

Bamboo leaf (*Bambusa vulgaris*) extracts by steam distillation and gas chromatography-mass spectrometry characterization of the compounds present in essential oil

Hau T. Phan, Tay M. Nguyen, Sang V. Vo, An T. Huynh, Quyen T. Nguyen, Anh T. Ton, & Minh T. L. Tran*

Faculty of Biological Sciences, Nong Lam University, Ho Chi Minh City, Vietnam

ARTICLE INFO

Research Paper

Received: September 27, 2024

Revised: November 07, 2024

Accepted: November 21, 2024

Keywords

α -ionone

Bamboo

Bambusa vulgaris

Hydro-distillation

Terpenoid

*Corresponding author

Tran Thi Le Minh

Email:

ttlminh@hcmuaf.edu.vn

ABSTRACT

Today, with the development of science and technology, products using chemical-based fragrance, medicine have become increasingly popular, raising concerns about potential impacts human health. This study aimed to extract essential oils from native bamboo leaves (*Bambusa vulgaris*). In addition, the study identified the biological compounds in essential oils and preliminary assessed the total terpenoid content in the samples, using α -ionone as a standard solution for the determination procedure. The essential oil content was 19.50 ± 6.2 mg/100 g. The bamboo leaf essential oil extracted from the fine grinding samples exhibited antioxidant activity against DPPH (2,2-diphenyl-1-picrylhydrazyl). Total silicate of the bamboo's hydrosol was 0.81 mg/L. Essential oils were analyzed by gas chromatography-mass spectrometry, which identified a total of eight compounds. The components in essential oil were α -ionone, trans- β -ionone, hexahydrofarnesyl acetone, farnesyl acetone, n-hexadecanoic acid, hexadecanoic acid, phytol, 9,12,15-octadecatrienoic acid. The total terpenoid content was 0.06% in the finely grinded samples.

Cited as: Phan, H. T., Nguyen, T. M., Vo, S. V., Huynh, A. T., Nguyen, Q. T., Ton, A. T., & Tran, M. T. L. (2025). Bamboo leaf (*Bambusa vulgaris*) extracts by steam distillation and gas chromatography-mass spectrometry characterization of the compounds present in essential oil. *The Journal of Agriculture and Development* 24(6), 82-92.

1. Introduction

Bamboo is widely used for a variety of purposes. Bamboo offers advantages in the tropical zone, such as the strength, straightness, smoothness, lightness, hardness and hollowness of the culms. They can be easily split into sizes and thicknesses for purposes without requiring extensive labor or preparation. These qualities make them suitable for a range of applications. Despite advancements, bamboo remains essential in Southeast communities. Recently, they have gained entry into the market as pulp for paper production, parquet flooring material and bamboo plywood. Even as a canned vegetable. In Southeast Asia their primary uses include construction material, crafting types of baskets and serving as a vegetable. Additionally, they are utilized as material for paper making industry and manufacturing instruments and handicrafts.

Bamboo plays an important role in traditional medicine of all Asian countries. It has a wide contribution in curing heart-related diseases, diabetes, antioxidant, inflammatory, etc. The diversity of species, parts of the tree, with lots of extraction methods show that bamboo has potential in producing a vast amount of compounds valuable in medicines and cosmetics (Singhal et al., 2013; Choi et al., 2017).

Essential oils are aromatic, volatile liquids obtained from plant material through steam distillation and named after the plant from which they are derived. Essential oils can be defined as either products or mixtures of fragrant substances or as mixtures of fragrant and odorless substances. These fragrant substances are chemically pure compounds that are volatile under normal conditions. Essential oils vary greatly, sometimes due to genetic causes, but also because of climate, rainfall, or geographic origin. They are composed principally of lipophilic and highly volatile secondary plant metabolites, principally mono- and sesquiterpenes, but other types of

compounds such as allyl and isoallyl phenols may also be present. Other substances that have been identified in volatile oils include coumarins, anthraquinones, and alkaloids, which are often distillable, while some diterpenes, fat, and other nonvolatile compounds can be obtained from essential oils by methods other than distillation (Ríos et al., 2016). Essential oil production has become a new industry throughout the world. Due to current trends, essential oil is not only a fragrance of perfume, or a flavor of food, nor a stimulation for our digestive system; it is also used in the pharmaceutical industry to perform magnificent results during healing processes: curing skin diseases, preventing dementia, becoming a resource for biosynthesis of other chemicals, etc.

Bamboo essential oil has many biological activities such as antifungal, antioxidant, antimicrobial and improving immune function (Yang et al., 2019; Alias et al., 2023). The chemical components of bamboo leaves essential oil are determined by the solvent extraction method. There is little research that determines the chemical components of bamboo leaves essential oil are determined by the water distillation method. All those components are then analysed by the GC-MS (gas chromatography-mass spectrometry) system.

The GC-MS is a mix of two primary analytical tools: the chemical separation capacity of GC with MS, determining chemicals identification and their measurement concentration. For separating the volatile sample components, usually GC is applied. The instrument vaporizes a liquid sample by heating and carries it as gas such as helium or hydrogen. A gas (referred to as a carrier gas or mobile stage) drags the sample through an extended, thin glass-threaded pipe (column) which is coated with a chemical substance (stationary phase). The vaporized compounds move through the column but are

retarded when they come in contact with the stationary phase. As no two molecules are the same, other chemicals will travel through the column in slightly different amounts of time based on their chemical nature. The chemicals were separated and sent to the mass spectrometer. The GC separates compounds that are subsequently vaporized and measured by a detector and the mass spectrometer (MS) is a detector. While GC provides retention time and peak intensity data, the addition of mass spectrometry allows identification based on characteristic fragment ions unique to each compound. For example, mass information can be employed to identify what a molecule is and how many of it exists in substance; along with structural as well as chemical properties (Kanani et al., 2008).

The free radicals are molecules or fragments of particles having one electron at the molecular orbital or atomic orbitals which is also a reactive oxygen species (ROS), and yet a diverse range of oxygen species, including hydrogen peroxide (H_2O_2), one powerful oxidizing functional group formed by cells during aerobic respiration process and immune system editing (Baliyan et al., 2022).

Antioxidants are a type of chemical that neutralizes oxidative damage, so they donate electrons to free radicals, thereby making them harmless. Oxidative stress for the most part is related to free radicals. When free radicals formed oxygen mixed with certain chemicals, the threat they produced was gone when combined with key cellular components such as chemical heredity (DNA), proteins and cell membrane. Antioxidants will neutralize these free radicals to stop all the mayhem that comes with them, by wrapping themselves around it instead of harming cells. Secondary metabolites produced by plants include a wide range of antioxidants. Hence the present work aimed to investigate that either leaves of this plant possess free-radical

scavenging capacity using 2,2-diphenyl-1-picrylhydrazyl (DPPH) test technique (Baliyan et al., 2022).

2. Materials and Methods

Sample's preparation

Fresh bamboo leaves were collected in Thu Dau Mot city, Binh Duong province, Vietnam. The bamboo leaves samples were then removed from the petiole, washed, cut (2 - 3 cm length and 1 cm width) and eventually finely ground and sieved through 1 mm.

Extraction using steam distillation

Extraction using steam distillation is a method used to extract essential oil and isolate antioxidant, antimicrobial compounds from plants, especially medicinal ones (Chemat & Boutekedjiret, 2015). The steam that went through the plant's material created a mixture of steam and volatile compounds. After that the mixture was cooled and condensed as a thin, separate phase immiscible with and above the water. The upper part was essential oil, containing compounds that dissolve in oil, while the lower part was hydrosol, containing compounds that dissolve in water. Hydrosol samples were analyzed for silicate content according to CASE. TN0131-2020 method were exported results by the Viet Tin Analysis Testing Company Limited.

Measuring moisture and essential oil content of samples

Drying bamboo leaves at high temperatures such as 105°C, both water and essential oils would evaporate. In order to calculate the water content in essential oil plants, the essential oil content must be subtracted after the sample had dried. The principle of measuring moisture content of samples was based on the difference between the sample's mass before and after drying (Te, 2018).

Moisture content of the sample would subtract the weight of essential oil evaporated during the drying process (Pimentel et al., 2006). Prepared a clean container, dried at 105°C, let it cool in a desiccant tank and weighed it. Put 2 g samples into the container, dried at 105°C in 3 - 4 h. Let it cool in a desiccant tank in at least 20 min and weighed the total weight of the container and samples. Moisture content was calculated using the equation:

$$\% \text{ moisture content} = \frac{m - (m_1 - m_0)}{m} \times 100$$

where m_0 (g) was the weight of the container after drying; m_1 (g) was the weight of the container and samples after drying; m (g) was the weight of the samples before drying.

Quantifying essential oil in the samples

Essential oil was quantified using the equation

$$H_{EO} = \frac{m_{EO}}{m} \times 100$$

where H_{EO} (mg/100 g) was the amount of essential oil; m_{EO} (mg) was the weight of essential oil after the extraction; m (g) was the weight of samples.

Collecting the essential oil

Collecting essential oil by decantation: Essential oil sample after the distillation extracting process was collected from the separated mixture by decantation. Water remaining in the essential oil was separated by silica gel desiccant (silica gel self indicator; Cas 112926-00-8; Xilong).

Collecting essential oil by solvent: Essential oil sample after the distillation process was extracted with ether, replicated 3 times, each time with 30 mL ether. After that the sample was separated from the solvent and water using high heat (55°C) and low-pressure condition.

Total terpenoid content determination

Applying and modifying the basic procedure established by Ghorai et al. (2012), with some adjustments. The procedure consisted of 9 steps:

1. Mixed 0.2 g of raw essential oil with 2 mL methanol 95%.
2. Added 1.5 mL chloroform to each 2 mL microcentrifuge tube and then added 200 μ L sample to each.
3. Vortexed the sample mixture thoroughly and left it to rest for 3 min.
4. Added 100 μ L concentrated sulfuric acid (H_2SO_4) to each 2 mL microcentrifuge tube.
5. Then, the assay tube must be incubated at room temperature for 1.5 - 2 h in the dark.
6. At the end of the incubation time, a reddish-brown precipitation was formed in each assay microcentrifuge tube. Then, carefully and gently decanted all of the supernatant reaction mixture liquid without disturbing the precipitation.
7. Added 1.5 mL of 95% (v/v) methanol and vortexed thoroughly until all the precipitate dissolve completely in the methanol.
8. Transferred the sample from the assay tube to the colorimetric cuvette to read the absorbance at 538 nm (95% (v/v) methanol was used as a blank).
9. Calculated a standard curve from the blank corrected at a wave-length at 538 nm of the α -ionone standard solution (α -ionone; W259403; Sigma-Aldrich). Calculated the total terpenoid concentration of the essential oil sample as α -ionone equivalents using the regression equation of the α -ionone standard curve.

Identify and semi quantitative the concentration of chemicals in the essential oil using GC-MS method

Bamboo leave essential oil was diluted with methanol (0.1 g essential oil samples and 2 mL methanol, vortex). The samples were filtered through a PTFE syringe filter with a 0.22 µm pore size before the final analysis using GC-MS.

The composition of diluted essential oil samples was investigated by gas chromatographic-mass spectrometry (GC-MS Agilent 6890N/5973) with a DB-5MS capillary column (30 m × 0.25 mm i.d., 0.25 µm, 5% phenyl-methylpolysiloxane; Agilent J&W). Helium flow rate: 1 mL/min. The column temperature programming increased from 150 to 230°C, at 40 C/min and held for 2 min. The injector and detector temperatures were 220 and 230°C, respectively. The ionization energy was 70 eV. The analytical sample volume was 1 µL. The compounds were identified based on a comparison of their mass spectra using the data in NIST 14 (National Institute of Standards and Technologies, Mass Spectra Libraries).

Determination of antioxidants by DPPH radical scavenging activity

The antioxidant activity of bamboo leaves essential oil was measured on the basis of the scavenging activity of the stable 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical. One mL of 0.1 mM DPPH solution in methanol was mixed with 1 mL of various concentrations (30 - 155 mg/mL) of bamboo leaves essential oil. The mixture was then allowed to stand for 30 min incubation in the dark. Ascorbic acid was used as the reference standard. One mL methanol and 1 mL DPPH solution was used as the control. The decrease in absorbance was measured using UV-Vis Spectrophotometer at 517 nm and the IC₅₀ (inhibitory concentration 50%) was calculated (Özkan et al., 2004). The percentage of inhibition was calculated using the following formula:

$$\% \text{ of DPPH radical inhibition} = \frac{\text{Control} - \text{Sample}}{\text{Control}} \times 100$$

3. Results and Discussion

3.1. Measuring moisture and essential oil content of samples

Bamboo leaves were freshly collected, washed, cut or finely ground. The samples had a green color and a faint fragrance.

Table 1. Quantified moisture content and essential oil of the samples (converted to dry sample)

Samples	Moisture content (%)	Essential oil content (mg/100 g)
Cut	50.33 ± 1.2	10.77 ± 2.5
Finely grinded	24.67 ± 0.6	19.50 ± 6.2

Results showed that moisture content in the fresh bamboo leave essential oil was relatively low, it took up 50.33 ± 1.15% in cut samples; on the other hand, it was 24.67 ± 0.6% in grinded samples, due to evaporation during the grinding process. The amount of essential oil in grinded samples reached 19.50 ± 6.2 mg/100 g, which was approximately 2 times higher than in cut samples (10.77 ± 2.5 mg/100 g). The grinding method permitted to

break down the glands containing the essential oil so that essential oil was extracted more.

Many researches show that the environmental factors: weather, temperature and moisture, etc. can affect the essential oil content, compounds within the plants (Acimovic et al., 2021; Acimovic et al., 2022). Besides, harvest time also affects the essential oil content in the samples. The results

in Table 1 were collected in the dry season. On the other hand, in the rainy season, the essential oil content could be up to 30 ± 2.4 mg/100 g. The essential oil highest yield was produced in the rainy season. Some studies also evaluated essential oil harvested in different seasons. *Thymus linearis* Benth. was assessed the seasonal variation in the chemical composition and biological activities of essential oils extracted. The rainy season produced more essential oils than the dry season, but the highest antioxidant capacity was recorded in oil extracted in the winter season (Kabdal et al., 2022).

3.2. Determination of antioxidants by DPPH radical scavenging activity

DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging activity is a technique used in determining antioxidant activity of chemicals or natural compounds. Together with that is ascorbic acid as a positive control due to its strong and stable antioxidant activity. We determined the antioxidant activity based on the ascorbic acid standard solution. The standard curve had the equation: $y = 1824.8x - 8.3358$, and a high coefficient of determination, $R^2 = 0.9897$.

Table 2. DPPH radical scavenging activities of bamboo leaves essential oil samples

Vitamin C		Bamboo leaves essential oil	
Concentration (mg/mL)	% of inhibition DPPH radical (IC)	Concentration (mg/mL)	% of inhibition DPPH radical (IC)
0.01	11.56	30,92	27.57
0.02	28.13	38,65	29.66
0.03	45.20	77,30	42.81
0.04	60.56	115,95	52.46
0.05	86.59	154,60	68.84
IC ₅₀ : 0.032 mg/mL		IC ₅₀ : 101.10 mg/mL	

DPPH: 2,2-diphenyl-1-picrylhydrazyl; IC₅₀: Inhibitory concentration 50%.

The antioxidant activity of the essential oil inhibition against DPPH radical (IC) was from 27.57 to 68.84%, IC₅₀ was 101.10 mg/mL (Table 2). Results showed that the antioxidant activity of bamboo leaves essential oil after 30 min of reaction was less effective than ascorbic acid. But according to Mishra et al. (2012), reaction time of the antioxidant activity of secondary compounds varies. Sesamol reaches the steady state of the reaction in under 20 min. On the other hand, curcumin needs even more than 180 min to complete the reaction. In this research we expected that α -Ionone needed more time to complete the reaction as well.

There is little research about chemical components and biological activities of bamboo leaves. According to Indira et al. (2022), ethanol

extraction method and water distillation method, both of them have antioxidant properties. But the antioxidant activity of the bamboo leaves essential oil is lower than that of the tea leaves. Deeper research of Tundis et al. (2023) shows bamboo leaves extract has cytotoxicity in HepG₂ cells. According to Hu et al. (2011), antioxidant activity using the DPPH method of bamboo leaves essential oil has no remarkable difference. Although the authors give no information about IC₅₀ value, they do show the ascending order of the antioxidant activity of 4 bamboo breeds: *Phyllostachys vivax* f. *aureocaulis* > *Pleioblastus gramineus* > *Pseudosasa amabili* > *Indocalamus latifolius*. The research also indicates that bamboo leaves essential oil has antioxidant activity. The antioxidant activity has low value so

more research about bamboo leaves' antioxidant activity of different breeds, habitats, harvest period, etc.

Recommendations for further research in monoterpenoid, especially as a standard solution; use other bamboo breeds.

3.3. Calculating total silicate compounds of the essential oil

Bamboo's hydrosol containing biological silicates was an outstanding aspect, which can eventually substitute the silicate originating from chemical processes. The chemical silicates being used in the food, cosmetic and medicine industry are safe for use in products that may be incidentally breathed in (Elmore & CIREP, 2003). But due to nowadays tendency, people are willing to use products that have organic origins. The

total silicate compounds found in our bamboo's hydrosol was 0.81 mg/L. In the near future, we are going to analyse more thoroughly about the concentration of silicate to the dry matter.

3.4. Identify the chemical components of the essential oil

The essential oil of ground bamboo leaves was analyzed using GC-MS, which revealed the presence of 8 bioactive compounds (Table 3). Results from the GC-MS process identified 8 chemicals belonging to terpenoid group (α -ionone, trans- β -ionone, hexahydrofarnesyl acetone, farnesyl acetone and phytol), fatty acid (palmatic acid), ester (hexadecanoic acid, ethyl ester; 9,12,15-octadecatrienoic acid, ethyl ester, (Z,Z,Z)-). Phytol had the highest peak size while α -ionone had the lowest peak size.

Table 3. Table of chemical components inside bamboo essential oil

Chemical components	Peak size (%)
α -ionone	1.09
trans- β -ionone	2.91
Hexahydrofarnesyl acetone	15.6
Farnesyl acetone	1.67
n-hexadecanoic acid	20.63
Hexadecanoic acid, ethyl ester	3.99
Phytol	42.96
9,12,15-octadecatrienoic acid, ethyl ester, (Z,Z,Z)-	2.82

Phytol is a diterpene of long chain unsaturated acyclic alcohols family. Phytol and some of its derivatives display numerous biological activities. Phytol is an important natural compound and potentially can be utilized in the fragrance market as well, also stands a possibility for many applications in pharmaceuticals industries along with other biotechnological sectors.

Phytol has the potential to be a novel medication candidate for treating conditions including chronic polyneuropathy, Refsum's

disease, Zellweger's disease hyperpipecolic acidemia, and Rhizomelic chondrodysplasia punctata (Taj et al., 2021). Using the GC-MS method, phytol was identified in *Bambusa vulgaris* (44%), *Merremia Vitifolia* (49%), *Polygala javana* (1.28%) (Alagammal et al., 2012; Tahya et al., 2021; Ogunmoyole, 2022). Numerous active substances, such as terpenoids, phenolics, flavonoids, tannins, glucosinolates, alkaloids, etc., are present in the plant extracts. Crude extracts or essential oil from leaves, stems,

and roots are used commonly in traditional medicine. Synergy and antagonism in natural product extracts addressed in numerous research. In traditional medicine, the total amount of phenolic, flavonoid or terpenoid is often evaluated. Gallic acid and quercetin were often used in quantitative phenolics, flavonoids. Among the chemicals found in Table 2, ionone is a monoterpenoid. Different studies have documented the specific properties and potential benefits of β -ionone in human health regarding important pharmacological activities: anti-inflammatory, cancer-preventing, antibacterial, antifungal. (Paparella et al., 2021). There has been no simple and effective method to determine the overall terpenoid content. Standards for assessing terpenoid content can be established using monoterpenoids. GC-MS results identify ionone inside the bamboo essential oil. Ionone is a monoterpenoid so that it can be used as a standard solution in the quantifying total terpenoid content process.

3.5. Quantify total terpenoid content

Terpenoid is a group of bioactive compounds that is used in pharmaceutical, cosmetic and food industries. Terpenoids are the major constituents of bamboo's essential oils. Quantifying total terpenoid content methods that are usually used are sulfuric acid procedure (Ghorai et al., 2012) and petroleum ether (Malik et al., 2017).

Monoterpenoids have been used as a standard solution, such as linalool (Ghorai et al., 2012; Łukowski et al., 2021). The principle of this reaction is still under research. We determined the total terpenoid content based on the α -ionone standard solution. The standard curve (Figure 1) had a high coefficient of determination, $R^2 = 0.9758$.

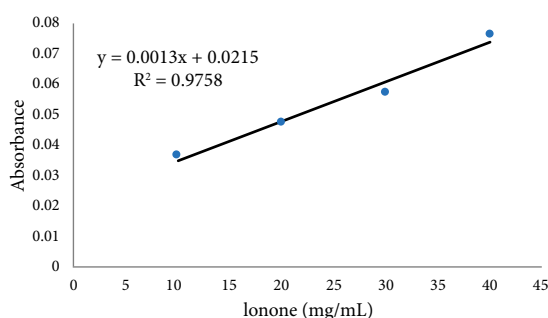


Figure 1. α -ionone standard curve.

Table 4. Proportion of essential oil and total terpenoid content in the essential oil

Samples	Density (g/mL)	Total terpenoid content (%)
Finely grinded	0.78	0.06

The total terpenoid content in bamboo leaves essential oil was 0.06%. Terpenoids have biological activities that help improve our health such as antifungal, anti-inflammatory, pain-killer, hypoglycemia, anti-virus and anti-parasite (Łukowski et al., 2022). Traditionally, crude extract is used to make medicine. It has

3 potential biological activities: antagonistic, additive and synergistic. The terpenoid determination in essential oil is a crucial step in standardization in traditional medicine. How the oscillation of the chemical component in the essential oil affects the biological activity of the medicine is still to be researched.

4. Conclusions

Our research aimed at extracting essential oils from native bamboo species. At the same time, identifying biological compounds in essential oils and preliminary assessing the determination of total terpenoid content in the samples, with vision to use α -ionone as a standard solution for the determination procedure. The result of moisture content of essential oils was 24.67% in finely grinded samples, 50.33% in cut samples. The essential oil content was 19.50 mg/100 g in finely grinded samples, and 10.77 mg/100 g in cut samples. The IC₅₀ value in the DPPH assay was 101.10 mg/mL. The essential oil yield was 0.827 mg/100 g and the IC₅₀ value in the DPPH assay was 2.705 mg/mL. Total terpenoid content in finely grinded samples was 0.06%. We identified 8 chemicals belonging to terpenoid group (α -ionone, trans- β -ionone, hexahydrofarnesyl acetone, farnesyl acetone, phytol), fatty acid (palmatic acid), ester (hexadecanoic acid, ethyl ester; 9,12,15-octadecatrienoic acid, ethyl ester, (Z,Z,Z)-).

Conflict of interest

All authors declare that they have no conflicts of interest.

Acknowledgements

We would like to express our gratitude to our primary supervisor, Assoc. Prof. Tran Thi Le Minh, who guided us throughout this project. We would also like to thank the Management of Nong Lam University for encouragement. Thanks to the fund from Nong Lam University for this research under grant No. CS-SV23-KHSH-10.

References

- Aćimović, M., Lončar, B., Jeremić, J. S., Cvetković, M., Pezo, L., Pezo, M., Todosijević, M., & Tešević, V. (2022). Weather conditions influence on lavandin essential oil and hydrolate quality. *Horticulturae* 8(4), 281. <https://doi.org/10.3390/horticulturae8040281>.
- Aćimović, M., Pezo, L., Zeremski, T., Lončar, B., Jeromela, A. M., Jeremic, S. J., Cvetković, M., Sikora, V., & Ignjatov, M. (2021). Weather conditions influence on hyssop essential oil quality. *Processes* 9(7), 1152. <https://doi.org/10.3390/pr9071152>.
- Alagammal, M., Tresina, P. S., & Mohan, V. R. (2012). GC-MS determination of bioactive components of polygala javana DC. *International Journal of Current Pharmaceutical Research* 4(2), 42-44.
- Alias, A. H. D., Razak, N. Q. A., Yusoff, M. H. M., Chin, K. H., Kamal, M. L., Uyup, N. H., Abdullah, S., Ridzuan, N. S., Saaid, M., & Shafie, M. H. (2023). Antioxidant and antimicrobial activities of essential oils extracted from bamboo (*Bambusa vulgaris*) leaves and its application in skincare products: A review. *Biocatalysis and Agricultural Biotechnology* 54(4), 102930. <https://doi.org/10.1016/j.bcab.2023.102930>.
- Baliyan, S., Mukherjee, R., Priyadarshini, A., Vibhuti, A., Gupta, A., Pandey, R. P., & Chang, C. M. (2022). Determination of antioxidants by DPPH radical scavenging activity and quantitative phytochemical analysis of *Ficus religiosa*. *Molecules* 27(4), 1326. <https://doi.org/10.3390/molecules27041326>.

- Chemat, F., & Boutekedjiret, C. (2015). Extraction // Steam distillation. *Reference Module in Chemistry, Molecular Sciences and Chemical Engineering*, 1-12. <https://doi.org/10.1016/B978-0-12-409547-2.11557-4>.
- Choi, M. H., Seo, Y. J., & Shin, H. J. (2017). Application of domestic bamboo stems mainly for inner beauty product development: A review. *KSBB Journal* 32(1), 1-8. <https://doi.org/10.7841/ksbbj.2017.32.1.1>.
- Elmore, A. R., & CIREP (Cosmetic Ingredient Review Expert Panel). (2003). Final report on the safety assessment of aluminum silicate, calcium silicate, magnesium aluminum silicate, magnesium silicate, magnesium trisilicate, sodium magnesium silicate, zirconium silicate, attapulgit, bentonite, Fuller's earth, hectorite, kaolin, lithium magnesium silicate, lithium magnesium sodium silicate, montmorillonite, pyrophyllite, and zeolite. *International Journal of Toxicology* 22 (1 Suppl.), 37-102. <https://doi.org/10.1177/1091581803022S115>.
- Ghorai, N., Chakraborty, S., Gucchait, S., Saha, S. K., & Biswas, S. (2012). Estimation of total Terpenoids concentration in plant tissues using a monoterpene, Linalool as standard reagent. *Research Square* 55, 1-5. <https://doi.org/10.1038/protex.2012.055>.
- Giese, M. W., Lewis, M. A., Giese, L., & Smith, K. M. (2015). Development and Validation of a Reliable and Robust Method for the Analysis of Cannabinoids and Terpenes in Cannabis. *Journal of AOAC International* 98(6), 1503-1522. <https://doi.org/10.5740/jaoacint.15-116>.
- Hu, C. J., Liao, H. B., Yuan, K., Hu, J. H., & Lin, X. C. (2011). Chemical composition and antioxidant activity of essential oil of bamboo leaves from four species in China. *Asian Journal of Chemistry* 23(6), 2543-2547.
- Indira, A., Santosh, O., Koul, A., & Nirmala, C. (2022). Comparative assessment of the antioxidant potential of bamboo leaves, along with some locally and commercially consumed beverages in India. *Advances in Bamboo Science* 1, 100007. <https://doi.org/10.1016/j.bamboo.2022.100007>.
- Kabdal, T., Kumar, R., Prakash, O., Nagarkoti, K., Rawat, D. S., Srivastava, R. M., Kumar, S., & Dubey, S. K. (2022). Seasonal variation in the essential oil composition and biological activities of *Thymus linearis* Benth. Collected from the Kumaun region of Uttarakhand, India. *Biochemical Systematics and Ecology* 103, 104449. <https://doi.org/10.1016/j.bse.2022.104449>.
- Kanani, H., Chrysanthopoulos, P. K., & Klapa, M. I. (2008). Standardizing gc-ms metabolomics. *Journal of Chromatography B* 871(2), 191-201. <https://doi.org/10.1016/j.jchromb.2008.04.049>.
- Łukowski, A., Jagiełło, R., Robakowski, P., Adamczyk, D., & Karolewski, P. (2022). Adaptation of a simple method to determine the total terpenoid content in needles of coniferous trees. *Plant Science* 314, 111090. <https://doi.org/10.1016/j.plantsci.2021.111090>.
- Malik, S. K. (2017). Qualitative and quantitative estimation of terpenoid contents in some important plants of Punjab, Pakistan. *Pakistan Journal of Science* 69(2), 150-154. <https://doi.org/10.57041/pjs.v69i2.364>.

- Ogunmoyole, T. (2022). Bambusa vulgaris leaf extracts contain myriad of bioactive phytochemicals: a possible attestation of its medicinal relevance. *The Journal of Phytopharmacology* 11(5), 315-323. <https://doi.org/10.31254/phyto.2022.11501>.
- Özkan, G., Sagdiç, O., Baydar, N. G., & Baydar, H. A. S. A. N. (2004). Note: Antioxidant and antibacterial activities of Rosa damascena flower extracts. *Food Science and Technology International* 10(4), 277-281. <https://doi.org/10.1177/1082013204045882>.
- Paparella, A., Shaltiel-Harpaza, L., & Ibdah, M. (2021). β -Ionone: Its occurrence and biological function and metabolic engineering. *Plants* 10(4), 754. <https://doi.org/10.3390/plants10040754>.
- Pimentel, F. A., Cardoso, M. D. G., Salgado, A. P. S., Aguiar, P. M., Silva, V. D. F., Morais, A. R. D., & Nelson, D. L. (2006). A convenient method for the determination of moisture in aromatic plants. *Química Nova* 29, 373-375. <https://doi.org/10.1590/S0100-40422006000200031>.
- Ríos, J. L. (2016). Essential oils: What they are and how the terms are used and defined. In Victor, R. P. (Ed.). *Essential oils in food preservation, flavor and safety* (3-10). London, UK: Academic Press. <https://doi.org/10.1016/B978-0-12-416641-7.00001-8>.
- Singhal, P., Bal, L. M., Satya, S., Sudhakar, P., & Naik, S. N. (2013). Bamboo shoots: A novel source of nutrition and medicine. *Critical Reviews in Food Science and Nutrition* 53(5), 517-534.
- Tahya, C. Y., & Karnelasatri, K. (2021). Gas chromatography-mass spectrometry analysis and α -glucosidase inhibitory activity of n-hexane extract of Bilajang Bulu (*Merremia Vitifolia*) leaves. *Walisongo Journal of Chemistry* 4(2), 162-172.
- Taj, T., Sultana, R., Shahin, H., Chakraborty, M., & Ahmed, M. G. (2021). Phytol a phytoconstituent, its chemistry and pharmacological actions. *Gis Science Journal* 8(1), 395-406.
- Te, B. Y. (2018). *Vietnam Pharmacopoeia* V. Ha Noi: Medical Publishing House. Retrieved April 1, 20124, from <https://dokumen.pub/vietnamese-pharmacopoeia-v-duoc-dien-viet-nam-v-english-version-5nbsped.html>.
- Tundis, R., Augimeri, G., Vivacqua, A., Romeo, R., Sicari, V., Bonofiglio, D., & Loizzo, M. R. (2023). Anti-inflammatory and antioxidant effects of leaves and sheath from bamboo (*Phyllostacys edulis* J. Houz). *Antioxidants* 12(6), 1239. <https://doi.org/10.3390/antiox12061239>.
- Yang, Y. F., Zhao, L. L., Shao, Y. X., Liao, X. D., Zhang, L. Y., Lin, L. U., & Luo, X. G. (2019). Effects of dietary graded levels of cinnamon essential oil and its combination with bamboo leaf flavonoid on immune function, antioxidative ability and intestinal microbiota of broilers. *Journal of Integrative Agriculture* 18(9), 2123-213. [https://doi.org/10.1016/S2095-3119\(19\)62566-9](https://doi.org/10.1016/S2095-3119(19)62566-9).
- Yuejun, H., Yue, Y., Tang, F., Guo, X., & Wang, J. (2010). Chemical compositions and antioxidant capacity of essential oils from different species of the bamboo leaves. *Scientia Silvae Sinicae* 46(7), 120-128.