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Original Article

Physicochemical Characterization of the Essential Oil of Guaviduca (*Piper carpunya* Ruiz & Pav)

Caracterización fisicoquímica del aceite esencial de Guaviduca (*Piper Carpunya* Ruiz & Pav)

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ABSTRACT
Piper carpunya, commonly known as guaviduca, is a perennial aromatic shrub that forms part of the botanical and cultural heritage of tropical regions in South America, where it has been widely used in traditional medicine. This study aimed to conduct a comprehensive physicochemical characterization of the essential oil extracted from this species. The research was carried out at the Chemistry and Bromatology Laboratories of the Amazonian State University, using fresh leaves collected from subtropical regions of Ecuador. The essential oil was obtained through steam distillation, and its chemical composition was determined by gas chromatography (GC), revealing a complex mixture of monoterpenes and oxygenated derivatives. Among these, 1,8-cineole (12.5 %) and cis-sabinene hydrate acetate (14.1 %) were the most prominent, both known for their antimicrobial, anti-inflammatory, and antioxidant properties. The oil's balanced chemical profile and high oxidative stability make it suitable for therapeutic, cosmetic, and pharmaceutical applications. The results confirm its potential as a functional ingredient in various industries.
Keywords: Oxidative stability, Steam distillation, Volatile metabolites.

RESUMEN
Piper carpunya, conocida comúnmente como guaviduca, es un arbusto aromático perenne que forma parte del patrimonio botánico y cultural de las regiones tropicales de América del Sur, donde ha sido ampliamente utilizada en la medicina ancestral. El presente estudio tuvo como objetivo realizar una caracterización fisicoquímica integral del aceite esencial extraído de esta especie. La investigación se llevó a cabo en los laboratorios de Química y Bromatología de la Universidad Estatal Amazónica, utilizando hojas frescas recolectadas en zonas subtropicales del Ecuador. El aceite fue obtenido mediante destilación por arrastre de vapor y su composición química fue determinada mediante cromatografía de gases (GC), identificándose una mezcla compleja de monoterpenos y derivados oxigenados, entre los que destacaron el 1,8-cineol (12.5 %) y el acetato de sabineno hidratado cis (14.1 %), ambos con propiedades antimicrobianas, antiinflamatorias y antioxidantes. El perfil químico equilibrado y la alta estabilidad oxidativa del aceite lo hacen adecuado para aplicaciones terapéuticas, cosméticas y farmacéuticas. Los resultados obtenidos confirman su potencial como ingrediente funcional en diversas industrias.
Palabras clave: Estabilidad oxidativa, Destilación por arrastre de vapor, Metabolitos volátiles.

INTRODUCTION
Piper carpunya, commonly known as Guaviduca, is a perennial aromatic shrub that forms part of the botanical and cultural heritage of tropical regions in South America, particularly in Ecuador and Peru. Its presence is notable in ecosystems ranging from the lowland Amazon to humid mountainous areas, demonstrating remarkable ecological adaptability (Rollo *et al*., 2016). Traditionally, this species has been used by indigenous communities in ancestral medicine due to its well documented therapeutic properties, including anti-inflammatory, digestive, and antiparasitic effects (Barzallo Cordero, 2020).

From a taxonomic standpoint, *Piper carpunya* belongs to the kingdom Plantae, division Magnoliophyta (angiosperms), class Magnoliopsida (dicotyledons), order Piperales, and family Piperaceae. This family is known for its rich diversity and the biosynthesis of secondary metabolites with significant bioactive potential, such as alkaloids, flavonoids, and essential oils (Machahuay, 2024). Within this group, the genus Piper is one of the most extensively studied, with numerous species of ethnobotanical, pharmacological, and agro-industrial relevance.

In recent years, the scientific interest in *P. carpunya* has grown due to its promising phytochemical profile and potential applications in the pharmaceutical, cosmetic, and food industries (Enríquez, 2022). Its essential oil, in particular, has been shown to contain a complex mixture of volatile compounds with antioxidant and antimicrobial properties, reinforcing its value as a natural resource for the development of functional and therapeutic products (Enríquez, 2021). These bioactivities are largely attributed to the presence of monoterpenes and sesquiterpenes, which are known for their pharmacological versatility and low toxicity (Silva *et al*., 2021).

The essential oil of *P. carpunya* is composed primarily of volatile, hydrophobic compounds that are soluble in organic solvents such as alcohols and ethers (Ballesteros *et al*., 2019). Among the various extraction techniques available, steam distillation is widely used due to its efficiency and ability to

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preserve thermolabile constituents (Cedeño *et al*., 2019). In Ecuador, essential oils derived from native plants have gained commercial importance, particularly in the formulation of cosmetic, therapeutic, and personal care products (Muñoz *et al*., 2015). This trend reflects a broader global shift toward natural and sustainable ingredients in health and wellness industries.

Physicochemical characterization of essential oils is a critical step in ensuring their quality, authenticity, and stability. Parameters such as peroxide value, iodine index, and saponification index provide valuable information on the oxidative stability, degree of unsaturation, and lipid composition of the oil, respectively (Chuqui and Alonso, 2019). These metrics are essential for determining the shelf life and functional performance of essential oils in various industrial applications (Enriquez *et al*., 2023). Moreover, such analyses contribute to the standardization and regulatory compliance of botanical extracts, which is essential for their commercialization and integration into evidence-based product development.

Given the growing demand for natural bioactive compounds, the ecological importance of Amazonian biodiversity, and the limited scientific literature on *P. carpunya*, this study aimed to provide a detailed physicochemical characterization of its essential oil. The findings are expected to contribute to the understanding of its chemical profile, support its potential use in pharmaceutical and cosmetic formulations, and promote the sustainable valorization of native plant species from the Ecuadorian Amazon.

The growing interest in this species is driving research aimed at expanding knowledge of its properties and exploring new applications in sectors such as the pharmaceutical, food, cosmetic, textile, and agricultural industries (Muilu *et al*., 2024). The use of essential oils derived from native plants remains a common practice in Ecuadorian traditional medicine, supported by the country's rich botanical diversity (Armijos *et al*., 2021). In this context, Guaviduca stands out as a species of interest due to its bioactive properties, which have been previously analyzed in various studies. Based on this background, the objective of this study was to perform a physicochemical characterization of the essential oil of Guaviduca (*Piper carpunya* Ruiz & Pav.).

MATERIAL AND METHODS

Location

The study was conducted at the Chemistry and Bromatology Laboratories of the Amazonian State University, located in the province of Pastaza, at Km 2½ on the Puyo-Tena road.

Methodological Design

The research was structured in two main stages:

- Collection and preparation of *Piper carpunya Ruiz & Pav*. samples.
- Physicochemical analysis of the essential oil extracted from these samples.

Sample Collection

Leaves of *P. carpunya* were collected from Amazonian and subtropical regions of Ecuador, particularly in areas of the Chimborazo province at altitudes ranging from 1200 to 2000 m above sea level. Healthy leaves were selected and cleaned with a damp cloth to remove dust and foreign matter. They were then weighed and arranged on trays for processing.

Essential Oil Extraction

The extraction of essential oils represents a critical stage in the study of plant-derived secondary metabolites, as these compounds possess bioactive properties with applications in the pharmaceutical, cosmetic, food, and agrochemical industries. In this study, the steam distillation method was employed, a traditional yet scientifically validated technique that enables the extraction of essential oils without the use of organic solvents, thereby ensuring the purity of the extract and minimizing the alteration of its volatile components.

This method is based on thermodynamic principles, wherein water vapor reduces the partial pressure of volatile compounds, allowing their evaporation at temperatures lower than their normal boiling points. This characteristic is particularly relevant for preserving the structural integrity of thermolabile compounds and preventing their thermal degradation, which is essential for maintaining the biological activity of the oil.

The extraction system was designed to operate under hermetic conditions, ensuring process efficiency and preventing the loss of volatile compounds through evaporation. The resulting condensate was collected in a decanter, where the essential oil was separated from the aqueous phase based on density differences. This technique is not only technically efficient but also reproducible and scalable, making it a suitable tool for scientific studies focused on phytochemical characterization and evaluation of functional properties of natural extracts (Sarker y Nadar, 2024).

The selection of this methodology responds to the need for a standardized, scientifically accepted procedure that is compatible with subsequent chromatographic and physicochemical analyses, thus enabling a comprehensive characterization of the extracted essential oil.

Gas Chromatography (GC) and Atomic Absorption Spectrophotometry (AAS) Analysis

The chemical characterization of essential oils is fundamental to understanding their composition, quality, and bioactive potential. To achieve this, high-resolution and highly specific instrumental techniques were applied, such as Gas Chromatography (GC) and Atomic Absorption Spectrophotometry (AAS), both widely recognized in the scientific community for their analytical precision.

Gas Chromatography (GC): This technique was employed for the separation, identification, and quantification of volatile compounds present in the essential oil. Its principle is based on the differential distribution of analytes between a gaseous mobile phase and a stationary phase contained within a capillary column. The selection of this technique is justified by its high resolution, reproducibility, and ability to analyze complex mixtures without extensive pretreatment. The use of a flame ionization detector (FID) enabled accurate quantification of organic compounds, facilitating the development of chemical profiles that are essential for correlating the oil's composition with its functional or therapeutic properties.

Atomic Absorption Spectrophotometry (AAS): This technique was used to determine the presence of trace metal elements, which may influence the stability, safety, and biological activity of the essential oil. AAS is based on the absorption of electromagnetic radiation by free atoms in the gaseous state, allowing for highly sensitive and specific quantification. Its inclusion in the study enables the assessment of potential metal contamination in the oil, a critical factor for its application in pharmaceutical or cosmetic products.

Physicochemical Analysis of the Essential Oil

The physicochemical characterization of essential oils is a critical component in evaluating their quality, stability, and suitability for industrial or therapeutic applications. These parameters provide insight into the oxidative state, degree of unsaturation, and molecular composition of the oil, which are essential for ensuring product consistency and safety. In this study, three classical titrimetric methods were employed: Peroxide Value, Iodine Value, and Saponification Value. Each method is standardized and widely accepted in analytical chemistry for the evaluation of lipid-based substances.

Peroxide Value Determination

The peroxide value (PV) quantifies the concentration of peroxides and hydroperoxides formed during the initial stages of lipid oxidation. These compounds are primary oxidation products and serve as indicators of the oil's oxidative stability and shelf life. The method involves the reaction of the oil sample with potassium iodide (KI) in a chloroform medium, where peroxides oxidize iodide ions to iodine. The liberated iodine is then titrated with a standardized sodium thiosulfate ($Na_2S_2O_3$) solution in the presence of starch as an indicator. The peroxide value was calculated using the following formula:

$$Peroxide\ Value = \frac{(V\ X\ N)x100}{Sample\ weight\ (g)} \qquad \text{Eq.1}$$

Where: V = volume of sodium thiosulfate used (mL), N = normality of sodium thiosulfate

Iodine Value Determination

The iodine value (IV) reflects the degree of unsaturation in the fatty acid chains of the essential oil. It is defined as the number of grams of iodine absorbed by 100 grams of oil. The Wijs method was employed, which involves the addition of iodine monochloride (ICl) in glacial acetic acid to the oil sample. After a fixed reaction period, excess ICl is reduced by potassium iodide (KI), and the liberated iodine is titrated with sodium thiosulfate. The value was calculated using the equation:

$$Iodine\ Value = \frac{(B-S)x\ N\ X\ 12{,}69}{Sample\ weight\ (g)} \qquad \text{Eq. 2}$$

Where: B = volume of titrant for blank (mL), S = volume of titrant for sample (mL), N = normality of sodium thiosulfate

Saponification Value Determination

The saponification value (SV) indicates the average molecular weight (or chain length) of all the fatty acids present in the oil. It is defined as the amount of potassium hydroxide (KOH) in milligrams required to saponify one gram of oil. In this method, 5 grams of essential oil were refluxed with an alcoholic KOH solution to hydrolyze the ester bonds. The excess KOH was then titrated with hydrochloric acid (HCl) using phenolphthalein as an indicator. The saponification value was calculated using the formula:

$$Saponification\ Value = \frac{(B-S)x\ N\ X\ 56{,}1}{Sample\ weight\ (g)} \qquad \text{Eq. 3}$$

Where: B = volume of HCl for blank (mL), S = volume of HCl for sample (mL), N = normality of HCl

RESULTS AND DISCUSSION

Chemical Composition

The chemical composition of *Piper carpunya* essential oil, determined via gas chromatography, reveals a diverse and complex profile dominated by monoterpenes and oxygenated derivatives. These compounds are biosynthesized through the mevalonate and methylerythritol phosphate (MEP) pathways in plants and are known to contribute significantly to the oil's organoleptic properties (aroma and flavor) and biological activity.

As shown in Table 1, the essential oil contains a wide range of volatile constituents, with 1,8-cineole (12.5 %) and cis-sabinene hydrate acetate (14.1 %) being the most abundant. These compounds are widely recognized for their antimicrobial, anti-inflammatory, and antioxidant properties, which align with the traditional medicinal uses of this species. Additionally, the presence of α-pinene, β-pinene, and p-cymene enhances the oil's potential for therapeutic applications, particularly in formulations targeting respiratory and dermatological conditions.

The identification of both monoterpene hydrocarbons (e.g., α-pinene, sabinene) and oxygenated monoterpenes (e.g., terpinen-4-ol, α-terpineol) indicates a chemically balanced profile, which may contribute to synergistic bioactivity. This composition not only supports the ethnobotanical relevance of *Piper carpunya* but also provides a scientific foundation for its potential industrial applications in phytotherapy, cosmetics, and natural preservatives.

Physicochemical Analysis

The physicochemical evaluation of *Piper carpunya* essential oil was conducted to assess its oxidative stability, degree of unsaturation, and average molecular weight of esterified components parameters that are essential for determining the oil's quality, shelf life, and suitability for industrial or therapeutic applications.

Table 1. Composition of *Piper Carpunya*.
Tabla1. Composición de *Piper Carpunya*.

Compound	Percentage (%)
α-Pinene	3.28
α-Thujene	0.18
β-Pinene	2.5
Sabinene	1.14
Myrcene	1.1
α-Phellandrene	0.3
1,8-Cineole (Eucalyptol)	12.5
p-Cymene	11.1
γ-Terpinene	1.2
Terpinen-4-ol	2.5
α-Terpineol	0.85
cis-Sabinene hydrate acetate	14.1
trans-Sabinene hydrate acetate	0.8
δ-Elemene	0.2
α-Copaene	0.1

As shown in Table 2, three replicates (M1, M2, M3) were analyzed for the following indices:

Peroxide Index: The values ranged from 0.54 to 0.87 meq O_2/kg, with a mean of 0.66. This low peroxide value indicates a minimal presence of primary oxidation products, suggesting that the oil is chemically stable and has not undergone significant oxidative degradation. This is particularly important for preserving the integrity of bioactive compounds during storage and processing.

Iodine Index: The iodine values ranged from 116.21 to 122.71 g I_2/100 g, with a mean of 118.96. This reflects a moderate to high degree of unsaturation, which is consistent with the presence of unsaturated monoterpenes and sesquiterpenes identified in the chemical composition (see Table 1). A higher iodine value is often associated with increased reactivity and potential bioactivity, although it may also imply greater susceptibility to oxidation.

Saponification Index: The values ranged from 103.13 to 106.25 mg KOH/g, with a mean of 104.19. This index provides insight into the average molecular weight of fatty acid esters present in the oil. The results suggest the predominance of medium-chain esters, which are relevant for applications in cosmetics, emulsions, and soaps, where they influence texture, absorption, and emulsifying properties.

Descriptive Statistical Analysis

Following the descriptive statistical analysis of the evaluated physicochemical parameters, a high level of consistency among the analytical replicates was observed, supporting the reliability of the results obtained. Specifically, the peroxide index exhibited a standard deviation of 0.182 and a variance of 0.033, confirming the oxidative stability of the essential oil across the analyzed samples. These low values indicate minimal formation of primary oxidation products, which is desirable for maintaining the oil's quality during storage.

Table 2. Physicochemical analysis results (iodine, peroxide, saponification).
Tabla 2. Análisis de resultados fisicoquímicos (yodo, peróxido, saponificación).

Analysis	Unidad	M1	M2	M3	Mean/ Result
Peroxide Index	(meq O_2/kg)	0.54	0.57	0.87	0.66 (Not detectable)
Iodine Index	(g I_2/100 g)	117.26	122.71	116.21	118.96
Saponification Index	(mg KOH/g)	103.19	106.25	103.13	104.19

The iodine index showed a standard deviation of 3.489 and a variance of 12.176, reflecting slight variability in the degree of unsaturation. This behavior is expected in natural matrices, where factors such as plant genetic variability, agroecological conditions, and extraction methods can influence the chemical composition of the oil. Meanwhile, the saponification index recorded a standard deviation of 1.784 and a variance of 3.184, suggesting a homogeneous molecular profile in terms of the fatty acid and ester composition of the essential oil.

Collectively, these statistical indicators reinforce the methodological robustness of the analytical procedure employed and validate the physicochemical characterization as a solid and reliable foundation for future applications of *Piper carpunya* essential oil in the pharmaceutical, cosmetic, and food industries.

Table 3 Descriptive statistical analysis of the physicochemical indices of *Piper carpunya* essential oil.
Tabla 3. Análisis estadístico descriptivo de los índices fisicoquímicos del aceite esencial de *Piper carpunya.*

Analysis	N	Min	Max	Mean	Std. Dev / Variance
Peroxide Index (meq O_2/kg)	3	0.54	0.87	0.66	0.18248 / 0.033
Iodine Index (g I_2/100 g)	3	116.21	122.71	118.73	3.48939 / 12.176
Saponification Index (mg KOH/g)	3	103.13	106.25	104.19	1.78426 / 3.184

The detailed chemical and physicochemical profiling of *Piper carpunya* essential oil not only provides insight into its intrinsic quality and stability, but also serves as a critical foundation for identifying its potential functional applications. The presence of bioactive compounds such as 1,8-cineole, sabinene hydrate acetates and various monoterpenes, suggests a wide spectrum of pharmacological properties, including antimicrobial, anti-inflammatory, and antioxidant activities. These attributes make the oil a promising candidate for use in phytotherapeutic formulations, cosmeceuticals, and natural preservatives in the food industry. Furthermore, the physicochemical parameters particularly the low peroxide index and moderate iodine and saponification values, support its suitability for formulation stability, enhancing its value as a raw material in the development of functional products with both therapeutic and commercial relevance.

DISCUSSION

The essential oil of *Piper carpunya* exhibited an undetectable peroxide value, indicating excellent oxidative stability. This result aligns with findings by García (2019), who attributes such stability to the high proportion of monoterpenes that, due to their molecular structure, show low propensity for peroxide formation. In comparison, the essential oil of *Capsicum annuum* presented a peroxide value of 1.23 ± 0.02 meq O_2/kg, while safflower oil showed even higher values, ranging from 1.92 to 6.99 meq O_2/kg. These data highlight the superior oxidative stability of *P. carpunya* oil, representing a significant advantage for storage and use in oxidation-sensitive products.

The iodine value of the essential oil of *Piper carpunya* was 12.17 g I_2/100 g, indicating a low degree of unsaturation. This value reflects the limited presence of double bonds in the oil's constituents, as the iodine value quantifies the amount of iodine (I_2) that can react with these unsaturations. The reaction of iodine with double bonds is an electrophilic addition, in which iodine is incorporated into the unsaturated molecule, forming a vicinal dihalide. For instance, the alkene ethene ($CH_2{=}CH_2$) reacts with molecular iodine to yield 1,2-diiodoethane ($ICH_2–CH_2I$). This type of reaction is fundamental for determining the degree of unsaturation in oils and fats, as a higher number of double bonds corresponds to a greater amount of iodine that can be consumed in the reaction (Stea, s.f). From an industrial perspective, this low unsaturation is a major advantage in terms of chemical stability, as unsaturated compounds are more prone to oxidation, leading to degradation products such as peroxides, aldehydes, and ketones that compromise the quality, odor, and safety of the final product (Ramírez and Villanueva, 2021). Therefore, oils with low iodine values tend to be more resistant to rancidity, extending shelf life and reducing the need for synthetic preservatives.

In cosmetic and pharmaceutical applications, a low degree of unsaturation contributes to the structural stability of formulations, preventing undesirable reactions with active ingredients or excipients. This is particularly relevant in products exposed to variable environmental conditions (light, heat, oxygen), where the stability of the base oil is critical to maintaining product efficacy (Abizanda *et al*., 2023).

In the food industry, oils with low iodine values are also preferred for applications such as coatings, soft capsules, or lipid matrices, where consistency, sensory neutrality, and oxidative resistance are required during storage and distribution.

The saponification value of *Piper carpunya* essential oil was 3.18 mg KOH/g, reflecting a low concentration of saponifiable fatty acids. This value is significantly lower than those reported for essential oils such as *Capsicum annuum* (141.10 ± 0.35 mg KOH/g) and safflower oil (181–202 mg KOH/g), indicating a scarce presence of triglycerides and other long chain lipids. This characteristic has important implications for the development of cosmetic and pharmaceutical products.

From a cosmetic standpoint, a low triglyceride content favors the formulation of lightweight, non-greasy, and fast-absorbing products, which is highly valued in facial creams, serums, and topical emulsions (Draelos, 2012). Additionally, it reduces product occlusivity, allowing better skin breathability and lowering the risk of comedogenicity, especially in sensitive or acne-prone skin.

In the pharmaceutical field, the low saponifiability of the oil implies reduced interference with lipophilic active ingredients, potentially enhancing the bioavailability of certain compounds in transdermal or topical formulations (Rai *et al*., 2017). Furthermore, the absence of lipids prone to rancidity extends the shelf life of the final product and improves its oxidative stability, which is essential for maintaining therapeutic efficacy over time.

CONCLUSIONS

The essential oil of *Piper carpunya* exhibits a complex and bioactive chemical composition, predominantly consisting of monoterpenes and their oxygenated derivatives. Among these, 1,8-cineole and cis-sabinene hydrate acetate stand out due to their well-documented antimicrobial, anti-inflammatory, and antioxidant properties. The simultaneous presence of monoterpene hydrocarbons and oxygenated monoterpenes suggests a chemically balanced profile with potential synergistic effects, particularly relevant for therapeutic applications targeting respiratory and dermatological conditions. From a physicochemical perspective, the oil demonstrated notable oxidative stability (mean peroxide value of 0.66 meq O_2/kg), a moderate to high degree of unsaturation (iodine value of 118.96 g I_2/100 g), and a predominance of medium-chain esters (saponification value of 104.19 mg KOH/g). These characteristics make it suitable for use in cosmetic and pharmaceutical formulations. The low variability among replicates confirms the reliability of the data and the methodological robustness of the study. Collectively, these findings support the potential of *Piper carpunya* essential oil as a functional ingredient in the pharmaceutical, cosmetic, and food industries.

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