Research article

A promising blueberry from Colombia: antioxidant activity, nutritional and phytochemical composition of *Cavendishia nitida* (Kunth) A.C.Sm.

Elizabeth Gil Archila [a,*], Felipe Rojas-Bautista [a], Nestor Garcia [b], Jorge Andres Carvajal Vasquez [b]

[a] *Grupo de Investigación en Fitoquímica, Department of Chemistry, Faculty of Sciences, Pontificia Universidad Javeriana, P. O. Box 111321, Bogotá D.C., Colombia*
[b] *Unidad de Ecología y Sistemática, Department of Biology, Faculty of Sciences, Pontificia Universidad Javeriana, P. O. Box 111321, Bogotá D.C., Colombia*

ABSTRACT

Many Neotropical representatives of Ericaceae have fruits with antioxidant activity and high nutritional value. However, in Colombia, these fruits are little consumed and are considered underutilized. One such example is the berries of *Cavendishia nitida* (Kunth) A.C.Sm. In this study, the nutritional value, the total phenolic, flavonoid and anthocyanin contents, and antioxidant activity of *C. nitida* fruit were performed. From the leaves, an ethanolic extract was made, which was then fractioned to measure its antioxidant activity and analyze its chemical composition. The results indicate that the fruit of *C. nitida* can be classified as potentially edible, due to its minerals and vitamins contents. Five anthocyanins were detected in the berries; while in the leaves extract six terpenes and one flavonol were identified. The ethyl acetate fraction of the leaves extract exhibited strong antioxidant activity with the DPPH$^{\bullet}$ and ABTS$^{\bullet+}$ radicals tested. We also found a strong correlation between the total phenolic and flavonoid contents and the values of percentage of inhibition of DPPH$^{\bullet}$ and ABTS$^{\bullet+}$ in all the samples tested. The results of this study suggest that the berries of *C. nitida* are promising as edible fruits, and beneficial for human and animal health. However, even though the communities of the region use this berry as food, the toxicity of fruits must be evaluated to confirm that their consumption is safe for humans.

1. Introduction

Wild edible fruits have contributed significantly to the human diet (Bacchetta et al., 2016). Colombia is a territory with a wide diversity of wild fruits, which are an integral part of the diet of rural inhabitants (López Diago and García Castro, 2021). Wild fruits are often richer in nutrients and bioactive compounds, such as anthocyanins and flavonoids, than cultivated species (Bacchetta et al., 2016; Li et al., 2016). Studies on the composition of wild fruits have increased in recent years, especially in relation to their antioxidant, antimicrobial, anti-inflammatory, and anticancer activities, showing that the consumption of these fruits is beneficial for human health and in the prevention of chronic diseases (Li et al., 2016).

Ericaceae is a large family of flowering plants with almost 128 genera and about 4000 species (Luteyn, 2002). The fruits of the Ericaceae family are known for their high antioxidant content compared to other species from different families. As a result, these berries are considered "super-fruits" (Dastmalchi et al., 2011; Rashidinejad, 2020). The edible berries of the genus *Vaccinium* are the most widely studied and cultivated.

Research on *Vaccinium* berries has focused on the phenolic, flavonoid, and anthocyanin contents and antioxidant capacity, given the health benefits of these bioactive compounds (Dastmalchi et al., 2011; Ma et al., 2013; Rashidinejad, 2020). However, there are more than six hundred species of berry-producing Ericaceae native to the Neotropics (Luteyn, 2002), almost 270 species are found in Colombia with very few studies on them, and it is clear that these plants are underutilized (Dastmalchi et al., 2011).

Among these Ericaceae are the species of *Cavendishia*, most of which are endemic to the Neotropics, predominantly in cold montane forests between 1000 m and 3000 m and several species are found above the tree line up to 4650 m in the páramo ecosystem (Luteyn, 2002). The Neotropical Ericaceae have developed a tolerance to the conditions of the mountainous regions (Luteyn, 2002), in Colombia these species have adapted to the environmental conditions of the páramo and sub-páramo ecosystems, including low temperatures, high ultraviolet radiation, fog, high precipitation levels and strong winds (Luteyn, 1999). As a consequence, these plants have developed chemical adaptations that include the accumulation of anthocyanins and phenolic compounds as a

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* Corresponding author.
E-mail address: egil@javeriana.edu.co (E. Gil Archila).

Figure 1. Flowers and green berries (A - left), and wild berries at ripening stage (B - right) of *Cavendishia nitida*.

protective response to reactive oxygen species (ROS) to cope with environmental conditions and the environmental stress that these conditions can cause (Alonso-Amelot, 2008).

Although the fruits of *Cavendishia* are consumed by rural communities in Colombia (López Diago and García Castro, 2021), there have been few studies focusing on their chemical and nutritional properties. It is known that the fruits of *Cavendishia bracteata* contain flavonoids, quinones, tannins, saponins, coumarins, and triterpenoids (Sanabria-Galindo et al., 1997; Plazas González, 2015). Likewise, the leaves of species of *Cavendishia* have been found to contain stilbenes, flavone glycosides, flavonoids, flavonols, proanthocyanidins and terpenes (Dastmalchi et al., 2011; Garcia, 1992; Luteyn et al., 1980), while quercetin, myricetin, and some stilbenes have been isolated from the leaves of *Cavendishia nitida* (Luteyn et al., 1980). However, to our knowledge, there is no nutritional information, and chemical studies have been conducted on the fruit.

C. nitida, from the Ericaceae family, is a shrub that is endemic to Colombia (Figure 1), commonly known as "Uva camarona", "uvo", or "uva", its fruits are in the form of red berries, which are consumed by inhabitants of the "Altiplano Cundiboyacense", a region in the center of the country (Luteyn, 1983).

In the present study, the nutritional value of *C. nitida* fruits is evaluated for the first time, through an analysis of its minerals, vitamins and proximate composition. The total phenolic, total flavonoid and anthocyanin content was quantified, and the antioxidant capacity was assessed. The same analyses were also performed for the leaf extract, and the chemical composition of this extract was studied.

2. Material and methods

2.1. Plant materials

Fruits (550 g) and leaves (2 kg) of *C. nitida* were collected in February 2019 at páramo El Tablazo, near the municipality of Subachoque, Cundinamarca, Colombia [5° 00′ 37″ N 74° 11′ 34″ W], which lies 2900 m above mean sea level (mamsl). Some of the fresh fruits (50 g) were freeze dried (-80 °C) for the total phenolic and total flavonoid analyses. The anthocyanin and proximal analyses were performed using fresh samples (500 g). For the leaf extract, the leaves were dried and ground before solvent extraction.

A specimen was taxonomically registered at the Herbarium of the Pontificia Universidad Javeriana, under code N. García 764 (HPUJ: 030161). The material was collected in accordance with the framework contract for Access to Genetic Resources and its derivative products No. 212 of July 19, 2018, signed by the Ministry of Environment and Sustainable Development and the Pontificia Universidad Javeriana.

Table 1. Concentrations of the standards using in the calibration curve for the determination of anthocyanin of *C. nitida*.

Concentration range	Concentration of each anthocyanin standard (µg mL^{-1})					
	C3Ga	C3G	C3A	P3G	M3G	Pe3G
C1	44.00	11.00	44.00	7.70	44.00	44.00
C2	22.00	5.50	22.00	3.85	22.00	22.00
C3	11.00	2.75	11.00	1.92	11.00	11.00
C4	5.50	1.37	5.50	0.96	5.50	5.50
C5	2.75	0.69	2.75	0.48	2.75	2.75
C6	1.37	0.34	1.37	0.24	1.37	1.37
C7	0.69	0.17	0.69	0.12	0.69	0.69

C3Ga: cyanidin 3-*O*-galactoside, C3G: cyanidin 3-*O*-glucoside, C3A: cyanidin 3-*O*-arabinoside, P3G: peonidin 3-*O*-glucoside, M3G: malvidin 3-*O*-glucoside, and Pe3G: petunidin 3-*O*-glucoside.

Table 2. Physicochemical and nutritional values of *C. nitida* fruits.

Parameters	Values*
pH	3.31 ± 0.04
Total acidity, %	0.76 ± 0.02
Total soluble solids, °Brix	10.6 ± 3.9
Moisture, %	83.31 ± 0.03
Crude protein, g per 100g dw	0.29 ± 0.01
Crude fat, g per 100g dw	0.13 ± 0.01
Total dietary fiber, g per 100g dw	3.26 ± 0.20
Crude ash, g per 100g dw	0.30 ± 0.02
Total carbohydrates, g per 100g dw	16.0 ± 0.7
Calorific Value, Kcal per 100g dw	66.2 ± 0.6
Potassium, mg K per 100g dw	236.8 ± 17.5
Calcium, mg Ca per 100g dw	11.5 ± 2.5
Sodium, mg Na per 100g dw	114.9 ± 13.4
Iron, mg Fe per 100g dw	1.3 ± 0.2
Phosphorus, mg P per 100g dw	84.9 ± 6.7
Ascorbic acid, mg per 100g fw	62.0 ± 2.1
Thiamine, mg per 100g fw	0.05 ± 0.01
Riboflavin, mg per 100g fw	0.79 ± 0.06
Total anthocyanins, mg C3G per 100g fw	503.1 ± 34.2

* Values are the average of triplicates; C3G = cyaniding 3-*O*-glucoside.

Table 3. Yield percentages of extracts and fractions of *C. nitida*.

Extract/Fraction	Percentage yield (%w/w)
ECn1	15.4
ECn2	48.0
Fr1	2.0
Fr2	4.2
Fr3	15.9
Fr4	13.4
Fr5	62.9

2.2. pH, total soluble solids and total acidity

The pH and total soluble solids of the *C. nitida* fruits were determined using a pH meter (Hanna Instruments HI 2210, Woonsocket, RI) and a digital Hanna refractometer (Hanna Instruments, Woonsocket, RI), 0–85% range at 20 °C, respectively. The total titratable acidity was determined according to Association of Analytical Chemists International (A.O.A.C) method (AOAC, 2003).

2.3. Proximate analysis

The moisture content was determined by the gravimetric method at 105 °C until constant weight. The crude protein content was calculated by multiplying the nitrogen content obtained by the Kjeldahl method (International Organization for Standardization, 2009) by factor 6.25. The total fat, dietary fiber and ash contents were determined according to the respective A.O.A.C methods (AOAC, 2003).

2.4. Preparation of extract of C. nitida leaves and fruits

730 g of dried, ground leaves was extracted by maceration with ethanol at room temperature. The ethanolic extract obtained (ECn1) was flocculated with water:acetone (2:1 v/v) and subsequently filtered and fractionated.

2.5 g of freeze-dried fruits was powdered in liquid nitrogen and ultrasound-assisted extraction was carried out using methanol (ECn2).

2.4.1. Fractionation of the ethanolic extract of C. nitida leaves (ECn1)

84 g of ECn1 was partitioned by continuous liquid-liquid extraction with solvents of increasing polarity, obtaining five fractions: n-hexane (Fr1), dichloromethane (Fr2), ethyl acetate (Fr3), n-butanol (Fr4) and an aqueous residue (Fr5).

2.22 g of Fr1 was fractionated by Column Chromatography (CC) using mobile phase n-hexane:ethyl acetate (gradient 0–100%), obtaining a yellow oil (**Cn1**, 0.1142 g) which was analyzed by Gas Chromatography coupled to a Mass Spectrometry (GC-MS); a white solid (**Cn2**, 0.1380 g), which was analyzed by GC-MS and purified by crystallization with chloroform – hexane to obtain a solid **3**; a white solid (**Cn3,** 0,0843 g), which was recrystallized from chloroform – n-hexane to obtain solid **5**; and finally a white solid (**6**, 0.0923 g).

Fractions Fr3 and Fr4 were monitored by RP18 TLC (Merck), using methanol:water (8:2) as mobile phase and spraying with revealing natural product - polyethylene glycol reagent (NP/PEG). 2 g of Fr3 was fractionated by CC using sephadex LH20 and MeOH:H$_2$O (gradient 0–100%), obtaining a yellow solid **7** (0.0638 g).

For the separations by CC silica gel 60 (63–120 μm) was used, and the TLC were performed on silica gel 60 or RP–18 chromatoplates, with detection under UV light (254, 366 nm), iodine vapors, NP/PEG reagent and vanillin/H$_2$SO$_4$ followed by heating. The metabolites obtained were identified by IR, UV/vis, and NMR spectroscopy, chromatography, and mass spectrometry.

The yellow oil (**Cn1**) and white solid (**Cn2**) were analyzed by GC-MS on an Agilent Technologies 7890AGC gas chromatograph coupled to a mass spectrometer Hewlett Packard 5973 with quadrupole analyzer, electron ionization (IE) at 70 eV in full scan mode at 4.75 scan/s, in the mass range m/z 20–300 uma, a split/splitless injector, and GC column Rtx-5MS of 30 m × 0.25 mm (id) x 0.25 μm (df). The oven was set to a temperature of 80 °C (1 min), then increased to 310 °C (10min) @ 10 °C min^{-1}. The temperatures of the ionization chamber and transfer line were 230 °C and 285 °C, respectively. The gas carrier used was helium (99.995%, Aga Fano, S.A), with a constant flow of 1 mL min^{-1}. The
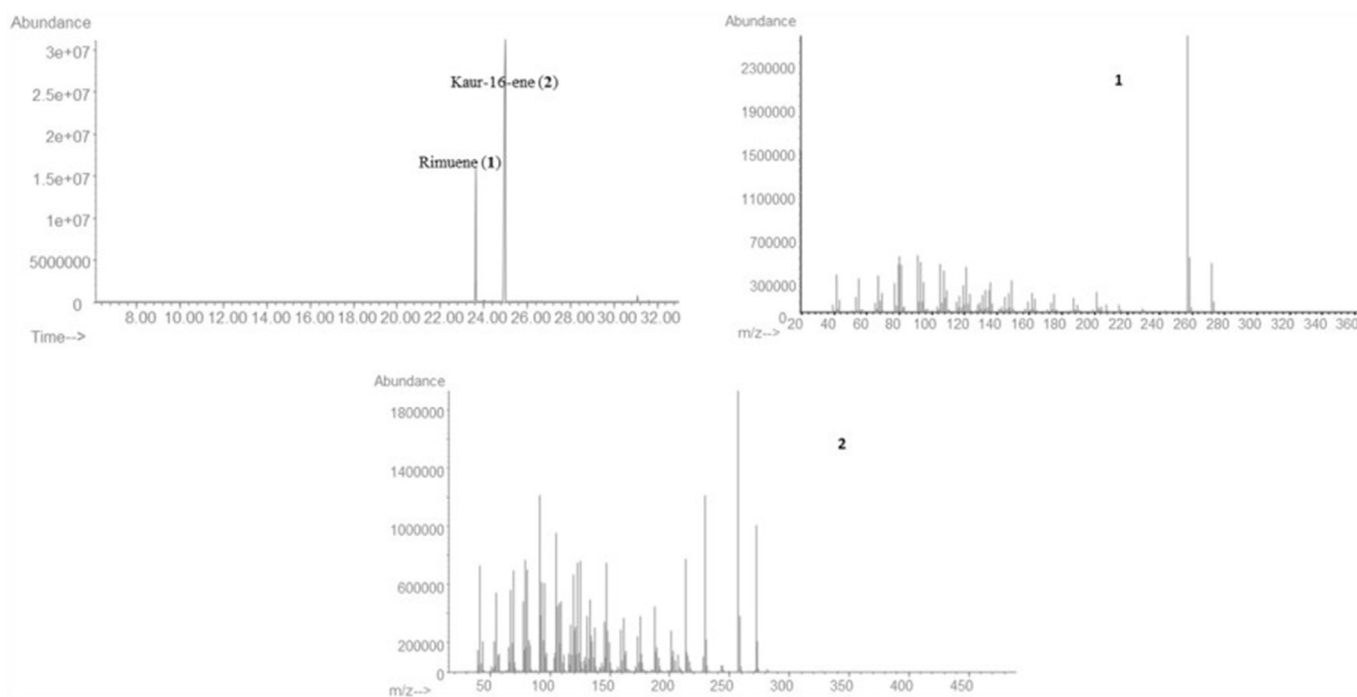

Figure 2. GC-MS total ion chromatogram (TIC) of **Cn1** and 1 - mass spectrum of Rimuene (**1**); 2 – mass spectrum of Kaur-16-ene (**2**).
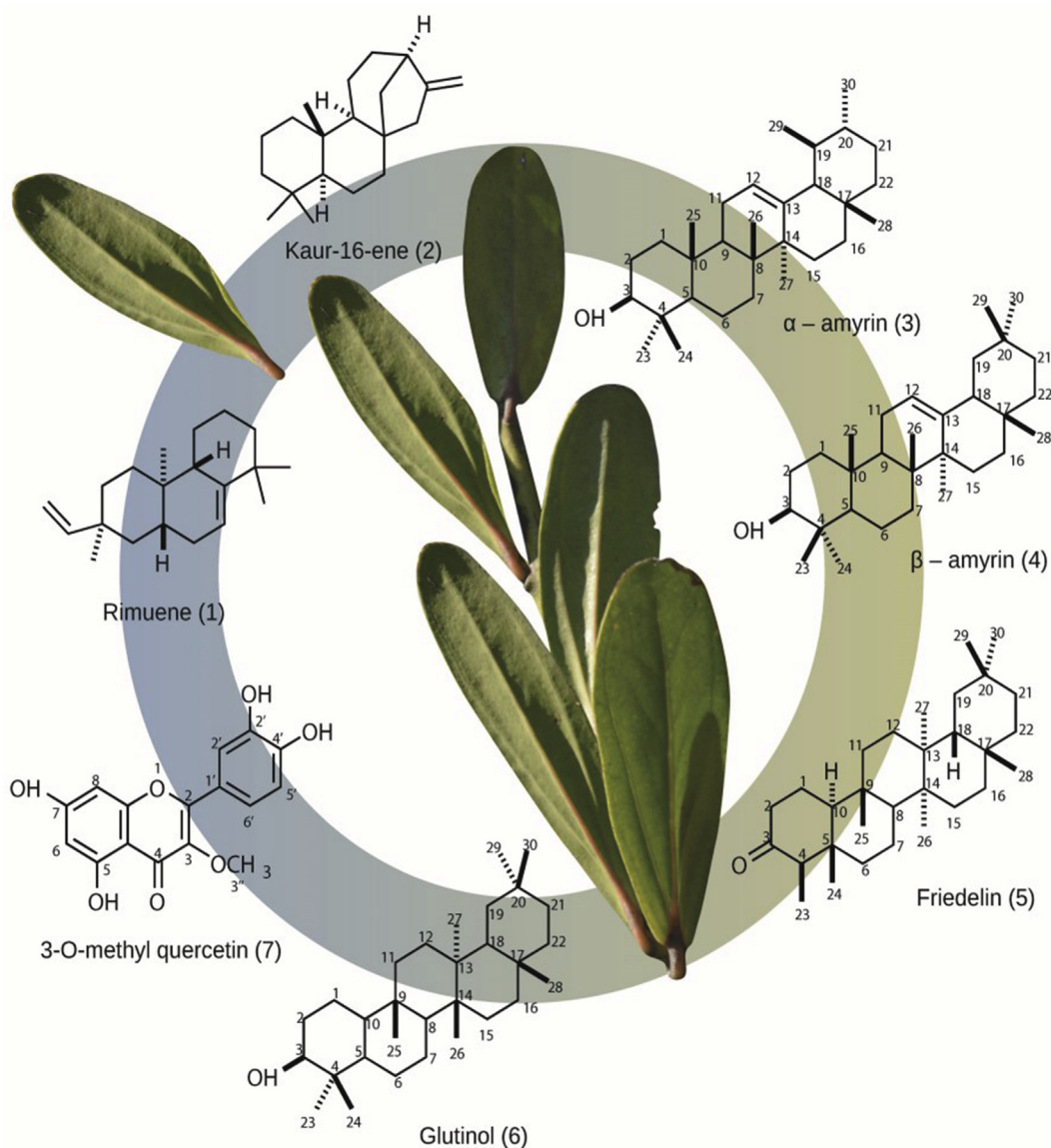
Figure 3. Metabolites isolated from leaves of *C. nitida*. Compounds **1** to **7** are first reported for the species.

components present in the fractions were identified by comparison of the acquired mass spectrum with those reported in the Willey8 and NIST14 databases.

2.5. Analysis of total phenolic compounds

The total phenolic content was determined by the Folin-Ciocalteu method (Ainsworth and Gillespie, 2007; Llivisaca et al., 2018; Wootton-Beard et al., 2011). 400 μL of Folin-Ciocalteu reagent (10% v/v) was added to 200 μL of extract or fraction (2.5 mg mL^{-1}). After 5 min, 1600 μL of Na$_2$CO$_3$ (7.4% w/v) was added and the solution was left to rest for 2 h at room temperature. Finally, the absorbance at 765 nm was measured. The total phenolics content was determined by the equation obtained from the calibration curve, using gallic acid as standard, and the results are expressed as mg of gallic acid equivalents (GAE) per g of fresh weight (fw).

2.6. Analysis of total flavonoids

The total flavonoid content was determined by the AlCl$_3$ method (Woisky and Salatino, 1998). 150 μL of AlCl$_3$ 2% w/v, 150 μL of 1M HCl

and 150 μL of 1M CH$_3$COOK was added to 50 μL of extract or fraction (2.5 mg mL^{-1}). Subsequently, 850 μL of methanol was added. The solution was left to rest, in the dark, at room temperature, for 40 min and the absorbance at 425 nm was measured. The total flavonoid content was determined by the equation obtained from the calibration curve using quercetin as standard, and the results are expressed as mg of quercetin (QE) per g of fresh weight (fw).

2.7. Analysis of anthocyanins

2.7.1. Analysis of total monomeric anthocyanin

The total monomeric anthocyanin content was determined by the pH differential method (Giusti and Wrolstad, 2001) and the absorbencies were measured at 510 and 700 nm. The anthocyanin content was calculated as cyanidin 3-glucoside (C3G), with the extinction coefficient (ε) of 26900 L cm^{-1} mol^{-1} and molecular mass (449.2 g mol^{-1}). The results are expressed as mg of C3G equivalents per g of fw.

2.7.2. Analysis of anthocyanin contents by UPLC-DAD

The anthocyanin content was determined by UPLC-DAD (Brown and Shipley, 2011) using a Shimadzu Prominence Nexera-I (Kyoto, Japan),
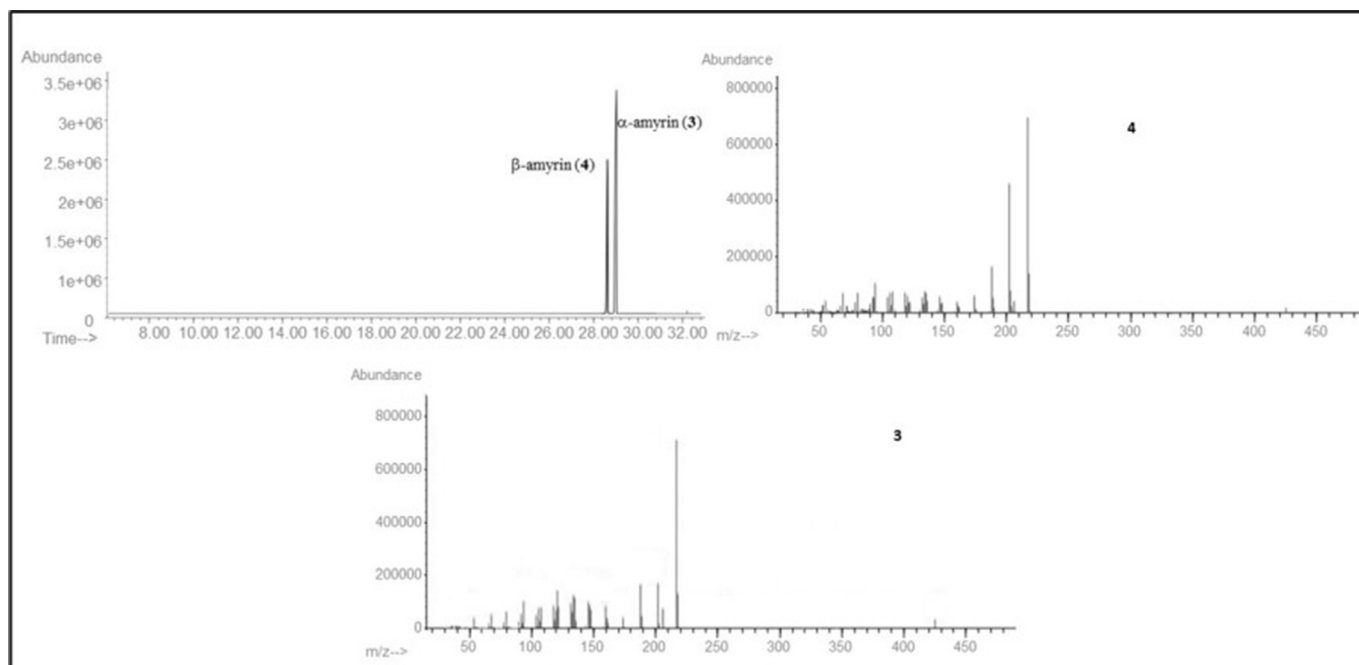
Figure 4. GC-MS total ion chromatogram (TIC) of **Cn2** and **3** - mass spectrum of α-amyrin (**3**); **4** – mass spectrum of β-amyrin (**4**).
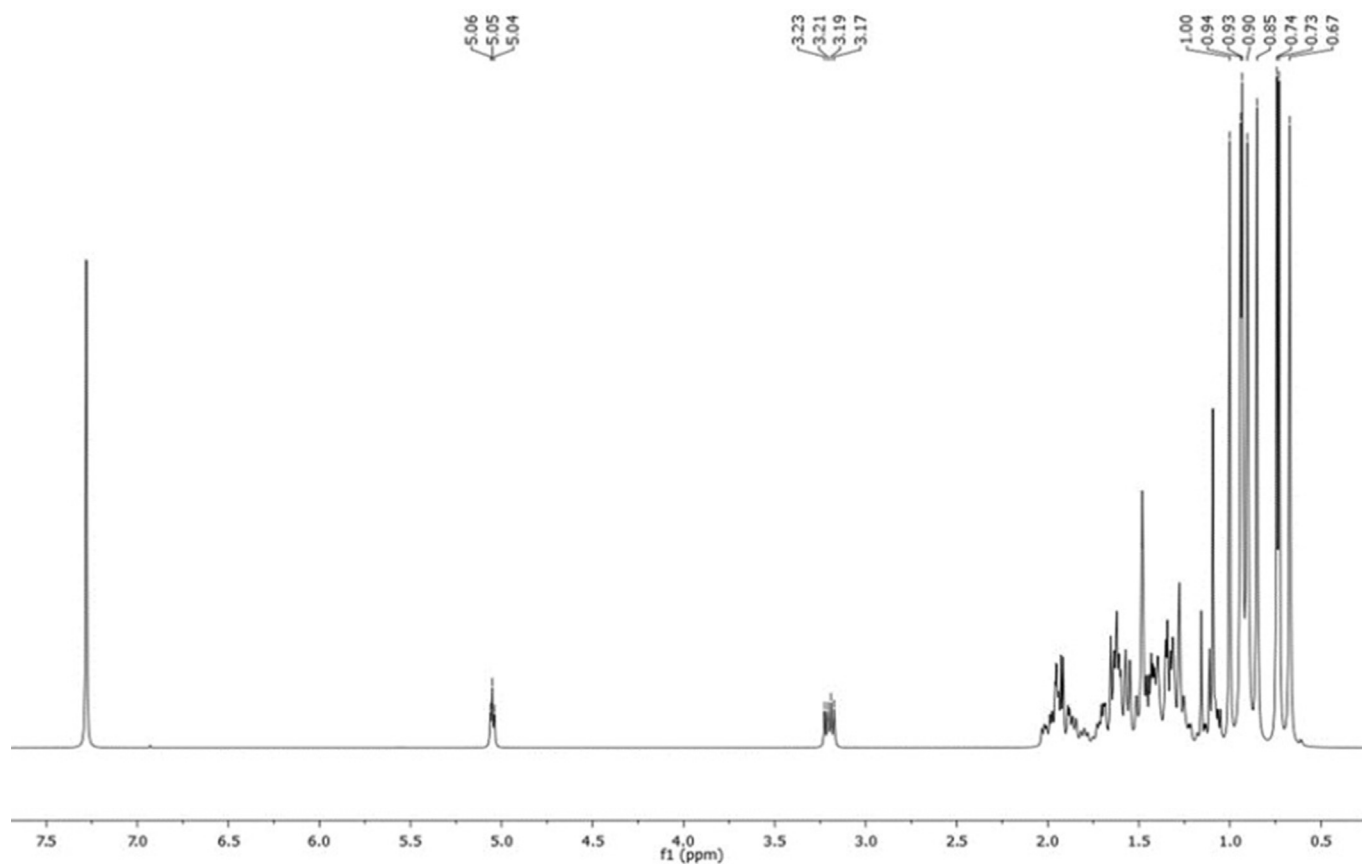

Figure 5. ^{1}H-NMR spectrum (CDCl$_3$) of a-amyrin (**3**).

with an SPD-M20A DAD system. The data collection was performed using Shimadzu LC Solution software. For the sample preparation and UPLC analyses, deionized water, and solvents such as methanol, acetonitrile (ACN), and 88% formic acid (v/v), were used. A Phenomenex Kinetex® C18 column (100 mm × 2.1 mm id x 2.6 μm particle size) was used, at a temperature of 40 °C. The mobile phases were (A) formic acid (2%) and (B) acetonitrile-formic acid (1%), and the solvents used were HPLC grade (Merck, Darmstadt, Germany). For the separation, ACN/HCOOH gradient was used, starting with 5–11% B for 4.17 min, then 11–18% B for 9.58 min, 18–35% for 0.42 min, and finally 35-5% B for 2 min. The
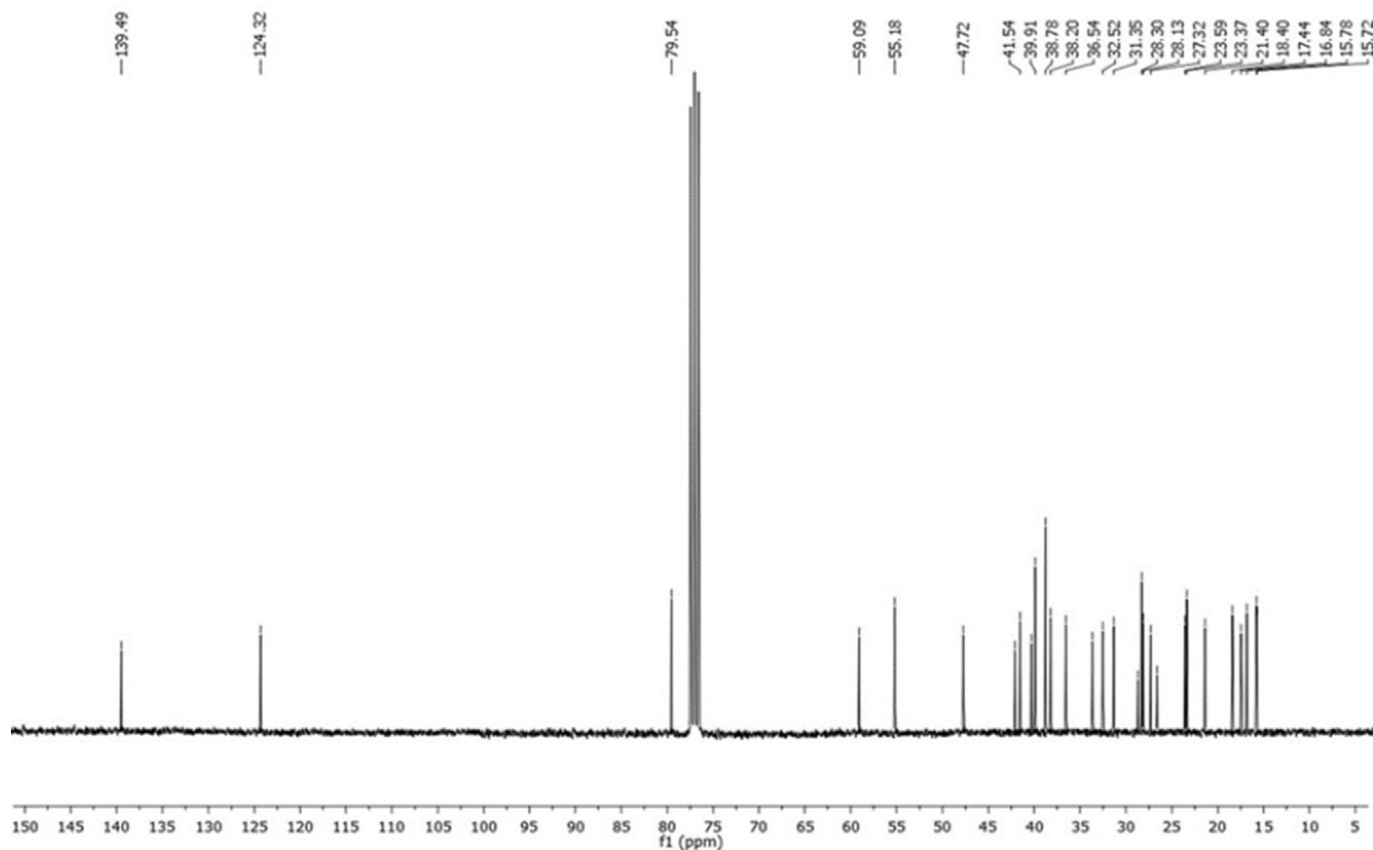
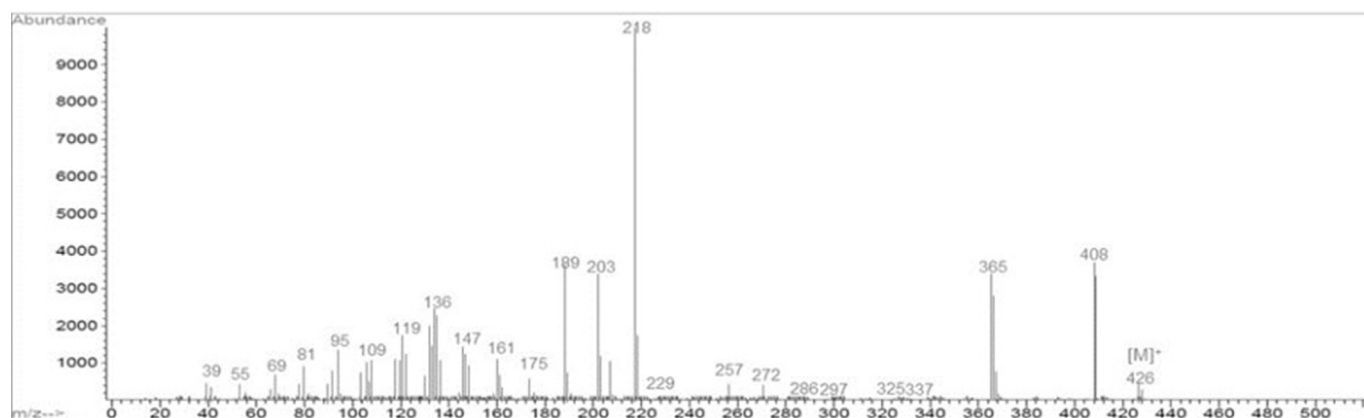**Figure 6.** ^{13}C-NMR spectrum (CDCl$_3$) of a-amyrin (**3**).

Figure 7. Mass spectrum of α-amyrin (**3**).

injection volume and flow rate were 3 μL and 0.5 mL min^{-1}, respectively and detection was achieved at 520 nm. For each extract or fraction, 250 mg was weighed in 20 mL of methanol, from which 1 mL had been previously filtered.

For the compound identification, the retention times and UV/vis spectrum of each peak in the chromatogram were compared to the standards, and the anthocyanin content was calculated by the equation obtained from the calibration curve using six standards: cyanidin 3-O-galactoside (C3Ga), cyanidin 3-O-glucoside (C3G), cyanidin 3-O-arabinoside (C3A), peonidin 3-O-glucoside (P3G), malvidin 3-O-glucoside (M3G), and petunidin 3-O-glucoside (Pe3G). Table 1 shows the standard concentrations. Anthocyanin standards were obtained from Sigma-Aldrich (St. Louis, MO, USA) and PhytoLab (Vestenbergsgreuth, Germany). Due to the unavailability of some standards, such as delphinidin

anthocyanins, this type of anthocyanin was tentatively identified by UPLC-ESI/MS based on accurate mass and fragmentation ion patterns of ion peaks compared with previous theoretical and experimental mono-isotopic masses reported for the Ericaceae family, using a mass accuracy <5 ppm (Ma et al., 2013).

UPLC-ESI/MS analyses were performed on a Shimadzu® LCMS-9030 QqQ–time-of-flight (Q-TOF) LC–mass spectrometer equipped with a UV/vis detector (SPD-20AV) (Shimadzu Scientific Instruments, Columbia, MD, USA). The ESI interface was controlled by workstation LabSolutions™ LCMS for LCMS-9030. Mass spectrums were acquired in both positive and negative modes over the range m/z 100–1000. The capillary voltages were set at +3 kV and -2.8 kV, and the cone voltage was 20 V. The nebulization and desolvation gas used was nitrogen. The desolvation and cone gas flow rates were 300 and 20 L h^{-1}, respectively. The
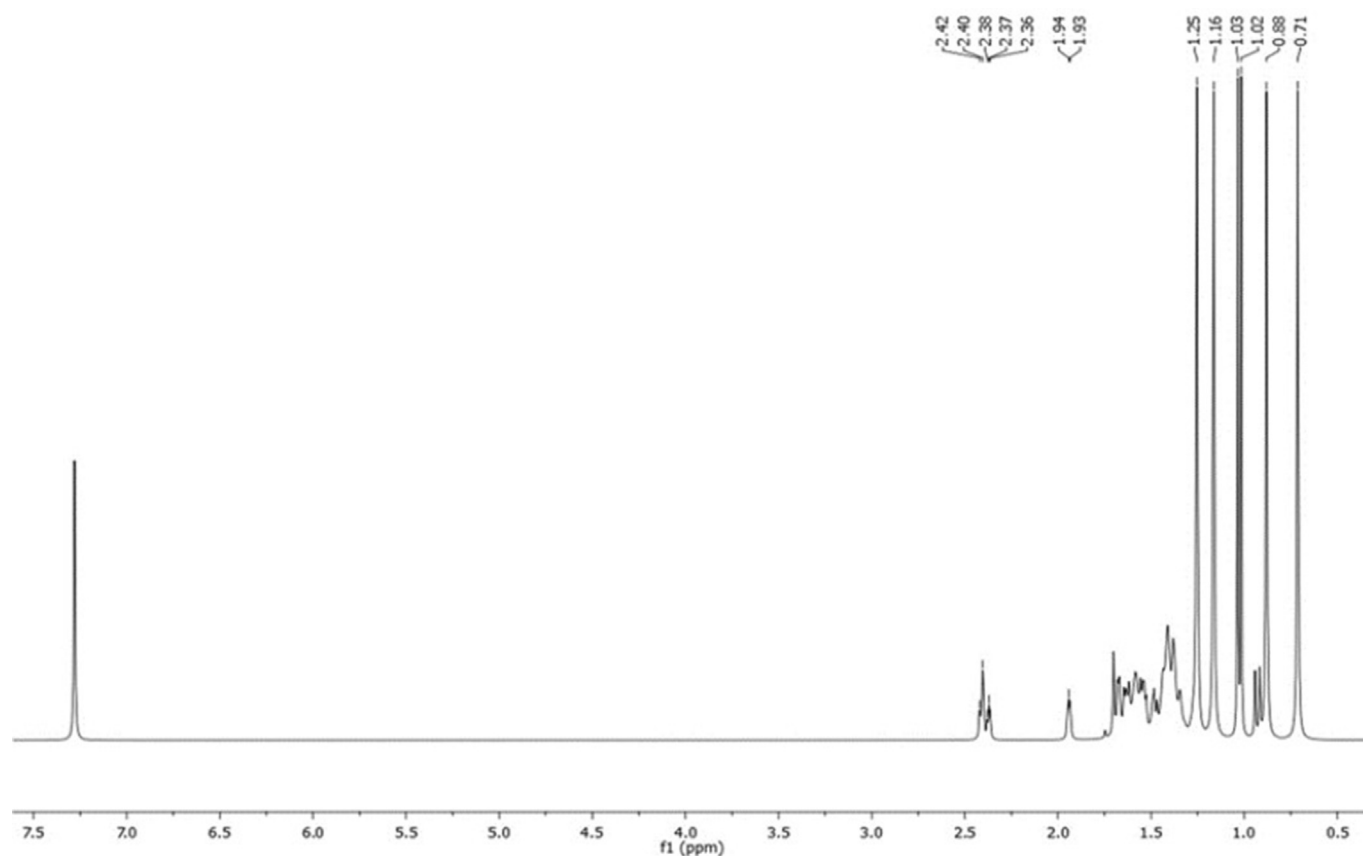
Figure 8. ^{1}H-NMR spectrum (CDCl$_3$) of Friedelin (**5**).

desolvation temperature was 400 °C, and the source temperature was 120 °C. Positive and negative ESI data were collected using a scan time of 500 ms (Ma et al., 2013).

2.8. Antioxidant activities by radical scavenging capacity of DPPH$^\bullet$ and ABTS$^{\bullet+}$ assays

The antioxidant activity of the extracts (ECn1 and ECn2) and fractions were determined by radical scavenging capacity of 1,1-diphenyl-2-picryl-hydrazyl (DPPH$^\bullet$) at 520 nm, and radical scavenging capacity ABTS$^{\bullet+}$ at 740 nm, both read on a FLUOStar Omega plate reader (BMG Labtech) Methanol was used as negative control, and Trolox as positive control, at concentrations of 0–10 mg L^{-1} (Garzón et al., 2010; Giraldo Vásquez and Ramírez Aristizabal, 2013; Guija-Poma et al., 2015; Llivisaca et al., 2018; Nuengchamnong and Ingkaninan, 2017; Wootton-Beard et al., 2011). The DPPH$^\bullet$ and ABTS$^{\bullet+}$ free radical scavenging activity were calculated as mean inhibitory concentration (IC$_{50}$).

2.9. Statistical analysis

The results are representative of three independent replicates and are expressed as mean $\pm$ SD. The correlation between antioxidant activity and phenolic and flavonoid contents of *C. nitida* was determined by the Pearson correlation test, previous tests of homoscedasticity, and normality of the data. The analyzes were conducted using the RStudio program, Version 1.2.1335, of the corTest package.

3. Results and discussion

3.1. Physicochemical characteristics

Cavendishia nitida can be considered a wild edible fruit (López Diago and García Castro, 2021) and its nutrition value has not yet been

investigated. We determined some quality parameters of the fruit, which are described in Table 2. The total acidity (as citric acid %) and total soluble solids (°Brix) are related to the flavor of the fruit, and the pH gives an indication of the ability of the fruit to withstand microbial growth [26]. The color of the fruit is influenced by the pH, among other factors. Anthocyanins are red at low pH and turn blue as the pH increases (Khoo et al., 2017).

The results of the proximal analysis of *C. nitida* berries are shown in Table 2. The high moisture content (83.31%) in the fruits is similar to the values reported for other berries (Padmanabhan et al., 2015), and makes them more susceptible to spoilage due to microbial contamination, reducing the shelf life of the fresh fruit. The ash measurement indicates the mineral content in food (Rashidinejad, 2020). The ash values for *C. nitida* (0.30%) are similar to those of other berries (Padmanabhan et al., 2015). *C. nitida* fruits are a source of dietary fiber, with 3.26% of fruit weight consisting of fiber, which is similar to the values found for blueberries of *Vaccinium* ssp. (3–3.5%) (Michalska and Łysiak, 2015).

Enzymes require minerals (Table 2) to catalyze metabolic reactions. Potassium (236.9 mg per 100 g, dry weight) was the most abundant element in the fruits of *C. nitida*, followed by sodium (114.9 mg per 100 g, dry weight), phosphorus (84.9 mg per 100 g, dry weight), calcium (11.5 mg per 100 g, dry weight) and iron (1.3 mg per 100 g, dry weight).

Ascorbic acid is used as an antioxidant and preservative, helping to extend the shelf life of the fruits (Skrovankova et al., 2015; Valente et al., 2011). The content of ascorbic acid in the fruits is cultivar-dependent. In *C. nitida* fruit, ascorbic acid (62.0 mg per 100 g, fresh weight) (Table 2) is present in higher concentrations than the average value for blueberries (10 mg per 100 g, fresh weight) (Michalska and Łysiak, 2015; Shivembe and Ojinnaka, 2017), and is similar to the content found in strawberries and raspberries (Skrovankova et al., 2015). The vitamin content, as thiamine (0.05 mg per 100 g, fresh weight) and riboflavin (0.79 mg per 100 g, fresh weight), is similar to that of other berries (Michalska and Łysiak, 2015; Golubtsova, 2017).
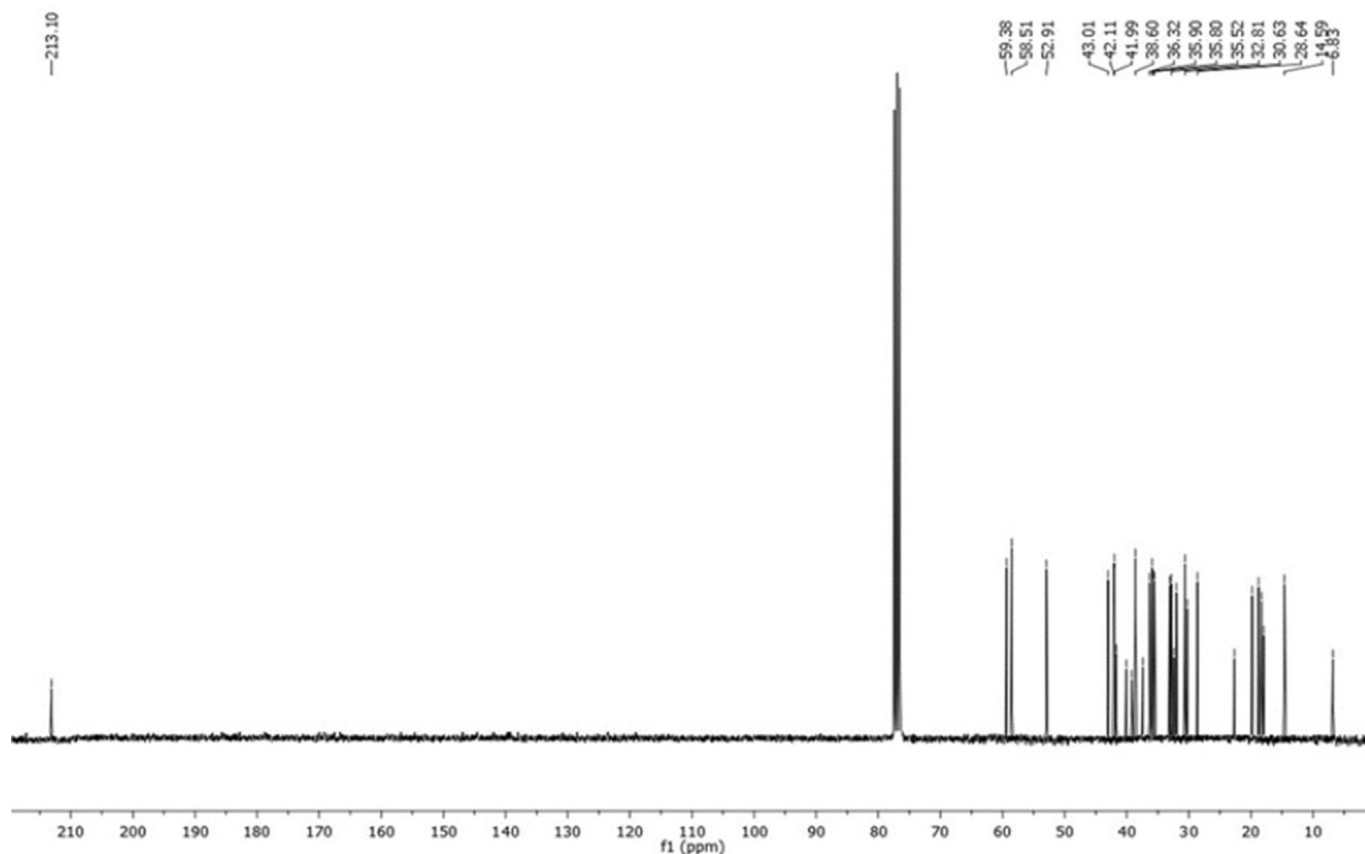
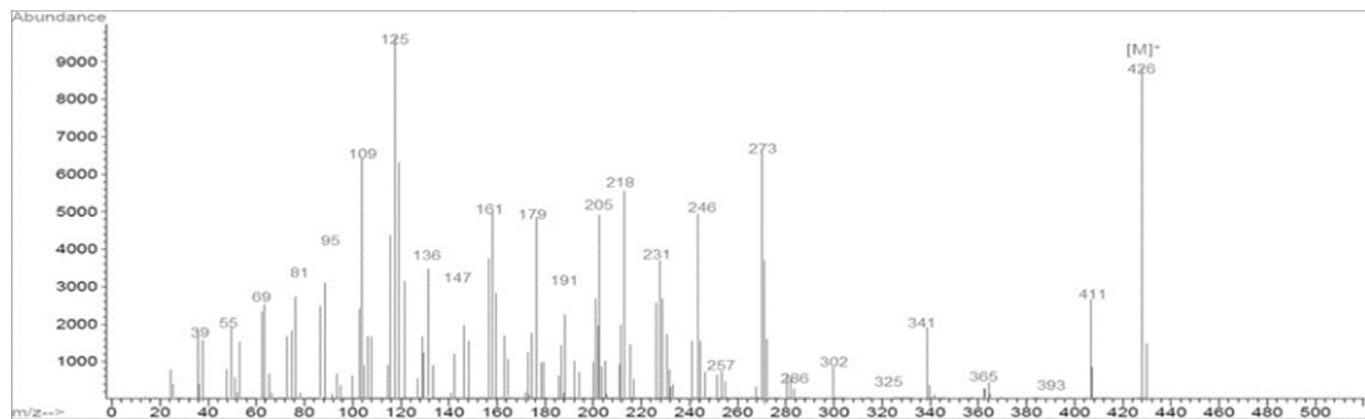**Figure 9.** ^{13}C-NMR spectrum (CDCl$_3$) of Friedelin (**5**).

Figure 10. Mass spectrum of Friedelin (**5**).

3.2. Cavendishia nitida extracts and fractions

Table 3 shows the yield percentages of the crude extracts of the leaves (ECn1) and fruits (ECn2) of *C. nitida*, and the fractions of ECn1 (Fr1 – Fr5).

In the GC-MS analysis of **Cn1** (Figure 2), two compounds were determined: Rimuene (**1**) and Kaur-16-ene (**2**) (Figure 3). Rimuene (**1**) is a diterpene, and is not taxonomically restricted, although it has been reported in plants of the genus *Cavendishia* and others of the family Ericaceae (Salasoo, 1988; Zamudio et al., 2019). It has also been isolated from plants of different families, such as Podocarpaceae, Cupressaceae, and Illiciaceae (Vijayakumar et al., 2012). Studies with extracts containing this compound have reported anticancer and antimicrobial activity, however, it is unknown whether they are caused specifically by

this compound (Sylvestre et al., 2005; Vijayakumar et al., 2012). Kaur-16-ene (**2**), another diterpene, has been reported for other species of the genus *Cavendishia* (Zamudio et al., 2019), the Asteraceae family, specifically the genus *Pentacalia*, and the Cupressaceae family (Matsunaga et al., 2012). Kaurano-type compounds have antibacterial activity (Sylvestre et al., 2005).

From the analysis by GC-MS of white solid **Cn2** (Figure 4), two triterpenes were determined: α – amyrin (**3**) and β – amyrin (**4**) (Figure 3). These compounds have been reported in plants of the Ericaceae, Balanophoraceae, and Combretaceae families and there have been studies of their anti-inflammatory and antibacterial activity (Malca Garcia et al., 2015; Matulevich et al., 2016; Salih et al., 2018).

α – amyrin (**3**) was purified from **Cn2** by crystallization with chloroform – hexane to obtain a needle-shaped white solid **3**. soluble in
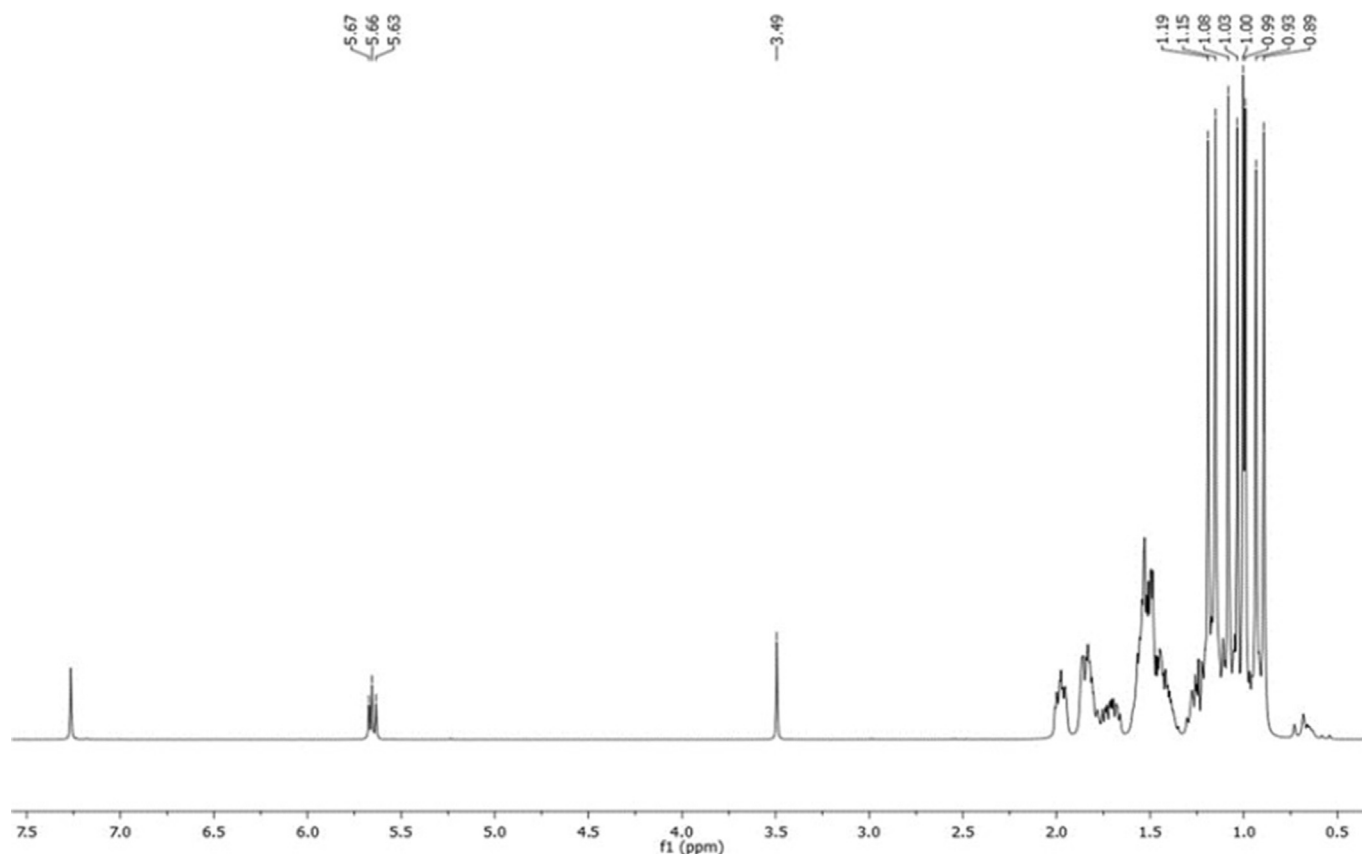
Figure 11. ^{1}H-NMR spectrum (CDCl$_3$) of Glutinol (**6**).

chloroform, m.p. 182–184 °C (lit. 182–183 °C, (Sirat et al., 2010)). IR (CHCl$_3$), ν (cm^{-1}): 3400, 2900, 1600, 1460, 1380, 1100. ^{1}H-NMR (300 MHz, CDCl$_3$) (Figure 5), δH (ppm): 5.05 (t, J = 3.2, H-5), 3.20 (dd, J = 5.0; 11.0, H-3), 1.96 (td, J = 4.5; 13.5, H-15β), 1.84 (dt, J = 3.0; 8.0, H-22), 1.76 (td, J = 5.0; 13.0, H-16β), 1.00 (s, H-27), 0.94 (s, H-28), 0.93 (s, H-23), 0.90 (s, H-26), 0.85 (d, J = 6.0, H-29), 0.74 (s, H-24), 0.73 (d, J = 7.0, H-30), 0.72 (s, H-25), 0.67 (d, J = 11.6, H-5). ^{13}C-NMR (75 MHz, CDCl$_3$) (Figure 6), δC (ppm): 139.5 (C-13), 124.3 (C-12), 79.5 (C-6), 59.1 (C-18), 55.2 (C-5), 47.7 (C-9), 42.1 (C-14), 41.5 (C-22), 39.9 (C-19), 39.9 (C-8), 38.6 (C-1), 38.2 (C-4), 36.5 (C-10), 33.6 (C-17), 32.5 (C-7), 31.3 (C-21), 28.7 (C-2), 28.3 (C-28), 28.1 (C-23), 27.3 (C-15), 26.6 (C-16), 23.6 (C-11), 23.4 (C-27), 21.4 (C-30), 18.4 (C-6), 17.4 (C-29), 16.8 (C-26), 15.8 (C-25), 15.7 (C-24). The ^{1}H and ^{13}C NMR data agree with literature (Sirat et al., 2010). EIMS: 70 eV, m/z (% intensity): 426 M$^+$, 408 (37), 365 (33), 218 (100), 203 (34), 189 (36), 136 (24), (Figure 7)

Friedelin (**5**) (Figure 3). needle-shaped white solid, recrystallized in hexane – AcOEt, m.p. 259–260 °C (lit. 261–262 °C, (Subhadhirasakul and Pechpongs, 2005)); IR (CHCl$_3$) ν (cm^{-1}): 2930, 1700, 1460, 1380. ^{1}H-NMR (300 MHz, CDCl$_3$) (Figure 8), δH (ppm): 2.42–2.40 (m, H-2), 2.38–2.36 (m, H-4), 1.95–1.93 (m, H-1), 1.75–1.34 (m), 1.25 (s, H-28), 1.16 (s, H-27), 1.03 (s, H-26), 1.02 (s, H-29), 0.94 (s, H-30), 0.90 (d, J = 6.4 Hz, H-23), 0.88 (s, H-25), and 0.71 (s, H-24). ^{13}C-NMR (75 MHz, CDCl$_3$) (Figure 9), δC ppm: 213.1 (C-3), 59.4 (C-10), 58.5 (C-4), 52.9 (C-8), 43.0 (C-18), 42.1 (C-5), 42.0 (C-2), 41.7 (C-6), 40.1 (C-14), 39.2 (C-22), 38.6 (C-13), 37.4 (C-9), 36.3 (C-16), 35.9 (C-11), 35.8 (C-19), 35.5 (C-29), 33.1 (C-21), 32.8 (C-15), 32.4 (C-28), 32.0 (C-30), 30.6 (C-12), 30.3 (C-17), 28.6 (C-20), 22.7 (C-1), 19.8 (C-26), 18.8 (C-27), 18.3 (C-7), 18.0 (C-25), 14.6 (C-24), 6.8 (C-23). The 1H and 13C NMR data agree with literature (Subhadhirasakul and Pechpongs, 2005). EIMS (Figure 10) m/z (% intensity): 426 ([M$^+$], 93), 411 (28), 341 (20), 302

(56), 274 (40), 273 (70), 246 (51), 231 (39), 218 (58), 205 (51), 179 (50), 125 (100), 109 (68).

Glutinol (**6**) (Figure 3). Amorphous white solid, m.p. 202–203 °C (lit. 201–203 °C, (Abdel-Sattar et al., 2015)); IR (CHCl$_3$) (cm^{-1}): 3450, 2950, 1600, 1380, 1090. ^{1}H-NMR (300 MHz, CDCl$_3$) (Figure 11), δH (ppm): 5.65 (t, H-6), 3.5 (s, H-3α), 1.19 (s, H-28), 1.15 (s, H-24), 1.08 (s, H-26), 1.03 (s, H-23), 1.00 (s, H-27), 0.99 (s, H-30), 0.93 (s, H-29), 0.89 (s, H-25). ^{13}C-NMR (75 MHz, CDCl$_3$) (Figure 12), δC ppm: 141.6 (C-5), 122.3 (C-6), 76.3 (C-3), 49.6 (C-10), 47.4 (C-8), 43.2 (C-18), 41.0 (C-4), 39.2 (C-13), 39.1 (C-22), 38.0 (C-14), 36.1 (C-16), 35,3 (C-19), 35.1 (C-9), 34.8 (C-11), 34.6 (C-29), 33.1 (C-21), 32.5 (C-30), 32,3 (C-15), 32.2 (C-28), 30.4 (C-12), 30.2 (C-17), 29.0 (C-23), 28.2 (C-20), 28.0 (C-2), 25.4 (C-24), 23.6 (C-7), 19.6 (C-26), 18.4 (C-27), 18.2 (C-1), 16,2 (C-25). The ^{1}H and ^{13}C NMR data agree with literature (Abdel-Sattar et al., 2015).

3-*O*-methyl quercetin (**7**) (Figure 3). Yellow crystals, recrystallized in methanol – H$_2$O, m.p. 275–276 °C. UV-VIS (MeOH), λ (nm): 256, 358; (AlCl$_3$) 270 y 433; (AlCl$_3$/HCl) 274 y 408; (MeONa) 268 y 405; (AcONa) 273 y 400; (AcONa/H$_3$BO$_3$) 260 y 380. IR ν (cm^{-1}): 3426, 1465, 1630, 1260. ^{1}H NMR NMR (300 MHz, acetone-d$_6$) (Figure 13), δH (ppm): 3.70 (s, H, OCH$_3$-3″), 12.69 (s, H, OH-5), 6.30 (d, J = 1.8 Hz, H-6), 10.70 (s, H, OH-7), 6.39 (d, J = 2.01 Hz, H-8), 7.56 (d, J = 1.98 Hz, H-2′), 10.72 (s, H, OH-3′), 10.79 (s, H, OH-4′), 6.87 (d, J = 8.0 ′Hz, H-5′), 7.40 (dd, J = 1.98, 8.1 Hz, H-6′). ^{13}C NMR (75 MHz, acetone-d$_6$) (Figure 14), δC (ppm): 175.7 (C-4), 162.1 (C-7), 160.3 (C-5), 154.9 (C-9), 151.9 (C-2), 148.6 (C-4′), 143.1 (C-3′), 137.5 (C-3), 122.8 (C-1′), 120.2 (C-6′), 115.7 (C-5′), 115.5 (C-2′), 105.0 (C-10), 96.9 (C-8), 91.7 (C-6), 59.1 (OCH$_3$-3″), ^{1}H and ^{13}C NMR data were consistent with the literature (Kumar et al., 2016). ESI-MS (m/z) 315 [M-H] $^+$ (Figure 15).

Triterpenoids have been reported in plants of the genus *Cavendishia* and others of the family Ericaceae (Salasoo, 1988; Zamudio et al., 2019)
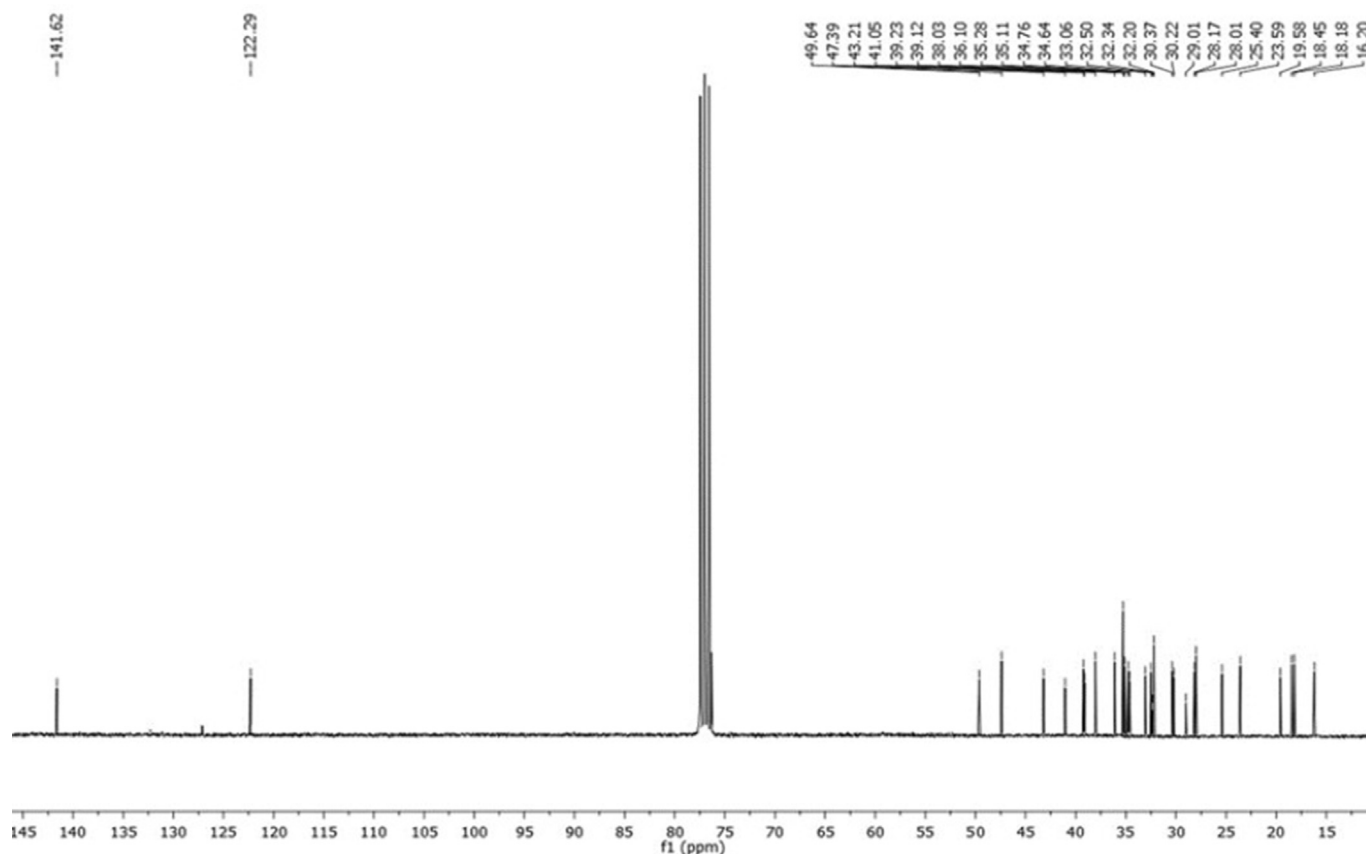
Figure 12. ^{13}C-NMR spectrum (CDCl$_3$) of Glutinol (**6**).

and are components that have aroused great interest as anti-inflammatory agents, the presence of triterpenes in *C. nitida* could suggest their potential pharmacological use. In fact, some communities in Colombia mention the use of *C. bracteata* leaves, in decoction, to treat arthritis.

3.3. Total phenolics, flavonoids, anthocyanins, and antioxidant activity

Berries of the Ericaceae family (blueberry, cranberry) are great food sources and rich in bioactive compounds (total phenolics, flavonoids, anthocyanins, and ascorbic acid) (Skrovankova et al., 2015) Phenols and flavonoids are compounds with high pharmacological activity: they have antiviral, anti-inflammatory, antifungal activity, and antioxidant activities that regulate the formation of reactive oxygen species and decrease the degradation processes of macromolecules, such as lipid peroxidation. Due to this activity, they are used as food additives (Gutiérrez et al., 2010; Havsteen, 2002; Heim et al., 2002; Ilić et al., 2021; Pourcel et al., 2007; Shakil et al., 2008; Sharma et al., 2019). The total content of phenolic compounds in berries is cultivar-dependent, growing conditions and maturity (Skrovankova et al., 2015).

Table 4 shows the values of phenols (mg of gallic acid equivalents (GAE) per g fw) and total flavonoids (mg of quercetin equivalents (QE) per g of fw) present in the extracts and fractions analyzed. The leaves extract (ECn1) has the highest content of the two metabolites analyzed, while the fruit extract (ECn2) has the lowest content. This study showed the same behavior as *Cavendishia bracteata* (Plazas González, 2015). This trend could be explained by a greater presence of tannins in the leaves compared to the other organs of the plant, a tendency reported for other plants belonging to Ericaceae (Abreu Guirado et al., 2008). The total phenolic content (3.9 mg GAE per g fw) and flavonoids (2.5 mg QE per g fw) in *C nitida* fruits is comparable with the values reported in the literature for other berries (Dastmalchi et al., 2011; Rashidinejad, 2020; Skrovankova et al., 2015).

Leaves and fruits of *C. nitida* were collected at 2900 mamsl. At this altitude, the plants are subjected to stress for low temperature and intense sunlight, with the consequent oxidative stress (Taiz et al., 2014). Under these conditions, the synthesis of flavonoids, anthocyanins and other phenolic compounds increases, as a mechanism to mitigate damage to the plant (Ramakrishna and Ravishankar, 2011).

3.4. Total anthocyanins content

Plants of the Ericaceae family, such as blueberry or cranberry, are among the main sources of anthocyanins in edible plants (Hyun et al., 2015). *Cavendishia nitida* produces berries of up to 14.33 mm in diameter, with colors ranging from red to purple, indicating high anthocyanin content. The total monomeric anthocyanin content in cranberries is 25–100 mg per 100 g of fresh weight (fw) and in blueberries, it is 25–495 mg per 100 g fw. This composition is dependent on cultivar, growing conditions and maturity (Padmanabhan et al., 2015; Rashidinejad, 2020). *Cavendishia nitida* fruits contain 503.1 mg of C3G equivalents per g of fw (Table 2), a value that is comparable with blueberries. Due to the high antioxidant potential of anthocyanins, these compounds present in blueberries are expected to inhibit oxidative processes related to vascular diseases and cancer (Ilić et al., 2021; Martín-Gómez et al., 2021; Neto, 2007).

3.5. Analysis of anthocyanin content by UPLC-DAD.

Figure 16 shows the chromatographic profile of *Cavendishia nitida* fruits. Comparing the retention times and UV/vis data of the fruit extract with the data for six standards: cyanidin 3-*O*-galactoside (C3Ga), cyanidin 3-*O*-glucoside (C3G), cyanidin 3-*O*-arabinoside (C3A), peonidin 3-*O*-glucoside (P3G), malvidin 3-*O*-glucoside (M3G), and petunidin 3-*O*-glucoside (Pe3G), three anthocyanins were identified (Table 5): cyanidin
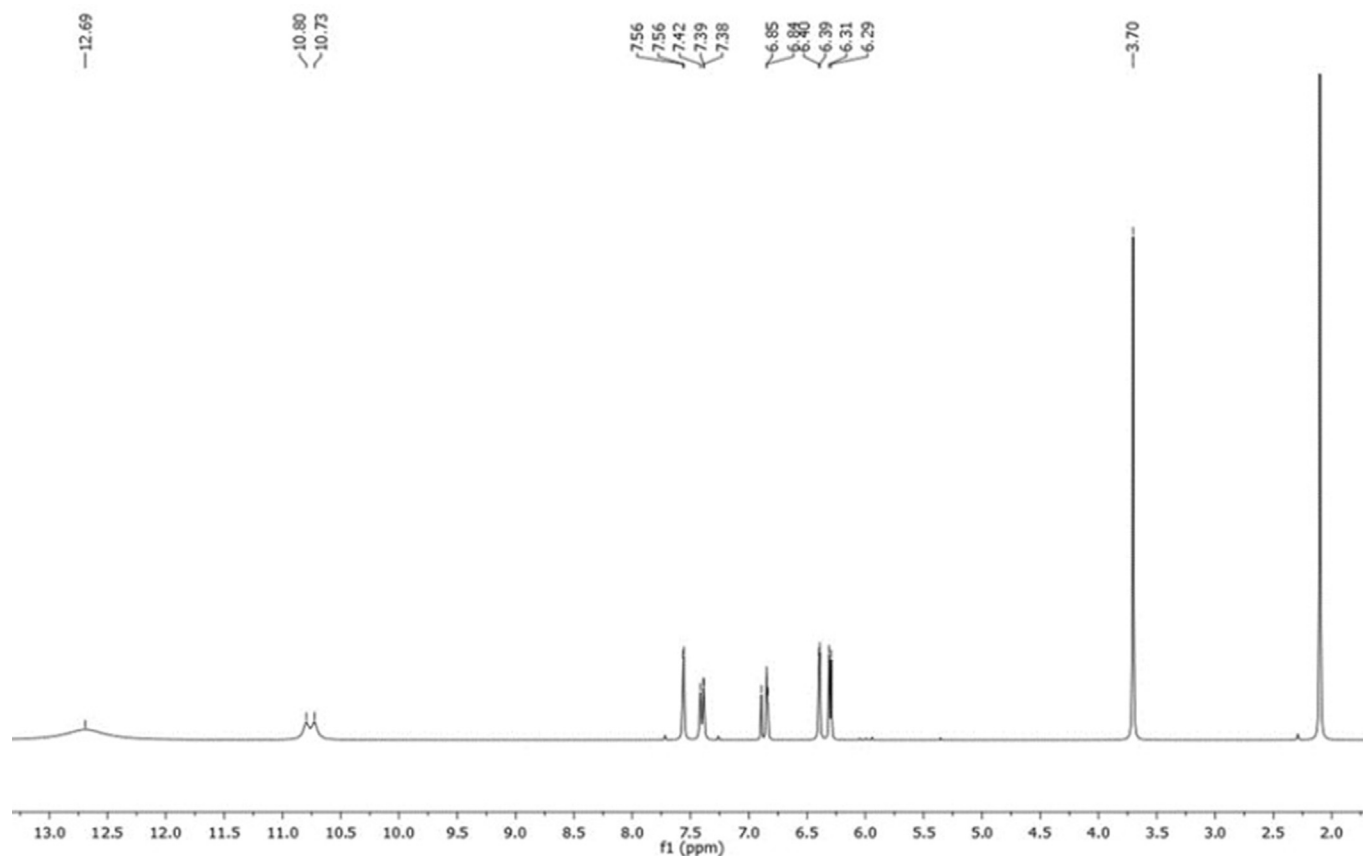
Figure 13. [^1]H-NMR spectrum (acetone-d[6]) of 3-O-methyl quercetin (**7**).

3-O-glucoside (C3G) the most abundant anthocyanin (59% of the total peak area), petunidin 3-O-glucoside and peonidin 3-O-glucoside. According to UV/vis and MS-MS data the two remaining peaks from Figure 16 were tentatively identified as delphinidin 3-O-hexoside and peonidin 3-O-galactoside. In the UPLC-ESI/MS-MS analysis of these two peaks (Table 5), delphinidin 3-O-hexoside (peak 1) revealed, in positive mode, a molecular ion at m/z 465.1013 and fragment ion at m/z 303.0504 corresponding to aglycone delphinidin, while peonidin 3-O-galactoside (peak 4) revealed, in positive mode, a molecular ion at m/z 463.1250 and fragment ion at m/z 301.0708 corresponding to aglycone peonidin. Based on Ma et al. (2013), the monoglycosides of anthocyanidin are eluted on the C-18 column in the order of increasing retention time: galactoside, glucoside, and arabinoside. Therefore, the sugar moiety ascribed to peak 4 was determined by this elution series rule as galactoside, considering that peak 5 corresponds to peonidin 3-O-glucoside. Mass spectra of delphinidin 3-O-hexoside, peonidin 3-O-galactoside, petunidin 3-O-glucoside, cianidin 3-O-glucoside, and peonidin 3-O-glucoside are presented in Figures 16, 17, 18, and 19.

Among berries, those belonging to the Ericaceae family contain the highest amount of antioxidants, mainly composed of anthocyanins, which give the ripe fruits their color. For example, the glycosides of cyanidin, delphinidin, and pelargonidin provide the red, blue, and purple colors, respectively, of fresh blueberries (Liu et al., 2020; Rashidinejad, 2020). Berries of the genus *Cavendishia* contain monoglycosides of delphinidin, cyanidin, petunidin, peonidin, and malvidin (Ma et al., 2013), while in *C. nitida* berries, no malvidin glycosides were detected. The foregoing is important, considering the antioxidant and beneficial properties for human health of these compounds, which is largely due to the consumption of its fruits (Guija-Poma et al., 2015; Jungmin, 2006; Merzlyak et al., 2008).

Brown et al. (2012) reported high values of C3G (80 μg g^{-1} dw), P3G (1500 μg g^{-1} dw), C3A (500 μg g^{-1} of dw) and P3A (600 μg g^{-1} dw) for fruits of various cultivars of *Vaccinium macrocarpon* compared to those calculated for *C. nitida* fruit.

An ecological aspect that can affect the anthocyanin content is the size of the fruit. In fruits of different species of the genus *Vaccinium* it was observed that there is a relationship between the accumulation of anthocyanins and the size of the fruit: the smaller the fruit, the greater the accumulation of these compounds (Gao and Mazza, 1994). This could explain the low anthocyanin content in the fruits of *C. nitida*, due to the berries of the *Cavendishia* genus are one of the largest in this plant family. According to Villagra et al. (2014) studies on the fruits of the genus *Gaultheria* that do not exceed 8 mm have reported values of phenolic compounds higher than those found for *C. nitida*.

3.6. Antioxidant activity of leaves and fruits of C. nitida

Oxidative stress occurs due to the production of radicals, and is a cause of multiple cardiovascular and neurodegenerative diseases. Ericaceae berries act as free radical scavengers, due to their well-known high antioxidant content (Dastmalchi et al., 2011).

For *C. nitida*, the fractions of the leaf extract enriched in flavonoids (Fr3 and Fr4) presented high antioxidant activity. Furthermore, the high anthocyanin content in the fruits of *C. nitida* suggests that these berries can be used as sources of bioactive compounds, with possible uses as antioxidants and colorants, and as ingredients in functional foods.

ABTS$^{\bullet+}$ and DPPH$^{\bullet}$ scavenging activities of the extracts of fruits and leaves of *C. nitida*, and of the fractions of leaves are shown in Table 6, the EtOH crude extract leaves (ECn1) had the highest inhibitory activity, followed by EtOAc fraction (Fr3), BuOH fraction (Fr4), and finally, MeOH crude extract of the fruits (ECn2).

Table 6 shows higher IC$_{50}$ values for ABTS$^{\bullet+}$, compared to those obtained for DPPH$^{\bullet}$. This trend corroborates the results obtained in a study conducted on various foods (Floegel et al., 2011). Although the two
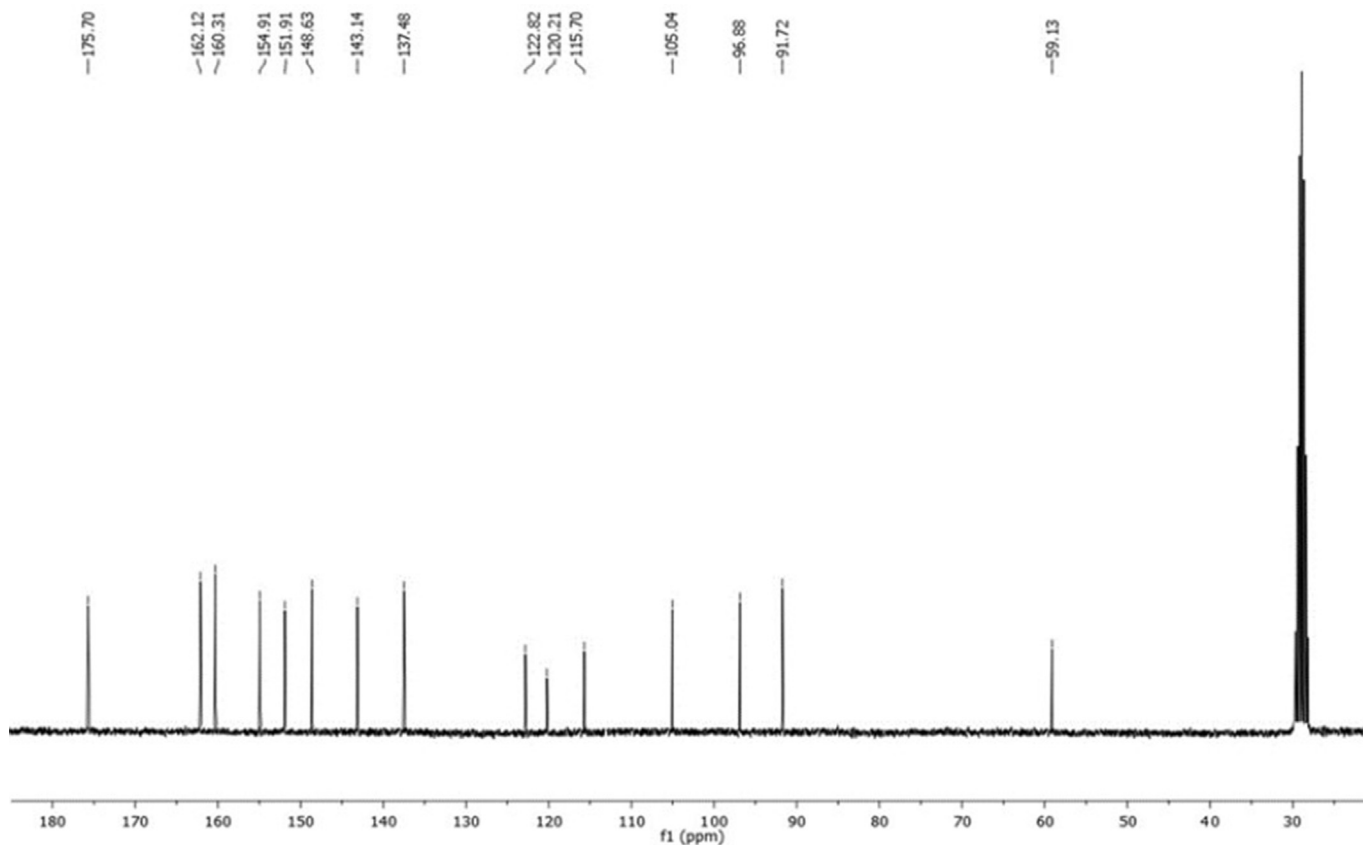
Figure 14. ^{13}C-NMR spectrum (acetone-d$_6$) of 3-*O*-methyl quercetin (**7**).
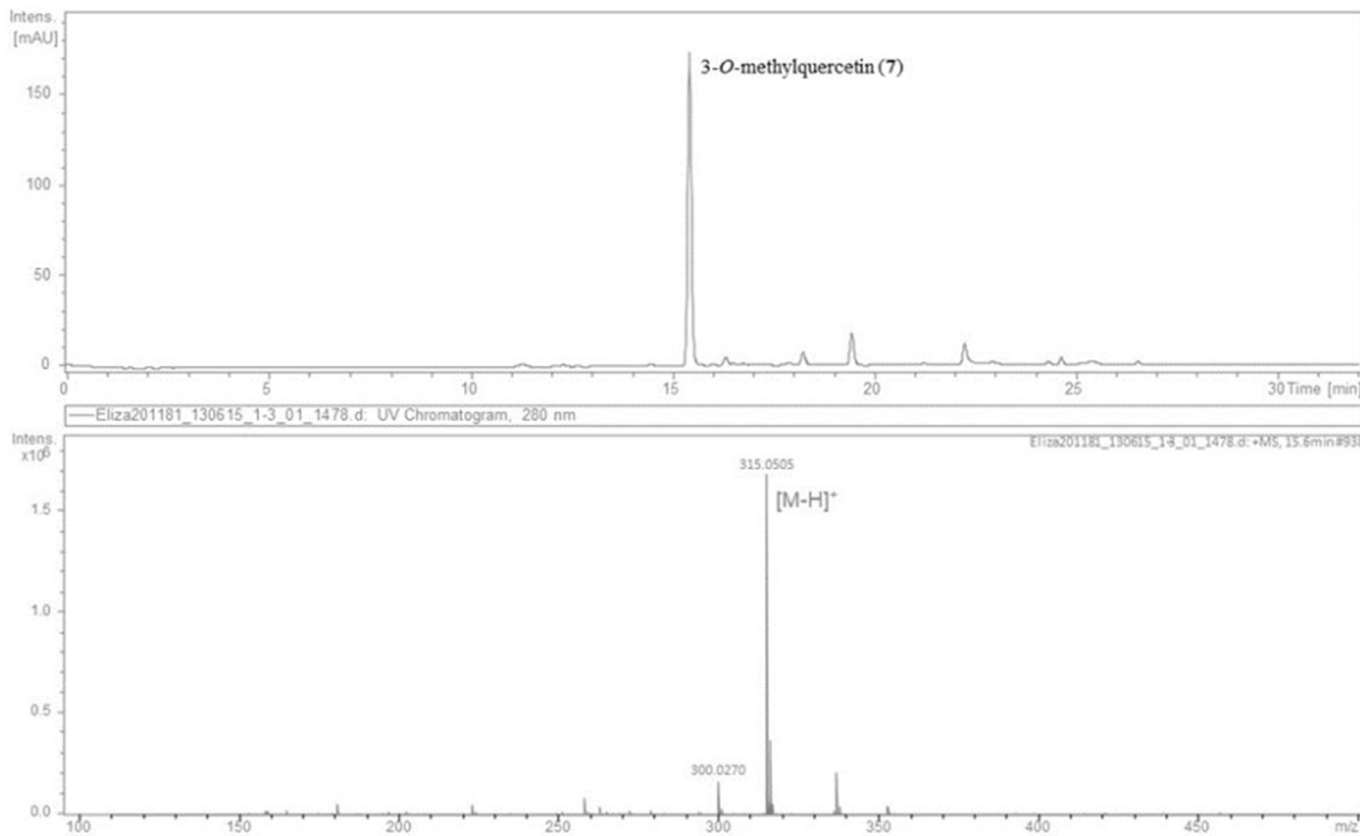

Figure 15. LC-MS Total ion chromatogram (TIC) and the full scan mass spectra of 3-*O*-methylquercetin (**7**).

Table 4. Total phenols and flavonoids content in extracts and fractions of *C. nitida.*

Extract/Analized Fraction	Total Phenol Content (mg GAE per g fw)	Total Flavonoid Content (mg QE per g fw)
ECn1	1012.8 ± 8.8	5206 ± 10.9
ECn2	3.9 ± 0.2	2.5 ± 0.1
Fr3	572.4 ± 5.6	1206 ± 7.1
Fr4	31.6 ± 0.8	4113.6 ± 12.4

Values are the average of triplicates.

trials (ABTS$^{\bullet+}$ and DPPH$^{\bullet}$ scavenging activities) are based on the same principle, this difference may have been due to three factors. The first is the different wavelengths at which the tests are carried out: ABTS$^{\bullet+}$ is measured at 740 nm, while DPPH$^{\bullet}$ is measured at 520 nm. The wavelength of the ABTS$^{\bullet+}$ assay is high enough to avoid interference in the absorbance of colored compounds such as anthocyanins and carotenoids, while the DPPH$^{\bullet}$ is not (Dastmalchi et al., 2011; Surveswaran et al., 2007). Secondly, the difference in the values could also be caused by the mechanism of the reaction in each case. The reaction in the DPPH$^{\bullet}$ assay depends on the steric accessibility of the compounds to the radical, so small antioxidants with high accessibility will report greater antioxidant activity, but other large ones that react quickly with peroxide radicals can react more slowly, or even be inert to DPPH$^{\bullet}$ due to steric inaccessibility; while for ABTS$^{\bullet+}$ this problem does not occur (Dastmalchi et al., 2011; Prior et al., 2005). Finally, the difference in values may have been due to the nature of the compounds in the sample. The ABTS$^{\bullet+}$ radical is soluble in an organic or aqueous medium, which allows it to react with lipophilic
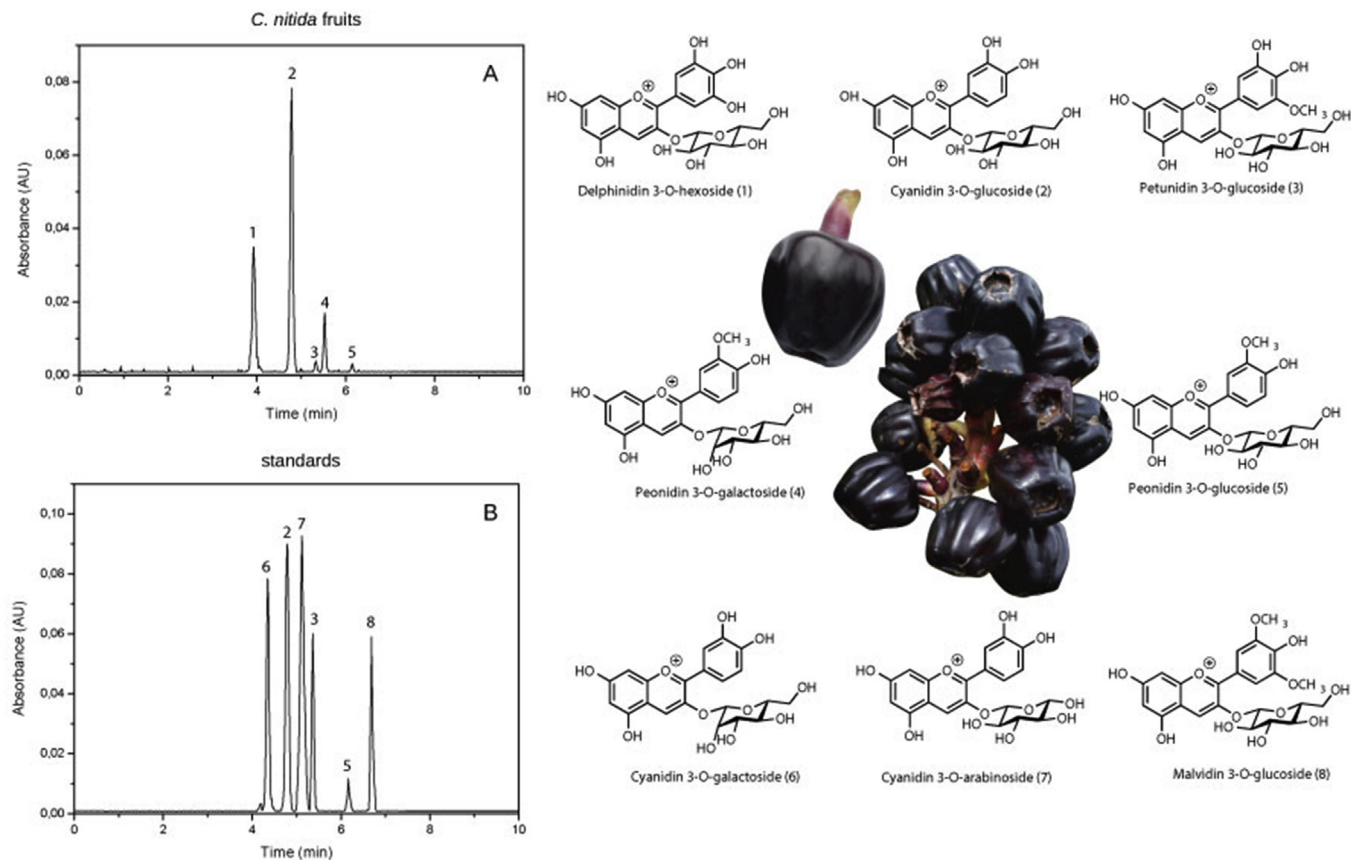
Figure 16. UPLC-PDA chromatograms of anthocyanins of (**A**) *C. nitida* fruits and (**B**) standards detected at 512 nm.

Table 5. Anthocyanins detected in *C. nitida.*

# Peak	Peak area (%)	Content, µg g^{-1} dw	λmax, nm	t$_R$, min	Molecular ion, m/z (MF, ppm)	Fragment ion exact mass, m/z (MF, ppm)	Tentative identification
1	22.3	-	521	3.924	465.1013 [M$^+$] (C$_{21}$H$_{21}$O$_{12}$, -2.58) 463.0869 [M − H]$^-$ (C$_{21}$H$_{19}$O$_{12}$, −1.62)	303.0504 [M − hexosyl]$^+$ (C$_{15}$H$_{11}$O$_7$, −0.3) 499.0644 [M − H + Cl]$^-$ (C$_{21}$H$_{20}$O$_{12}$Cl, −0.06); 509.0924 [M − 2H + HCOOH]$^-$ (C$_{22}$H$_{21}$O$_{14}$, 1.5)	Delphinidin 3-*O*-hexoside
2	58.9	2519	516	4.748	449.1075 [M]$^+$ (C$_{21}$H$_{21}$O$_{11}$, −1.97)	287.0558 [M − glucosyl]$^+$ (C$_{15}$H$_{11}$O$_6$, 0.83)	Cyanidin 3-*O*-glucoside
3	3.3	192	523	5.312	479.1187 [M]$^+$ (C$_{22}$H$_{23}$O$_{12}$, −0.52)	317.0663 [M − glucosyl]$^+$ (C$_{16}$H$_{13}$O7, 0.54)	Petunidin 3-*O*-glucoside
4	13.1	-	520	5.527	463.1250 [M]$^+$ (C$_{22}$H$_{23}$O$_{11}$, 2.08)	307.0708 [M − galactosyl]$^+$ (C$_{16}$H$_{13}$O$_6$, 1.5) 497.0855 [M − H + Cl]$^-$ (C$_{22}$H$_{22}$O$_{11}$Cl, −1.0); 507.1143 [M − 2H + HCOOH]$^-$ (C$_{23}$H$_{23}$O$_{13}$, −0.85).	Peonidin 3-*O*-galactoside
5	2.4	115	520	6.144	463.1249 [M]$^+$ (C$_{22}$H$_{23}$O$_{11}$, 1.86)	301.0715 [M − hexosyl]$^+$ (C$_{16}$H$_{13}$O$_6$, 0.95)	Peonidin 3-*O*-glucoside

Peak area (%) = Peak area (%) UPLC-DAD; t$_R$ = retention time; MF = molecular formula.
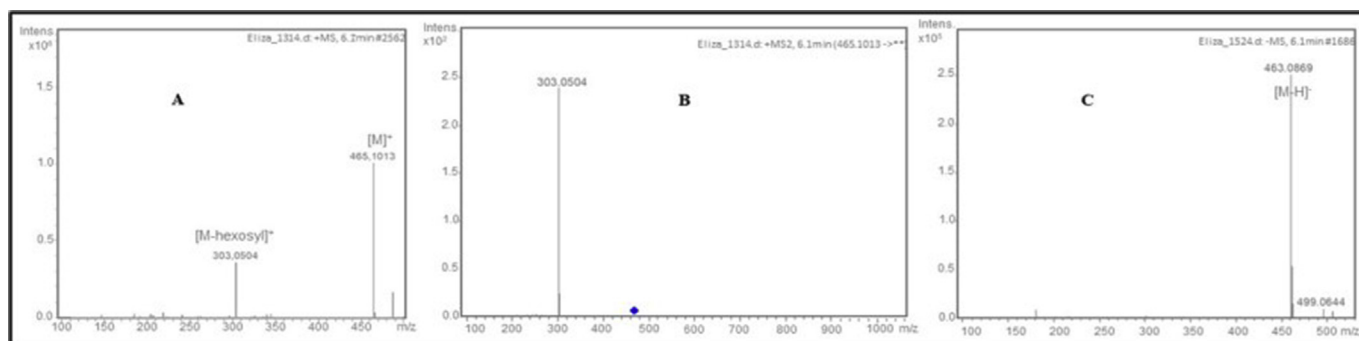
Figure 17. Mass spectra of delphinidin 3-O-hexoside obtained in positive ion mode (A), negative ion mode (C), and (B) MS-MS spectrum of m/z 465.1013.
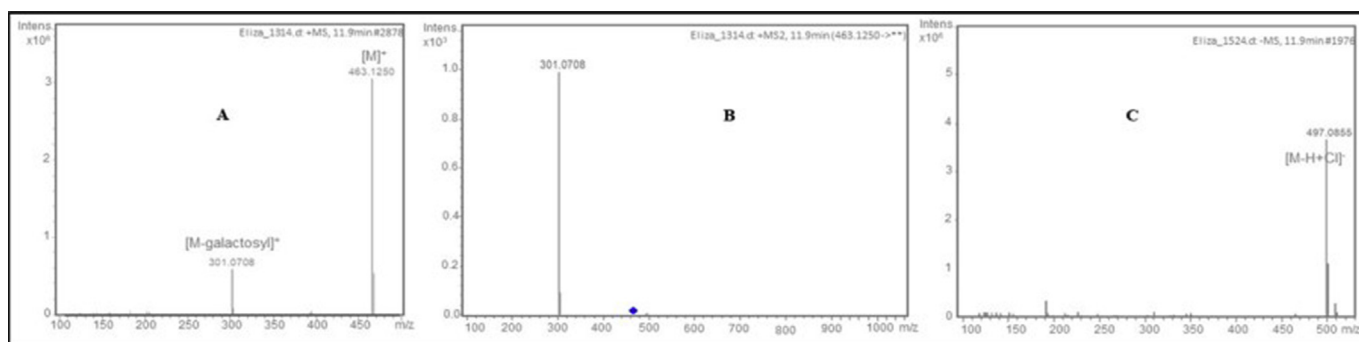

Figure 18. Mass spectra of peonidin 3-*O*-galactoside obtained in positive ion mode (A), negative ion mode (C), and (B) MS-MS spectrum of m/z 463.1250.
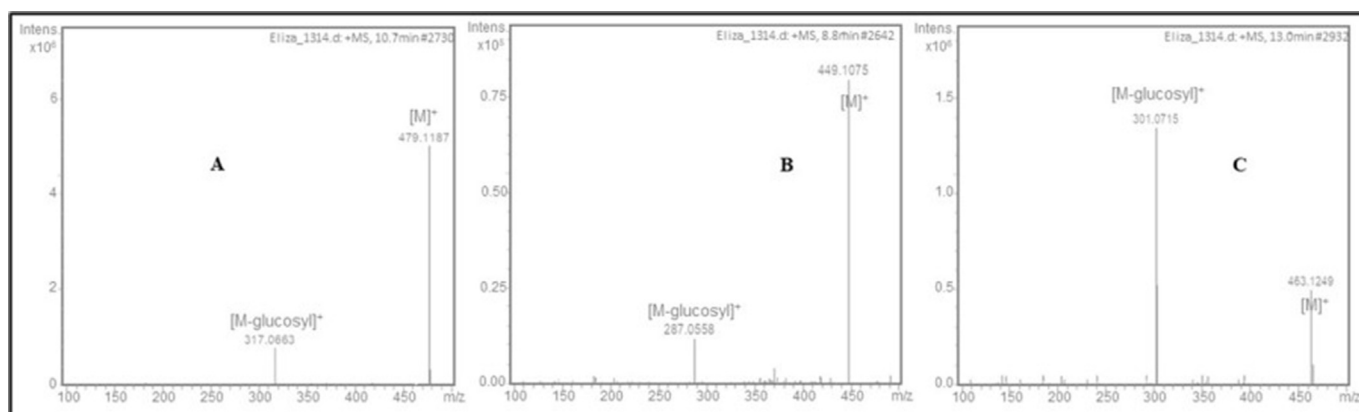

Figure 19. Mass spectra obtained in positive ion mode of petunidin 3-*O*-glucoside (A), cianidin 3-*O*-glucoside (B), and peonidin 3-*O*-glucoside (C).

Table 6. DPPH• and ABTS•+ Scavenging (mg L^{-1}) from extracts and fractions of *C. nitida* needed to inhibit 50% of oxidative damage (free radical).

Extract/Fraction	IC$_{50}$ DPPH$^{\bullet}$ (mg L^{-1})	IC$_{50}$ ABTS$^{\bullet+}$ (mg L^{-1})
ECn1	8.12 ± 0.02	21.90 ± 0.22
ECn2	65.86 ± 0.13	145.43 ± 0.88
Fr3	12.14 ± 0.05	29.01 ± 0.11
Fr4	17.51 ± 0.09	67.38 ± 0.32

Table 7. Pearson's correlation coefficient between the content of total phenols and flavonoids with the percentage of inhibition to DPPH• and ABTS•+ in extracts and fractions of *C. nitida*.

Extract/Fraction	Pearson correlation coefficient (r)	
	DPPH•	ABTS•+
ECn1	0.9732	0.9669
ECn2	0.9735	0.9830
Fr3	0.9291	0.9774
Fr4	0.9833	0.9819

and hydrophilic compounds, while the DPPH$^{\bullet}$ radical is only soluble in an organic compound, therefore it only reacts with lipophilic compounds. The antioxidant activity of hydrophilic substances will not be considered (Dastmalchi et al., 2011; Surveswaran et al., 2007).

The assumptions of normality and homoscedasticity were evaluated for the data on the antioxidant activity and phenolic and flavonoid

contents, observing normal distribution and homogeneous variances (P = 0.8721). Therefore, Pearson's correlation coefficient was calculated for analysis. There was a negative correlation between the IC$_{50}$ values for both ABTS$^{\bullet+}$ and DPPH$^{\bullet}$ in relation to the total phenol and flavonoid

contents (r < - 0.5). This is because at a higher levels of flavonoid and phenolic compounds, a lower sample concentration will be necessary to inhibit 50% of the free radicals (IC$_{50}$), giving them higher antioxidant capacity (Giraldo Vásquez and Ramírez Aristizabal, 2013). The leaf extract (ECn1) and ethyl acetate fraction (Fr3) exhibited strong antioxidant activity (Table 6).

On the other hand, there was a strong correlation (Pearson's correlation coefficient) between total phenolic and flavonoid contents and the values of the percentage of inhibition of ABTS$^{\bullet+}$ and DPPH$^{\bullet}$ in all samples tested (r > 0.9) (Table 7). This means that these compounds present in the extracts and fractions analyzed are the main responsible for the radical scavenging activity DPPH$^{\bullet}$ and ABTS$^{\bullet+}$ (Dastmalchi et al., 2011) This has been observed in other studies carried out on plants of the genus *Vaccinium* (Castrejón et al., 2008; Çelik et al., 2008; Giovanelli and Buratti, 2009). The antioxidant activity of flavonoids and phenolic compounds is caused by their ability to transfer electrons to free radicals in order to stabilize them thanks to their structure (Havsteen, 2002).

4. Conclusion

This study analyses, for the first time, the nutritional compositions, the total phenolics, flavonoids, and anthocyanins contents and the antioxidant activity of *C. nitida* fruit. The results of the nutritional analysis, bioactive compounds and antioxidant activity suggest that *C. nitida* fruits have potential as very promising edible fruits, useful for human and animal health. However, even though the communities of the region use this berry as food, it is necessary to carry out toxicity tests to evaluate the safety of their food use. These berries are a good source of anthocyanin and phenolics compounds, which are related to excellent antioxidant properties, making them good sources of natural antioxidants, natural colorants, and ingredients of functional foods, and providing added value to the production chain associated with the consumption of native Colombian fruits. In addition, the presence of notable antioxidant activities in the EtOH extract and EtOAc fraction indicates that *C. nitida* could be used as a crude drug and dietary supplement with potential health benefits. Terpenes such as rimuene, α- and β-amyrin, kaur-16-ene, friedelin and glutinol; the flavonoid 3-*O*-methyl quercetin and anthocyanins such as delphinidin 3-*O*-hexoside, cyanidin 3-*O*-glucoside, petunidin 3-*O*-glucoside, peonidin 3-*O*-galactoside, and peonidin 3-*O*-glucoside are reported here for the first time for the species.

Declarations

Author contribution statement

Elizabeth Gil Archila, Jorge Andres Carvajal Vasquez: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Felipe Rojas-Bautista: Conceived and designed the experiments; Wrote the paper.

Nestor Garcia: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Data availability statement

Data included in article/supplementary material/referenced in article.

Declaration of interests statement

The authors declare no conflict of interest.

References

Abdel-Sattar, E., Abou-Hussein, D., Petereit, F., 2015. Chemical constituents from the leaves of *Euphorbia ammak* growing in Saudi Arabia. Pharmacogn. Res. 7 (1), 14–17.

Abreu Guirado, O., Cuéllar Cuéllar, A., Prieto, S., 2008. Fitoquímica del género *Vaccinium* (Ericaceae). Rev. Cubana Plantas Med. 13 (3).

Ainsworth, E.A., Gillespie, K.M., 2007. Estimation of total phenolic content and other oxidation substrates in plant tissues using Folin-Ciocalteu reagent. Nat. Protoc. 2 (4), 875–877.

Alonso-Amelot, M.E., 2008. High altitude plants, chemistry of acclimation and adaptation. Stud. Nat. Prod. Chem. 34, 883–982.

Association of Official Analytical Chemists (AOAC), 2003. Official Methods of Analysis of AOAC International. Association of Analytical Communities, Gaithersburg, MD, USA.

Bacchetta, L., Visioli, F., Cappelli, G., Caruso, E., Martin, G., Nemeth, E., Bacchetta, B., Bedini, G., Wezel, A., van Asseldonk, T., van Raamsdonk, L., Mariani, F., 2016. A manifesto for the valorization of wild edible plants. J. Ethnopharmacol. 191, 180–187.

Brown, P.N., Shipley, P.R., 2011. Determination of anthocyanins in cranberry fruit and cranberry fruit products by high-performance liquid chromatography with ultraviolet detection: single-laboratory validation. J. AOAC Int. 94 (2), 459–466.

Brown, P.N., Murch, S.J., Shipley, P., 2012. Phytochemical diversity of cranberry (*Vaccinium macrocarpon* Aiton) cultivars by anthocyanin determination and metabolomic profiling with chemometric analysis. J. Agric. Food Chem. 60 (1), 261–271.

Castrejón, A.D.R., Eichholz, I., Rohn, S., Kroh, L.W., Huyskens-Keil, S., 2008. Phenolic profile and antioxidant activity of highbush blueberry (*Vaccinium corymbosum* L.) during fruit maturation and ripening. Food Chem. 109 (3), 564–572.

Çelik, H., Ozgen, M., Serçe, S., Kaya, C., 2008. Phytochemical accumulation and antioxidant capacity at four maturity stages of cranberry fruit. Sci. Hortic. 117 (4), 345–348.

Dastmalchi, K., Flores, G., Petrova, V., Pedraza-Peñalosa, P., Kennelly, E.J., 2011. Edible Neotropical blueberries: antioxidant and compositional fingerprint analysis. J. Agric. Food Chem. 59 (7), 3020–3026.

Floegel, A., Kim, D.O., Chung, S.J., Koo, S.I., Chun, O.K., 2011. Comparison of ABTS/ DPPH assays to measure antioxidant capacity in popular antioxidant-rich US foods. J. Food Compos. Anal. 24 (7), 1043–1048.

Gao, L., Mazza, G., 1994. Quantitation and distribution of simple and acylated anthocyanins and other phenolics in blueberries. J. Food Sci. 59 (5), 1057–1059.

Garcia, H., 1992. Flora medicinal de Colombia. Bogotá. Botánica Médica 285–289.

Garzón, G.A., Narváez, C.E., Riedl, K.M., Schwartz, S.J., 2010. Chemical composition, anthocyanins, non-anthocyanin phenolics and antioxidant activity of wild bilberry (*Vaccinium meridionale* Swartz) from Colombia. Food Chem. 122 (4), 980–986.

Giovanelli, G., Buratti, S., 2009. Comparison of polyphenolic composition and antioxidant activity of wild Italian blueberries and some cultivated varieties. Food Chem. 112 (4), 903–908.

Giraldo Vásquez, L.M., Ramírez Aristizabal, L.S., 2013. Evaluación de la actividad antioxidante de extractos de *Palicourea guianensis* (Rubiaceae). Rev. Cubana Farmac. 47 (4), 483–491.

Giusti, M., Wrolstad, R.E., 2001. Characterization and measurement of anthocyanins by UV-visible spectroscopy. Curr. Protocol. Food Anal. Chem. F1.2.1–F1.2.13.

Golubtsova, J., 2017. Commodity characteristics and quality assessment of fruit and berry raw materials and products of processing thereof. J. Pharmaceut. Sci. Res. 9 (7), 1091–1098.

Guija-Poma, E., Inocente-Camones, M.A., Ponce-Pardo, J., Zarzosa-Norabuena, E., 2015. Evaluación de la técnica 2,2-Difenil-1-Picrilhidrazilo (DPPH) para determinar capacidad antioxidante. Horizonte Médico (Lima) 15 (1), 57–60.

Gutiérrez, Gaitén, Y. I., Miranda Martínez, M., Henriques Amelia, T., del Barrio Alonso, G., 2010. Flavonoids analysis of a butanol fraction obtained from *Phyllanthus orbicularis* HBK. Rev. Cubana Farmac. 44 (3), 367–373.

Havsteen, B.H., 2002. The biochemistry and medical significance of the flavonoids. Pharmacol. Ther. 96 (2–3), 67–202.

Heim, K.E., Tagliaferro, A.R., Bobilya, D.J., 2002. Flavonoid antioxidants: chemistry, metabolism and structure-activity relationships. JNB (J. Nutr. Biochem.) 13 (10), 572–584.

Hyun, T.K., Song, S.C., Song, C.K., Kim, J.S., 2015. Nutritional and nutraceutical characteristics of *Sageretia theezans* fruit. J. Food Drug Anal. 23 (4), 742–749.

Ilić, D.P., Troter, D.Z., Stanojević, L.P., Zvezdanović, J.B., Vukotić, D.D., Nikolić, V.D., 2021. Cranberry (*Vaccinium macrocarpon* L.) fruit juice from Serbia: UHPLC- DAD-MS/MS characterization, antibacterial and antioxidant activities. LWT 146, 111399.

International Organization for Standardization, 2009. Food and Feed Products — General Guidelines for the Determination of Nitrogen by the Kjeldahl Method. Switzerland, Geneva.

Jungmin, Lee, 2006. AOAC official method 2005.02 total monomeric anthocyanin pigment content of fruit juices, beverages, natural colorants, and wines pH differential method first action 2005. Off. Methods Anal. AOAC Int. (OMA) 37.1.68.

Khoo, H.E., Azlan, A., Tang, S.T., Lim, S.M., 2017. Anthocyanidins and anthocyanins: colored pigments as food, pharmaceutical ingredients, and the potential health benefits. Food Nutr. Res. 61 (1), 1361779.

Kumar, A.D.N., Bevara, G.B., Kaja, L.K., Badana, A.K., Malla, R.R., 2016. Protective effect of 3-*O*-methyl quercetin and kaempferol from *Semecarpus anacardium* against H₂O₂ induced cytotoxicity in lung and liver cells. BMC Compl. Alternative Med. 16 (1), 1–13.

Li, Y., Zhang, J.J., Xu, D.P., Zhou, T., Zhou, Y., Li, S., Li, H.B., 2016. Bioactivities and health benefits of wild fruits. Int. J. Mol. Sci. 17 (8).

Liu, J., Zhuang, Y., Hu, Y., Xue, S., Li, H., Chen, L., Peng, F., 2020. Improving the color stability and antioxidation activity of blueberry anthocyans by enzymatic acylation with p-coumaric acid and caffeic acid. LWT. Elsevier 130, 109673.

Llivisaca, S., Manzano, P., Ruales, J., Flores, J., Mendoza, J., Peralta, E., Cevallos-Cevallos, J.M., 2018. Chemical, antimicrobial, and molecular characterization of mortiño (*Vaccinium floribundum* Kunth) fruits and leaves. Food Sci. Nutr. 6 (4), 934–942.

López Diago, D., García Castro, N.J., 2021. Frutos silvestres comestibles de Colombia: diversidad y perspectivas de uso. Biota Colombiana. Instituto de Investigacion de Recursos Biologicos Alexander von Humboldt (IAVH) 22 (2), 16–55.

Luteyn, J.L., 1983. Published for organization for flora neotropica by the New York botanical garden. Ericaceae.

Luteyn, J., 1999. Paramos: A Checklist of Plant Diversity, Geographical Distribution, and Botanical Literature (Memoirs of the New York Botanical Garden Volume 84). Estados Unidos: The New York Botanical Garden, New York.

Luteyn, J.L., 2002. Diversity, adaptation, and endemism in neotropical Ericaceae: biogeographical patterns in the vaccinieae. Bot. Rev. 55–87.

Luteyn, J.L., Harborne, J.B., Williams, C.A., 1980. A survey of the flavonoids and simple phenols in leaves of Cavendishia (Ericaceae). Brittonia 32 (1), 1.

Ma, C., Dastmalchi, K., Flores, G., Wu, S.B., Pedraza-Peñalosa, P., Long, C., Kennelly, E.J., 2013. Antioxidant and metabolite profiling of North American and Neotropical blueberries using LC-TOF-MS and multivariate analyses. J. Agric. Food Chem. 61 (14), 3548–3559.

Malca Garcia, G.R., Joachim Sieler, L.H., Bussmann, R.W., 2015. Constituents of *Corynaea crassa* "Peruvian viagra". Revista Brasileira de Farmacognosia 25 (2), 92–97.

Martín-Gómez, J., García-Martínez, T., Varo, M.A., Mérida, J., Serratosa, M.P., 2021. Phenolic compounds, antioxidant activity and color in the fermentation of mixed blueberry and grape juice with different yeasts. LWT 146, 111661.

Matsunaga, S.N., Chatani, S., Nakatsuka, S., Kusumoto, D., Kubota, K., Utsumi, Y., Enoki, T., Tani, A., Hiura, T., 2012. Determination and potential importance of diterpene (kaur-16-ene) emitted from dominant coniferous trees in Japan. Chemosphere 87 (8), 886–893.

Matulevich, J., Gil, E., Ospina, F., 2016. Phytochemical study and anti-inflammatory activity of leaves, flowers and fruits of *Bejaria resinosa* Mutis ex L. (pegamosco). Rev. Cubana Plantas Med. 21 (3), 332–345.

Merzlyak, M.N., Chivkunova, O.B., Solovchenko, A.E., Naqvi, K.R., 2008. Light absorption by anthocyanins in juvenile, stressed, and senescing leaves. J. Exp. Bot. 59 (14), 3903–3911.

Michalska, A., Łysiak, G., 2015. Bioactive compounds of blueberries: post-harvest factors influencing the nutritional value of products. Int. J. Mol. Sci. 16 (8), 18642–18663.

Neto, C.C., 2007. Cranberry and blueberry: evidence for protective effects against cancer and vascular diseases. Mol. Nutr. Food Res. 51 (6), 652–664.

Nuengchamnong, N., Ingkaninan, K., 2017. An on-line LC-MS/DPPH approach towards the quality control of antioxidative ingredients in Sahastara. Songklanakarin J. Sci. Technol. 39 (1), 123–129.

Padmanabhan, P., Correa-Betanzo, J., Paliyath, G., 2015. Berries and related fruits. In: Encyclopedia of Food and Health, first ed. Elsevier.

Plazas González, E.A., 2015. Tamizaje fitoquímico preliminar, evaluación de la actividad antioxidante in vitro y toxicidad de seis especies de Ericaeas colombianas. Rev. Cubana Plantas Med. 20 (2), 182–199.

Pourcel, L., Routaboul, J.M., Cheynier, V., Lepiniec, L., Debeaujon, I., 2007. Flavonoid oxidation in plants: from biochemical properties to physiological functions. Trends Plant Sci. 12 (1), 29–36.

Prior, R.L., Wu, X., Schaich, K., 2005. Standardized methods for the determination of antioxidant capacity and phenolics in foods and dietary supplements. J. Agric. Food Chem. 53 (10), 4290–4302.

Ramakrishna, A., Ravishankar, G.A., 2011. Influence of abiotic stress signals on secondary metabolites in plants. Plant Signal. Behav. 6 (11), 1720–1731.

Rashidinejad, A., 2020. Blueberries. In: Nutritional Composition and Antioxidant Properties of Fruits and Vegetables. Elsevier, pp. 467–482.

Salasoo, I., 1988. Epicuticular Wax Hydrocarbons of Ericaceae in the Pacific Northwest of U.S.A. Biochemical Systematics and Ecology. Pergamon Press 16 (7/8), 619–622.

Salih, E.Y.A., Julkunen-Tiitto, R., Lampi, A.M., Kanninen, M., Luukkanen, O., Sipi, M., Lehtonen, M., Vuorela, H., Fyhrquist, P., 2018. *Terminalia laxiflora* and *Terminalia brownii* contain a broad spectrum of antimycobacterial compounds including ellagitannins, ellagic acid derivatives, triterpenes, fatty acids and fatty alcohols. J. Ethnopharmacol. 227, 82–96.

Sanabria-Galindo, A., López, S.I., Gualdrón, R., 1997. Estudio fitoquimico preliminar y letalidad sobre *Artemia salina* de plantas colombianas. Rev. Colomb. Cienc. Quimico-Farm. 26 (1), 15–19.

Shakil, N.A., Pankaj, S., Kumar, J., Pandey, R.K., Saxena, D.B., 2008. Nematicidal prenylated flavanones from *Phyllanthus niruri*. Phytochemistry 69 (3), 759–764.

Sharma, A., Shahzad, B., Rehman, A., Bhardwaj, R., Landi, M., Zheng, B., 2019. Response of phenylpropanoid pathway and the role of polyphenols in plants under abiotic stress. Molecules 24 (13), 2452.

Shivembe, A., Ojinnaka, D., 2017. Determination of vitamin C and total phenolic in fresh and freeze dried blueberries and the antioxidant capacity of their extracts. Integr. Food Nutr. Metabol. 4 (6), 4–9.

Sirat, H.M., Susanti, D., Ahmad, F., Takayama, H., Kitajima, M., 2010. Amides, triterpene and flavonoids from the leaves of *Melastoma malabathricum* L. J. Nat. Med. 64 (4), 492–495.

Skrovankova, S., Sumczynski, D., Mlcek, J., Jurikova, T., Sochor, J., 2015. Bioactive compounds and antioxidant activity in different types of berries. Int. J. Mol. Sci. 16 (10), 24673–24706.

Subhadhirasakul, S., Pechpongs, P., 2005. A terpenoid and two steroids from the flowers of *Mammea siamensis*. Songklanakarin J. Sci. Technol. 27, 555–561.

Surveswaran, S., Yi-Zhong, C., Harold, C., Mei, S., 2007. Systematic evaluation of natural phenolic antioxidants from 133 Indian medicinal plants. Food Chem. 102 (3), 938–953.

Sylvestre, M., Legault, J., Dufour, D., Pichette, A., 2005. Chemical composition and anticancer activity of leaf essential oil of *Myrica gale* L. Phytomedicine 12 (4), 299–304.

Taiz, L., Zeiger, E., Møller, I.M., Murphy, A., 2014. Plant Physiology and Development, sixth ed. Sinauer. Sunderland (chapter 24).

Valente, A., Gonçalves Albuquerque, T., Sanches-Silva, A., Costa, H.S., 2011. Ascorbic acid content in exotic fruits: A contribution to produce quality data for food composition databases. Food Res. Int. 44 (7), 2237–2242.

Vijayakumar, A., Duraipandiyan, V., Jeyaraj, B., Agastian, P., Karunai Raj, M., Ignacimuthu, S., 2012. Phytochemical analysis and in vitro antimicrobial activity of *Illicium griffithii* Hook. f. & Thoms extracts. Asian Pac. J. Trop. Dis. 2 (3), 190–199.

Villagra, E., Campos-Hernandez, C., Cáceres, P., Cabrera, G., Bernardo, Y., Arencibia, A., Carrasco, B., Caligari, P.D.S., Pico, J., García-Gonzales, R., 2014. Morphometric and phytochemical characterization of chaura fruits (*Gaultheria pumila*): A native Chilean berry with commercial potential. Biol. Res. 47 (1).

Woisky, R.G., Salatino, A., 1998. Analysis of propolis: Some parameters and procedures for chemical quality control. J. Apicult. Res. 37 (2), 99–105.

Wootton-Beard, P.C., Moran, A., Ryan, L., 2011. Stability of the total antioxidant capacity and total polyphenol content of 23 commercially available vegetable juices before and after *in vitro* digestion measured by FRAP, DPPH, ABTS and Folin-Ciocalteu methods. Food Res. Int. 44 (1), 217–224.

Zamudio, Vasco, S. P., Cardona, Castrillón, W. F., Pelaez, Matulevich, J. A., Díaz Barrera, L.X., 2019. Estudio fitoquímico de hojas de Cavendishia compacta (Ericaceae) y evaluación de su actividad antiinflamatoria. Rev. Colomb. Cienc. Quimico-Farm. 48 (1), 61–79.