C. angustifolia* from Odisha, India was found to be effective against *E. coli*, *S. aureus*, *E. faecalis*, *P. aeruginosa*, *B. subtilis*, *Aspergillus niger*, *Aspergillus flavus*, *Fusarium oxysporum* and *C. albicans* with MIC values ranging from 12.5 to 50 µg/mL (31). Meanwhile, this EO possessed ABTS and DPPH radical scavenging activities with *IC*₅₀ values of 83.6 and 139.8 µg/mL, respectively (31). Albaqami et al. provided that the leaf EO of *C. angustifolia* from Thissir, Indianna has been reported to exhibit cytotoxic activities against MCF-7 and MDA-MB-231 cells with *IC*₅₀ values of 64.17 and 70.31 µg/mL, respectively (16). In addition, this EO also possessed DPPH, ABTS, and H₂O₂ radical scavenging activities with *IC*₅₀ values of 16.08, 12.81, and 8.08 µg/mL, respectively (16). Albaqami et al. also showed that the leaf EO of *C. angustifolia* was also displayed activity against *P.*
aeruginosa, E. coli, S. aureus and S. enterica with MIC values of 0.75, 1.00, 1.00, and 1.25 μg/mL, respectively (16).

Other Curcuma species

Van et al. showed that the rhizome the EO of Curcuma thorellii Gagnep. collected from Vietnam possessed potent antibacterial effects against five pathogenic bacteria, including P. aeruginosa, E. coli, S. enteritidis, S. typhimurium and B. cereus with the diameter of inhibition zone of 23.5, 20.3, 22.8, 23.2 and 22.6 mm, respectively (9). The EO of the whole plant of Curcuma sauhynhensis Škorničk. & N.S. Lý from Vietnam showed strong antimicrobial effects against B. cereus, S. aureus, E. faecalis, and C. albicans with MIC values of 64 μg/mL (43). The rhizome EO of another species collected from Vietnam, Curcuma pambrosima Škorničk. & N.S. Lý, was also found to be effective against four tested microbial strains, including B. cereus, E. faecalis, S. aureus, and C. albicans with MIC values of 64.0, 64.0, 256.0, and 16.0 μg/mL (44). In addition, the rhizome EO of Curcuma mutabilis Škorničk. Showed strong antiproliferative effects against K562 and HCT116 cells with IC₅₀ values of 6.8 and 8.5 μg/mL, respectively while this EO possessed weak DPPH and ABTS radical scavenging activities (45). Kebede et al. provided the DPPH radical scavenging effect of the EOs extracted from three varieties of Curcuma domestica Valeton collected from Ethiopia, including Bonga 57/71, HT3/2002, and Dame with IC₅₀ values of 44.32, 32.25, and 23.05 μg/mL (46).

Narayanankutty et al. showed the biological properties of the EOs of Curcuma amada Roxb. obtained from different methods, including microwave assisted extraction, steam distillation, ultrasound assisted extraction, and hydrodistillation (47). Accordingly, these four EOs possessed the strongest antibacterial effect against P. aeruginosa (MIC = 4.0, 4.5, 3.0, 4.0 μg/mL, respectively), followed by S. enteritidis (MIC = 5.5, 5.5, 3.5, 4.3 μg/mL, respectively). E. coli (MIC = 6.0, 6.5, 4.0, 4.5 μg/mL, respectively), S. enteritidis (MIC = 6.5, 8.5, 4.8, 5.0 μg/mL, respectively) (47). Moreover, these four EOs had larvicidal activities against Aedes aegypti, Culex tritaeniorhynchus, and Armigeres subalbatus, in which the EOs from microwave assisted extraction showed the highest effect with LC₅₀ values of 75.22, 32.12, and 34.17 μg/mL, respectively (47). Furthermore, two pests of stored foods such as Sitophilus oryzae and Tribolium castaneum were inhibited by the EOs extract from these four methods. The result showed that these four EOs showed fungicidal toxicity against S. oryzae with LC₅₀ values of 36.4, 32.7, 24.3, 23.7 μg/L of air, respectively while RC₅₀ values of 7.22, 6.17, 4.26, 5.08μg/L of air, respectively; and LD₅₀ values of 188.7, 165.2, 140.6, 156.4 μg/mm² respectively were shown by the repellent and contact toxicities towards the same pest (48). Meanwhile, T. castaneum was sensitive to the four EOs with LC₅₀ values of 26.2, 28.1, 16.6, 15.8, respectively for fungicidal toxicity whereas RC₅₀ values of 9.54, 9.28, 6.12, 6.58 μg/L of air, respectively; and LD₅₀ values of 208.5, 199.4, 178.6, 169.7 μg/mm², respectively were shown by the repellent and contact toxicities towards the same pest (47).

The rhizome EOs of six Curcuma species from China, including Curcuma elata Roxb., Curcuma kwangsiensisvar. Nanlingensis N. Liu et X.Y. Ma, Curcuma nankunshanensis N. Liu, X.B.Ye & Juan Chen, Curcuma sichuanensis X.X.Chen, Curcuma yunnanensis N.Liu & S.J.Chen, and Curcuma rubescens Roxb. have been reported to possess several biological properties. For instance, these EOs possessed cytotoxic activities against LNCaP and HepG2 cells with IC₅₀ values of 18.40 and 167.75, 16.58 and 156.43, 3.04 and 163.56, 1.26 and 183.50, 7.93 and 153.06, 3.15 and 198.18μg/mL, respectively (71). Also, the rhizome EO of these species had an inhibitory effect on some bacterial and fungal strains, including E. coli, P. aeruginosa, S. aureus, C. albicans and S. cerevisiae with MIC values ranging from 423.25 to 676.47 μg/mL, 215.20 to 598.75 μg/mL, 403.46 to 693.64 μg/mL, 176.92 to 396.46 μg/mL, and 183.18 to 436.62 μg/mL, respectively (21). Moreover, at dose of 25, 50 and 100 mg/kg, the anti-inflammation of these EOs were 24.61, 30.34, 54.64% (C. elata); 11.74, 22.56, 36.19% (C. kwangsiensis var. nanlingensis); 23.8, 37.74, 55.23% (C. nankunshanensis); 13.19, 25.64, 68.43% (C. sichuanensis); 10.3, 21.93, 29.8% (C. yunnanensis); and 8.26, 12.34, 20.54% (C. rubescens), respectively (21).

Curcuma xanthella Skorničk. is a rare species and it was discovered as a new species from Vietnam in 2013. Recently, Van et al. provided that the EOs isolated from the aerial parts of this species collected from two different habitats (sandy coastal soil and red basaltic soil) in Binh Chau-Phuoc Buu Nature Reserve, Vietnam. Accordingly, these EOs had an inhibitory effect on five bacterial strains, including Staphylococcus saprophyticus, S. aureus, Salmonella enteritidis, Listeria monocytogenes, and Vibrio parahaemolyticus (48).

Conclusion

This brief review showed the update synopsis of the biological properties of EOs isolated from Curcuma plants which were reported in the last five years. These EOs possessed various bioactivities such as antimicrobial, antioxidant, anti-inflammatory, anti-trypanosomal, antileishmanial, anti-acetylcholinesterase, antiproliferative, cytotoxic, larvicidal and insecticidal activities.

Authors’ contributions

Hong Thien Van designed this article, searched the data and resolved all the queries of editors and reviewers. Hong Thia Le participated in editing as well as providing many valuable comments to complete the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

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