

# Analysis of volatile compounds and antioxidant activity of Colombian ginger (*Zingiber officinale*) essential oil obtained by hydrohydraulic distillation assisted by microwave radiation

## Análisis de compuestos volátiles y actividad antioxidante del aceite esencial de jengibre colombiano (*Zingiber officinale*) obtenido por destilación hidrodráulica asistida por radiación de microondas

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**Abstract** *Zingiber officinale* is a plant of the Zingiberaceae family. The rhizome is widely used in gastronomy for its aroma and flavour. Essential oils (EO) are natural compounds; they have 25 to 70 components with different concentrations.  $\alpha$ -Zingiberene and  $\alpha$ -Felandrene are the main components of the essential oil with volumes between 20 % and 70 %. EO extraction, samples from 10 Colombian geographical locations were used and processed by microwave radiated hydrodistillation (MWHD) and stored at 4 °C in amber vials. 50  $\mu$ L of EO and 1.0  $\mu$ L of (n-tetradecane) internal standard were dissolved in dichloromethane to a final volume of 1.0 ml. The EO components were performed on a triple quadrupole mass detector gas chromatograph (BRUKER 450GC-320). For its antioxidant activity (AA) the methodology of Prior for DPPH\* and ABTS+ was used. The extractions showed a yield between 0.053 and 0.109 per cent, and 300 g of the sample at 700 watts and 40 minutes of the process were used. The chromatographic profile showed 43 components referring to ketones, alcohols, cyclic ethers, aldehydes, and 23 hydrocarbons, with  $\alpha$ -Zingiberene being the majority, considered as a molecular marker of this EO. The AA presents significant differences between the samples evaluated for the localities studied.

Keywords: chromatography; microwave; antioxidant activity; natural products; aromatic plants.

**Resumen** *Zingiber officinale* es una planta de la familia Zingiberaceae. El rizoma es muy utilizado en gastronomía por su aroma y sabor. Los aceites esenciales (EO) son compuestos naturales; tienen de 25 a 70 componentes con diferentes concentraciones.  $\alpha$ -Zingiberene y  $\alpha$ -Felandrene son los componentes principales del aceite esencial con volúmenes entre el 20 % y el 70 %. Para la extracción del aceite esencial (OE) se utilizaron muestras de 10 ubicaciones geográficas colombianas, obtenidas por hidrodestilación radiada por microondas (MWHD) y almacenadas a 4 °C en viales de color ámbar. Se disolvieron 50  $\mu$ l de EA y 1,0  $\mu$ l de patrón interno (n-tetradecano) en diclorometano hasta un volumen final de 1,0 ml. Los componentes de OE se realizaron en un cromatógrafo de gases con detector de masas cuádruple triple (BRUKER 450GC-320). Para su actividad antioxidante (AA) se utilizó la metodología de Prior para DPPH\* y ABTS+. Las extracciones mostraron un rendimiento entre 0.053 y 0.109 por ciento; y se utilizaron 300 g de muestra a 700 vatios y 40 minutos de proceso. El perfil cromatográfico mostró 43 componentes referidos a cetonas, alcoholes, éteres cíclicos, aldehídos y 23 hidrocarburos, siendo el  $\alpha$ -Zingibereno el mayoritario, considerado como marcador molecular de este OE. La AA presenta diferencias significativas entre las muestras evaluadas para las localidades estudiadas.

**Palabras clave:** cromatografía; microondas; actividad antioxidante; productos naturales; plantas aromáticas.

## Introduction

Ginger (*Zingiber officinale*) is a plant of the Zingiberaceae family, whose underground stem is a horizontal rhizome widely used in gastronomy for its aroma and spicy flavor (Tapiero-Cuellar, 2017). This plant can be 90 cm tall, with 20 cm long leaves. It grows in all the tropical regions of the world and the varieties with the highest economic value and highest quality generally come from Australia, India and Jamaica, while the most commercialized varieties are grown in China and Peru, (Leyva *et al*, 2007).

Essential oils (EO) are complex natural compounds; that they present between 25-70 components with different concentrations and exhibit two or three main components with a concentration between 20 % and 70 % compared to the rest of the components (Li *et al.*, 2014). These are liquid and volatile compounds distributed in all parts of the plants, which can be extracted by different mechanisms: steam entrainment, microwave radiated hydrodistillation, and supercritical fluids, among others, (Márquez, 2011; Hossain *et al*, 2012). These can be alcohols, ketones, ethers, aldehydes that are produced and stored in the secretory channels of plants (Baldwin *et al.*, 1999; Van Opstaele *et al*, 2012; Hosni *et al*, 2013).

Microwaves are electromagnetic radiation with frequencies between 0.3 to 300 GHz. Domestic and industrial equipment operate at 2.45 GHz, (Ferhat *et al*, 2006; León *et al*, 2015). Due to their nature, they have electric and magnetic fields, which are perpendicular to each other, (Contreras-Puentes *et al*, 2012). The electric field is responsible for heating by bipolar rotation and ion conduction, producing collisions with the surrounding molecules and allowing the release of thermal energy to the medium, (León *et al.*, 2015). When using microwave radiation-assisted hydrodistillation extraction (MWHHD), the heat produces the expansion and rupture of the cell walls, facilitating the exit of the EO to the surrounding solvent, (Pandey *et al*, 2014).

Moisture content is essential in MWHHD because the water heats up more and promotes the release of analytes into the surrounding environment, (Ferhat *et al.*, 2006).

In general, the large number of compounds present in EOs are terpenes or terpenoids. Its C<sub>5</sub> isoprene unit in the hydrocarbon chain is a distinctive structural feature that differs from that of other natural products. According to the amount of (C<sub>5</sub>)<sub>n</sub> present in the hydrocarbon skeleton, they are classified as monoterpenoids (C<sub>5</sub>)<sub>2</sub>, sesquiterpenoids (C<sub>5</sub>)<sub>3</sub>, diterpenoids (C<sub>5</sub>)<sub>4</sub>, sesterpenoids (C<sub>5</sub>)<sub>5</sub>, triterpenoids (C<sub>5</sub>)<sub>6</sub>, and tetraterpenoids (C<sub>5</sub>)<sub>8</sub> and according to their shape, they can be classified as open-chain or cyclic terpenoids with one or more rings (Patrignani *et al*, 2015). Another class of chemical compound present in EO are phenylpropanoids such as anethole, methi-eugenol, and safrole among others, (Umagiliyage *et al*, 2017; Grande-Tovar *et al*, 2018). They are characterized by having in their structure a propylene group linked to a benzene ring (Tapiero-Cuellar *et al*, 2019).

Typically, EOs are composed primarily of terpenic hydrocarbons (myrcene, pinene, terpinene, limonene, p-cymene,  $\alpha$ -, and  $\beta$ -phellandrene) and terpenoids (oxygen-containing hydrocarbons) as acyclic monoterpene alcohols (menthol, monocyclic alcohols, 4-carvomenthol, terpineol, carveol, borneol), aliphatic aldehydes (citral, citronelal, perillaldehyde), aromatic phenols (carvacrol, thymol, safrole, eugenol), bicyclic alcohol (verbenol), monocyclic ketones (Mentone, pulegone, carvone) bicyclics (thujone, verbenone, fenchone), acids (citronellic acid, cinnamic acid) and esters (linalyl acetate). The constituents of mono and sesquiterpenoid essential oils are formed by condensation of isopentenyl pyrophosphate units (Murugesan *et al*, 2020).

Ginger rhizomes content of essential oil varies from 1.0 to 1.5 %. Mainly sesquiterpenes constitute between 50 % and 66 % of the

oil composition. Among the sesquiterpene hydrocarbons, 20 % to 30 % are: (-) -  $\alpha$ -zingiberene, (-) -  $\beta$ - bisabolene (12%), (+) ar-curcumene (19%) and farnesol (10%). Ss-sesquifelandrene and ar-curcumene are mainly responsible for the ginger aroma, while a-therpineol and citral give rise to the citric aroma of lemon, (Di Vaio *et al*, 2010; Murugesan *et al.*, 2020).

Mass Coupled Gas Chromatography (GC-MS) analysis allows the identification of secondary metabolites present in EO, using comparative applications of mass spectral libraries (NIST/EPA/NIH). In addition, it allows a qualitative analysis to be performed on a 1  $\mu$ L sample and when a standard substance is available, the calibration of the equipment can consolidate an exact quantitative analysis of the sample (Li *et al.*, 2014; Pulido-Arango *et al* 2018).

Aromatic spices and their essential oils have been of great interest, both in the food industry and in scientific research, (Silva-Espinoza, 2013). Its antioxidant and antimicrobial properties allow it to compete with other currently used natural and synthetic antioxidants, (Li *et al*, 2010; Oliveira de Veras *et al.*, 2020). Besides ginger EO properties are linked to many bioactive substances, such as flavonoids, terpenoids, carotenoids, and vitamins, among others, they provide great health benefits against the oxidative rancidity of foods due to their high antioxidant activity (Zhai *et al*, 2016; Rezgui *et al.*, 2020).

Antioxidants are substances that inhibit the cellular oxidation of toxins such as free radicals (Acosta *et al*, 2011). These toxic substances can come from natural digestion, food metabolism, environmental conditions, consumption of drugs and alcohol, causing oxidative damage to proteins, lipids, enzymes and DNA, (Duarte, 2011; Asensio *et al*, 2015). Living cells have a good scanning mechanism to avoid excess cell damage caused by free radicals. However, with aging and external causes, these mechanisms become inefficient, requiring dietary

antioxidant supplementation, (Granados-Conde, 2012). Under this condition, EO from aromatic plants is under evaluation for their antioxidant activity (Muñoz-Acevedo, 2009; Murugesan *et al.*, 2020).

Natural antioxidants are found in numerous plant sources, with fruits and vegetables being the most important, (Cerón-Salazar, 2009). Lignocellulosic materials from agri-food and forest residues can also be considered as natural sources of this type of antioxidants, despite being previously processed matrices (Luis Duarte *et al*, 2016). An example is pineapple rinds that are used to obtain different compounds with phenolic activity.

Natural antioxidants are Phenolic Compounds (PC) that are divided into different groups, according to their basic structure, (Zamar *et al*, 2005). These perform various physiological functions and are involved in the growth, reproduction, and defence of plants against various pathogens, (Hosni *et al*, 2013). PC has a hydroxylated benzene ring as a common element, where functional groups such as esters, methyl esters, glycosides are included, (Leyva *et al*, 2007). Groups are characterized by the number of carbon atoms in their basic molecular skeleton (Harlen and Jati, 2018) and according to their structure, they are classified as: cinnamic acid, benzoic acid, flavonoid, proanthocyanin or condensed tannin, stilbene, coumarin, sapogenin, lignan, and lignin, among others (Alma *et al*, 2007).

Average daily consumption of polyphenols is affected by eating habits and diets as the main sources are fruits and vegetables. These compounds have protective effects against some serious diseases such as cancer and cardiovascular diseases, (Hosni *et al*, 2013). In addition, they have a wide range of physiological properties such: anti-allergenic, anti-atherogenic, anti-inflammatory, antimicrobial, antioxidant, antithrombotic, cardioprotective, and vasodilatory effects. Antioxidants can also exert an oxidizing effect

depending on the concentration, generating negative repercussions for health, (Castro-Escorcia *et al.*, 2019).

The objective of this research considered extracting ginger (*Zingiber officinale*) Essential oil from 10 Colombian localities by microwave radiation-assisted hydrodistillation (MWHHD), characterizing its physicochemical properties, evaluating its chemical composition by gas chromatography-mass spectrometer (GC-MS), and evaluate its antioxidant activity against the 2,2-diphenyl-1-picrylhydrazyl (DPPH\*), 2,2'-Azinobis [3-ethylbenzothiazoline-6-sulfonic acid]-diammonium salt (ABTS+) and Oxygen radical absorbance capacity (ORAC) methods.

## Materials and methods

### Vegetal material

Ginger rhizomes from six Colombian sites located in Andean region were used to extract the essential oil. The samples were collected at cropping sites, transported, and stored at 4°C to the Laboratorio de Análisis Microbiológico y Físicoquímico de Alimentos -LAMFA of Sena-Centro Agropecuario de Buga.

### Microwave-assisted hydrodistillation of essential oils

The EOs of the rhizomes were obtained by microwave radiated hydrodistillation (MWHHD). A modified Clevenger kit with a capacity for 500 grams of sample was used. Distillation was performed using 300 g samples of fresh ground material. The variables for the extractions of each sample were made for 40 minutes in four 10-minute cycles at a power of 700 watts. The EOs obtained were stored in amber vials at 4°C.

### Physicochemical evaluation of ginger essential oil

The physicochemical properties of the EOs of the different localities were analyzed in terms of the density according to the method described in

ISO 279: 1981, solubility in ethanol considering ISO 875: 1999, and refractive index made with a refractometer with bath thermostatic according to ISO 280: 1998. The analyzes were performed in triplicate for each of the samples obtained.

### Gas Chromatography coupled to Masses

Samples were prepared by dissolving 50 µL of EO and 1.0 µL of (n-tetradecane) internal standard in dichloromethane to a final volume of 1.0 mL. The characterization was carried out by GC-MS. The components of the oils were recognized on a gas chromatograph (BRUKER 450 GC) with a triple quadrupole mass detector (BRUKER 320). For the identification of the compounds, the databases ADAMS 2004, NIST 2002, and WILEY 138K will be identified. Shown is a DB-5MS Fused Silica Polar Capillary Column (J & W Scientific, Folsom, CA, USA).

### Antioxidant activity of ginger essential oil

To determine the antioxidant capacity of EO, the methodology standardized by Prior, Wu, and Schaich (2005), Rosales *et al.* (2020) and Roth (2009) for DPPH\* and ABTS+ was used. Where 75 µL of the sample was considered which was added to 150 µL of methanolic DPPH\* solution (100 ppm). Subsequently, it was incubated at room temperature for 30 minutes. Samples were determined spectrophotometrically at 550 nm in a UV-Visible Evolution Thermo Scientific spectrophotometer. Ascorbic acid (25 µg/mL was used as a positive control of DPPH\* radical uptake). Differences from DPPH\* standard solution were determined by ANOVA, p-values <0.05 were considered significant.

The ABTS+ radical was formed after the reaction of 3.5 mM ABTS+ with 1.25 mM potassium persulfate (final concentration). Once the ABTS radical was formed, it was diluted with ethanol until obtaining an absorbance of  $0.7 \pm 0.05$  at 734 nm. To a volume of 190 µL of the ABTS+ radical dilution, 5, 20 and 40 µL



of the EO sample were added and incubated at room temperature for 7 minutes; after this time, the disappearance of the ABTS+ radical was determined spectrophotometrically at 734 nm. Ascorbic acid (5µg/mL) was used as a positive control of ABTS+ radical uptake and the IC<sub>50</sub> was calculated by evaluating the serial concentrations of ginger EO by linear regression analysis.

The ORAC method measures the ability of antioxidants in the sample to protect the protein from oxidative damage, (Prior *et al.*, 2005). For the evaluation, Trolox was used as standard and controlled conditions of temperature (37 °C) and pH (7.4). The readings were made at an excitation wavelength of 493 nm and an emission wavelength of 515 nm. 1x10<sup>-2</sup>M fluorescein solutions in PBS (75 mM) and 0.6 M AAPH in PBS (75 mM) were used as protein. The sample was prepared by mixing 21 µl of fluorescein, 2,899 µl of PBS, 5,20 and 40 µl of the ginger EO and 50 µl of AAPH. The protective effect of the antioxidant was calculated using the area differences under the fluorescein decay curve with the blank and the sample. The result was compared with the curve obtained for the Trolox and the results were expressed in micromoles of Trolox equivalents for every 100 grams of sample (µmol Tx/100 g sample).

## Results and Discussion

The ginger rhizomes have similar characteristics in terms of functional analysis, Table 1. The humidity in the samples is between 83.92 ± 0.127 and 85.67 ± 0.215. The Dosquebradas Risaralda sample is the one with the lowest moisture content. As for protein, fat, and fiber values, there are no significant differences (p-values <0.05) between the origins of the samples, reporting homogeneity for the territory studied.

The AOs obtained from the three Colombian geographical areas show a yield between 0.053 and 0.109 % for 300 g of sample with 700 watts and 40 minutes of the process. The samples

obtained from the Manizales area are the ones with the highest yield (Table 2). The refractive indices and the density of the different EOs are similar to each other. The samples processed from Manizales and Vijes show significant differences (p <0.05) regarding the volume obtained. These differences could be explained if biogeographic aspects are considered, such as soil mineral content and texture. The values recorded for process yields are consistent with those reported in MWHD for essential oils, (Ferhat *et al.*, 2006; Zhai *et al.*, 2016).

The color of the extracted ginger EOs presented a scale from light yellow to intense, miscible in ethanol and in ethyl ether corresponding to the naturalness of this type of compounds that are obtained from rhizomes such as those of ginger and turmeric, (Leyva *et al.*, 2007). The yield for the extracted oils was variable, the lowest being the Sotaquirá (0.053 ± 0.003) and the highest in the samples of the coffee zone for the case of Manizales (0.109 ± 0.007), the Mosquera and Buga samples presented significant yields.

The chromatographic analysis was performed for the samples with the highest percentage of performance. A parameter that is relevant for the quantities obtained when presenting similar refractive indices as a quality benchmark.

Table 3 lists the main constituents of ginger essential oil. Identification of volatiles was performed by comparing the data obtained against the NIST mass spectrum library database. In this case, 43 components, 14 alcohols, have been identified, with α-Zingiberene and α-Felandrene having the highest concentration (42.2 and 4.32), two groups of aldehydes, ketones, and cyclic ethers. In addition, 23 hydrocarbons were identified, the majority being α-Zingiberene, considered as a molecular marker of this essential oil.

Cubemene, Curcumene, Germacrene, Zingiberene, and Bisabolene are very common compounds in the essential oil and oleoresin of ginger. In addition, recognized for its

**Table 1.** Average values of the proximal analysis of ginger rhizomes from some Colombian localities

Sample	Moisture (%)	Protein (%)	Fat (%)	Fiber (%)	Carb (%)
RZ-SQ	84,37±0,127 <sup>a</sup>	2,23±0,015 <sup>a</sup>	4,05±0,015 <sup>a</sup>	0,610±0,010 <sup>a</sup>	5,937±0,02 <sup>a</sup>
RZ-2Q	83,92±0,056 <sup>a</sup>	2,29±0,010 <sup>a</sup>	4,10±0,017 <sup>a</sup>	0,580±0,001 <sup>a</sup>	5,833±0,015 <sup>a</sup>
RZ-MZ	84,40±0,122 <sup>ab</sup>	2,22±0,006 <sup>a</sup>	4,11±0,040 <sup>a</sup>	0,617±0,006 <sup>a</sup>	5,890±0,020 <sup>a</sup>
RZ-VJ	84,16±0,135 <sup>ab</sup>	2,24±0,010 <sup>a</sup>	4,11±0,015 <sup>a</sup>	0,637±0,021 <sup>a</sup>	5,757±0,021 <sup>a</sup>
RZ-BG	84,37±0,078 <sup>ab</sup>	2,31±0,010 <sup>a</sup>	4,16±0,015 <sup>a</sup>	0,643±0,035 <sup>a</sup>	5,760±0,010 <sup>a</sup>
RZ-SV	84,52±0,155 <sup>ab</sup>	2,33±0,010 <sup>a</sup>	4,12±0,025 <sup>a</sup>	0,633±0,015 <sup>a</sup>	5,677±0,015 <sup>a</sup>
RZ-MQ	84,69±0,176 <sup>ab</sup>	2,29±0,015 <sup>a</sup>	4,13±0,020 <sup>a</sup>	0,610±0,017 <sup>a</sup>	5,773±0,015 <sup>a</sup>
RZ-TJ	85,29±0,119 <sup>abc</sup>	2,24±0,020 <sup>a</sup>	4,16±0,021 <sup>a</sup>	0,627±0,015 <sup>a</sup>	5,690±0,010 <sup>a</sup>
RZ-DT	85,67±0,215 <sup>abc</sup>	2,25±0,015 <sup>a</sup>	4,15±0,023 <sup>a</sup>	0,707±0,015 <sup>a</sup>	5,773±0,015 <sup>a</sup>
RZ-ST	85,41±0,150 <sup>abc</sup>	2,32±0,010 <sup>a</sup>	4,15±0,025 <sup>a</sup>	0,730±0,010 <sup>a</sup>	5,890±0,010 <sup>a</sup>

RZ-SQ: Salento, Quindío; RZ-2Q: Dosquebradas, Risaralda; RZ-MZ: Manizales, Caldas; RZ-VJ: Vijes, RZ-BG: Guadalajara de Buga, RZ-SV: Sevilla Valle del Cauca; RZ-MQ: Mosquera, Cundinamarca; RZ-TJ: Tunja, RZ-DT: Duitama, RZ-ST: Sotaquirá Boyacá.

**Table 2.** Average values obtained in the operation of extraction of essential oil of Ginger from some Colombian localities

Location	Zone	N	Quantity	Performance %	Density g/cm3	RI -
Altiplano Boyacá/Cund.	RZ-DT	3	0,190 ± 0,010b	0,063 ± 0,003b	0,877 ± 0,001	1,445 ± 0,001a
	RZ-ST	3	0,160 ± 0,010d	0,053 ± 0,003d	0,877 ± 0,001	1,461 ± 0,029a
	RZ-TJ	3	0,203 ± 0,020cd	0,068 ± 0,007bcd	0,877 ± 0,001	1,445 ± 0,001a
	RZ-MQ	3	0,217 ± 0,015bc	0,072 ± 0,001bc	0,876 ± 0,001	1,445 ± 0,001a
Z. Cafetera	RZ-2Q	3	0,173 ± 0,006cd	0,058 ± 0,002cd	0,876 ± 0,002	1,445 ± 0,001a
	RZ-MZ	3	0,327 ± 0,021 <sup>a</sup>	0,109 ± 0,007a	0,876 ± 0,001	1,445 ± 0,001a
	RZ-ST	3	0,193 ± 0,064bc	0,064 ± 0,005bc	0,876 ± 0,001	1,450 ± 0,008a
Valle	RZ-BG	3	0,227 ± 0,015b	0,076 ± 0,005b	0,878±0,001	1,445 ± 0,001a
	RZ-SV	3	0,197 ± 0,015bcd	0,066 ± 0,005bcd	0,877±0,001	1,445 ± 0,001a
	RZ-VJ	3	0,187 ± 0,015bc	0,062 ± 0,005bc	0,877±0,001	1,445 ± 0,002a

n = number of extractions. Operation at 700 watts and operating times of 40 min. Different letters in the columns reveal statistical differences between the groups.

antioxidant and antimicrobial properties. The observed results are consistent with other works reported in the literature (Acosta *et al*, 2011; Ali *et al.*, 2015; Tapiero-Cuellar *et al*, 2017). That the EO has been used in agri-food matrices.

The results of the DPPH\* and ABTS+ radical scavenging activity of the ginger EO from the Manizales Caldas area varied between  $0.29 \pm 0.04$  and  $0.74 \pm 0.03 \mu\text{g/mL}$  for the DPPH\*, and from  $5.71 \pm 0.01$  to  $18.1 \pm 0.67 \mu\text{g/mL}$  for ABTS+. Indicating that the higher the concentration of the sample, the greater the capacity for capturing the radicals. It is important to indicate that

the type of extraction can generate conditions of reactivity and solubility, promoting the existence of other compounds with antioxidant potential in the matrix. The relationship between inhibitory concentrations, the Anti-Radical Activity (AA) against the DPPH\* radical for the EO of ginger show significant differences (P-value <0.05), among each other.

The treatments with higher concentrations are more reactive. For AAs at  $40 \mu\text{g/mL}$  there are significant differences (P-value <0.05), according to the Fisher test, with high concentrations being the most effective for

**Table 3.** Volatile components present in microwave-extracted ginger EO

Function	Compound	HT (min)	%	Compound	HT (min)	%
Alcohol	Nerolidol	16.48	0,38	Terpinen-4-ol	11.43	0,78
	2-Heptanol	6.78	0,016	L- $\alpha$ -Terpineol	11.63	0,95
	1-Octen-3-ol	8.12	0,12	trans-Piperitol	11.82	0,34
	3-Octanol	8.40	0,16	Geraniol	12.36	1,62
	Dehydrolinalool	10.1	2,13	Thymol	12.93	2,12
	cis-2-Menthenol	10.8	0,05	Carvacrol	13.06	1,83
	cis-Verbenol	11.1	0,09	Elemol	16.41	0,03
Aldehyde	Citral	12.7	0,98	Citronellal	10.91	2,36
Ketonas	Sulcatone	8.20	1,16	Verbenone	14,70	1,02
Ether	Eucalyptol	9.06	1,48	Artemiseol	11.33	1,46
Cyclic hydrocarbon	$\alpha$ -Farnesene	15.8	1,32	$\alpha$ -Terpinolen	9.900	0,45
	$\alpha$ -Thujeno	7.24	0,04	Linalool	10.10	1,24
	1R- $\alpha$ -Pinene	7.38	0,66	$\alpha$ -Copaene	14.22	0,92
	Canphene	7.67	1,67	$\beta$ -Elemene	14.38	0,04
	$\alpha$ -Felandrene	8.04	4,64	$\beta$ -Cubeben	14.80	0,04
	L- $\beta$ -Pinene	8.15	0,05	$\alpha$ -Curcumene	15.54	0,51
	$\alpha$ -Felandrene	8.61	4,32	D-Germacrene	15.62	2,67
	$\alpha$ -Terpinene	8.78	0,26	$\alpha$ -Zingibereno	15.71	42,2
	p-Cimeno	8.91	0,36	$\beta$ -Bisabolene	15.87	0,14
	D-Limonene	8.99	0,84	$\delta$ -Cadinene	16.03	0,04
	$\gamma$ -Terpinenol	9.46	0,02	$\beta$ -Sesquifelandrene	16.08	1,57
	trans- $\beta$ -Terpineol	9.67	0,05			

each of the tests. This is associated with a large number of phenolic compounds and their high reactivity. In the evaluations of the different concentrations, those of 40  $\mu\text{g/mL}$  presented a higher IC<sub>50</sub> value than the control (ascorbic acid) (Table 4).

The highest AA obtained the concentration of 40  $\mu\text{g/mL}$  of ginger EO obtained by MWHD. The hydrophilic ORAC value was  $0.062 \pm 0.01\mu\text{mol Trolox} / 100 \text{ g}$  of sample. The result shows that the ginger EO has a high capacity to inhibit the discoloration of the fluorescein molecule in minimal amounts. Significant differences ( $P < 0.05$ ) were found between the methods and concentrations used in determining the results. Furthermore, the values show a higher AA when

**Table 4.** Antioxidant activity of ginger essential oil from the Manizales, Caldas area and extracted by hydrodistillation radiated by microwaves

Location	Sample conc. $\mu\text{g/mL}$	DPPH*	ABTS+	ORAC
EO-Mz	5	$0,29 \pm 0,04^a$	$5,71 \pm 0,01^a$	$0,062 \pm 0,01^a$
	20	$0,41 \pm 0,02^b$	$12,1 \pm 0,02^b$	$0,153 \pm 0,01^b$
	40	$0,74 \pm 0,03^c$	$18,1 \pm 0,67^c$	$0,283 \pm 0,01^c$

\* Data are expressed in mmol Trolox//. a, b, c, Superscripts represent statistical differences between methods and concentrations.

a higher sample concentration was used; and in the case of ORAC, the lowest consumption value expressed in  $\mu\text{mol Trolox}$  represents the highest antioxidant activity on fluorescein discoloration.

## Conclusion

The microwave-assisted hydrodistillation process (MWHd) allowed essential oils to be obtained from ginger rhizomes in short times and acceptable yields of secondary metabolites. The matrices of the Manizales area presented higher extraction performance and with conditions of similar quality to the other areas studied. The comparison of the antioxidant capacity between the DPPH \* ABTS \* and ORAC tests showed a linear behavior indicating that at higher concentrations of EOs the activity is greater at the time of trapping free radicals.

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