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Chemical Composition of Active Compounds in Standardized Cinnamon Simplicia (*Cinnamomum verum*)

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ABSTRACT

Cinnamon (*Cinnamomum verum*) is widely recognized as a spice with a distinctive aroma that has a variety of applications in the culinary and health industries, due to its diverse active compounds. Standardization is essential to ensure the quality and uniformity of cinnamon raw materials. Previous studies primarily focused on identifying the most abundant compounds and bioactivity testing. However, a comprehensive analysis of the chemical composition of active compounds in different solvent extracts and essential oils has not been fully reported. This study aims to explore the chemical composition of active compounds in standardized cinnamon simplicia. Standardization parameters include water-soluble extractive, ethanol-soluble extractive, moisture content, ash content, microbial contamination levels, and qualitative and quantitative phytochemical analysis. Cinnamon was extracted using water, n-hexane, and steam distillation to obtain water extract, n-hexane extract, and essential oil, respectively, which were then analyzed by LC-MS and GC-MS. In general, all parameters set for the standardization of cinnamon simplisia met the applicable quality standards. The total phenolic content obtained was 3.99 ± 0.14 mgGAE/g, flavonoid content was 1.54 ± 0.10 mgQE/g, and total terpenoid content was 1.35 ± 0.13 mg/g. Furthermore, this study identified that the dominant active compounds in water extracts were polyphenols; n-hexane extracts contained major active compounds in terpenoids. At the same time, cinnamon essential oil showed the largest content of cinnamaldehyde. These findings provide important information regarding the chemical composition of cinnamon and its contribution to potential applications in the pharmaceutical and natural products industries.

Keywords: Active compounds; Cinnamon; Essential Oils; Simplicia; Standardization

INTRODUCTION

Cinnamon (*Cinnamomum verum*) has been widely used in various parts of the world as a spice and a traditional medicine (Pathak & Sharma, 2021). As a spice, this plant has long been used to treat indigestion, diabetes, acne, respiratory, and urinary problems. Essential oils of cinnamon bark relieve aching joints and numb pain (J. Wang *et al*., 2020). The diverse applications and health benefits of cinnamon make it a fascinating subject of research, particularly regarding the standardization and identification of its active compounds. In this research process, it is essential to evaluate the quality and consistency of cinnamon powder through the standardization and analysis of active compounds in various solvents.

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Standardization of cinnamon simplicia aims to ensure that the product meets specific quality standards, making it reliable in industrial and medical use (Taurina & Andrie, 2022). The standardization parameters refer to the Indonesian Ministry of Health regulations regarding traditional medicinal raw materials, which are divided into two categories, namely specific and non-specific parameters (Husni *et al*., 2021). Specific parameters focus on active compounds that play a direct role in the pharmacological effects of herbal medicines. This aims to qualitatively and quantitatively identify the content of these active compounds. This parameter includes herbal medicine identity, organoleptic, microscopic, level of soluble compounds in solvents such as ethanol and water, and chemical content test. Non-specific parameters are not directly related to pharmacological activity, but are important to

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ensure the quality, stability, and safety of the herbal medicine. These parameters assess physical and chemical aspects that can affect the quality of the material, including drying loss, total ash content, acid-insoluble ash content, specific gravity, microbial and heavy metal contamination, and residual organic solvents (Ngibad *et al*., 2024; Taurina & Andrie, 2022). With proper standardization, cinnamon products can be guaranteed for their purity and the diversity of their active compounds.

Active compounds from cinnamon can be extracted using various methods and solvents. Two commonly used solvents are water and n-hexane. Water is often used to extract polar compounds, while n-hexane is more effective in extracting non-polar compounds. This difference results in variations in the profile of active compounds obtained from both extracts (Ofoegbu *et al*., 2022; Rachmanita *et al*., 2022). Therefore, an in-depth understanding of the active compound profiles of aqueous and n-hexane extracts is essential to optimally explore the therapeutic potential of cinnamon. To obtain a comprehensive overview of the chemical composition of cinnamon, analysis of the active compounds was conducted using advanced chromatographic methods. Liquid Chromatography-Mass Spectrometry (LC-MS) was used to identify active compounds soluble in water and n-hexane solvents. LC-MS enabled the detection and quantification of these compounds with high accuracy (Syarpin *et al*., 2023), providing important information on the chemical profile of cinnamon simplicia.

Moreover, cinnamon essential oil, which is extracted using distillation techniques, plays an important role in imparting the aroma and therapeutic properties of this spice (Knauth & Acevedo-hernandez, 2022). Gas Chromatography-Mass Spectrometry (GC-MS) was used to analyze the essential oil components, identifying the volatile compounds contributing to its characteristic aroma and biological potential (Mothana *et al*., 2013). This analysis provides insight into the presence and concentration of active components such as cinnamaldehyde, eugenol, and others (Knauth & Acevedo-hernandez, 2022).

This study aims to provide a chemical composition of active compounds in standardized cinnamon simplicia by integrating data from simplicia standardization, LC-MS analysis of active compounds, and essential oil identification via GC-MS. The results are expected to contribute to developing higher-quality and applicable products in the healthcare and culinary industries.

MATERIALS AND METHODS

Procedures

Preparation of cinnamon simplicia

Cinnamon bark was obtained from Fresh Market, which was then cleaned to remove dust and dirt such as soil, gravel, and grumbling that stick to the cinnamon sticks. Then, the process of reducing the size to a length of 3 cm facilitated the drying process. Cinnamon was dried using an oven at a temperature of 60°C for 6 hours. Furthermore, the simplicia was ground using a commercial Waring blender until powdered, then the sieving process used a 60-mesh screen so that the cinnamon powder produced a uniform size (Djarot *et al*., 2023).

Simplicia standardization

Water content

A 5 g sample was put into a porcelain cup that had been tared and then dried in an oven at 105°C for 5 hours. The sample was then placed in a desiccator and weighed. Drying and weighing were continued at an interval of 1 hour until the difference between two consecutive weighings was no more than 0.25%. The water content of simplicia was calculated using the following formula:

$$water\ content\ (\%) = \frac{w0-w1}{w0} x100\% \quad (1)$$

Where w0 is the initial weight of the simplicia and w1 is the final weight of the simplicia (Djarot *et al*., 2023).

Ash content

A sample of 2 to 3 g was placed in a silicate crucible that has been incinerated and tared. After that, the sample was incinerated until the charcoal was consumed, cooled, and weighed. The ash content of simplicial was calculated by the following formula (Djarot *et al*., 2023):

$$ash\ content\ (\%) = \frac{w1}{w0} x100\% \quad (2)$$

Total microbial contamination

The number of microbial contaminants was determined by total plate count (TPC) and total fungal count (TFC). Serial dilution of samples was carried out using 0.85% NaCl until a dilution of 10^{-5} was obtained. Each dilution was inoculated on plate count agar (PCA) media for TPC and potato dextrose agar (PDA) media for TFC. Incubation was carried out at 30°C for 24-48 hours. The number of colonies that grew was counted according to standard plate count requirements (Ekawati & Yusmiati, 2018).

Water-soluble extract

The sample was weighed to a total of 5 g and placed into a sealed flask. Then, 100 mL of chloroform-saturated water (1 mL chloroform: 100 mL distilled water) was added, shaken several times for the first 6 hours, and left to sit for 18 hours. Afterward, the mixture was filtered, and 20.0 mL of the filtrate was evaporated until dry in a flat-bottomed vaporizer cup heated to 105°C and tared. The remaining substance was heated at 105°C to achieve a fixed weight. The water-soluble extract was calculated using the following formula (Pusmarani *et al*., 2019):

$$water\ soluble\ extract\ (\%) = \frac{weight\ of\ extract\ (g)}{weight\ of\ sample\ (g)} x \frac{100}{20} x 100\% \quad (3)$$

Ethanol-soluble extract

The sample was weighed at 5 g and placed in a sealed flask. Then, 100 mL of ethanol was added and shaken several times during the first 6 hours, before being left for 18 hours. To prevent ethanol evaporation, rapid filtration was employed. The filtrate (20.0 mL) was evaporated to dryness in a flat-bottomed vaporizer cup that was heated to 105°C and calibrated. The remainder was heated at 105°C until a constant weight was achieved. The ethanol-soluble extract was calculated using the same formula as that used for the calculation of the water-soluble extract (Pusmarani *et al*., 2019).

Phytochemical screening

A total of 100 g of cinnamon simplicia were macerated in 500 mL of water solvent for 3 hours before being ultrasonically extracted for 30 minutes. The homogenate was filtered, and the filtrate was used to conduct phytochemical screening (Shaikh & Patil, 2020). Using a standard color reaction test, phytochemical screening was conducted on flavonoids, alkaloids, steroids, triterpenoids, saponins, and polyphenols (Wijayanti *et al*., 2024). Flavonoids were detected by adding the extract to concentrated HCl and Mg metal. A positive result is indicated by the formation of a red, orange, or purple color. Alkaloids were detected using three reagents: Mayer, Dragendorff, and Bouchardat. A positive result is indicated by the formation of a white or yellowish precipitate, brown precipitate, and a reddish-brown precipitate, respectively. Steroids and triterpenoids were detected by dissolving the extract in chloroform, then anhydrous acetic acid and concentrated sulfuric acid were added carefully. The formation of a green or blue color indicates the presence of steroids, while the formation of a red, purple, or pink color indicates the presence of triterpenoids. To detect saponin, the extract was dissolved in water and shaken vigorously for several minutes. The formation of stable foam as high as 1-10 cm that does not disappear for at least 30 minutes indicates the presence of saponin. To confirm, the foam that forms should not disappear with the addition of 1 drop of 2N HCl. To detect polyphenols, the extract was mixed with $FeCl_3$ (ferric chloride) solution. The formation of green, blue, purple, or black indicates the presence of polyphenols, with different colors representing different types of polyphenols.

Sample preparation for quantitative phytochemical analysis

Cinnamon powder (2 g) was added to 100 mL of distilled water and sonicated for 30 minutes. The mixture was then filtered, and the filtrate was diluted with distilled water to yield a sample with a concentration of 4,000 ppm.

Total phenolic content

The Folin-Ciocalteu method was applied to determine the total phenolic content. A 0.5-mL sample was mixed with 5 mL of 10% Folin-Ciocalteu reagent, followed by 4 mL of 7.5% Na_2CO_3, and left at room temperature for 30 minutes. The absorbance was measured at 758 nm. The calibration curve was based on a gallic acid standard (20-60 ppm)(Baba & Malik, 2015).

Total flavonoid content

A 1 mL sample was mixed with 3 mL of 96% ethanol, 0.2 mL of aluminum chloride ($AlCl_3$ 10%), 0.2 mL of potassium acetate 1 M, and 5.6 mL of distilled water, was then shaken and allowed to stand at room temperature for 30 minutes. The absorbance was measured at 427 nm. The calibration curve used a quercetin standard (20-100 ppm) (Chandra *et al*., 2014).

Total terpenoid content

The dried extract was weighed at 100 mg, combined with 9 mL of 70% ethanol, and then allowed to stand for 24 hours. Extraction was performed using a liquid-liquid method with a separatory funnel and 10 mL of petroleum ether. The extract was collected and evaporated in a water bath to remove moisture, then weighed to determine the percentage of total terpenoid content using the following formula (Malik *et al*., 2017):

$$Total\ terpenoid\ content\ (\%) = \frac{w1}{w0} x 100\% \quad (4)$$

Extraction and LC-MS analysis

Cinnamon simplisia weighing 25 g was placed in a beaker glass, then 250 mL of solvent was added and stirred. The solvents used were water and n-hexane separately. The maceration was carried out for 3 hours at room temperature, then sonicated (200 W, 40 KHz) for 30 minutes at 70°C. The extract obtained was filtered, and the residue was re-macerated with each solvent. The re-macerated filtrate was combined with the initial filtrate and then concentrated to a thickness of 50 mL using a rotary evaporator under vacuum at 55°C. The concentrated extract was centrifuged for 10 minutes to remove any solids that may have escaped during filtration. The extract was stored in a freezer until frozen, then lyophilized for 62 hours to obtain a powder-form dry extract (Andishmand *et al*., 2023).

The Shimadzu LCMS 8040 LC/MS was used for high-resolution MS/MS analysis (Teoh *et al*., 2023). The LCMS properties include model Shimadzu LCMS 8040 LC/MS, column Shimadzu Shim Pack FC-ODS (2 mm x 150 mm, 3 μm), injection volume of 1 μL, capillary voltage of 3.0 kV, column temperature of 35°C, mobile phase methanol of 96% with isocratic mode, flow rate of 0.5 mL/min, sampling cone of 23.0 V, MS focused ion mode ion type [M]+, collision energy of 5.0 V, desolvation gas flow of 60 mL/hour, desolvation temperature of 350°C, fragmentation method: low energy CID, ionization: ESI, scanning of 0.6 sec/scan (mz: 10-1000), source temperature of 100°C, and run time of 60 minutes.

LC-MS was identified by comparing the mass-to-charge (m/z) data and fragmentation patterns obtained from the sample with data in compound databases or with standard compounds. This process involves matching the mass spectrum of the sample with a reference spectrum to identify the compounds contained therein. Databases used include the National Institute of Standards and Technology (NIST) Mass Spectral Library, Wiley Registry of Mass Spectral Data, MassBank, ChemSpider, PubChem, and other specific databases such as the Human Metabolome Database (HMDB).

Distillation of essential oils and GC-MS analysis

To extract the oil, 100 g of crushed cinnamon bark was placed in a distillation flask (1 L), then connected to the steam generator with a glass tube and a condenser. The essential oils were volatilized by heating the water at 100°C for 5 to 10 hours. The recovered mixture was left to settle before being extracted for oil. The product was collected and separated with a separatory funnel following the steam distillation process. The essential oils settled on the bottom layer of the separatory funnel and were separated several times until no oil remained in the funnel (Wong *et al*., 2014).

Cinnamon essential oils GC-MS analysis was carried out on a Shimadzu QP2010 SE system. The operating conditions included helium as the carrier gas, 0.75 mL/min flow rate, injector, column oven temperatures: 50°C, injection temperature: 250°C, injection mode: split, flow control mode: pressure, pressure: 100.0 kPa, 0.1 μL sample volume, 36.1 kPa pressure, total flow: 681.2 mL/min, column flow: 1.69 mL/min, linear, velocity: 47.2 cm/sec, purge flow: 3.0 mL/min, split ratio: 400.0, detector temperatures: 250°C, and Willey library data (Chairunnisa *et al*., 2017).

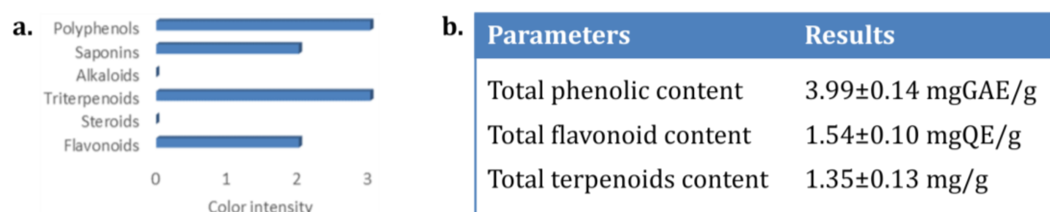
Oven temperature program

Rate	Temperature (°C)	Hold time (min)
-	50.00	2.00
5.00	140.00	2.00
10.00	280.00	2.00

GCMS-QP2010 plus, ion source temp: 200.00°C, interface temp: 200.00°C, solvent cut time: 2.00 min, detector gain mode: relative to the tuning result, detector gain: +0.00 kV, threshold: 1,000 MS table, start time: 5.00 min, end time: 37.80 min, ACQ mode: scan, event time: 0.50 sec, scan speed: 625, sStart m/z: 50.00, and end m/z: 350.00.

RESULTS

Cinnamon simplicia standardization was conducted by analyzing non-specific and specific parameters, including physical, chemical, and biological analysis. Non-specific parameters observed include ash content, water content, total plate count, and total fungal count. Specific parameters assessed were water-soluble extract, ethanol-soluble extract, and phytochemical analysis. The results are presented in Table I and Figure 1. Non-specific parameters for cinnamon simplicia showed water and ash content of less than 10%, while total microbial contamination was below 10^4 cfu/g. Specific parameters, including water-soluble and ethanol-soluble extracts, were 1.09±0.16% and 2.01±0.14%, respectively. Cinnamon simplicia exhibited phytochemical content as shown in Figure 1a, featuring flavonoids and saponins at moderate intensity, and triterpenoids and polyphenols at high intensity. Quantitative phytochemical analysis (Figure 1b) revealed higher phenolic content than flavonoids and terpenoids.Cinnamon simplicia was extracted with water and n-hexane to evaluate the profile of active compounds



Parameters	Results
Total phenolic content	3.99±0.14 mgGAE/g
Total flavonoid content	1.54±0.10 mgQE/g
Total terpenoids content	1.35±0.13 mg/g

Figure 1. Qualitative (a) and quantitative (b) phytochemical analysis of cinnamon simplicia

Table I. Analysis of specific and non-specific parameters of cinnamon simplicial

Standardization parameter		Results
Non-specific	Water Content	9.50±0.25%
	Ash Content	8.37±0.21%
	Total Plate Count	$1.5x10^3$ cfu/g
	Total Fungal Count	$1.1x10^3$ cfu/g
Specific	Water-soluble Extract	1.09±0.16%
	Ethanol-soluble Extract	2.01±0.14%

soluble in each solvent. In addition, distillation was conducted to obtain cinnamon essential oils. LC-MS identified active compounds in water extracts and n-hexane extracts, while GC-MS analyzed essential oils. Cinnamon extraction using water as a solvent yields 66 active compound components. Figure 2 shows that the most abundant compound group in the cinnamon water extract is the polyphenols group (67.48%), which is dominated by flavonoid glycosides (24.52%) and proanthocyanidins (23.91%). Cinnamon extraction using n-hexane yielded 51 active compound components. Figure 3 indicates that the most abundant compound group in the cinnamon n-hexane extract is terpenoids (50.05%), which consist of monoterpenoids (15.03%), diterpenoids (3.84%), and sesquiterpenoids (31.17%).

The GC-MS analysis identified 40 components of cinnamon essential oil. Figure 4 shows that the largest component of essential oil in cinnamon is the phenolic group (92.75%), which consists of cinnamaldehyde (CID637511) at 89.47%, along with other phenolics including cinnamyl acetate (CID5282110), cis- cinnamaldehyde/(z)- 3- phenylacrylaldehyde (CID6428995), dihydrocinnamaldehyde (CID7707), amphetaminil (CID 28615), 4-butylbenzoic acid, 2-methoxyethyl ester (CID 91723640), and p-hexylacetophenone (CID 123462), each with a percentage less than 2%. Other groups found in cinnamon essential oils include terpenoids (7.12%), which are composed of monoterpenoids (3.26%), sesquiterpenoids (2.46%), monoterpenoid alcohol (0.81%), and sesquiterpenoid alcohol (0.59%). Additionally, another compound is benzaldehyde (0.15%). The composition of cinnamon compounds obtained from LC-MS and GC-MS analysis is detailed in the supplementary file.

DISCUSSION

Standardization aims to improve product quality and safety by ensuring consistent pharmaceutical and therapeutic quality. Standardization entails identifying specific and nonspecific parameters in simplicia and extracts of natural ingredients (Taurina & Andrie, 2022). The standardized simplicia was evaluated with the related rules. According to the Indonesian Herbal Pharmacopoeia, simplicia should have no more than 10% water content. The Decree of Minister of Health of the Republic Indonesia No. 261/MENKES/SK/IV/2009 states that the extract's ash content should not exceed 10.2%. The regulation of the National Agency of Drug and Food Control on traditional medicine quality requirements for contamination by microbes should not exceed 10^4 cfu/g for total plate count and 10^3 cfu/g for total fungal count (Ngibad *et al.*, 2024). Water content is proportional to the length of storage. Simplicia can be stored longer due to its low water content, which inhibits microorganism growth and enzymatic reactions. The ash content represents the mineral content of the cinnamon. The higher ash content indicates high mineral content (Taurina & Andrie, 2022). Cinnamon simplicia meets the requirements according to those regulations, with a water content of less than 10%, ash content of less than 10.2%, total microbial contaminants of less than 10^3 cfu/g, and total fungal contaminants of less than 10^4 cfu/g. These findings show that the processing of simplicia was appropriate.

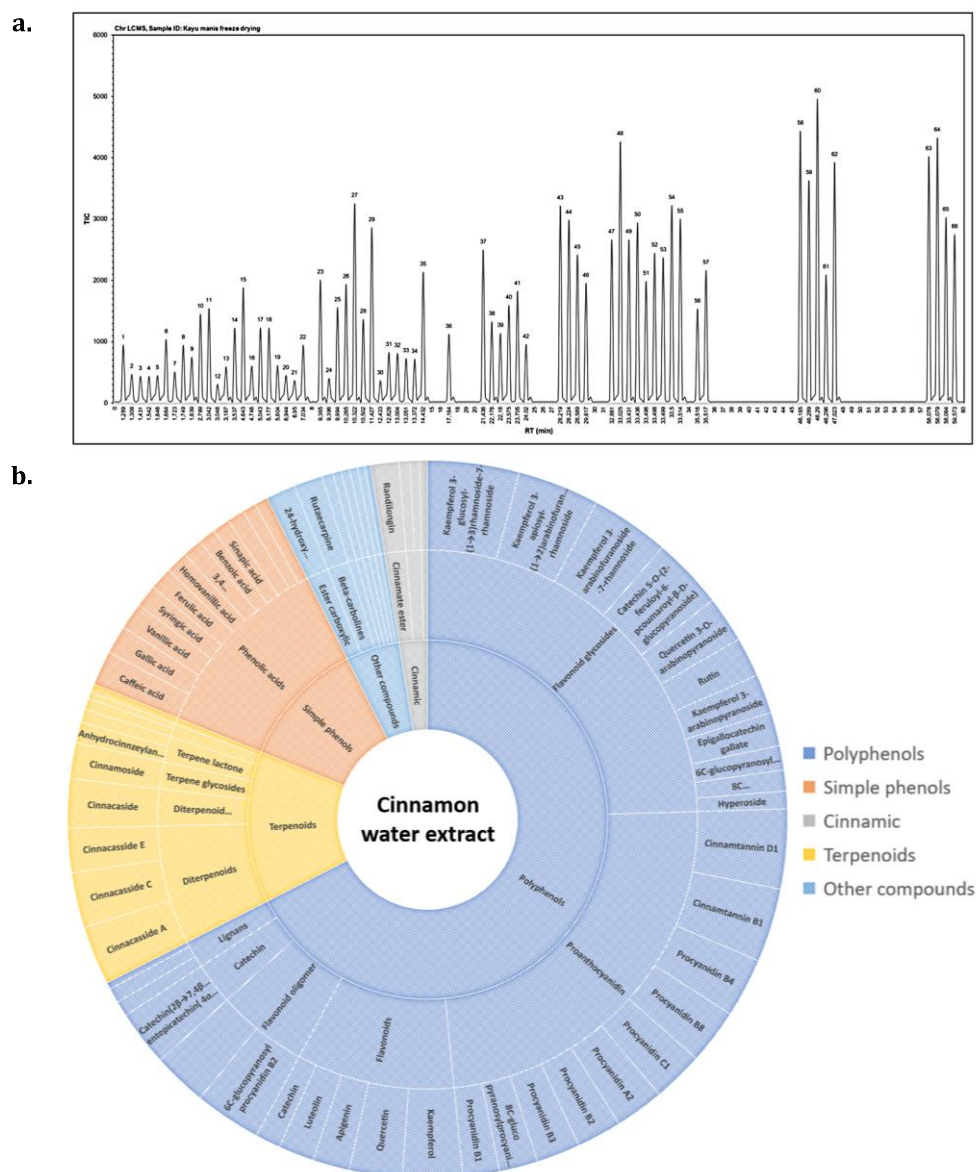


Figure 2. Profile of cinnamon active compounds in water solvent, a. LC-MS chromatogram, b. summary diagram

In this study, the specific parameters analyzed were the levels of soluble compounds in solvents evaluated gravimetrically as an initial picture of the chemical content of simplicia in ethanol and water solvents. Water-soluble extract shows how much polar compound content is in simplicia, whereas ethanol-soluble extract shows the number of dissolved compounds in ethanol. In terms of quality, measuring the ethanol-soluble extract content is almost identical to determining the water content (Husni *et al*., 2021). Cinnamon simplicia showed a higher ethanol-soluble extract, indicating that more compounds are dissolved in organic solvents. According to the Ministry of Health of the Republic of Indonesia, determining dissolved compound levels has no bearing on pharmacological effects. However, it can be used to estimate semi-polar compounds (which dissolve in ethanol) and polar compounds (which dissolve in water).

In addition, World Health Organization (WHO) regulates standardization and quality control of herbals to evaluate the physicochemical properties of crude drugs, which includes aspects such as crude material selection and handling, safety, efficacy, and stability evaluation of finished product, documentation of safety and risk based on experience, provision of product information to consumers, and promotion. Parameters to be assessed for standardization include macro and

a.

b.

Figure 3. Profile of cinnamon active compounds in n-hexane solvent, a. LC-MS chromatogram, b. summary diagram

microscopic examination, foreign organic matter, ash value, moisture content, extractive value, crude fiber, qualitative chemical evaluation, chromatographic examination, quantitative chemical evaluation, and toxicological studies (Pradhan *et al*., 2015). Herbal medicine quality standards may vary depending on the country, intended use, and applicable regulations. Therefore, it is important to refer to relevant and appropriate standards in the context of herbal medicine use (Kunle *et al*., 2012). Phytochemical screening results are slightly different from previous studies, which found that cinnamon contains flavonoids, triterpenoids, saponins, polyphenols, alkaloids, and steroids (Fernandez A & Sasikala, 2021; Winda & Prasetyo, 2023). In this study, alkaloids and steroids were not detected in cinnamon simplicia. This is assumed to be due to the low levels of these compounds, causing them to be undetectable during testing by the color reaction test. Furthermore, sensitive testing using LC-MS was unable to detect both compounds due to the limitations of the column used, which is less suitable for the separation of alkaloids and steroids.

Cinnamon simplicia was further analyzed using LC-MS to identify active compounds contained in it. Quantification in HPLC with a UV detector and LC-MS has different principles due to the various detection

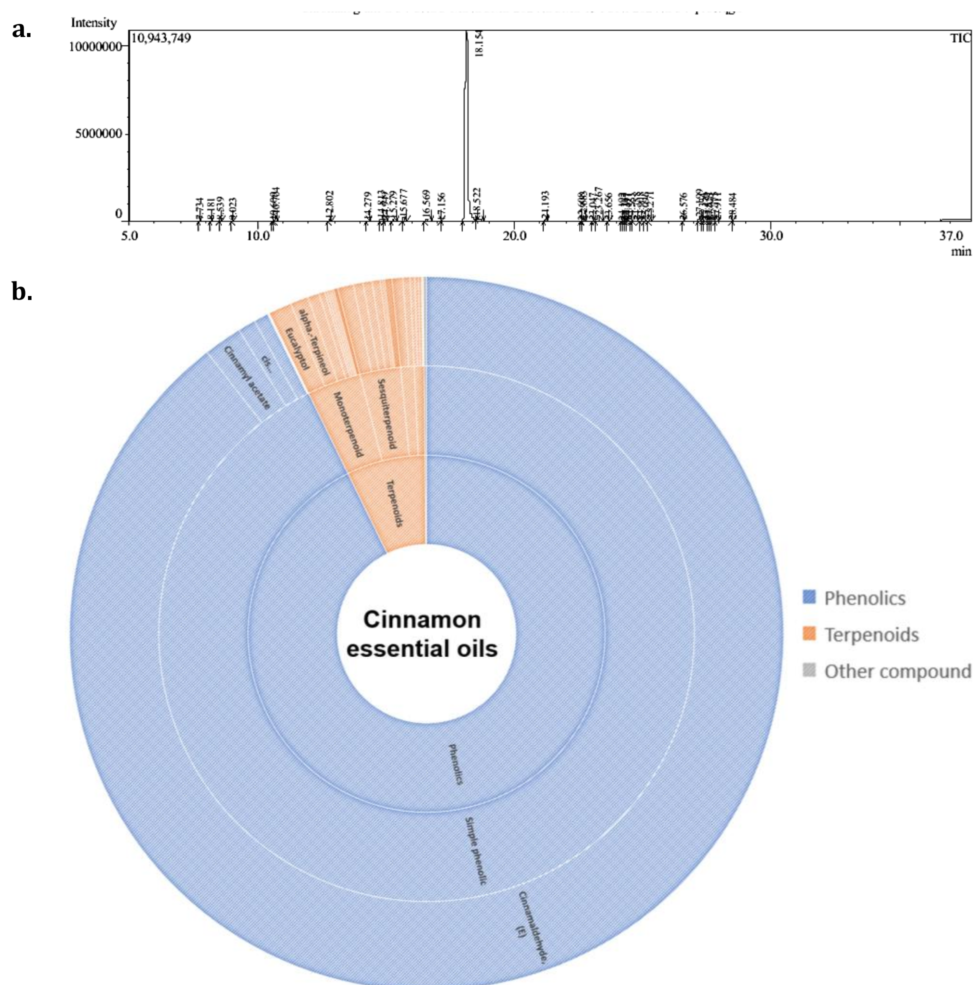


Figure 4. Profile of cinnamon essential oil, a. LC-MS chromatogram, b. summary diagram

mechanisms. In HPLC-UV, the higher absorbance signal does correlate directly with the concentration of the compound as it follows the Lambert-Beer law, where absorbance is proportional to concentration. However, in LC-MS, the Total Ion Current (TIC) signal does not always represent the concentration accurately because it is affected by the ionization factor of the compound. HPLC-UV Quantification Mechanism uses a UV detector to measure the absorbance of a compound at a specific wavelength. A linear relationship between signal and concentration holds if the compound has a stable molar extinction coefficient (Chawla & Ranjan, 2016; Tumanduk *et al*., 2023). The mechanism of LC-MS quantification is TIC, the total number of ions detected at each analysis time. The TIC signal depends on the ionization efficiency of the compound, which is influenced by chemical properties (polarity, molecular weight) and instrument parameters (voltage, temperature, compounds with more efficient ionization (e.g. polar compounds) will produce higher TIC signals even though the concentration is the same as less polar compounds. The disadvantages of using TIC for quantification are Ionization variation (Compounds with different structures have different ionization affinities, so TIC does not reflect the actual concentration), Matrix Interference (Interfering compounds in the sample can enhance or suppress the ionization of the target compound (ion suppression/ enhancement)) and Limited Resolution (TIC peaks may be a combination of several overlapping compounds, especially in complex samples) (Suhendi *et al*., 2023; Tang *et al*., 2022). Therefore, it is not recommended to use the TIC signal as the basis for absolute quantification in LC-MS due to the unreliability caused by ionization variation. Methods such as SRM, internal standards, and calibration curves are more reliable to guarantee accuracy. However, in this study, TIC was still

used, assuming that the ionization efficiency of the target compound had been adequately characterized.

Cinnamon extraction for LC-MS analysis was done using two different solvents, water and n-hexane, yielding distinct chemical component profiles of active compounds. Likewise, with the chemical components in essential oils. Cinnamon water extract contained more polyphenol group, which is a phenolic compound, whereas n-hexane extract was dominated by terpenoids. The polarity of solvents used for extraction affects the extraction efficiency of phenolic compounds (Kaczorova *et al*., 2021). Phenolic compounds have a polarity that varies from polar to non-polar. These compounds include phenolic acids, flavonoids, stilbenes, lignins, and condensed tannins (Wijayanti *et al*., 2024).

Active compounds in plants are primarily extracted using organic solvents and water-based formulations. However, questions remain about the best solvent for polyphenol extraction due to varying results from previous studies. The extraction of polyphenols in lychee flowers is more efficient with acetone, whereas polyphenols in walnut green husks and *Phoradendron californicumo* oak are more efficient using polar solvents for extraction (Alara *et al*., 2021). In this study, polyphenols demonstrated efficiency in extraction using aqueous solvents.

Among the polyphenol group, flavonoid glycosides were found in the highest levels in the water extract of cinnamon because these compounds have high polarity *(Johnson et al*., 2021). Generally, flavonoid glycosides exhibit many bioactivities, including anticancer, anti-infective, anti-malarial, anti-obesity, and anti-tyrosinase properties (Johnson *et al*., 2021). However, detailed information on the bioactivity of the flavonoid glycosides group—including kaempferol 3-glucosyl-(1→3) rhamnoside-7-rhamnoside, kaempferol 3-apiosyl-(1→2) arabinofuranoside-7-rhamnoside, kaempferol 3-arabinofuranoside-7-rhamnoside, catechin 5-O-(2-feruloyl-6-pcoumaroyl-β-D-glucopyranoside), and quercetin 3-O-arabinopyranoside—is still very scarce, indicating significant potential for further research.

The next most abundant compound group in the water extract of cinnamon is proanthocyanidins. Proanthocyanidins are plant secondary metabolites that perform various biological functions, including antioxidant activity, anti-inflammatory, antibacterial, anticancer, antiviral, and anti-aging effects (Li *et al*., 2023). Cinnamtannin D1 has been reported to protect pancreatic β-Cells from glucolipotoxicity-induced apoptosis (X. Wang *et al*., 2020*)* and attenuate autoimmune arthritis (Shi *et al*., 2019). Cinnamtannin B1 acts as an antioxidant and inhibitor of platelet aggregation (López *et al*., 2008). This compound also showed potential therapeutic benefits for colon cancer (Carriere *et al*., 2018). Procyanidins have been identified as antinutritional compounds of great variety and complex structure, resulting in their limited application in the food, agricultural, and livestock industries (Valencia-hernandez *et al*., 2021).

Other groups in cinnamon water extract are terpenoids, simple phenols, and other compounds. Terpenoids constitute a substantial class of natural secondary metabolites in plants, exhibiting diverse biological properties such as antioxidant, antimicrobial, anti-inflammatory, anti-allergic, anticancer, antimetastatic, antiangiogenic effects, and the induction of apoptosis, and are regarded for potential use in the food and health sector industries (Camara *et al*., 2024). Simple phenols such as phenolic acids have tremendous antioxidant activity and other health benefits (Kumar & Goel, 2019), including antimicrobial (Wijayanti *et al*., 2021), anti-inflammatory (Wijayanti et al., 2022), and anti-aging properties (Wijayanti *et al*., 2023).

Terpenoids dominate the cinnamon n-hexane extract. Terpenoids include diverse compounds with varying polarities due to their volatility(Ismail & Chua, 2020). Among the terpenoid group, sesquiterpenoids compose the most components in cinnamon extracts. Sesquiterpenoids in plants are generally found in the form of volatile oils(Sinaga *et al*., 2022). Therefore, extraction with non-polar solvents such as n-hexane can be obtained in high concentrations. Sesquiterpenoids have numerous biological functions, including cytotoxicity, antiplasmodial, antimicrobial, antidiabetic, antiviral, and anti-inflammation (Riyadi *et al*., 2023). The sesquiterpenoids group consists of β-caryophyllene (CID5281515), α-corocalene (CID5316074), α-farnesene (CID5281516), viridiflorene (CID10910653), cis-calamenene (CID6429077), β-cadinene (CID10657), etc. The β-caryophyllene showed selective anti-proliferative effects on colorectal cancer cells(Dahham *et al*., 2015). This compound also showed neuroprotective, sedative, anxiolytic, anti-depressive, and anticonvulsant effects (Francomano *et al*., 2019). β-caryophyllene, α-corocalene, and α-farnesene have been identified as the constituent components of

volatile compounds in *Apis mellifera* Propolis (de Oliveira *et al*., 2021). Both β-caryophyllene and α-corocalene are also components of the essential oil in stems, leaves, and fruits of *Illicium lanceolatum* (Zhao *et al*., 2024). The α-corocalene has also been found in the essential oil of *Calamintha nepeta* (Mancini et al., 2013). An α-farnesene has been reported to be utilized as a food additive, fragrance, biofuel, pest control, antimicrobial, and antivirus, including reducing symptoms of COVID-19 (Habibah *et al*., 2023). Viridiflorene has been identified in the essential oil of *Piper gaudichaudianum* with anti-inflammatory activity(Soares *et al*., 2022). In comparison, cis-calamenene has been found to be the primary compound of *Leptospermum scoparium*, *Origanum vulgare*, and *Litsea cubeba* essential oils with acaricidal activity (Duque *et al*., 2021).

The next most abundant compound group in n-hexane extract is monoterpenoids. Monoterpenoids are a type of terpene composed of two isoprene units that are widely distributed in plants and used in pharmacy and medicine. Monoterpenoids have pharmacological properties such as anti-inflammatory, antibacterial, and antiviral. Monoterpenoids are used as food ingredients, soaps, perfumes, and insecticides (Gao *et al*., 2020). Monoterpenoids group found in cinnamon consists of α-terpineol (CID17100), myrcene (CID31253), 2,6-dimethyl-1,7-octadiene3,6-diol (CID548927), carvacrol (CID10364), α-fenchyl alcohol (CID6997371), etc.

The α-terpineol is the primary essential oil component of *Origanium vulgare* and *Ocimum canum*, with various biological properties including cardiovascular and antihypertensive effects, antioxidant, anticancer, antinociceptive, antiulcer, anticonvulsant and sedative, anti-bronchitis, skin penetration enhancing, and insecticidal activity (Khaleel *et al*., 2018). Myrcene can be found in the essential oils of hops, cannabis, citrus, verbena, bays, and lemongrass, and is often used as a food additive, cosmetic, soap, and detergent (Surendran *et al*., 2021). Carvacrol is a volatile oil component with antioxidant properties and can be found in *Leucas virgata* (Mothana *et al*., 2013) and *Illicium lanceolatum* fruits (Zhao *et al*., 2024). In contrast, α-fenchyl alcohol has been identified in *Alpinia galangal* and *Cyperus rotundus* and showed potent anti-inflammatory activity (Rajput *et al*., 2018).

In line with a previous study by (Knauth & Acevedo-hernandez, 2022), this study found cinnamaldehyde to be the main component of cinnamon essential oil. Cinnamaldehyde is responsible for the natural flavor and fragrance of cinnamon. This compound exhibits various biological activities, including antibacterial, antifungal, antiviral, antioxidant, antidiabetic, anti-inflammation, anti-cancer, and anti-neurodegenerative (Ibi & Kyuka, 2022). Cinnamaldehyde has also been reported as the essential oil constituent component of clove flower (*Syzygium aromaticum*) (Pandey *et al*., 2024), resins of *Boswellia serrata* (Poornima & Deeba, 2020), and sweet basil leaves (*Ocimum basilicum)* (Tateishi *et al*., 2024).

Another compound in cinnamon essential oil is benzaldehyde. Benzaldehyde is an antimicrobial compound that shows anti-aflatoxigenic activity (Jermnak *et al*., 2023). Benzaldehyde produced by *Photorhabdus temperate* has been reported to have insecticidal, antimicrobial, and antioxidant activity (Ullah *et al*., 2015). This study identified 40 components of cinnamon essential oil, classified as phenolics, terpenoids, and other compounds. These findings support previous research that dsiscovered 13 components of cinnamon essential oil (Knauth & Acevedo-hernandez, 2022).

The current study revealed various types of active compounds in cinnamon, each exhibiting different chemical compositions based on the solvent and analysis used. The chemical components within the active compounds of cinnamon, across all types of extracts including water extracts, n-hexane extracts, and essential oils, demonstrate significant bioactivity, particularly as antioxidants, antimicrobials, and anti-inflammatory agents. Investigating active compounds from a range of solvents can serve as a foundation for further development in food, cosmetic, and pharmaceutical products. This is further supported by the diverse bioactivity of cinnamon, which can contribute to enhancing public health. Conversely, several compounds identified in cinnamon extract lack known bioactivity, warranting additional investigation.

CONCLUSION

This study successfully standardized cinnamon simplicia and identified the main active compounds in various cinnamon extracts. The standardization results showed that all tested parameters met the applicable quality standards, ensuring that cinnamon raw materials possess sufficient consistency and quality for industrial applications. The exploration of active compounds revealed that the cinnamon aqueous extract contained the largest amounts of polyphenols,

the n-hexane extract was rich in terpenoids, and the cinnamon essential oil had the highest content of cinnamaldehyde. These findings provide valuable insights into the chemical composition of cinnamon, which may influence its functionality in various applications, especially in the pharmaceutical and natural products industries. With this information, further development can occur in the utilization of cinnamon and its therapeutic potential.

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CONFLICT OF INTEREST

The authors confirmed that there is no conflict of interest.

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