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CHEMICAL COMPOSITION AND ACTIVITY OF THE ESSENTIAL OIL FROM 25 CINNAMOMUM SPECIES. A MINI-REVIEW OF THE LITERATURE

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Abstract: The *Cinnamomum* genus, found in different tropical and subtropical regions worldwide, has proven over the years its economic importance in several areas, such as the food (one of the finest spices), agronomical, pharmaceutical, and perfumery industries. *Cinnamomum zeylanicum* is the most studied species and thus used for its properties as a spice but also in therapy, through its major compounds, cinnamaldehyde, linalool, and eugenol. Because of the lower price, *Cinnamomum cassia* is increasingly replacing *Cinnamomum zeylanicum* in the global market, despite the warning of leading health agencies about its negative impact on health due to the high content of coumarin, a carcinogenic and hepatotoxic compound. The need to identify active and therapeutic important compounds in the composition of other species of *Cinnamomum*, involving lower costs and less toxic by a low concentration or absence of coumarin, is big and decisive for the consumers' health. The aim of this review is to emphasize the major compounds of the essential oil extracted from 25 *Cinnamomum* species, harvested from several regions of Asia, with special regard to the presence of coumarin, but also on the yield of the extracted essential oil and its activities. PubMed and Google Scholar are used as the search engine in this research and the latest studies are considered. The results obtained showed that the majority of compounds identified in the leaves of the species harvested in the Asian region belong to the mono-, respectively to the sesquiterpenoids class and that of aldehydes. The toxic compound, coumarin, has been identified in increased concentrations only in *C. cassia* (China) and *C. burmannii* (Indonesia), in the other species either it was absent, or it was in very low concentration. This study and its results may represent a base for other research on chemical composition, but also on therapeutic activities of *Cinnamomum* species.

Keywords: *Cinnamomum species,* essential oil, chemical composition, coumarin.

INTRODUCTION

Cinnamomum contains about 350 species found in different tropical and subtropical regions worldwide (America, Southeast Asia, Africa, and Australia). It is mostly raised in China, Seychelles, Madagascar, and Sri Lanka and it's cultivated on a small scale in Vietnam and India [1]. It belongs to one of the most primitive families of plants, the Lauraceae family (Kumar *et al.*, 2019; Xing *et al.*, 2023; Salleh *et al.*, 2015).

Over the years, the *Cinnamomum genus* has proven its economic importance in industrial sectors such as the food (one of the finest spices), agronomical, pharmaceutical, and perfumery industries.

An important role in using *Cinnamomum* is the essential oil (Eo) extracted in large quantities from different species of *Cinnamomum*, especially from leaves and barks, rich in chemical constituents (Kumar *et al.*, 2019; Li *et al.*, 2022).

The leaf is one of the plant organs with the most abundant metabolites, including Eos, most of these metabolites have the characteristics of defending against biological and abiotic stresses. The composition of Eos includes a wide range of compounds, including terpene hydrocarbons, simple and terpene, alcohols, aldehydes, ketones, phenols, esters, ethers, organic acids, and lactones (Wanner *et al.*, 2016). According to the number of isoprene units, terpenoids can be divided into monoterpenoids, sesquiterpenes, or diterpenes. The presence of these compounds was attributed to the great antimicrobial, antifungal, anti-inflammatory, and antioxidant, but also to antidiabetic and antitumoral properties of *Cinnamomum species*.

According to several studies, cinnamaldehyde, eugenol, camphor, linalool, eucalyptol, (E)-cinnamyl acetate and cadinene are the major constituents present in cinnamon bark, leaf, root, and fruit, respectively. Different growth environments, phenological stages, varieties, and also the production of essential oil can affect the composition, yield, and quality of plant Eo's (Zhao *et al.*, 2023).

The traditional distillation methods for the extraction of essential oils are of great significance and are still being operated in Sri Lanka. Hydrodistillation and steam distillation are the most commonly used methods. Hydrodistillation is the most favored method for the production of essential oil from cinnamon (Seneratne and Pathirana, 2020).

A special interest represents *Cinnamomum zeylanicum*, a species cultivated mostly in Sri Lanka, which has proven over the years to play an important role, both in the food and agronomic, industry, but also in the treatment of various ailments by the presence in particular of cinnamic aldehyde, eugenol, and linalool. Recent studies prove the involvement of this plant product and the majority of compounds in the treatment of type 2 diabetes. It represents the species with the most studies on both the composition and the bioactive, therapeutical properties (Seneratne and Pathirana, 2020).

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On the other hand, *C. cassia* is the main competitive product for *Cinnamomum zeylanicum*. It is sold in the world market with the label of *cinnamon*.

The most important producers and exporters are China, Indonesia, and Vietnam.

Because of the lower price, it is increasingly replacing *C. zeylanicum* in the global market, despite the warning of leading health agencies about its negative impact on health due to the high content of coumarin, a carcinogenic and hepatotoxic compound. *C. zeylanicum* compared to *cassia* is lighter brown in color, softer, and sweeter. Despite the morphological differences, in powdered form, it is not easy to distinguish *cassia* from *cinnamon,* and therefore *cinnamon* is often adulterated with *cassia*. A study made on cinnamon samples obtained from the Italian market revealed that about 51% of cinnamon samples consisted of *cassia*, 10% were a blend of *cassia* and *C. zeylanicum*, whereas only 39% were *C. zeylanicum* (Seneratne and Pathirana, 2020).

Therefore, the need to identify active and therapeutically important compounds in the composition of other species of *Cinnamomum*, involving lower costs and less toxic by a low concentration or absence of coumarin, is big and decisive for the health of the consumers.

Purpose

The present work aimed to characterize and compare the chemical composition of 25 *Cinnamomum* species, harvested from different regions of Asia, 2 of them are the well-known, studied species, *Cinnamomum zeylanicum* and *Cinnamomum cassia*, and the other 23 species, endemic tree species, with limited studies and uses. The research will have a special regard on the 3 major compounds, the presence of coumarin in the essential oil extracted from leaves, its yield, and activity.

Methods

PubMed and Google Scholar were used as the search engine in this study. The search was conducted up to 2024, using the keywords *Cinnamomum*, leaves, chemical composition, coumarin, and essential oil. The inclusion criteria for this review were: relevant articles written in English, from 2007 to 2024, related to *Cinnamomum* species, their major chemical compounds identified in the essential oil, and their main activities proved in the related studies.

RESULTS AND DISCUSSIONS

In total, there were 25 *Cinnamomum* species analyzed with special regard on the yield of EO and the 3 major compounds identified in the leaves. The origin of the species are different regions of Asia: China (*C. glanduliferum, C. longepaniculatum, C. loureirii, C. camphora, C. bodinieri, C. cassia*), Malaysia (*C. griffithii, C. macrocarpum*), India (*C. heyneanum, C. palghatensis, C. malabatrum, C. filipedicellatum*), Taiwan (*C. insularimontanum, C. reticulatum, C. micranthum, C. osmophloeum*), Vietnam (*C. rigidifolium, C. melastomaceum, C. cambodianum, C. kunstleri, C. rigidifolium, C. curvifolium, C. mairei*), Indonesia (*C. burmannii*) and Sri Lanka (*C. zeylanicum*).

All essential oils presented in the studies were extracted using hydrodistillation.

According to Table 1, the highest mean of extracted volatile oil has been extracted from 2 species from China, *C. glanduliferum* (5,42%) and *C. loureii* (2,06%), and *C. insularimontanum* (2,01%), from Taiwan.

The majority compound identified in the composition of *Cinnamomum* species belongs mainly to the class of monoterpenoids, but also to that of aldehydes and sesquiterpenoids.

In the species harvested from China, the major compounds belonging to the monoterpenoid class are represented by camphor (*C. glanduliferum* and *C. bodinieri*), 1,8-cineole (*C.longepaniculatum*), trans-cinnamaldehyde (*C. loureirii* and *C. cassia*) and that belonging to the sesquiterpenoid class, by trans-nerolidol (*C. camphora*).

In those harvested from Malaysia, the monoterpenoid class is represented by: methyl eugenol (*C. griffithii*) and safrole (*C. macrocarpum*), and in India by: methyl eugenol (*C. heyneanum*), bicyclogermacrene (*C. palghatensis*), linalool (*C. malabatrum*), and cryptone (*C. filipedicellatum*).

In Taiwan, the *Cinnamomum* species showed a majority also in monoterpenes, like 1,8-cineole (*C. insularimontanum*), L-α- terpineol (*C. reticulatum*), but also in aldehydes, like n-decanal (*C. micranthum*) and trans-cinnamaldehyde (*C. osmophloeum*). The major compounds identified in the species from Vietnam are represented by the monoterpenes: linalool (C. *rigidifolium, C. melastomaceum, C. cambodianum*), methyl eugenol (*C. kunstleri*), ß- pinene (*C. curvifolium*), 1,8-cineole (*C. mairei*) and the sesquiterpene, α-seliene (*C. rigidifolium*).

C. burmannii from Indonesia has trans-cinnamaldehyde and *C. zeylanicum*, (E)-cinnamaldehyde, as major compounds.

In terms of the presence of coumarin, the studied species showed either a small concentration of coumarin (<0.01%) or none at all. In the Eo extracted from the leaves of *C. cassia,* one could identify an important amount of coumarin (6%) and also in the Eo of *C. burmannii* (10%)leaves.

It should be noted, however, that the presence of coumarins was identified only in the leaves of 20-year-old *C. burmanni* tree. In the others, 5 and 12 years old, coumarins were absent (Table 2).

The studies revealed the role of the majority of compounds in the therapeutical and biological activity of the species. Thus the main actions of the species by the presence of these compounds are antioxidant, antibacterial, fungistatic, anti-inflammatory, antidiarrheal, antispastic, anticholinesterase and hypoglycemic activity, but also insecticidal, larvicidal, and repellent activity (Table 1).

Results of the present study also revealed the fact that the major chemical constituents in leaf volatile oils varied between species, regions where they were harvested, and maturity of the leaf. Pedo-climatic factors also may influence the presence and concentration of chemical compounds.

Table 1.
Chemical composition, yield, and activity of Eos from *Cinnamomum species* in the studies selected through this review

Plant	Origin	Eo yield (% v/w)	Major compounds of Eo	Mean content (%)	Classification	Activity	Reference
C. glanduliferum	China	**5,42**	**L-camphor**	**84,01**	**MT**	insecticide	Yuan-Tong Qi *et al.* 2024
			cosmen	4,62	alkatetraene		
			1,8-cineole	2,97	MT	gastroprotective	
C. longepaniculatum	China	**1,85**	**1.8 cineole**	**57,5**	**MT**	antioxidant	Zhao Xin *et al.* 2023
			sabinene	13,05	MT		Wei C. *et al.* 2023
			terpinen-4-ol	10,92	MT		
C. loureirii	China	**2,06**	**trans-cinnamaldehyde**	**74,31**	**aldehyde**	traditional flavorant, insecticide, antioxidant	Xing Huanling *et al.* 2023
			linalool	1,72	MT		Seshadri VD *et al.* 2020
			camphor	1,30	MT		
C. camphora	China	1,18	**trans- nerolidol**	**60,3**	**ST**	antibacterial, fungistatic, insecticidal, and repellent	Wan *et al.* 2022
			acid-1,7,7-trimethyl-bicyclo(2.2.1)hept-2-yl ester	20,88	ester		
			guaiol	2,71	ST		
C. bodinieri	China	0,30	**camphor**	**40,81**	**MT**	anti-inflammatory, antidiarrheal, antispastic	Luo Y *et al.* 2014
			1,8-cineole	24,87	MT		
			α- terpineol	8,75	MT		
C. cassia	China	1,54	**trans-Cinnamaldehyde**	**30,36**	**aldehyde**	antioxidant, antifungal, antibacterial	Wang R *et al.* 2009
			3-Methoxy-1,2-propanediol	29,3	glycol		
			o-Methoxy-cinnamaldehyde	25,39	aldehyde		
C. griffithii	Malaysia	not available	**methyl eugenol**	**38,5**	**MT**	antioxidant	Salleh W *et al.* 2015
			safrole	6,4	MT	anticholinesterase	
			α-cubebene	3,9	ST		
C. macrocarpum	Malaysia	not available	**safrole**	**59,5**	**MT**	antioxidant	Salleh W *et al.* 2015
			methyleugenol	11,1	MT		
			γ-gurjunene	3,9	ST		
C. heyneanum	India	1,20	**methyl eugenol**	**60,3**	**MT**	hypoglycemic	Sriramavaratharajan V *et al.* 2024
			safrole	27,80	MT		
			n-octanol	1,8	alcohol		
C. palghatensis	India	0,45	**bicyclo germacrene**	**19,5**	**ST**	hypoglycemic	Sriramavaratharajan V *et al.* 2024
			(E-)- Caryophyllene	14	ST		
			linalool	9,6	MT		
C malabatrum	India	0,72	**linalool**	**38,26**	**MT**	antioxidant	Kuttithodi MA *et al.* 2023
			cinnamaldehyde	12,01	aldehyde	antibacterial	
			caryophyllene	11,43	ST		
C. filipedicellatum	India	0,22	**cryptone**	**36,6**	**MT**	antibacterial	Rameshkumar KR *et al.* 2006
			p-cymene	10,8	MT		
			cumin aldehyde	7,7	aldehyde		
C. insularimontanum	Taiwan	**2,01**	**1,8-cineole**	**35,94**	**MT**	anti-inflammatory	Chen CY *et al.* 2022
			α- eudesmol	6,17	ST		
			pinene	7,55	MT		
C. reticulatum	Taiwan	not available	**L-α- terpineol**	**16,00**	**MT**	antioxidant	Li Y *et al.* 2022
			1,2,3,4- tetrahydro-1,6-dimethyl-4-(1-methyl ethyl)naphthalene	11,68	hydrocarbon		
			(+)-γ-Cadinene	6,30	ST		
C. micranthum	Taiwan	0,59	**n-Decanal**	**50,10**	**aldehyde**	anti-mildew	Hsu KP *et al.* 2022
			(E)-ß-Ocimene	7,90	MT		
			(E)-Nerolidol	6,5	ST		
C. osmophloeum	Taiwan	1,02	**trans-Cinnamaldehyde**	**79,85**	**aldehyde**	antibacterial, antiinsecticid, antifungal	Cheng SS *et al.* 2007
			Benzenepropanal	7	benzene		
			Benzaldehyde	5,35	aldehyde		
C. rigidifolium	Vietnam	0,15	**linalool**	**19,40**	**MT**	unspecified	Wanner KR *et al.* 2016
			α-Pinene	13,80	MT		
			cis-Verbenol	8,90	MT		
C. melastomaceum	Vietnam	0,40	**linalool**	**19,90**	**MT**	repelent-anti-mosquito	Pham TV *et al.* 2023
			α- terpineol	6,90	MT	larvicidal	
			(E-)- Caryophyllene	10,50	ST		
C. cambodianum	Vietnam	0,21	**linalool**	**33,1**	**MT**	unspecified	Son LC *et al.* 2014
			terpinen-4-ol	12,3	MT		
			cis-Sabinene hydrate	6,2	MT		
C. kunstleri	Vietnam	0,2	**methyl eugenol**	**22,5**	**MT**		Truong DH *et al.* 2024
			terpinen-4-ol	19,2	MT		
			1,8-cineole	7,4	MT		
C. rigidifolium	Vietnam	0,25	**α-seliene**	**24,5**	**ST**		Truong DH *et al.* 2024
			ß-caryophyllene	23	ST		
			α-copaene	5,7	ST		
C. curvifolium	Vietnam	0,32	**ß- pinene**	**23,8**	**MT**	antispastic,abdominal pain	Dai DN *et al.* 2019
			sabinene	14	MT		
			camphene	12,1	MT		
C. mairei	Vietnam	0,24	**1,8-cineole**	**23,1**	**MT**		Dai DN *et al.* 2019
			α-pinene	13,1	MT		
			ß-pinene	9	MT		
C. burmannii	Indonesia	1,20	**trans-cinnamaldehyde**	**84,12**	**aldehyde**	antibacterial, antifungal	Fajar A *et al.* 2019
			cinnamyl acetate	16,1	acetate ester		
			cinnamyl alcohol	3,98	alcohol		
C. zeylanicum	Sri Lanka	1,44	**(E)- cinnamaldehyde**	**35,6**	**aldehyde**	antibacterial, larvicidal, and insecticidal activity	Narayanankutty A. *et al.* 2021
			linalool	18,92	MT		
			eugenol	18,69	MT		

(*MT- monoterpene, **ST- sesquiterpene)

Table 2.
Mean content (%) of coumarin identified in Cinnamomum species studies selected through this review

Plant	Mean content (%) of coumarin	Reference
C. glanduliferum	no	Yuan-Tong Qi *et al.* 2024
C. longepaniculatum	no	Zhao Xin *et al.* 2023 Wei C. *et al.* 2023
C. loureirii	unknown	Xing Huanling *et al.* 2023
C. camphora	no	Wan *et al.* 2022
C. bodinieri	no	Luo Y *et al.* 2014
C. cassia	**6,36%**	Wang R *et al.* 2009
C. griffithii	no	Salleh W *et al.* 2015
C. macrocarpum	no	Salleh W *et al.* 2015
C. heyneanum	no	Sriramavaratharajan V *et al.* 2024
C. palghatensis	no	Sriramavaratharajan V *et al.* 2024
C malabatrum	unknown	Kuttithodi MA *et al.* 2023
C. filipedicellatum	unknown	Rameshkumar KR *et al.* 2006
C. insularimontanum	unknown	Chen CY *et al.* 2022
C. reticulatum	no	Li Y *et al.* 2022
C. micranthum	no	Hsu KP *et al.* 2022
C. osmophloeum	no	Cheng SS *et al.* 2007
C. rigidifolium	no	Truong DH *et al.* 2024
C. melastomaceum	no	Pham TV *et al.* 2023
C. cambodianum	no	Son LC *et al.* 2014
C. kunstleri	no	Truong DH *et al.* 2024
C. rigidifolium	no	Truong DH *et al.* 2024
C. curvifolium	no	Dai DN *et al.* 2019
C. mairei	no	Dai DN *et al.* 2019
C. burmannii	**10%** (from 20 years leaves)	Fajar A *et al.* 2019
C. zeylanicum	no	Narayanankutty A. *et al.* 2021

(***- unknown=** the study presents only the major compounds of the essential oil and not the entire list of chemical compounds identified in the Eo,
**** - no-** the study presents the list with the chemical compounds of the Eos, coumarin wasn't identified, or it was identified in a small amount <0.01%)

CONCLUSION

Results of the present study showed that the majority of compounds identified in the leaves of the species harvested in the Asian region belong to the mono-(camphor, 1,8-cineole, eugenol, safrole, linalool, cryptone, ß-pinene) respectively to the sesquiterpenoids (nerolidol, germacrene) class and that of aldehydes (cinnamaldehyde, decanal). The toxic compound, coumarin, has been identified in high concentrations only in *C. cassia* (China) (6,36%) and *C. burmannii* (Indonesia) (10%), in other species either it was absent, or it was in very low concentration.

Results also revealed the fact that the major chemical constituents in leaf volatile oils and their yield (%v/w) varied between species, regions where they were harvested, and maturity of the leaf. Pedo-climatic factors also may influence the presence and concentration of chemical compounds.

The great number of *Cinnamomum species* rich in important chemical components, especially known for their bioactivities may represent a challenge for the world of science.

Further studies on other *Cinnamomum* species than *C. zeylanicum* and *C. cassia* may, on the one hand, develop the industrial sectors such as food, agronomical, and perfumery, but also the pharmaceutical ones and, on the other hand, they may provide safe products for consumers.

This study and its results may represent a base for other research on chemical composition, but also on therapeutic activities of *Cinnamomum* species.

AUTHORS CONTRIBUTIONS

Conceptualization, M.L.M.; methodology, M.L.M., data collection, M.L.M., data validation, M.L.M and E.C.;data processing M.L.M., E.C.; writing- original draft preparation, M.L.M.; writing-review and editing, M.L.M.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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