Trop J Nat Prod Res, April 2024; 8(4):6807-6813 **ISSN 2616-0684 (Print)**
ISSN 2616-0692 (Electronic)

Tropical Journal of Natural Product Research

Available online at https://www.tjnpr.org

Original Research Article

Study on the Production and Composition of Essential Oil from *Cinnamomum cassia* Bark in Yen Bai Province of Vietnam

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ARTICLE INFO

Article history:
Received 17 December 2023
Revised 01 April 2024
Accepted 06 April 2024
Published online 01 May 2024

ABSTRACT

Yen Bai province has 50,000 hectares under cinnamon cultivation, which is the largest of cultivation area in Vietnam. Cinnamon essential oil is mainly extracted from the stem bark and leaves of *Cinnamomum cassia* (L.) J. Presl. The essential oil yield varies depending on species and extraction methods. The aim of this study was to investigate the effect of critical parameters including extraction time, average particle size and material mass to water volume ratio on the yield of essential oil and to evaluate its chemical constituents. The stem bark of *Cinnamomum cassia* was sourced from Yen Bai province, Vietnam. The powdered stem bark (500 g) was extracted with 2.5 L of distilled water by hydro-distillation for 180 minutes. The chemical composition of the essential oil obtained was determined by Gas Chromatography – Mass Spectrometry (GC-MS) analysis. Morphological changes to the cinnamon bark powder before and after hydro-distillation was assessed by Scanning Electron Microscopy (SEM) and Fourier Transform Infra-Red (FTIR) Spectroscopy. Essential oil (14.95 mL) was obtained corresponding to a percentage yield of 3.38%. The GC-MS analysis identified 11 bioactive compounds in the cinnamon essential oil. Cinnamaldehyde was the major compound in cinnamon essential oil constituting about 93.3% of the total oil composition. Generally, cinnamon from Yen Bai province in Vietnam provides a high value essential oil with a high percentage of cinnamaldehyde, and a potential for many applications.

***Keywords*:** Stem bark, *Cinnamomum cassia*, Hydro-distillation, Essential oil, Yen Bai province

Introduction

Cinnamon is an evergreen tree and its bark is one of the oldest spices known since 3000 BC.[1] The cinnamon plant belongs to the Lauraceae family and the genus Cinnamomum.[2] Cinnamomum has about 250 species distributed in China, India and Australia in which *Cinnamomum cassia* or commonly called Chinese Cinnamon has been wildly cultivated in Southeast Asia since ancient age.[3, 4] When the plant is about 3 years old, the bark is ready to be harvested from small branches or shoots. Cinnamon is a functional and medicinal plant with delicately fragrant aroma and a warm sweet flavour which is grown mostly in Asia and some in South and Central America and Australia.[1, 4] Vietnam is among the largest exporter of cinnamon in the world exporting over 292 million USD worth of cinnamon monthly. By the end of October 2023, Vietnam exported 74,744 tons of cinnamon worth about 220.3 million USD. There are four major cinnamon growing areas in Vietnam, these include Yen Bai, Quang Ninh, Thanh Hoa - Nghe An and Quang Nam - Quang Ngai provinces. Yen Bai is the province with the largest cinnamon cultivation in Vietnam, the cultivation are mainly in Van Yen, Tran Yen, Van Chan, Yen Binh and Luc Yen districts.[5]

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Citation: Do TCV, Nguyen QT, Pham TTY, Do TK. Study on the Production and Composition of Essential Oil from *Cinnamomum cassia* Bark in Yen Bai Province of Vietnam. Trop J Nat Prod Res. 2024; 8(4):6807-6813. https://doi.org/10.26538/tjnpr/v8i4.9

Official Journal of Natural Product Research Group, Faculty of Pharmacy, University of Benin, Benin City, Nigeria

This tree has become a key agricultural product contributing to the economic development of the northern mountainous province of Yen Bai, providing the local people with a new source of income. The province has planned processing facilities for cinnamon tree bark and wood for essential oil production, and promotes the application of processing technology for improving the quality and value of cinnamon products.[5] For a long time, people have known the effects of bioactive compounds from cinnamon bark used not only as a spice but also as a medicinal tree for many diseases related to skin, aches, pulmonary and liver disorders, and gastrointestinal problems such as stomach cramps, diarrhea, constipation, cough, and indigestion.[2] Recently, Cinnamon has been known for its ability to support the treatment of obesity by boosting insulin function,[6] and has shown a lot of pharmacological properties such as antibacterial, anti-inflammatory, antidiabetic, anticancer, antiangiogenenic, antioxidant, antityrosinase as well as anti-viral activities.[2, 6-10] Cinnamon has also been used as biopesticides and bioherbicides in plant protection and preservation,[11] and flavouring agent in food industries.[12, 13] Cinnamon essential oil obtained from the bark and leaves of cinnamon contains cinnamaldeyde, cinnamyl-acetate, eugenol, linalool, and camphor whose composition varies depending on the genus of cinnamon, namely; *Cinnamomum zeylanicum*, *Cinnamomum cassia*, *Cinnamomum osmophleum*, *Cinnamomum pauciflorum*, *Cinnamomum burmannii*, *Cinnamomum tamala* and *Cinnamomum camphora*.[3, 9, 13] The essential oil yields from the stem bark are significantly higher than that from the twigs and leaves, with the percentage yield ranging from 0.72 - 3.08%, in which cinnamaldehyde constitute the highest content of 63-95% of the oil.[12, 14, 15] The essential oil yield from the leaves is about 0.72 - 1.54% comprising different volatile chemical constituents with a significantly lower contents of cinnamaldehyde (12.8 - 30.3%) and a high content of linalool (67.6%), and eugenol (17.6-92.7%).[3,14] In fact, cinnamon bark oil is more expensive than the leaf oil,[13] and *Cinnamomum cassia* has been reported to produce the highest essential oil yield among the

Cinnamomum genus.[3] Essential oil yield of cinnamon depends on its variety, origin of raw materials, type and scale of equipment, and extraction techniques. To obtain a maximum yield, it is important to apply a suitable extraction method. Soxhlet extraction using organic solvent may be one option for cinnamon extraction but its disadvantages are long extraction time and high temperatures leading to thermal degradation of some compounds.[7,8,12] Steam distillation is also one of the simple and effective method for cinnamon extraction.[9,12] Hydro-distillation is the most popular and traditional technique of essential oil extraction which involves the use of boiling water at 100ºC to volatilize substances from cinnamon barks or leaves while maintaining the quality of bioactive compounds, but it requiring enough time and energy to obtain maximum oil yields.[3,14,15] Recently, some modern extraction methods have been applied such as supercritical carbon dioxide,[8,16,17] microwave-assisted extraction that can achieve high oil yields up to 4.83% (w/w) and 92-95% cinnamaldehyde.[18,19] Ultrasound-assisted hydro-distillation extraction has been employed to enhance cinnamon oil yield up to about 27% with a shorter extraction time of about 60 minutes compared to conventional hydrodistillation.[20] However, these methods are expensive due to requirements of high cost equipment and/or chemicals, infeasibility of application in an industrial scale, but have the potential to obtain high quality essential oil in term of pharmaceutical applications. In the literature, there have been limited reports of essential oil extraction from *Cinnamomum cassia* bark grown in Vietnam. Therefore, in this study, *Cinnamomum cassia* bark originating from Yen Bai province of Vietnam was selected as raw material for essential oil production by hydro-distillation in a 10 L capacity equipment while investigating the influence of distillation time, raw material sizes, material mass to water volume ratios on the essential oil yield and evaluation of its composition with the aim of scientifically confirming the quality and value of Vietnam's *Cinnamomum cassia* essential oil.

Materials and Methods

Plant collection and identification

Cinnamon bark from *Cinnamomum cassia* (L.) J. Presl was purchased from the Hanoi MM Mega Market in January 2023. The plant was grown in Yen Bai province of Vietnam. The stem bark was harvested in August-September 2022 and was dried under the sun for five days prior to its purchase. The plant material was identified at the Institute of Biotechnology and Food Technology, Industrial University of Ho Chi Minh City, Vietnam. A herbarium specimen was prepared and deposited with a voucher number CC031022VST.9.

Extraction of essential oil

The general procedure of the experimental set up is described in Figure 1. Dried cinnamon bark (500 g) was crushed, then sieved with meshes of different sizes. The finely powdered cinnamon bark was dried at 105ºC in the oven for 48 h, weighed, and the moisture content was determined. The dried powdered sample was loaded into a 10 L hydro-distillation unit (Model TX05-02, China). Reverse osmosis water (2.5 L) was added, boiled at 100ºC by induction (Bluestone, ICB-6728, China), boiling continued at a medium heat mode for hours to obtain a maximum yield of crude oil. The condensed liquid was moved into a 500 mL glass funnel for oil separation. The crude essential oil separated as a yellow liquid on the surface of the water. The water was removed by draining, and the crude essential oil was dried with anhydrous sodium sulphate (Na_2SO_4) to obtain the pure essential oil. The essential oil was weighed, and then stored in a dark air-tight glass container and kept in the refrigerator at 4ºC.

Determination of the effect of distillation time on essential oil yield

Powdered cinnamon bark (500 g) with particle size of 2-3 mm was extracted with distilled water (5 L) by hydro-distillation for up to 6 h. The condensed liquid was collected every one hour into a 500 mL funnel to separate the essential oil. The volume of the oil was measured and the yield calculated at each time point. From the result obtained, the optimized extraction time for the maximum yield of cinnamon essential oil was determined for later experiments.

Determination of the effect of raw material size on essential oil yield

Cinnamon bark (500 g per batch) with original moisture content 7% was ground and sieved by meshes into four different sizes of 0.2-0.3, 0.5-1, 2-3 and 10-20 mm. Each batch was extracted with 5 L of distilled by hydro-distillation for 3 h. The essential oil yield for each batch was calculated, and based on the results obtained, the optimal size of raw material was chosen for the later experiments.

Determination of the effect of material to water ratio on essential oil yield

In this investigation, 500 g of the raw material with the selected 2-3 mm size were prepared. Different volumes of distilled water (1.5, 2.5, 3.5, 5 and 7 L) were sequentially added into the hydro-distillation equipment. This gave a mass to volume ratio (m/V) in g/mL or kg/L of raw material and water per batch of 1/3, 1/5, 1/7, 1/10 and 1/14, respectively. The distillation time was kept at 3 h. The essential oil yield for each batch was calculated, and the optimal m/V ratio was determined.

Determination of essential oil yield

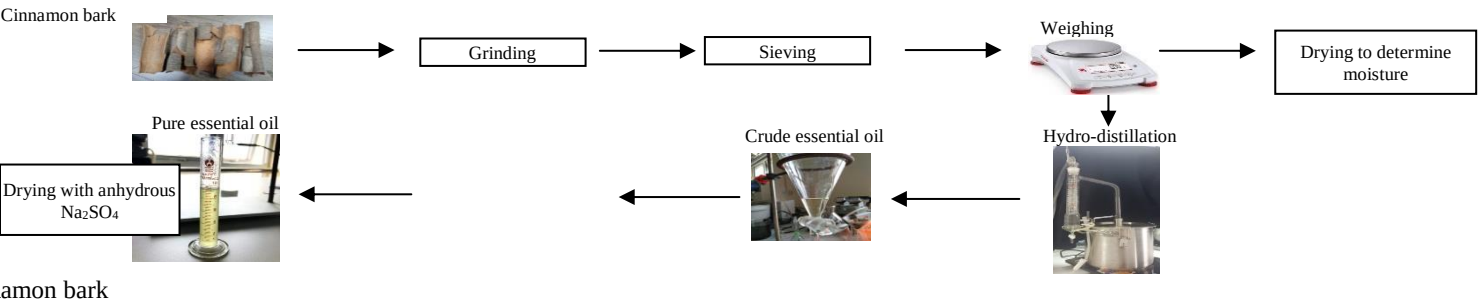
The volume of the essential oil produced was determined by volumetric method using burettes or pipettes (Duran, Germany), and results were expressed as mL of oil harvested per kg of plant materials used for each experiment (mL/kg).

$$\text{The yield of essential oil (\%)} = \frac{m_{oil}}{m_{DM}} x\ 100 \qquad (1)$$

Where; m_{oil} = weight of essential oil in g
m_{DM} = weight of dry material in g

GC-MS analysis of the essential oil

The chemical composition of the essential oil was determined using Nexis GC-2030, MS 2020 (Shimadzu, Japan) which used SH-Rxi-5Sil MS model column with dimension of 30 m x 0.25 mm i.d. x 0.25 µm. The mass spectra were taken at 70 eV. The samples were diluted by adding 10 µL of sample to 1 mL of methanol and vortexed for 15 minutes. Then, 2.0 µL volume of the diluted samples were injected in the split mode ratio of 1/25 with a column temperature of 50°C for 2 min at 20°C/min, the temperature was sequentially risen to 100°C for 2 min at 4°C/min and 240°C for 1 min at 15°C/min, and finally increased to 280ºC for 5 min for a complete column clean-up. The injector, MS quaqdrupole and MS source were set at 250, 150 and 230ºC, respectively. The carrier gas was helium with a flow rate of 1.0 mL/min. The identification of oil components was determined by their retention times, authentic reference compounds, peaks matching from library search and published NIST/EPA/NIH mass spectral database (NIST14).



amon bark

Scanning Electron Microscopy (SEM) and Fourier Transform Infra-Red (FTIR) Spectroscopy

Morphological changes to the cinnamon bark powder before and after hydro-distillation were investigated through SEM analysis. These samples were observed by a JSM – IT800SHL system (JEOL, Japan). All the test samples were examined under a high vacuum condition at an accelerating voltage of 0.01 to 30 kV (10 to 2,000,000 magnifications) and analytical working distance at 0.5 nm. Functional groups in cinnamon bark before and after hydro-distillation were characterized by FT-IR analysis (Nicolet iS50, Thermo Electron Scientific, US). The spectral range with KBr/DTGS optics was 7,800 – 400 cm^{-1}.

Statistical analysis

Experiments were carried out in duplicate and results were expressed as means ± standard deviation (SD). Graphs were presented by Sigma Plot software 10.0. Data was processed using Microsoft Excel software 2016. Statistical analysis was done using paired t-Test (two sample for means) with p-values less than 0.05 regarded as significant difference.

Results and Discussion

Effect of distillation time on essential oil yield

The effect of distillation time on the essential oil yield of cinnamon is shown in Figure 2. It was seen from Figure 2A that the volume of cinnamon essential oil collected at every 60 min interval decreased sharply within the first 180 min. Notably, within the first 60 min and the next 60-120 min, a remarkably high volume of essential oil was obtained. The volumes of essential oil were 6.38 and 3.50 mL, corresponding to 59.0 and 32.4% of the total oil volume, at 60 min and 120 min, respectively. From 120-180 min, the volume of essential oil was drastically reduced to 0.73 mL and after 180 min, almost no essential oil was obtained. The total volume of oil in 240 min was 10.81 mL. In addition, it was calculated that the total yields of oil increased significantly after 60 and 120 min, with percentage yield determined as 1.45 and 2.23%, respectively (Figure 2B). However, in the interval of 120-180 min, the yield was slightly increased to 2.40%. After 180 minutes, the total yield reached a maximum value of 2.44% which was not significantly different from that obtained at 120-180 min ($p > 0.05$). Therefore, the optimal time for hydro-distillation of essential oil from cinnamon bark was 180 min (3 h). In another research by Guanghui Chen *et al*. (2020),[20] *Cinnamomum cassia* bark extracted in a 1 L Clevenger-type apparatus gave a maximum oil yield at an optimal time of 120 min (2 h). Some studies obtained maximum essential oil yield from cinnamon bark powder in a hydro-distillation Clevenger-type apparatus at 60°C for 6 h,[14] or at 100°C for 5 h.[15] While the study of Marongiu *et al*. (2007)[8] subjected 100 g of cinnamon bark to hydro-distillation for 4 h to obtain the maximum oil volume. The extraction time was different among the different studies because their experimental scale and raw material mass were different.

Effect of raw material size on essential oil yield

For hydro-distillation of essential oil, sizes of raw materials have a strong influence on the total oil yield. Therefore, the cinnamon bark from Yen Bai province in Vietnam was crushed, ground by a blender, and sieved by meshes of different sizes in a descending order of 5-10, 2-3, 0.5-1.0, and 0.2-0.3 mm. It was observed that smaller sizes of cinnamon bark resulted in a higher total volume and yield of oil (Figure 3). With coarsely ground plant material (5-10 mm), the volume and yield of essential oil were 8.43 mL and 1.90%, respectively which were significantly smaller than those of the smaller sized samples ($p < 0.05$). For the medium and finely ground samples with sizes of 2-3 mm, 0.5-1 mm and 0.2-0.3 mm, the volumes and yields of essential oil were 12 mL and 2.71%, 11.48 mL and 2.59%, 11.05 mL and 2.50%, respectively which were not significantly different from one another ($p > 0.05$). Among the sample sizes investigated, the powder in the size range of 0.2-1 mm had negative effects on the essential oil yield which was slightly reduced compared to the powder in the size range of 2-3 mm. Therefore, in order to get an efficient essential oil production that is time and labour saving, cinnamon bark needs to grinded to a medium size powder of about 2-3 mm. It can be suggested that when cinnamon bark is crushed and ground into smaller pieces with a suitable particle size, the layer of material has a certain porosity so that the steam created by the distillation process can pass through this layer evenly and easily to vaporize the volatile compounds. Because essential oil constituents are easily soluble in water, which are volatilized first in the steam, condensed and collected in receivers.

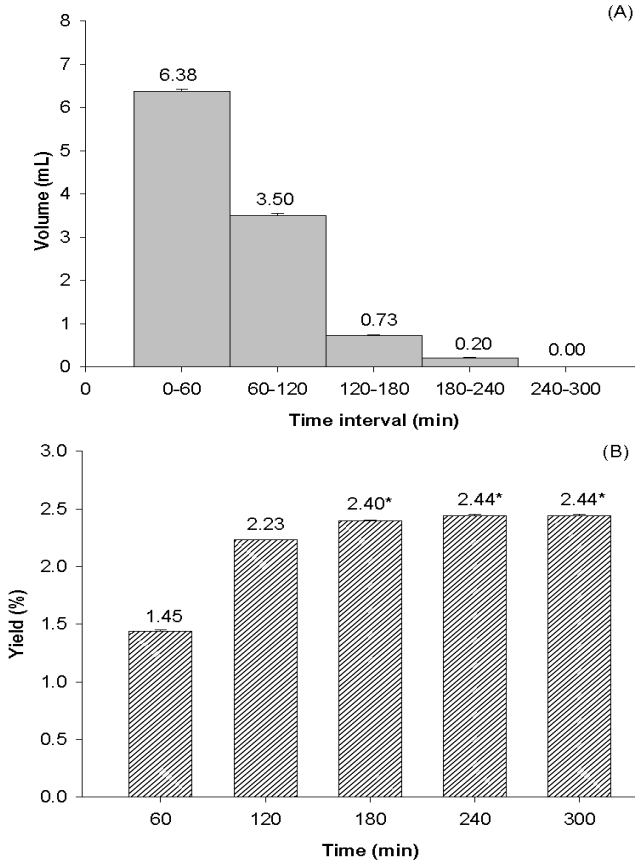


Figure 2: Effect of distillation time on essential oil yield from cinnamon bark. (A): Oil volume with time (B): Percentage oil yield with time. * indicates statistical difference at $p < 0.05$.

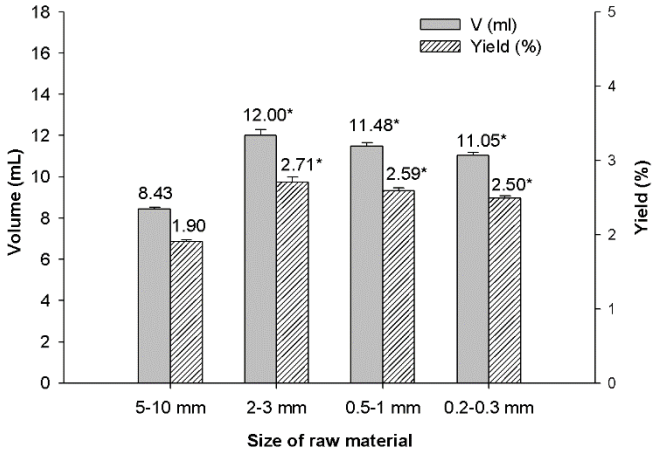


Figure 3: Effect of particle size of raw materials on essential oil yield from cinnamon bark. * indicates statistical difference at $p < 0.05$.

However, when the cinnamon bark is ground into very small size powder, porosity is reduced and vaporization of volatile constituents is inhibited. Thus, cinnamon bark should be ground to a medium size of

about 2-3 mm to obtain an optimal yield of essential oil. The present findings corroborated the findings from previous studies which showed that powdered cinnamon barks with sizes of about 1.0 mm, 0.25 - 1.00 mm, and 100 µm resulted in a maximum essential oil yield.[21-23] The optimal size selected was below 3 mm which is suitable for the 10 L capacity hydro-distillation equipment used in this study.

Effect of material to water ratio on essential oil yield

In this experiment, the ratios of material mass and water volume (m/V, g/mL) examined in each batch were 1/3, 1/5, 1/7, 1/10 and 1/14. As shown in Figure 4, it was observed that with the fixed starting mass of 500 g material and the distillation time of 180 min, increasing the volume of distilled water from 1500 mL to 2500 mL enhanced the total cinnamon oil yield from 9.51 to 14.95 mL or 2.15 to 3.38%. When the water volume was increased to 3500 mL, the volume and yield of essential oil did not increase, only about 14.06 mL or 3.18% of essential oil was obtained at this volume of water, which was not significantly different from the essential oil yield obtained with 2500 mL of water ($p > 0.05$). Increasing the distilled water volumes to 5000 mL and/or 7000 mL will not only prolong the boiling time, but also generate much steam, and the too much steam produced can overwhelm essential oil vaporization, hence the amount of essential oil condensed can be negatively affected and significantly reduced. On the other hand, using small quantity of water (1500 mL in this case), the distillation set up may run out of water within 180 min of hydro-distillation, and this often causes burning of the plant material, which impact negatively on the equipment and essential oil yield. In all, the optimal m/V (g/mL) ratio of material to water was chosen to be 1/5 or 500 g/2500 mL to produce a maximum yield of cinnamon essential oil within 180 min in the 10 L hydro-distillation apparatus. In the literature, studies have used material to water ratio of 1/7 for 40 g *Cinnamomum cassia* bark by both extraction methods of conventional hydro-distillation and ultrasound assisted hydro-distillation,[20] or 1/8 for 25 g of the 100 µm powdered cinnamon bark.[19] This indicates that the ratio of material to water for hydro-distillation of cinnamon bark depends on the scale of the extraction equipment and input mass of raw materials.

Chemical constituents of cinnamon essential oil

The GC chromatogram of the compounds in cinnamon essential oils from Yen Bai province of Vietnam is shown in Figure 5, while the compounds identified from the GC-MS analysis of the essential oil are presented in Table 1. Eleven (11) compounds were identified in the cinnamon essential oil from Yen Bai province. Cinnamaldehyde was the major compound in cinnamon essential oil accounting for 93.3% of the total oil by mass. Cinnamaldehyde or cinnamic aldehyde is a naturally occurring compound that gives cinnamon a pleasant, spicy unique odour and a sweet spicy taste. Cinnamaldehyde has interesting biological properties, such as antimicrobial, antitumor, antifungal, cytotoxic and antimutagenic effects.[16] Vietnamese cinnamon is grown in several provinces but mainly in Yen Bai province. Specifically, Yen Bai accounts for nearly 90% of total Vietnamese cinnamon. This land has soil and weather which are very favorable for growing high quality cinnamon. Vietnam is one of the best sources of high quality *Cinnamomum cassia*. Each year, Vietnam exports more than 4 billion tons of cassia products. Compared to cassia from Indonesia and China, Vietnamese cassia has slightly higher price, and much higher quality and oil content. As shown in Table 2, the chemical composition and yield of cinnamon essential oils vary significantly among countries. Cinnamon essential oil and cinnamaldehyde content in this study yielded 3.38% and 93.3%, respectively which were remarkably higher than that of the other countries. This result confirms that cinnamon sourced from Yen Bai province of Vietnam is an abundant source of cinnamaldehyde and high quality cinnamon essential oil for export in the world.

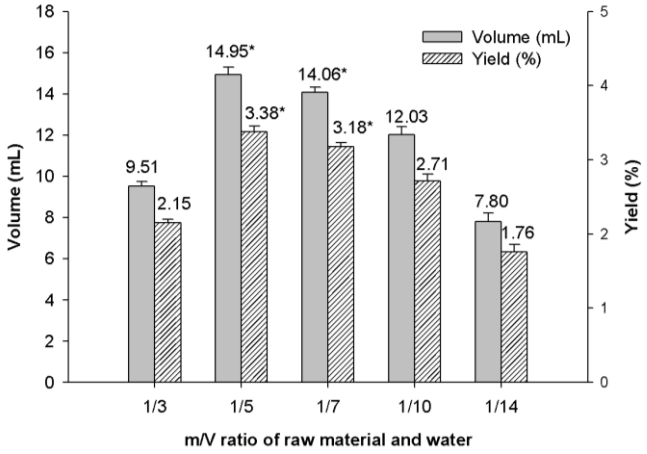


Figure 4: Effect of mass to volume ratio of raw material to water on essential oil yield from cinnamon bark; * indicates statistical difference at $p < 0.05$.

Table 1: Bioactive compounds of cinnamon essential oils identified by GC-MS

S/N	RT (min)	Compound	Molecular Formula	Yen Bai cinnamon essential oil	
				Area	Composition,%
1	5.784	Nopinen	$C_{10}H_{16}$	123,293	0.10%
2	6.290	Delta-3-Carene	$C_{10}H_{16}$	163,109	0.13%
3	6.645	D-Limonene	$C_{10}H_{16}$	246,676	0.19%
4	11.075	Cinnamaldehyde	C_9H_8O	677,538	0.52%
5	12.553	Cinnamaldehyde	C_9H_8O	120,189,083	92.79%
6	15.416	Copaene	$C_{15}H_{24}$	1,275,949	0.99%
7	16.095	Cinnamaldehyde dimethyl acetal	$C_{11}H_{14}O_2$	1,907,721	1.47%
8	16.714	Caryophyllene	$C_{15}H_{24}$	786,052	0.61%
9	17.477	Cinnamyl acetate	$C_{11}H_{12}O_2$	3,219,906	2.49%
10	19.229	Farnesol	$C_{15}H_{26}O$	232,702	0.18%
11	19.679	Delta-Cadinene	$C_{15}H_{24}$	704,411	0.54%
Total				129,526,440	100%

RT = Retention time

Table 2: Comparison of essential oil yield and Cinnamaldehyde content of Cinnamon bark among different studies

Origin of material	*Cinnamomum* genus	Extraction method	Yield (% w/w)	Composition of Cinnamaldehyde (%)	References
Mizoram, India	Stem bark of *Cinammoum verum* Bertch. & Presl	Hydro-distillation	2.13%	81.9%	14
Southern Peninsular, Malaysia	*Cinnamomum cassia* bark	Hydro- distillation	NA	80%	19
		Microwave-assisted hydro distillation	NA	85%	19
Peninsular, Malaysia	Bark of *Cinnamon cassia*	Supercritical CO_2 extraction	NA	75.2%	17
Sri Lanka	*Cinnamon zeylanicum* Bark	Supercritical CO_2 extraction	0.78%	72.1 to 95.3%	8
Malaysia	Bark of *Cinnamomum zeylanicum*	Steam distillation	1.538g/150g or 1.03%	94.7%	12
Yeongcheon, Republic of Korea	*C. loureirii*	Methanol extraction	NA	16.97 mg/g	7
Daejeon, Republic of Korea	*C. camphora*	Methanol extraction	NA	0.23 mg/g	7
Guangxi province, China	Fresh leaves of *Cinnamon cassia*	Hydro-distillation in a Clevenger-type apparatus	1.54%	trans-Cinnamaldehyde 30.36%	3
Guangxi, Guilin, China	Fresh bark of *Cinnamomum loureirii*	Hydro-distillation in 1000 mL flask	0.72 - 3.08%	trans-cinnamaldehyde 81.97%	15
Guangdong Province, China	*Cinnamomum cassia* bark	Ultrasound assisted hydro-distillation	2.14%	82.5%	20
		Hydro-distillation	1.68%	78.8%	
Yen Bai province, Vietnam	*Cinnamomum cassia* bark	Hydro-distillation	3.38%	93.3%	This study

NA : No information available

Results of SEM and FTIR analysis of cinnamon bark

Figure 6 shows the SEM photomicrographs of the cinnamon barks before and after hydro-distillation. The oil glands were seen and highlighted in the red boxes and arrows in Figures 6A and 6B at magnifications of 1,000x and 5,000x for the undistilled raw material, whereas they were not seen on the material surface in Figures 6C and 6D at the same magnification.

It could be explained that the hydro-distillation process heated the solvent (water) first then the material.[19] Therefore, the surface of the material after hydro-distillation had a high level of damaging rupture, the oil glands were broken and volatilized. The FTIR spectra for cinnamon bark powder before and after oil distillation are depicted in Figure 7. The peak at 3270 cm^{-1} was attributed to −OH stretching vibration in moisture in the bark powder. The peaks at 2918 and 2850 cm^{-1} correspond to =C-H bond and C-H bond of carbonyl group, respectively. The peak at 2360 cm^{-1} was attributed to CO_2 from air. The strong peak that appeared at 1605 cm^{-1} was assigned to C=C stretching. The absorption peak at 1513 cm^{-1} was attributed to the vibration in the aromatic moiety of lignin.[24] The absorption peak at 1441 cm^{-1} was assigned to C-OH bending vibration.[19] The peak displayed at 1256 cm^{-1} was attributed to C−O−C symmetric expansion and phenolic C−OH stretching vibration. The strong peak that appeared at 1027 cm^{-1} was corresponded to C−O−C stretching vibrations and C−OH deformation vibration. The peak that appeared at 780 cm^{-1} was attributed to =CH adsorption vibration of benzene rings.[19,25] It is important to note that the above listed peaks appeared intensively in the oil-extracted bark powder compared to the original bark powder. This demonstrated that hydro-distillation has actively affected cinnamon bark powder.

Conclusion

The study has shown that distillation time, particle size of raw material, ratio of material and water have significant effect on essential oil yield of cinnamon bark. It was found out that cinnamon bark with an input mass of 500 g, particle size of 2-3 mm, raw material to water ratio of 1/5 (g/mL) required 180 minutes of distillation time to get the optimum essential oil yield of 3.38%. GC-MS analysis of the essential oil detected 11 compounds in which cinnamaldehyde was the major compound accounting for 93.3% of the total oil by mass. In all, cinnamon bark in Yen Bai province of Vietnam is a rich source of essential oil in term of quality and quantity, and also provides a rich source of cinnamaldehyde globally.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

Acknowledgements

The authors gratefully acknowledge the support of Hanoi University of Industry, Vietnam.

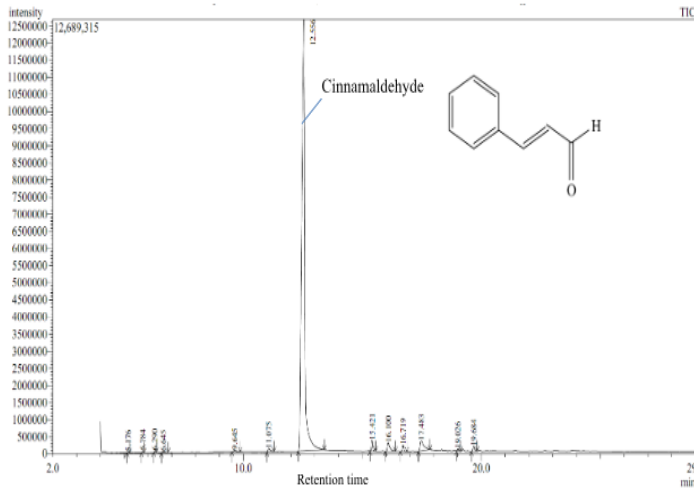


Figure 5: GC Chromatogram of essential oil of cinnamon bark from Yen Bai province, Vietnam

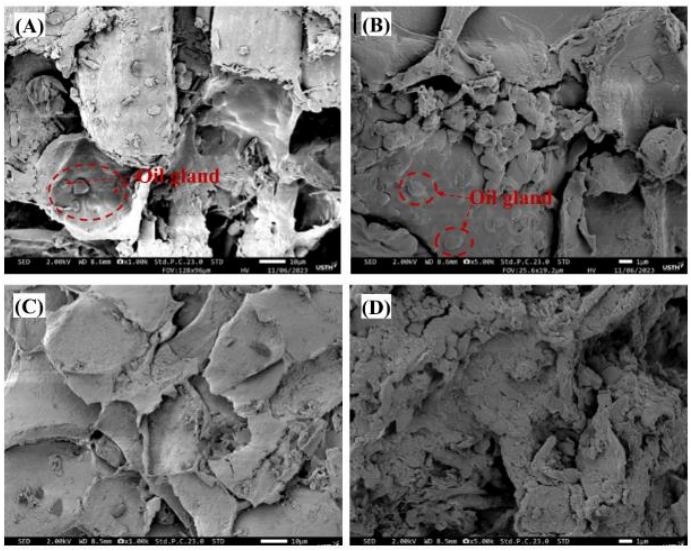


Figure 6: Scanning Electron Microscope (SEM) photomicrographs of raw cinnamon bark. (A): before distillation at magnification of 1,000x; (B): before distillation at magnification of 5,000x; (C): after distillation at magnification of 1,000x; (D): after distillation at magnification of 5,000x

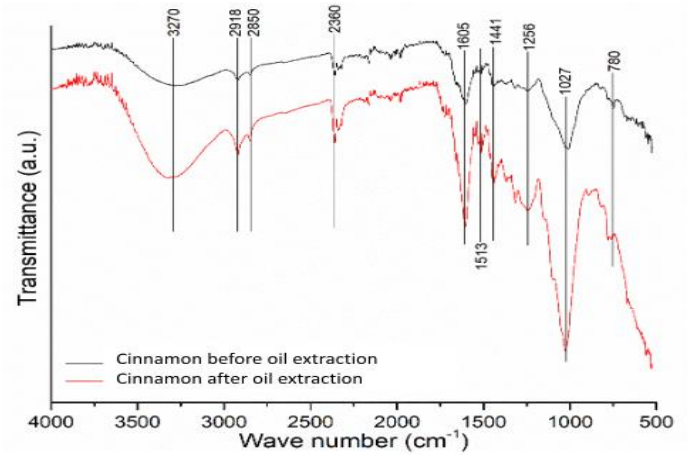


Figure 7: Fourier Transform Infra-Red (FTIR) spectrum of cinnamon bark before and after oil extraction.

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