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Assessment of Variability of Essential Oil Components in the Genus *Lindera* (Lauraceae) by Multivariate Analysis

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Essential oils hold tremendous medicinal attributes and are greatly exploited industrially worldwide. *Lindera* is an important genus of the Lauraceae family of plants which are known for their medicinal values. In the present study, eleven studies reported on *Lindera* essential oils were selected and reviewed. Then the variability of essential oil components in the genus *Lindera* were assessed by multivariate analysis. The chemical analysis enabled the identification of qualitative and quantitative differences among the essential oils. The essential oils were characterized by high proportions of germacrene B, spathulenol, nerolidol, β-caryophyllene, dihydromyrcene, furanosesquiterpenoid, sesquithuriferol, and linalool. Then, the differences in the chemical profiles of the essential oil were confirmed by the multivariate statistical analysis, which was determined *via* principal component analysis (PCA) and hierarchical clustering analysis (HCA). The analysis classified the *Lindera* species into four different clusters. Group A of cluster analysis (*L. obtusiloba*) was highly correlated with α-copaene and β-eudesmol and group B of cluster analysis (*L. strychnifolia, L. umbellata* and *L. pulcherrima*) were highly correlated with linalool and 1,8-cineole. Moreover, group C of cluster analysis (*L. erythrocarpa, L. pipericarpa, L. nacusua* and *L. glauca*) were highly correlated with spathulenol, α-humulene and β-phellandrene, whereas for group D (*L. chunii, L. communis* and *L. fragrans*) were highly correlated with β-farnesene and β-caryophyllene. This data analysis may be used for the identification and characterization of essential oils from different *Lindera* species that are to be used as raw materials of traditional herbal products. However, there is much variation in the essential oil compositions of *Lindera* essential oils, both within subspecies and between geographical locations; much additional investigation is necessary to more fully characterize the volatile phytochemistry of this plant.

Keywords: Lauraceae; *Lindera*; essential oil; multivariate; PCA; HCA

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Lauraceae, one of the most primitive families of plants, belongs to the Magnoliidae subclass, is a family of pantropical plants that includes trees and shrubs. It is composed of approximately 55 subgenera totalling over 3,000 species. The family is highly diversified in South-east Asia, Madagascar, Northern South America, and the east coast of Brazil [1]. The genus *Cinnamomum*, *Litsea*, *Lindera*, *Neolindera*, and *Parabenzoin* are the example of well-known subgenera in Lauraceae family [2].

Lindera is a genus of about 100 species of flowering plants. It can be found all over the world in tropical, subtropical climates, and temperate zones of Asia and Midwestern America [3]. Generally, the leaves are plain, stipule-free, opposite, spiral, whorled, and alternate. The flowers are differently accrescent and are bisexual, actinomorphic, tiny, regular, greenish-white, or yellow in colour, aromatic, and trimerous. Most of the flowers have six sepals that are arranged in two cycles. The fruits, which are baccate or drupaceous and frequently seated or surrounded by a persistent and cup-shaped corolla, have taxonomic significance [4]. Table 1 shows the medicinal uses of several *Lindera* species [4-18].

Essential oils as secondary metabolites involve complex mixtures of natural compounds with versatile organic structures, metabolites such as terpenes, phenols, and ketones represented with useful medicinal properties [19]. Essential oils have been utilised for thousands of years for their therapeutic and medicinal effects. In addition, essential oils are important natural sources and are used as raw materials for the production of fragrance compounds in cosmetics, as flavouring additives for food and beverages, as scenting agents in a variety of household products, and as intermediates

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in the synthesis of other perfume chemicals [20]. Meanwhile, essential oils from aromatic and medicinal plants have been known since antiquity to possess biological activities, most notably antibacterial, anti-inflammatory, antifungal, and antioxidant properties [21-23].

Some of the common medicinal uses of essential oils include in relieving pain in inflammation, boosting mood, fighting infections and boosting the immune system and promoting relaxation [24]. For example, the extracted eucalyptus oil from leaves was used to treat respiratory issues like cough and colds as this essential oil are rich in eucalyptol, 1,8-cineole, limonene, citronellal, and citral [25]. Besides, garlic essential oil contains a variety of organosulfur compounds, such as the most representative diallyl disulfides and diallyl trisulfides, which have attracted great interest in medicine, food, and agriculture [26]. Lavender essential oil has a sweet floral aroma and contains a high percentage of esters, mostly linalyl acetate. The oil is often used for its anti-inflammatory, calming, headache, relieving, sedative, and skin healing properties [27]. Peppermint essential oils are commonly used as a fragrance in soaps, cosmetics, and as spices since it possesses a fresh, minty and cooling effect due to menthol. Other chemical compounds are 1,8-cineole, methyl acetate, methofuran, isomenthone, limonene, β-pinene, α-pinene, germacrene, *trans*-sabinene hydrate and pulegone [28]. For medical use, peppermint oil can be taken orally as a dietary supplement for gastrointestinal complications [29]. Due to their numerous possible uses and advantages, *Lindera* essential oils are widely accessible in commerce and have gained popularity recently. This has shown that further investigation of this species is required in order to discover more about the information that affect the chemical components and composition of each species.

Table 1. Traditional uses of several *Lindera* species.

Species	Traditional uses
L. aggregata	Remedy for rheumatic, cardiac, and renal illnesses [4]
	Treat conditions affecting the digestive system, metabolism, inflammation, and urinary system [5]
L. akoensis	Used to treat stomach pain, fever, respiratory infections, headaches, migraines, and reducing inflammation or swelling [6]
L. angustifolia	Relieve the swelling caused by contusions, rheumatic pain, and stomachaches [7]
	Used to treat carminative diuretics and pain relievers especially in nervous headache and migraine [8]
L. erythrocarpa	Used to treat multiple cardioprotective and cancerous disorders [9]
	Treating digestive disorders, thirst, pain, and neuralgia [10]
	Used to treat diabetic properties and breast cancer [4]
L. fragrans	Acts as an effective barrier that prohibits mosquitoes, rheumatic numbness, and low back pain [11]
	Remedy for bad breath [12]
	Treat depressive-like behaviours that prolonged mild stress caused [13]
L. pulcherrima	Used as spice for the remedy of cold, fever, and cough [14]
L. radix	Used in pelvic inflammatory disease [15]
L. glauca	Treat several kinds of stomach and heart discomfort problems, rheumatoid arthritis, extravasation, and contusion [16]
L. neesiana	To treat indigestion, gastric disorders, constipation, and intestinal issues [17]
L. obtusiloba	Treatment for type II diabetes by lowering blood glucose levels as well as improved blood circulation, inflammation, fever, and abdominal pain [4]
L. umbellata	To treat neuralgia, stiff neck, and back pain [18]

A statistical method named multivariate analysis is used to analyze complex data sets that contain several variables or factors at once. Multivariate analysis has been widely employed in this sector to study the interactions between various chemical components because of the complexity and diversity of natural products [30]. Even though classical statistical analyses of massive amounts of heterogeneous data can yield valuable insights for the study of any particular variable, neither they nor the ability to group samples with uniform properties allow for a comprehensive understanding of the relationships between various variables. Multivariate statistical methods, such as hierarchical cluster analysis (HCA) and principal component analysis (PCA), which allow for the clustering of objects, identification of variability, and presentation of results in figures [31].

Principle component analyses (PCA) is well-known method where the multivariate exploratory data analyses tool that is used to determine the similarities and differences among samples, identify groups of samples and study correlations among the variables [32]. Besides, PCA are calculated to explore the relationship between the samples from various regions and their relation to a specific volatile compound, the GC-MS data was subjected to PCA. The PCAs can be plotted by visual inspection of the data to point out the hidden pattern in the dataset. PCA was used to reveal the interrelationships among the total species of the genus based on the essential oil that have common constituents of these species [33].

Hierarchical Cluster Analysis (HCA) is a method of statistical analysis used to identify relationships between variables. It involves grouping variables together based on their similarity, and then grouping those groups together based on their similarity [34]. The output of HCA is a dendrogram, which shows how the variables are grouped together. This can be useful in identifying patterns and relationships in large datasets. This method is now gaining acceptance as one of the approaches for quality control of herbal materials [35].

By doing a cluster analysis, it was possible to determine the variation of chemical components in each *Lindera* essential oil. It is an effective way to provide some evidence showing the relationship between the species in various regions and their chemical composition. The relationship between *Lindera* species and the chemical components of those oils were reported in this study by using PCA and HCA. Besides, the revealed patterns and interpretative schemes aid researchers in developing ideas about the possible activities of the phytocomplex's cluster of chemicals, as PCA and HCA are recognized as tools for quality control of herbal medicines [36].

EXPERIMENTAL

The selection of the article was conducted through searches using Scopus, PubMed, Scielo, Science-Direct, and Google Scholar. The keywords used were '*Lindera'* and 'essential oil'. Articles covering the period from the beginning of the database until June 2023 were all viewed. The protocol for performing the current study was developed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement (PRISMA) [37]. First, duplicate articles were excluded, titles and abstracts were then read, and the inclusion and exclusion criteria were applied. In this study, *Lindera* species reporting on the essential oils composition from the leaf part were selected. Lastly, all articles resulting from the previous stages were fully read, and the inclusion and exclusion criteria were applied again. At the end of the final step, the articles that fulfilled all criteria were selected for this study. Additionally, a manual search of the reference lists of the included studies were conducted. The inclusion criteria for the current study were original research articles in English. The exclusion criteria were articles without search terms in their title and abstract, review articles, articles without its full-text available, articles with- out one of the keywords, and articles without the composition of the essential oils. Overall, eleven *Lindera* species reporting on the essential oils composition from the leaf part were selected for multivariate statistical analysis. The details are presented in Table 2.

Statistical Software for Excel (XLSTAT) 2022's Pearson correlations were used for the analysis. The correlation matrix are shown graphically as a result of the PCA, which was completed first. Then, the process continued with HCA analysis, which aims to cluster the subjects with comparable characteristics. In this study, agglomerative hierarchical clusters (HCA) with unweight and pair-group average methods were used to do cluster analysis on *Lindera* species. As a result, *Lindera* species with comparable chemical components were clustered together into a cluster, which produced valuable indications for the prediction of chemical and bioactivity equivalent to the species [47].

Table 2. Previous studies on *Lindera* essential oils.

No.	Species [Lable]	Locality	Year	Components (No. %)	Yield (%)	References
1.	*L. chunii* [L. Chu]	China	2013	34 (96.2)	0.5	[38]
2.	*L. communis* [L. Com]	China	1999	23 (NM)	NM	[39]
3.	*L. erythrocarpa* [L. Ery]	Korea	2017	15 (63.7)	0.2	[10]
4.	*L. fragrans* [L. Fra]	China	2021	62 (76.4)	0.9	[11]
5.	*L. glauca* [L. Gla]	Vietnam	2022	34 (90.0)	0.2	[40]
6.	*L. nacusua* [L. Nac]	China	2016	22 (64.4)	0.1	[41]
7.	*L. obtusiloba* [L. Obt]	Korea	2011	27 (67.8)	4.3	[42]
8.	*L. pulcherrima* [L. Pul]	India	2009	35 (97.5)	1.2	[43]
9.	*L. pipericarpa* [L. Pip]	Malaysia	1993	22 (98.3)	1.0	[44]
10.	*L. strychnifolia* [L. Str]	China	2009	51 (94.5)	0.4	[45]
11.	*L. umbellata* [L. Umb]	Japan	2020	58 (91.4)	NM	[46]

NM: not mentioned

Table 3. Major components identified in *Lindera* essential oils.

No	Components	Percentage (%)										
		L. Chu	*L. Com*	*L. Ery*	*L. Fra*	*L. Gla*	*L. Nac*	*L. Obt*	*L. Pip*	*L. Pul*	*L. Str*	*L. Umb*
	Monoterpene Hydrocarbons											
1	α-Pinene	-	-	4.5	-	-	-	-	-	-	-	-
2	β-Phellandrene	-	-	-	-	19.0	-	-	-	-	-	-
3	Myrcene	-	-	-	-	17.9	-	-	-	-	-	-
4	(*E*)-β-ocimene	-	-	-	-	9.1	-	-	-	-	-	-
5	Limonene	-	-	-	-	-	-	-	5.5	-	-	-
6	Dihydromyrcene	-	-	-	-	-	-	-	11.1	-	-	-
7	β-Myrcene	-	-	-	-	-	-	-	-	-	-	7.6
	Oxygenated Monoterpenes											
8	Methyl cinnamate	-	-	8.5	-	-	-	-	-	-	-	-
9	1,8-Cineole	-	-	-	-	-	-	-	-	-	5.3	13.7
10	Linalool	-	-	-	-	-	-	-	-	-	-	42.8
	Sesquiterpenes Hydrocarbons											
11	Germacrene B	6.2	-	-	-	-	-	7.5	-	-	-	-
12	γ-Muurolene	4.4	-	-	-	-	-	-	-	-	-	-
13	β-Caryophyllene	-	6.7	14.4	4.0	29.2	8.7	32.1	32.1	5.4	-	-
14	α-Humulene	-	-	8.4	-	18.0	-	-	-	-	-	-
15	Germacrene D	-	-	4.8	-	-	-	-	-	26.0	-	-
16	Aromadendrene	-	-	-	-	17.1	-	-	-	-	-	-
17	γ-Cadinene	-	-	-	-	10.1	-	-	-	-	-	-
18	(*E*)-β-caryophyllene	-	-	-	-	14.6	-	-	-	-	-	-
19	β-Selinene	-	-	-	-	-	5.0	-	-	-	4.6	-
20	δ-Cadinene	-	-	-	-	-	-	-	-	-	-	-
21	α-Copaene	-	-	-	-	-	-	31.4	31.4	-	-	-
	Oxygenated Sesquiterpenes											
22	Globulol	11.6	-	-	-	-	-	-	-	-	-	-
23	Ledol	10.2	-	-	6.8	-	-	-	-	-	-	-
24	Spathulenol	-	22.5	-	27.6	4.6	-	-	-	-	-	-
25	Nerolidol	-	-	26.9	-	-	-	6.8	6.1	-	-	-
26	Humulene epoxide II	-	-	-	-	5.3	-	-	-	-	-	-
27	β-Eudesmol	-	-	-	-	-	-	-	-	5.0	-	7.6
28	Hedycaryol	-	-	-	-	-	-	-	-	-	-	-
29	α-Eudesmol	-	-	-	-	-	-	-	4.3	-	-	-
30	Furanodienone	-	-	-	-	-	-	-	-	49.1	-	-
31	Curzerenone	-	-	-	-	-	-	-	-	17.6	-	-
32	Furanosesquiterpenoid	-	-	-	-	-	-	-	-	79.3	-	-
33	Sesquithuriferol	-	-	-	-	-	-	-	-	-	35.9	-
34	14-oxy-α-Muurolene	-	-	-	-	-	-	-	-	-	16.5	-
	Others											
35	Neophytadiene	-	-	-	-	-	4.5	-	-	-	-	-
36	*endo*-1,3,3-Trimethyl-2-norbornanol	-	10.0	-	-	-	-	-	-	-	-	-
37	Geranyl acetate	-	-	7.8	-	-	-	-	-	-	-	-
38	Hexahydrofarnesyl acetone	-	-	-	-	-	6.8	-	-	-	-	-
39	Palmitic acid	-	-	-	-	-	4.4	-	-	-	-	-
40	Bornyl acetate	-	-	-	-	-	-	-	-	-	-	-
	Percentage	**32.4**	**39.2**	**75.3**	**38.4**	**144.9**	**29.4**	**77.8**	**90.5**	**182.4**	**62.3**	**71.7**

L. Chu – L. chunii, L. Com – L. communis, L. Ery – L. erythrocarpa, L. Fra – L. fragrans, L. Gla – L. glauca, L. Nac – L. nacusua, L. Obt – L. obtusiloba, L. Pip – L. pipericarpa, L. Pul – L. pulcherrima, L. Str – L. strychnifolia, L. Umb – L. umbellata

RESULTS AND DISCUSSION

In this study, eleven *Lindera* species from earlier research was analysed. The findings showed that most of *Lindera* species were reported mainly from China (5 studies), followed by Korea (2 studies), whereas Vietnam, Japan, India, and Malaysia each were reported in one study. The percentage yields of the essential oils ranged from 0.1 to 4.3%. The essential oil of *L. glauca* gave β-caryophyllene (29.25), α-humulene (18.0%), and aromadendrene (17.1%) as the major components [40]. In addition, *L. pipericarpa* and *L. pulcherrima* showed the highest percentage with 98.3% and 97.5%, respectively [43]. The major components identified in the essential oils are listed in Table 3. The essential oil of *L. pipericarpa* constituted about 60% of sesquiterpene hydrocarbons and identified dominantly with β-caryophyllene (32.1%) and α-copaene (31.4%) [44]. Besides, the essential oil of *L. pulcherrima* were made up predominantly of oxygenated sesquiterpenes, constituted of furanosesquiterpenoid and furanodienone with 79.3% and 49.1% of the total oil, respectively. Meanwhile, sesquithuriferol (35.9%) and 14-oxy-α-muurolene (16.5%) are shown as high concentration in *L. strychnifolia* essential oil [45]. Furthermore, other components which are *endo*-1,3,3-trimethyl-2-norbornanol and geranyl acetate, are also present as major components in *L. communis* and *L. erythrocarpa* oils, respectively [48]. Generally, the chemical variations discovered between the *Lindera* species might have possibly relied on the environment in which the plant existed and was collected in addition to seasonal variations at the time. These factors influence the plant's biosynthetic pathways and consequently, the relative proportion of the main characteristic components [49].

To evaluate whether the identified essential oils components could be useful in reflecting the taxonomic relationship among the different species and the components of all essential oil, PCA and HCA were used [50]. These statistical analyses have been used for the calculations to point out some considerations regarding their similarities between each of the *Lindera* species. Figure 1 shows the HCA analyses were separated into 4 clusters; Clusters I, II, III, and IV. In Cluster I there is only *L. obtusiloba* that include, while the results of PCA biplot analysis revealed that Cluster I could be distinguished by the presence of seven components, which are bornyl acetate, β-eudesmol, α-eudesmol, α-copaene, dihydromyrcene, hedycaryol and 2,2-bis(prop-2-enoxy-methyl)-butan-1-ol. Besides, *L. strychnifolia*, *L. umbellata*, and *L. pulcherrima* were in Cluster II that were characterised by the occurrence of eighteen components, which are germacrene B, globulol, γ-muurolene, hexahydro-farnesyl acetone, β-selinene, neophytadiene, palmitic acid, δ-cadinene, limonene, furanodienone, curzerenone, furanosesquiterpenoid, furanodiene, sesquithuriferol, 14-oxy-α-muurolene, 1,8-cineole, linalool and β-myrcene. Meanwhile, Clusters III have shown the highest number of *Lindera* species which are *L. erythrocarpa*, *L. pipericarpa*, *L. nacusua*, and *L. glauca*. The results of PCA biplot analysis revealed that Cluster III could be distinguished by the presence of seven components, which are germacrene D, α-humulene, (*E*)-β-ocimene, (*E*)-β-caryophyllene, humulene epoxide II, β-phellandrene, aromadendrene, γ-cadinene, myrcene, ledol, geranyl acetate and methyl cinnamate. In Cluster IV, it consists of *L. chunii*, *L. communis*, and *L. fragrans*. Based on PCA analyses results, the occurrence components were β-caryophyllene, *endo*-1,3,3-trimethyl-2-norbornanol, nerolidol, α-pinene, β-farnesene, and spathulenol.

The PCA results are shown in Figure 2. Five factors of accumulated variation (23.36-75.59%) of the data have been generated with a corresponding eigenvalue and percentage of variance (Table 3). The five principle components were considered to have the most important as it represents 23.36 of the accumulated variation with an eigenvalue of 10.05. Eigenvalue number was used to choose the number of principal components needed to be retained [51]. The components that contribute significantly to factor 1 are hedycaryol, bornyl acetate, α-copaene, β-farnesene, dihydromyrcene, α-eudesmol, and 2,2-bis(prop-2-enoxy-methyl)butan-1-ol with a eigenvalue and significance level of 10.05% and 23.36% respectively. β-phellandrene, myrcene, aromadendrene, γ-cadinene, (*E*)-β-ocimene, (*E*)-β-caryophyllene and humulene epoxide II were contributed to the factor 2, which explained 18.43% of the variance with an eigenvalue of 7.93. The third and fifth principal components explained 13.99% and 9.48% of the variance, respectively, while for the fourth principal component there were no related components significantly.

To evaluate the accuracy of this classification, the cluster obtained was further confirmed by PCA (Figure 2). Similarly, the species of *Lindera* were divided into 4 defined groups: Group I consisted of *L. obtusiloba* (L. Obt). Group II consisted of *L. strychnifolia* (L. Str), *L. umbellata* (L. Umb), and *L. pulcherrima* (L. Pul). Group III consisted of *L. erythrocarpa* (L. Ery), *L. pipericarpa* (L. Pip), *L. nacusua* (L. Nac) and *L. glauca* (L. Gla). Group IV consisted of *L. chunii* (L. Chu), *L. communis* (L. Com), and *L. fragrans* (L. Fra).

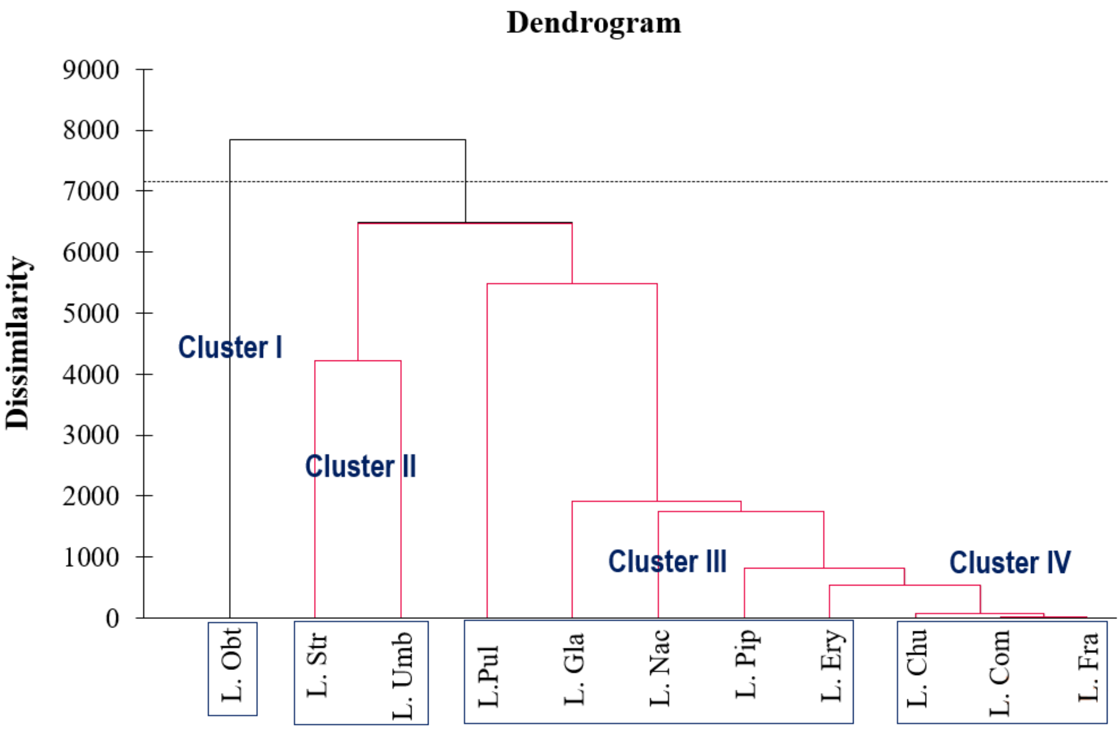

Figure 1. HCA analyses of *Lindera* essential oils.

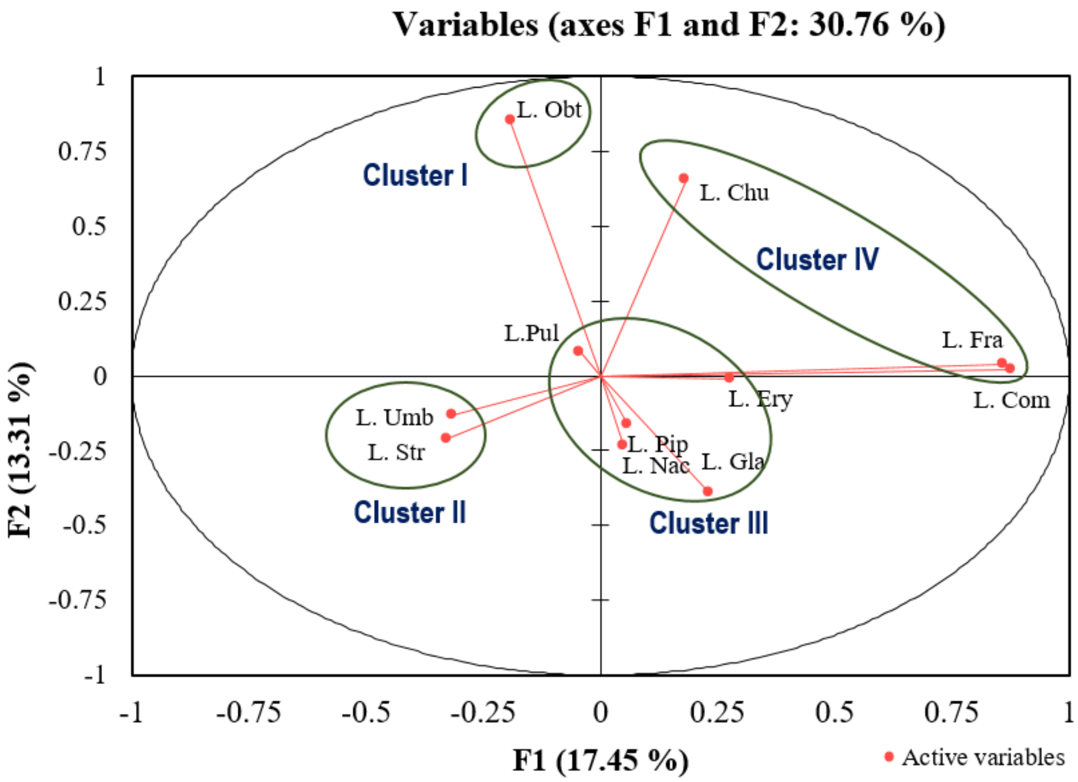

Figure 2. PCA analyses of *Lindera* essential oils.

Table 4. Eigenvalues and cumulative variance of factors obtained from principal component analysis (PCA) based on the chemical composition of essential oils of *Lindera* species.

Composition	Factors				
	1	**2**	**3**	**4**	**5**
Germacrene B	0.64	0.19	-0.16	-0.18	0.56
Globulol	-0.02	-0.17	-0.11	-0.33	0.71**
Ledol	-0.09	-0.17	-0.07	-0.38	0.70**
γ-Muurolene	-0.02	-0.17	-0.11	-0.33	0.71**
Spathulenol	-0.48	0.44	-0.07	-0.09	0.21
endo-1,3,3-Trimethyl-2-norbornanol	-0.10	-0.05	0.03	-0.15	0.09
β-Caryophyllene	0.05	0.49	0.57	-0.25	-0.26
Nerolidol	0.60	0.29	0.16	-0.33	-0.39
α-Humulene	-0.40	0.63	0.13	-0.17	-0.43
Germacrene D	-0.01	-0.08	0.83**	0.09	-0.35
α-Pinene	0.66	0.35	0.16	-0.26	-0.43
Methyl cinnamate	0.01	0.05	0.32	-0.43	-0.60
Geranyl acetate	0.01	0.05	0.32	-0.43	-0.60
β-Phellandrene	-0.54	0.79**	-0.14	0.20	0.02
Myrcene	-0.54	0.79**	-0.14	0.20	0.02
Aromadendrene	-0.54	0.79**	-0.14	0.20	0.02
γ-Cadinene	-0.54	0.79**	-0.14	0.20	0.02
(*E*)-β-ocimene	-0.54	0.79**	-0.14	0.20	0.02
(*E*)-β-Caryophyllene	-0.54	0.79**	-0.14	0.20	0.02
Humulene epoxide II	-0.54	0.79**	-0.14	0.20	0.02
Hexahydrofarnesyl acetone	-0.10	-0.22	-0.05	-0.30	-0.26
β-Selinene	-0.10	-0.42	-0.41	0.14	-0.41
Neophytadiene	-0.10	-0.22	-0.05	-0.30	-0.26
Palmitic acid	-0.10	-0.22	-0.05	-0.3	-0.27
δ-Cadinene	0.63	0.05	-0.45	0.41	-0.19
Limonene	0.645	0.14	-0.30	0.24	0.02
β-Eudesmol	0.65	0.2	0.51	0.47	0.13
Hedycaryol	0.88**	0.42	-0.12	0.08	0.03
Bornyl acetate	0.88**	0.42	-0.12	0.08	0.03
α-Copaene	0.69**	0.30	-0.05	-0.06	-0.03
β-Farnesene	0.88**	0.42	-0.12	0.08	0.03
Dihydromyrcene	0.88**	0.42	-0.12	0.08	0.03
α-Eudesmol	0.88**	0.42	-0.12	0.08	0.03
2,2-Bis(prop-2-enoxy-methyl)butan-1-ol	0.88**	0.42	-0.12	0.08	0.03
Furanodienone	-0.01	-0.16	0.79**	0.55	0.14
Curzerenone	-0.01	-0.16	0.79**	0.55	0.14
Furanosesquiterpenoid	-0.01	-0.16	0.79**	0.55	0.14
Furanodiene	-0.01	-0.16	0.79**	0.55	0.14
Sesquithuriferol	-0.03	-0.34	-0.49	0.48	-0.29
14-oxy-α-Muurolene	-0.03	-0.34	-0.49	0.48	-0.29
1,8-Cineole	-0.04	-0.44	-0.58	0.54	-0.23
Linalool	-0.02	-0.24	-0.29	0.24	-0.01
β-Myrcene	-0.04	-0.44	-0.58	0.54	-0.23
Eigenvalue	**10.05**	**7.93**	**6.02**	**4.44**	**4.08**
% of variance	**23.36**	**18.43**	**13.99**	**10.31**	**9.48**
Cumulative (%)	**23.36**	**41.80**	**55.80**	**66.10**	**75.59**

Note: **significant ≥70

The scatter plot showed the phytochemical distance among the samples in the plot that reflects their relationships. These strict correlations were also evidenced in biplots, where these species resulted very closed or overlapped, especially for *L. communis* (L. Com), *L. fragrans* (L. Fra) and *L. erythrocarpa* (L. Ery) because of the positive loadings in Group IV and the smallest negative value in group III, that due to the highest content of spathulenol (27.6-22.5%). Besides, the PCA revealed a weaker interrelationship in the composition of essential oils in Groups I and III. This might be a result of the high production in *L. obtusiloba* (L. Obt) which is α-copaene (31.4%) and dihydromyrcene (11.1%) while, in *L. glauca* (L. Gla) is β-phellandrene and aromadendrene with the percentage 19.0% and 17.1% respectively. These findings might be related to other elements that influence the genetic composition and places of origin of *Lindera* plants, which range from subtropical climates to temperate zones [16]. As a result, the pattern of variation in essential oil content may be a reflection of pressure in different ecological and geographic contexts (ecotypes). Although there is a notable variation in oil composition that needs to be minimized with further genetic research, the significant correlation between the multivariate analysis and essential oil constituents allows the identification of chemical similarities among *Lindera* species to evaluate their potential use as industrial products.

CONCLUSION

In conclusion, the data of this study indicates that there were significant differences in the chemical components of *Lindera* essential oils, which were collected from different regions. Besides, multivariate statistical analyses seem to be very useful to investigate and establish the natural correlation within complex taxonomic groups. The most useful technique seems to be is HCA and PCA because of its graphical presentation that permits a much more clear indication of the proximity between the different species. The PCA and HCA results analyses revealed that the selected oils were classified into four different clusters based on their similarities. However, additional research may be needed to identify the factors including genetics, environment, development stages, and biotic interactions that affect the production of secondary metabolites in plants. These data may be useful information when choosing species with economic potential for the pharmaceutical industry.

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