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ORIGINAL PAPER

Volatile compound profile and sensory features of cape gooseberry (*Physalis peruviana* Linnaeus): comparative study between cultivated and wild fruits

Mayra Saby Bazalar Pereda[1] · **Mónica Azucena Nazareno**[2] · **Carmen Inés Viturro**[1]

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Abstract
Physalis peruviana fruit has a unique and pleasant flavor which constitutes its main sensory strength. To better understand the cape gooseberry flavor, it is necessary to find correlations between its sensory traits and instrumental measurements. The main aim of this research was to characterize cultivated and wild cape gooseberry fruits of *Physalis peruviana* using the volatile profile and sensory analysis based on potential consumers. A total of 211 volatile compounds were identified by headspace solid-phase microextraction coupled to gas chromatography–mass spectrometry. In cultivated fruits, 170 compounds were found and 108 ones in wild fruits. Only 67 compounds were found in common in both fruits. Besides, 144 volatile compounds are reported for the first time. The sensory features of both fruits were defined by potential consumers who associated cultivated fruits with fruity and floral aromas, while wild fruits with herbaceous and fatty aromas. Sensory traits and volatile composition allowed jointly to characterize and differentiate each type of fruit. The results of the sensory analysis and the volatile compounds detected were correlated by means of principal component and multiple factor analysis, showing a clear difference in the aroma profile of both fruits.

Keywords *Physalis peruviana* L. · Volatile compounds · Sensorial analysis · Solid-phase microextraction

Introduction

Cape gooseberry (*Physalis peruviana* Linnaeus) is a native plant from the Andes region that transcends the history of the pre-Inca and Inca periods. According to Legge [1], *P. peruviana* is native to the Peruvian Andes; currently, this plant is cultivated in many South American countries such as Colombia, Peru, Ecuador and Argentina. In the case of Argentina, *P. peruviana* cultivation is quite recent and still scarce. *P. peruviana* fruit is highly appreciated all over the world. The most frequent common names by which the species *Physalis peruviana* L. is known are: "uchuva", "uvilla" and "aguaymanto" and in English-speaking countries, it is commonly known as cape gooseberry [2].

Cape gooseberry fruits were previously described concerning their nutritional and functional point of view [3, 4]. These reports have highlighted a remarkable antioxidant power and bioactive substance contents in cultivated and wild fruits from the Argentinean Northern Andean region; therefore, it is considered that these fruits have a high potential as health promoting food.

Flavor is an important aspect of food quality that is determined by taste and odor-active compounds. In the case of cape gooseberry, the fruit has a unique and pleasant flavor which constitutes its main sensory strength. To better understand the cape gooseberry flavor, it is necessary to find correlations between its sensory properties and instrumental measurements such as the volatile compound composition.

In the sensory analysis, a descriptive analysis conducted by a trained panel is the most frequently used method by the food industry to fully characterize the sensory properties of products [5]. However, the use of an untrained panel with consumers are nowadays more frequently used

✉ Mayra Saby Bazalar Pereda
mayrasbp@gmail.com

[1] Facultad de Ingeniería, Laboratorio PRONOA, CIITeD-CONICET, Universidad Nacional de Jujuy, Ítalo Palanca 10, San Salvador de Jujuy, Argentina

[2] Laboratorio de Antioxidantes y Procesos Oxidativos, Facultad de Agronomía y Agroindustrias, Instituto de Ciencias Químicas, Universidad Nacional de Santiago del Estero - CONICET, RN 9 Km 1125, Villa El Zanjón, Santiago del Estero, Argentina

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in sensory description methods in the food industry. An untrained panel allows to better understand the perception of products, providing a description based on consumers' perception and vocabulary [6]. Considering the current competitive market, it is relevant for food industries base their decisions on consumer preferences.

Regarding volatile compounds in fruits, these are diverse and consist of hundreds of different chemical compounds that comprise only 0.001–0.01% of the fruit's fresh weight. This diversity is partially responsible for the unique flavors found in different fruit species, as well as the differences between individual cultivars [7]. Many volatile compounds are not flavor active because they cannot be detected by the human olfactory system; however, there are other compounds that even in trace amounts may have significant effects on flavor due to their low odor-threshold values which is defined as the minimum concentration needed to produce an olfactory response. Therefore, the most abundant volatiles are not necessarily the most important contributors to flavor [7, 8].

Various techniques have been developed for the analysis of aroma compounds, and among these, solvent-based extractions and headspace extractions can be mentioned. Although there is some overlap between these groups [9]. Solid-phase microextraction (SPME) is one of the most widely used technique for aroma extraction, since the SPME procedure more closely reflects the true aroma profile of the fruits than that obtained by means of solvent extraction processes [10].

Several investigations of volatile compounds in cape gooseberry fruits using different extraction methodologies have been reported in the literature. However, to the best of our knowledge, no studies have been carried out in order to compare the volatile compounds profile of cultivated and wild fruits of *Physalis peruviana* and to detect possible correlations between such profile and the sensory characteristics based on potential consumers. In this context, the study of the volatile profile of cape gooseberry fruits integrated with their sensory features, could help to understand the relationship between volatile emission and the consumer perception, which can provide relevant information in the development of new functional foods made using these fruits. Therefore, the main aim of this research was to determine the volatile profile of cultivated and wild fruits of *Physalis peruviana* from the Argentinean Northern Andean region and to correlate with their sensory analysis based on potential consumers. Headspace solid-phase microextraction (HS-SPME) coupled to gas chromatography–mass spectrometry (GC–MS) was used to determine the volatile compound emissions of both types of fruits. Principal component and multiple factor analyses were used to detect relationships between volatile compound composition, sensory analysis results, and sensory characteristics defined by potential consumers.

Materials and methods

Plant material and chemicals

Cultivated and wild cape gooseberry fruits (CGB and WGB, respectively) were collected in the province of Jujuy, Northern Andean region from Argentina. Wild fruits were collected from cape gooseberry plants that naturally grow in the same soil and climatic conditions, while the cultivated fruits were harvested from a commercial field. Both fruits were collected in the stage of maturity in which they are consumed [3]. Three independent samples of CGB and WGB were randomly collected from 20 plants each. The samples were stored in a refrigerator and analyzed within a few hours. Fruit samples were divided and analyzed in triplicate.

A C_7–C_{24} *n*-alkanes mixture, used for determination of Kovats' retention indices, was purchased from Chem Service (West, PA 19,381, U.S.A).

Extraction of volatile compounds

A solid-phase microextraction (SPME) manual device equipped with 100 µm polydimethylsiloxane (PDMS) fiber (Supelco, Bellefonte, PA) was used. The fiber was conditioned in a GC injector port at 250 °C for 1 h before use. Approximately, 10 g of fruit was put into a 50-mL vial containing a micro stirring bar. The samples were equilibrated at 40 °C for 15 min. Then, the PDMS fiber was exposed to the headspace; the samples were stirred for 30 min at the same temperature. Afterwards, the SPME device was removed from the vial and inserted into the injection port of the GC system for thermal desorption for 3 min at 250 °C. Before each sampling procedure, fiber was reconditioned in a GC injector port at 250 °C for 10 min. This reconditioning procedure was enough to guarantee the absence of residual peaks in blank runs. HS-SPME analyses were performed in triplicate.

GC–MS analysis of volatile compounds

HS-SPME analyses were performed using an Agilent 7000C GC/ MS Triple Quad coupled to an Agilent 7890B GC system and equipped with a HP-5MS fused silica capillary column (30 m × 0.25 mm × 0.25 µm). The injections were performed in splitless mode. The carrier gas was helium at a constant flow of 1.2 mL/min. The column was initially kept at 60 °C for 1 min, then increased to 280 °C at a rate of 4 °C/min. Temperature was maintained at 280 °C for 4 min. Identification was carried out with standards and for those

not available, a tentative identification was done based on mass spectral data found on Wiley 7.0 and NIST libraries, literature data [11] and by the Kovats' retention indices (RI). RI were calculated using a mixture of *n*-alkanes (C_7_C_{24}) as standards. Finally, the quantification was made based on the relative percentages of areas obtained in the GC/FID analyses.

Sensorial analysis

In the sensory analysis, the sweetness, acidity and aroma of cultivated and wild cape gooseberry fruits were evaluated. These sensory attributes were selected considering the cape gooseberry sensory descriptors reported in the literature; the descriptors of sweetness, acidity and aroma are considered among the most important sensory attributes of this fruit [12–14]. Additionally, the overall acceptance (OA) was also evaluated in the sensory analysis. The sensory evaluation was conducted with an untrained panel of 75 panelists, potential consumers of cape gooseberry fruits. The panel was composed by women (70%) and men (30%), aging between 20 and 60 years old. Cape gooseberry cultivation is recent and still scarce in Argentina. All panelists did not know the fruit under study. The inclusion criteria were the regular consumption of fruits in general and the interest and availability of time to participate in the study. Consumers were invited to designate the intensity of the sensory attributes of the two fruits using a 10 cm unstructured linear scale, anchored at the extremities with *not acid* and *very acid* for acidity, *not sweet* and *very sweet* for sweetness, *not perceptible* and *very perceptible* for aroma. Consumers also evaluated both fruits in relation to overall acceptance using the 10 cm unstructured scale ranging from *dislike extremely* to *like extremely*. The test was conducted in a sensory laboratory in accordance with the ISO 8589 standard [15]. Written consents were obtained from the participants on the day of the tests. Before starting the session, consumers were given verbal instructions about the tasting testing procedure and the paper ballot. Samples were evaluated at room temperature and served in cups codified with 3-digit random numbers containing 4 cultivated or wild cape gooseberry fruits. Samples were served in random order. Panelists were also encouraged to make written comments on their paper ballots about the fruit samples when they considered it appropriate.

Statistical analysis

The results are presented as the mean value of the seventy-five responses ± standard deviation in the sensory analysis, and as the mean value of three repetitions ± standard deviation in the volatile compounds. Results were evaluated by one-way ANOVA followed by Tukey's test with $\alpha = 0.05$. Statistical evaluations were carried out using Minitab Express™ program trial version. Principal component analysis (PCA) and Multiple Factor Analysis (MFA) were carried out using the XLSTAT software, Perpetual version 2018.2.

Results and discussion

Comparison of volatile compounds between the cultivated and wild cape gooseberry fruits

A total of 170 and 108 compounds were identified in cultivated and wild fruits, respectively. The list of compounds is reported in Table 1. The identified compounds were divided into two large groups such as terpene compounds and non-terpene compounds. In the case of terpenes, the identified volatile compounds were classified as monoterpenes, sesquiterpenes and norterpenoids. In the case of non-terpene compounds, groups were esters, carboxylic acids, alkanes, aldehydes, alcohols, ketones, lactones, furans, derivatives of cinnamic acid, unsaturated hydrocarbons, pyrans and sulfur compounds. The distribution of the percentage composition of volatile compounds was: 50.37 and 55.10% for terpene compounds; while 49.63 and 44.90% for non-terpene compounds, in cultivated and wild cape gooseberry fruits, respectively. Figure 1 shows the relative peak area of each chemical family found in both fruits.

The major group in both cultivated and wild fruits was composed of terpenes. Terpenes are responsible for the characteristic aroma profile of many fruits (particularly citrus), herbs and spices [9]. There are two main types that may contribute significantly to the flavor, and these are (a) monoterpenes and sesquiterpenes and (b) irregular terpenes mainly produced by catabolic pathways and/or autoxidation [7]. Monoterpenes and sesquiterpenes were reported as volatile components responsible for a wide spectrum of aromas (woody, piney, turpentine-like, and herbaceous), mostly perceived as very pleasant [16]. Regarding monoterpenes, the main ones in cultivated cape gooseberry fruits were terpinolene, pinene < α- > and terpinen-4-ol, which impart notes of fruity, woody, and woody–earthy aroma, respectively [17]. Among these three main compounds, terpinen-4-ol and pinene < α- > were found only in cultivated fruits, while terpinolene was present in both fruits and represented 7 times larger relative area in cultivated fruits than in wild fruits. In the case of wild cape gooseberry fruits, the main monoterpenes were limonene, phellandrene < β- > and citronellol. These three compounds were also found in cultivated fruits in smaller percentages of relative area, but only limonene and phellandrene < β- > were significantly ($p \leq 0.05$) higher in wild fruits than in cultivated fruits. Limonene has a faint aroma of orange citrus peel, phellandrene < β- > is known for its characteristic herbal aroma notes in fruits,

Table 1 Volatile compounds of cultivated and wild cape gooseberry fruits (%)

Type of compound	RI	CGB	WGB
A. TERPENES			
a. MONOTERPENES			
Acyclic Monoterpenes			
Hydrocarbons			
Myrcene	998	0.28 ± 0.01	n.d
Ocimene < (E)-β- >	1053	0.05 ± 0.01[b]	0.20 ± 0.01[a]
Alcohols			
Citronellol	1224	0.42 ± 0.02[a]	0.46 ± 0.02[a]
Esters			
Artemisyl acetate*	1178	n.d	0.23 ± 0.01
Citronellyl acetate	1351	0.09 ± 0.01	n.d
Isobornyl n-butanoate*	1472	0.88 ± 0.04	n.d
Geranyl propanoate*	1477	0.19 ± 0.01	n.d
Citronellyl butanoate*	1527	0.58 ± 0.03	n.d
Geranyl tiglate*	1694	0.04 ± 0.01	n.d
Aldehydes			
Geranaldehyde	1271	0.34 ± 0.02	n.d
Ethers			
Citral < dimethoxy-(E)- > *	1331	n.d	0.05 ± 0.01
Cyclic Monoterpenes			
Monocyclic			
Hydrocarbons			
Mentha-1(7,8)-diene < ρ- > *	998	0.56 ± 0.03	n.d
Limonene	1027	0.25 ± 0.01[b]	1.21 ± 0.05[a]
Phellandrene < β- >	1027	0.34 ± 0.02[b]	0.81 ± 0.04[a]
Terpinene < γ- >	1063	0.20 ± 0.01	n.d
Mentha-2,4(8)-diene < ρ- > *	1076	0.24 ± 0.01[b]	0.32 ± 0.02[a]
Terpinolene	1088	1.53 ± 0.07[a]	0.21 ± 0.01[b]
Alcohols			
Linalool oxide < trans- > (furanoid)	1077	0.10 ± 0.01	n.d
Menthol	1168	0.08 ± 0.01	n.d
Terpinen-4-ol	1173	0.93 ± 0.04	n.d
Terpineol < α- >	1185	0.32 ± 0.01	n.d
Aldehydes			
Cyclocitral < β- >	1215	0.07 ± 0.01	n.d
With aromatic ring			
Cymen 8-ol < ρ- >	1180	0.35 ± 0.02[a]	0.03 ± 0.01[b]
Bicyclic			
Hydrocarbons			
Pinene < α- >	934	0.99 ± 0.05	n.d
Camphene	961	0.20 ± 0.01	n.d
Pinene < β- >	986	0.14 ± 0.01	n.d
Alcohols			
Myrtanol < cis- >	1251	0.13 ± 0.01	n.d
Verbanol*	1204	n.d	0.25 ± 0.01
Ethers			
Cineole < 1,8- >	1037	0.17 ± 0.01	n.d
Ketones			
Pinocamphone < trans- >	1155	n.d	0.09 ± 0.01
b. SESQUITERPENES			
Sesquiterpene Hydrocarbons			

Table 1 (continued)

Type of compound	RI	CGB	WGB
Ylangene < α- >	1375	0.07 ± 0.01^{b}	0.27 ± 0.01^{a}
Copaene < α- > *	1375	0.07 ± 0.01^{b}	0.27 ± 0.01^{a}
Daucene*	1379	0.69 ± 0.03	n.d
Elemene < β- > *	1389	1.05 ± 0.05^{a}	0.11 ± 0.01^{b}
Sesquithujene < 7-epi- > *	1390	n.d	0.11 ± 0.01
Sesquithujene*	1405	n.d	0.39 ± 0.02
Longifolene*	1409	1.02 ± 0.05^{a}	0.20 ± 0.01^{b}
Bergamotene < α-cis- > *	1410	1.02 ± 0.05^{a}	0.14 ± 0.01^{b}
Bergamotene < α-trans- > *	1428	n.d	0.82 ± 0.04
Thujopsene < cis- > *	1432	0.18 ± 0.01	n.d
Copaene < β- >	1432	0.50 ± 0.02	n.d
Elemene < γ- > *	1434	0.06 ± 0.01	n.d
Aromadendrene	1440	0.23 ± 0.01^{b}	0.97 ± 0.05^{a}
Farnesene < (Z)-β- >	1441	0.34 ± 0.02^{b}	0.47 ± 0.02^{a}
Spirolepechinene	1446	n.d	0.81 ± 0.04
Farnesene < (E)-β- >	1453	1.65 ± 0.08^{b}	4.55 ± 0.16^{a}
Aromadendrene < allo- > *	1458	0.33 ± 0.02	n.d
Muurola-4 (14), 5-diene < cis- > *	1461	0.26 ± 0.01	n.d
Macrocarpene < α- > *	1468	0.26 ± 0.01	n.d
Gurjunene < γ- > *	1476	0.29 ± 0.01^{a}	0.20 ± 0.01^{b}
Chamigrene < β- > *	1477	n.d	0.37 ± 0.02
Muurolene < γ- > *	1481	1.83 ± 0.10^{a}	0.14 ± 0.01^{b}
Curcumene < γ- > *	1482	n.d	0.32 ± 0.02
Amorphene < α- > *	1483	n.d	4.38 ± 0.10
Selinene < δ- > *	1491	0.30 ± 0.01^{b}	0.93 ± 0.05^{a}
Guaiene < cis-β- > *	1494	n.d	1.13 ± 0.06
Epizonarene*	1501	0.64 ± 0.03	n.d
Farnesene < (E,E)-α- >	1509	0.38 ± 0.02^{a}	0.24 ± 0.01^{b}
Bisabolene < β- > *	1510	0.38 ± 0.02^{a}	0.24 ± 0.01^{b}
Curcumene < β- >	1516	0.11 ± 0.01^{b}	1.03 ± 0.05^{a}
Cadinene < γ- > *	1514	1.02 ± 0.05	n.d
Cadinene < δ- > *	1523	1.11 ± 0.04^{a}	0.29 ± 0.01^{b}
Dauca-4(11),8-diene*	1528	6.27 ± 0.25	n.d
Cuprenene < γ- > *	1531	0.26 ± 0.01	n.d
Calamenene < cis- > *	1533	0.02 ± 0.01	n.d
Cadinene < α- > *	1536	0.46 ± 0.02	n.d
Calacorene < α- >	1542	0.41 ± 0.02^{a}	0.19 ± 0.01^{b}
Calacorene < β- > *	1561	0.36 ± 0.02	n.d
Corocalene < α- > *	1619	0.13 ± 0.01	n.d
Cadalene*	1675	0.33 ± 0.02	n.d
Sesquiterpene Alcohols			
Sesquisabinene hydrate < cis- > (IPP vs. OH)*	1541	0.05 ± 0.01^{b}	0.59 ± 0.03^{a}
Hedycaryol*	1546	0.55 ± 0.03	n.d
Muurol-5-en-4-β-ol < cis- > *	1550	0.40 ± 0.02^{a}	0.08 ± 0.01^{b}
Nerolidol < (E)- > *	1557	0.50 ± 0.02	n.d
Longipinanol < epi- > *	1558	0.50 ± 0.02^{b}	0.64 ± 0.02^{a}
Maaliol*	1565	0.35 ± 0.02	n.d
Thujopsan-2-α-ol*	1582	1.26 ± 0.05	n.d
Guaiol*	1595	n.d	2.21 ± 0.10
Cubenol < 1,10-di-epi- > *	1613	1.69 ± 0.08^{b}	18.71 ± 0.08^{a}
Cubenol < 1-epi- > *	1625	0.16 ± 0.01^{b}	2.63 ± 0.11^{a}

Table 1 (continued)

Type of compound	RI	CGB	WGB
Muurola-4,10 (14)-dien-1-β-ol*	1622	0.74 ± 0.03	n.d
Eudesmol < γ- > *	1624	0.46 ± 0.02	n.d
Muurolol < epi-α- > *	1638	1.08 ± 0.05	n.d
Cadin-4-en-7-ol < cis- > *	1639	n.d	0.52 ± 0.03
Cadinol < α- > *	1653	0.26 ± 0.01	n.d
Selin-11-en-4-α-ol*	1663	0.09 ± 0.01	n.d
Bisabolol < epi-α- > *	1688	n.d	0.32 ± 0.02
Germacra-4(15),5,10(14)-trien-1-α-ol*	1689	0.75 ± 0.04	n.d
Eudesm-7(11)-en-4-ol*	1700	0.04 ± 0.01[b]	0.35 ± 0.02[a]
Curcumenol*	1734	0.35 ± 0.02	n.d
Bisabolol oxide A < α- > *	1749	n.d	0.21 ± 0.01
Lanceol < (Z)- > *	1762	n.d	0.20 ± 0.01
Valencene < 13-hydroxy- > *	1767	0.32 ± 0.01	n.d
Sesquiterpene Ketones			
Salvial-4(14)-en-1-one*	1583	n.d	0.94 ± 0.05
Oplopenone < β- > *	1607	2.19 ± 0.10	n.d
Acorenone*	1698	0.48 ± 0.02	n.d
Bisabolone < (6R, 7R)- > *	1742	n.d	1.11 ± 0.05
Nootkatone*	1802	n.d	0.17 ± 0.01
Sesquiterpene Aldehydes			
Cedrenal < 1,7-diepi-α- > *	1636	0.05 ± 0.01	n.d
Isobicyclogermacrenal*	1734	0.09 ± 0.01[b]	0.32 ± 0.02[a]
Farnesal < (2E,6E)- > *	1738	0.15 ± 0.01	n.d
Bisabolenal < β- > *	1768	0.44 ± 0.02	n.d
Sesquiterpene Ethers			
Italicene ether < 10-epi- > *	1515	0.13 ± 0.01	n.d
Cedrene epoxide < α- > *	1572	0.14 ± 0.01	n.d
Caryophyllene oxide	1578	0.71 ± 0.03	n.d
Aromadendrene epoxide < allo- > *	1636	0.08 ± 0.01	n.d
Sesquiterpene Esters			
Bisabolol acetate < α- > *	1798	n.d	0.23 ± 0.01
c. NORTERPENOIDS			
Damascenone < (E)-β- > *	1383	0.12 ± 0.01	n.d
Ionone < (E)-α- > *	1430	0.50 ± 0.02	n.d
Ionone < dihydro-β- > *	1434	0.06 ± 0.00[b]	0.82 ± 0.04[a]
Geranyl acetone	1448	1.75 ± 0.08	n.d
β-Ionone-5,6-epoxide	1486	0.46 ± 0.02[a]	0.44 ± 0.02[a]
Ionone < (E)-β- >	1487	1.38 ± 0.06[a]	1.05 ± 0.05[b]
Calamenen-10-one < 10-nor- > *	1702	n.d	0.82 ± 0.04
Farnesyl acetone < (5E,9E)- > *	1915	0.59 ± 0.03[a]	0.31 ± 0.02[b]
B. ESTERS			
Ethyl hexanoate	996	0.07 ± 0.01	n.d
Prenyl isobutyrate*	1055	n.d	0.27 ± 0.01
Methyl benzoate	1089	0.40 ± 0.02[a]	0.13 ± 0.01[b]
Ethyl benzoate	1170	0.31 ± 0.01	n.d
Ethyl octanoate	1193	0.48 ± 0.02	n.d
Hexyl 2- methyl butanoate < n- > *	1233	n.d	0.32 ± 0.02
Cyclohexanol acetate < cis-2-tert-butyl- > *	1293	0.12 ± 0.01	n.d
Propyl octanoate	1294	0.06 ± 0.01	n.d
Ethyl *n*- nonanoate*	1297	0.66 ± 0.03	n.d
Methyl decanoate	1324	0.59 ± 0.03	n.d

Table 1 (continued)

Type of compound	RI	CGB	WGB
Isobutyl benzoate*	1333	0.15 ± 0.01^{b}	0.37 ± 0.02^{a}
Isobutyl octanoate	1346	0.62 ± 0.03	n.d
2-Ethyl-3-hydroxyhexyl-2-methylpropanoate*	1373	2.04 ± 0.09	n.d
Butyl octanoate	1385	0.85 ± 0.04	n.d
Ethyl decanoate	1393	7.41 ± 0.25^{a}	0.90 ± 0.04^{b}
Decyl acetate*	1406	n.d	0.17 ± 0.01
Isoamyl octanoate*	1443	0.69 ± 0.03	n.d
Pentyl benzoate*	1470	0.10 ± 0.01	n.d
Propyl decanoate	1491	0.82 ± 0.04	n.d
Ethyl undecanoate*	1496	0.90 ± 0.04	n.d
Methyl dodecanoate	1524	0.55 ± 0.02^{b}	0.88 ± 0.04^{a}
Isopentyl salicylate*	1532	0.53 ± 0.02	n.d
Isobutyl decanoate	1544	1.62 ± 0.07^{a}	0.63 ± 0.03^{b}
Hexyl benzoate < n- > *	1574	0.43 ± 0.02	n.d
Hexyl octanoate	1577	0.47 ± 0.02	n.d
n-Butyl *n*- decanoate	1579	0.95 ± 0.04^{a}	0.27 ± 0.01^{b}
Ethyl dodecanoate	1594	2.10 ± 0.10^{b}	3.25 ± 0.12^{a}
iso-Amyl *n*-decanoate*	1643	1.49 ± 0.07^{a}	0.58 ± 0.03^{b}
Methyl jasmonate < (Z)- > *	1652	0.51 ± 0.03^{b}	1.11 ± 0.05^{a}
Methyl tetradecanoate*	1726	0.57 ± 0.03^{b}	0.82 ± 0.04^{a}
Isobutyl dodecanoate	1744	1.43 ± 0.06^{a}	0.54 ± 0.03^{b}
Benzyl benzoate*	1760	0.13 ± 0.01	n.d
Butyl dodecanoate	1787	0.76 ± 0.04	n.d
Ethyl tetradecanoate*	1794	0.72 ± 0.04^{b}	0.98 ± 0.04^{a}
Salicylate < 2-ethylhexyl- > *	1803	0.05 ± 0.01^{b}	0.31 ± 0.02^{a}
Isopropyl tetradecanoate*	1828	1.28 ± 0.05^{b}	1.80 ± 0.08^{a}
9-Hexadecenoic acid, methylester, (Z)- *	1889	n.d	0.17 ± 0.01
11-Hexadecenoic acid, methylester*	1899	n.d	0.34 ± 0.02
Methyl hexadecanoate*	1922	0.70 ± 0.03^{b}	2.72 ± 0.10^{a}
Ethyl 9-hexadecenoate*	1968	0.15 ± 0.01^{b}	0.53 ± 0.03
Ethyl hexadecanoate*	1988	1.07 ± 0.05^{b}	2.39 ± 0.10^{a}
Isopropyl hexadecanoate*	2022	0.46 ± 0.01^{b}	0.52 ± 0.03^{a}
Hexadecanoic acid, propylester*	2095	n.d	0.39 ± 0.02
Linoleic acid methylester*	2107	1.90 ± 0.08	n.d
9-octadecenoic acid, methylester, (E)- *	2107	n.d	2.22 ± 0.10
Hexadecanoic acid, butylester*	2155	n.d	1.83 ± 0.08
Ethyl oleate*	2178	n.d	2.01 ± 0.10
Octadecanol acetate*	2210	n.d	0.32 ± 0.02
C. CARBOXYLIC ACIDS			
Tiglic acid*	905	0.49 ± 0.02^{b}	0.72 ± 0.03^{a}
Ethyl hexanoic acid < 2- > *	1116	0.22 ± 0.01	n.d
Benzoic acid	1157	0.66 ± 0.03	n.d
Octanoic acid	1177	n.d	0.02 ± 0.01
Decanoic acid	1363	0.32 ± 0.01^{a}	0.29 ± 0.01^{b}
Dodecanoic acid*	1560	1.50 ± 0.06^{b}	3.62 ± 0.12^{a}
Hexadecanoic acid*	1958	0.30 ± 0.01^{b}	1.48 ± 0.06^{a}
D. ALKANES			
Tetradecane < n- > *	1400	0.41 ± 0.02	n.d
Pentadecane < n- > *	1500	1.59 ± 0.06^{a}	0.47 ± 0.02^{b}
Heptadecane < n- > *	1700	1.38 ± 0.06^{a}	1.38 ± 0.05^{a}
Octadecane < n- > *	1800	0.49 ± 0.02^{a}	0.43 ± 0.02^{b}

Table 1 (continued)

Type of compound	RI	CGB	WGB
Nonadecane < n- > *	1900	n.d	0.14 ± 0.01
Docosane < n- > *	2200	0.08 ± 0.01	n.d
Pentacosane < n- > *	2500	0.13 ± 0.01	n.d
Heptacosane < n- > *	2700	0.07 ± 0.01	n.d
E. ALDEHYDES			
Heptanal	903	0.07 ± 0.01	n.d
Benzaldehyde	965	0.60 ± 0.03	n.d
Octanal < n- >	993	0.13 ± 0.01	n.d
Octen-1-al < (2E)- > *	1062	n.d	0.37 ± 0.02
Nonanal < n- >	1100	0.06 ± 0.01	n.d
Undecenal < (2E)- >	1361	0.16 ± 0.03[a]	0.13 ± 0.01[a]
Dodecanal*	1408	0.33 ± 0.02	n.d
Pentadecanal*	1717	0.46 ± 0.02[b]	2.94 ± 0.10[a]
F. ALCOHOLS			
4-Octanol	994	0.07 ± 0.01	n.d
Benzyl alcohol	1037	0.08 ± 0.01	n.d
Tetradecanol < n- > *	1676	1.19 ± 0.05[a]	0.39 ± 0.02[b]
Pentadecanol < n- > *	1776	0.21 ± 0.01	n.d
Hexadecanol < n- > *	1875	n.d	0.36 ± 0.02
Octadecanol < n- > *	2075	0.53 ± 0.03	n.d
G. KETONES			
4-Nonanone	1054	n.d	0.13 ± 0.01
Acetophenone < ρ-methyl- > *	1180	0.17 ± 0.01	n.d
Undecanone < 2- > *	1295	0.19 ± 0.01	n.d
2-Pentadecanone, 6, 10, 14- trimethyl- *	1837	0.35 ± 0.02[b]	1.33 ± 0.06[a]
H. LACTONES			
Hexalactone < γ- >	1052	0.02 ± 0.01	n.d
Octalactone < γ- >	1257	0.12 ± 0.01	n.d
Decalactone < γ- > *	1465	1.12 ± 0.05[a]	0.09 ± 0.01[b]
Dodecalactone < γ- > *	1679	0.07 ± 0.01	n.d
Undecalactone < γ- >	1574	n.d	0.39 ± 0.02
I. FURANS AND DERIVATIVES			
4-Methoxy-2,5-dimethyl-3(2H)-furanone	1064	0.05 ± 0.01 [b]	0.37 ± 0.02 [a]
Perillene*	1101	0.04 ± 0.01	n.d
Dihydroactinidiolide	1528	0.09 ± 0.01 [b]	1.45 ± 0.07 [a]
J. CINNAMIC ACID DERIVATIVE			
Methyl cinnamate < (E)- > *	1378	n.d	0.33 ± 0.02
Ethyl cinnamate < (E)- > *	1462	0.13 ± 0.01[b]	0.59 ± 0.03[a]
K. UNSATURATED HYDROCARBONS			
Tetradecene < 1- > *	1388	n.d	0.09 ± 0.01
Hexadecene < 1- > *	1582	n.d	0.63 ± 0.03
L. PYRANS AND DERIVATIVES			
Maltol*	1110	0.22 ± 0.01	n.d
Sclareoloxide*	1877	1.10 ± 0.05	n.d
M. SULFUR COMPOUNDS			
Mint sulfide*	1738	0.31 ± 0.01	n.d

CGB cultivated cape gooseberry, *WGB* wild cape gooseberry, n.d. not detected. *RI* retention index on HP-5MS column. Percentage relative area of three replicates, each value expressed as mean ± standard deviation.

[ab]Different superscripts within the same row indicate statistical differences ($p < 0.05$)

*Compounds indicated with an asterisk are reported for the first time in cape gooseberry fruits

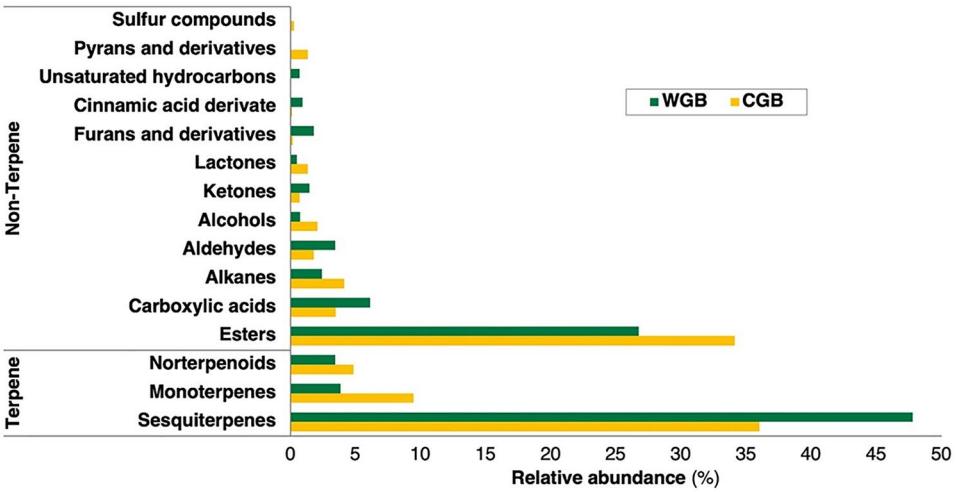

Fig. 1 Percentage distribution of volatile compounds by relative abundance in cape gooseberry fruits. WGB: wild cape gooseberry fruit, CGB: cultivated cape gooseberry fruit

while terpenoid alcohols like citronellol provide delicate aromas of roses and violets, it is abundant in herbs, spices and fruits and is essential for many flavorings [9]. These main monoterpene compounds in both fruits were reported in almost all the analyzes of volatiles carried out in cape gooseberry fruits [10, 16, 18, 19].

When comparing the relative area percentage in the classification of terpene compounds, it can be observed that the volatile profile in both cultivated and wild fruits was essentially represented by sesquiterpenes (Fig. 1), being the predominant compounds within this class, sesquiterpene hydrocarbons in cultivated fruits (22.03%) and sesquiterpene alcohols in wild fruits (26.46%) (Table 1).

Within the sesquiterpene hydrocarbon group, the predominant ones in cultivated cape gooseberry fruits were dauca-4 (11), 8-diene; muurolene < γ- > and farnesene < (E)-β- >, the latter two being characterized by imparting woody spicy notes [9]. Among these three major compounds, only farnesene < (E)-β- > has been reported in cape gooseberry fruits [18]; while muurolene < γ- > was reported in aromatic and medicinal plants [20] and dauca-4 (11), 8-diene in carrots and flowers of *Osmanthus fragrans* [21, 22]. In the wild cape gooseberry fruits, farnesene < (E)-β- > and amorphene < α- > were the most abundant sesquiterpene hydrocarbons. Although farnesene < (E)-β- > was also one of the majorities in cultivated fruits, it stood out for its higher relative area in wild fruits (4.55%) compared to 1.65% in cultivated fruits. Amorphene < α- > (4.38%) has only been identified in wild fruits and, like farnesene < (E)-β- >, is also characterized by imparting woody notes. Amorphene < α- > has not been reported in other investigations as a volatile compound in cape gooseberry fruits but has been reported in grapes [23]. The sesquiterpene alcohols that presented the highest percentage of relative area in wild fruits were cubenol < 1,10-di-epi- > (18.71%), cubenol < 1-epi- > (2.63%) and guaiol (2.21%). These last two compounds are characterized by imparting woody, balsamic and herbaceous notes. None of these three volatile compounds has been previously reported in cape gooseberry fruits. Cubenol < 1,10-di-epi- > was reported as a volatile compound in fruits of *Eugenia* and fruits of *Annona squamosa* [24, 25], while cubenol < 1-epi- > and guaiol were reported in fruits of *Myrcia sylvatica* [26] and in stem bark of *Nectandra lanceolata* [27]. Another sesquiterpene that stood out for its relative abundance is the ketone oplopenone < β- >, which represents 2.19% in cultivated cape gooseberry fruits. This compound has not been previously reported in investigations of the volatile profile in *Physalis peruviana* L. fruits; however, it has been reported in the essential oil of carrot flowers [28] and in fruits of *Rubus ulmifolius* [29].

The lowest percentage of relative area in the classification of terpene compounds was represented by norterpenoids in both cultivated (4.86%) and wild (3.44%) fruits (Fig. 1). Some of the norterpenoids are powerful odorants with threshold values in the ppt-range and are, thus, key compounds for the aroma of several fruits and vegetables [8]. The norterpenoids that stood out for the highest percentage of relative area were geranyl acetone and β-ionone. Geranyl acetone is degradation product of phytofluene acyclic carotenoid, whereas β-ionone is derived from the cyclic carotenoid, β-carotene [9]. Geranyl acetone was present only in cultivated cape gooseberry fruits (1.75%), while β-ionone was present in both cultivated and wild fruits (1.38 and 1.05%, respectively), showing significant statistical difference ($p \leq 0.05$) in both fruits (Table 1). Geranyl acetone and β-ionone are volatile compounds present in many fruits and provide, respectively, floral rose aroma and a distinctive smell of violet [9].

After terpenes, non-terpene esters were also abundant compounds in cape gooseberry fruits (Fig. 1). In total, 38 and 28 esters were detected in cultivated and wild fruits,

respectively, representing relative abundance of 34.14 and 26.77%. Volatile esters are formed by esterification of alcohol and carboxylic acids and constitute one of the largest and main group of volatile compounds identified in fruit aroma [17]. Esters with low molecular weight are present mainly in fruit and flowers. Esters with simple structures have characteristic fruity aromas; others have fruity aromas as well, but often nonspecific [29]. Aroma of many esters depends on their molecular structure and conformation. Short-chain esters have a fruity odor, but as the length of the chain increases, their smell can get more fatty, soapy or metallic [30]. Ethyl decanoate (7.41%), ethyl dodecanoate (2.10%), and 2-Ethyl-3-hydroxyhexyl-2-methylpropanoate (2.04%) were the esters found in higher relative abundance in the cultivated cape gooseberry fruits, while in wild fruits, ethyl dodecanoate (3.25%), methyl hexadecanoate (2.72%) and ethyl hexadecanoate (2.39%) were the most abundant (Table 1). Among the mentioned esters, only ethyl decanoate and ethyl dodecanoate were previously reported as volatile compounds in *Physalis peruviana* L. fruits [10, 19], also being reported in fruits such as pineapple, mango and plum [17]; these esters have often fruity and flowery aroma descriptors [7, 17]. 2-Ethyl-3-hydroxyhexyl-2-methylpropanoate was reported as a volatile compound in some fruits, such as apricots and plums [31], while methyl hexadecanoate and ethyl hexadecanoate were reported in mango, pineapple and strawberry [17]. Methyl hexadecanoate presents oily, waxy, and fatty odor description, while ethyl hexadecanoate provides a waxy and fruity aroma [32].

After non-terpene esters, carboxylic acids represent 6.13 and 3.49% relative abundance in wild and cultivated fruits, respectively (Fig. 1). Dodecanoic acid (3.62%) and hexadecanoic acid (1.48%) stood out in wild fruits, while dodecanoic acid also stood out in cultivated fruits (1.50%) (Table 1). Saturated and linear carboxylic acids contribute to the aroma, which are formed during repeated β- oxidation cycles followed by the action of an acyl-CoA hydrolase. Aliphatic acids up to C_{10} are used to accentuate certain aroma characteristics, they play a significant role in flavors due to their sharp, buttery, and cheese-like odors, not only on their own, such as in dairy flavors, but also as substrates for another flavor biosynthesis [17]. The longer chain acids are less intense, have very little odor and in the cases of dodecanoic and hexadecanoic acids, they are characterized by having a fatty-waxy odor [32].

Eight alkanes were detected in cape gooseberry fruits, of which seven are present in cultivated fruits and four are present in wild fruits, representing, respectively, 4.15 and 2.42% (Fig. 1). Pentadecane, heptadecane and octadecane were detected in both fruits, only pentadecane and octadecane were significantly ($p \leq 0.05$) higher in cultivated fruits than in wild fruits (Table 1). Alkanes probably contribute little to the aroma because they generally have high odor thresholds [33].

Aldehydes also were detected with a relative percentage of 1.81% in cultivated fruits and 3.44% in wild fruits (Fig. 1). These compounds are derived from fatty acids and amino acids and are very important for the flavor of most fruits and vegetables [9]. Aldehydes are extremely common components of any food, and many have a low odor threshold. The straight-chain unbranched aldehydes are ubiquitous. As the chain length increases beyond C_6, the aldehydes take on a dual character and have both fruity/floral and fatty descriptors, depending on the concentration. Octanal still has a fruity note with a fatty character [9]. However, as the number of carbon atoms rises, aldehydes have an increasingly fatty odor, aldehydes with more than 13 carbon atoms are characterized by a weak odor [30]. Dodecanal is characteristically sweet, waxy-herbaceous, very fresh, and clean-floral odor with a faint fatty undertone [32]. Pentadecanal is very faint, but delicately fresh-floral odor of good tenacity [32]. Aldehydes containing an aromatic ring such as benzaldehyde (known for its characteristics almond flavor note) are important components of foods [17].

The contribution to aroma by alcohols tends to be less than for aldehydes because the odor threshold of alcohols is considerably higher than that of the corresponding aldehydes, so they are normally less important to flavor profiles [17]. The C_6 and C_9 aldehydes and alcohols, produced through the fatty acid-derived lipoxygenase pathway, provide "fresh green" odors in numerous fruits [17]. The straight-chain alcohols are abundant in fruits, often increasing with maturity, whereas the longer chain alcohols can be very soapy [9]. A total of five and two alcohols were detected in cultivated and wild fruits, with relative abundances of 2.08 and 0.75%, respectively (Fig. 1). Only tetradecanol was detected in both fruits and was significantly ($p \leq 0.05$) higher in cultivated fruits than in wild fruits (Table 1). Tetradecanol has very faint, coconut-oily, mildly waxy odor of considerable tenacity [32].

In total, four ketones were detected in cape gooseberry fruits, but only one (6,10,14-trimethyl-2-pentadecanone) was present in both fruits. Some ketones have characteristic odors and are character impact compounds in some fruits [7]. In the ketone class, odd-numbered methyl ketones C_7, C_9, C_{11}, being formed via β-oxidation and decarboxylation of corresponding fatty acids, are well-known food odorants because of their nut-like aroma. Straight and branched chain ketones up to C_8 contribute to caramel notes in food [30], whereas the straight-chain methyl ketones, containing one carbonyl group in the 2-position, impart both a blue cheese and a fruity pear aroma [9].

Lactones are ubiquitous in foods. Their odor thresholds are usually very low and are well-known key aroma compounds in fruits, but they are also important in fat-containing

foods [8]. Five lactones were detected in the cape gooseberry fruits, of which four were present in cultivated fruits: γ-hexalactone (faint, sweet coconut with a fatty-herbaceous hay note), γ-octalactone, γ-decalactone and γ-dodecalactone which provide a fruity, peach and coconut-like background odor [7, 8]. Only γ-decalactone and γ-undecalactone were present in wild gooseberry fruits, the latter imparts a strong, fatty-sweet odor reminiscent of peach [8].

All the other chemical classes were present in very low amounts, with higher relative abundance of furans (1.82%), cinnamic acid derivative (0.92%) and unsaturated hydrocarbons (0.72%) in wild fruits, while sulfur compounds (0.30%) and pyrans and derivatives (1.32%) were only present in cultivated fruits.

Many volatile compounds were found in common in both fruits (67); among those, farnesene < (E)-β- >, cubenol < 1,10-di-epi- >, dodecanoic acid, ethyl dodecanoate and isopropyl tetradecanoate stood out for their relative abundance. Only 63 and 30 compounds in cultivated and wild cape gooseberry fruits, respectively, have been previously reported [10, 16, 18, 19]. This study offers new evidence concerning volatile emissions of cape gooseberry fruits; being detected 144 volatile compounds reported for the first time (new compounds were indicated with asterisks in Table 1).

Correspondence between volatile compounds and sensory evaluation

The sensory attributes of the two fruits were evaluated by 75 untrained panelists, potential consumers of cape gooseberry fruits. It is important to mention that the low number of attributes evaluated (three), the simple terminology of these attributes (sweetness, acidity, and aroma) and the number of panelists involved (75), allowed to obtain significant results in the sensory profiles of both fruits. The mean scores of the panelists when evaluating the three sensory attributes and overall acceptance are presented in Table 2. Statistically, the aroma perception and overall acceptance showed a significant difference between both fruits, the cultivated fruit being the one that presents the more perceptible aroma and higher overall acceptance than the wild fruit. Although there were no significant differences in acidity and sweetness between both fruits, a trend towards a higher perception of acidity could be observed in cultivated fruits than in wild fruits, while the trend towards higher sweetness is for wild fruits. These trends may be related to a higher acidity content in cultivated fruits and a higher content of total soluble solids in wild fruits [3]. Although all the panelists were unaware of the fruit, both the cultivated and wild ones presented overall acceptance scores above the average with a tendency to "like extremely", which is favorable for marketing these fruits either as fresh or processed.

A PCA was conducted to establish the multidimensional relationship between both fruits and the types of volatile compounds that were significantly different in both fruits, also considering the sensory descriptor Aroma and the Overall acceptance as supplementary observations. The PCA plot generated for the first two dimensions is shown in Fig. 2. A value of 100% of total variability was explained by the two principal components. As shown in the PCA score plot (Fig. 2), the cultivated cape gooseberry fruits were mainly related with esters and monoterpenes, while wild cape gooseberry fruits presented more sesquiterpene compounds. According to PCA data, the aroma profile is probably related mainly to the ester's composition in cultivated fruits and to the sesquiterpenes composition in wild fruits, as well as the composition of monoterpenes could contribute the volatility profile of the cultivated fruits; these differences could influence a higher aroma perception and overall acceptance in cultivated fruits.

The comments written by the panelists in the sensory evaluation indicated that they perceived fruity, floral, and more intense aromas in the cultivated fruits than in the wild fruits, as well as they related the cultivated fruit aroma with that of peach and mango. In the case of wild fruits, the panelists perceived herbaceous and fatty aromas. Fig. 3 shows the frequency of comments that were common to more than 5% of the panelists.

The sensory characteristics of the cultivated and wild fruits emitted by the panelists through their written comments, were correlated with the volatile compounds detected in both fruits by means of a Multiple Factor Analysis. Figure 4 shows the MFA map with 98.26% of the explained variance. It was observed two well differentiated groups. In one of them, the volatile compounds: sesquiterpenes, aldehydes, ketones, carboxylic acids, furans and derivatives, unsaturated hydrocarbons and cinnamic acid derivatives, are associated with "herbaceous aroma", "fatty aroma" and "little taste"; while monoterpenes, sulfur

Table 2 Sensory evaluation of cultivated and wild cape gooseberry fruits

Fruit type	Acidity	Sweetness	Aroma	Overall acceptance
Cultivated cape gooseberry	6.81 ± 0.72^{a}	5.32 ± 1.22^{a}	7.63 ± 0.64^{a}	8.50 ± 0.93^{a}
Wild cape gooseberry	5.25 ± 1.20^{a}	7.21 ± 1.05^{a}	5.60 ± 1.02^{b}	6.02 ± 0.80^{b}

Results are presented as mean scores of seventy-five panelists ± standard deviation

[ab]Different superscripts within the same column indicate statistical differences ($p < 0.05$)

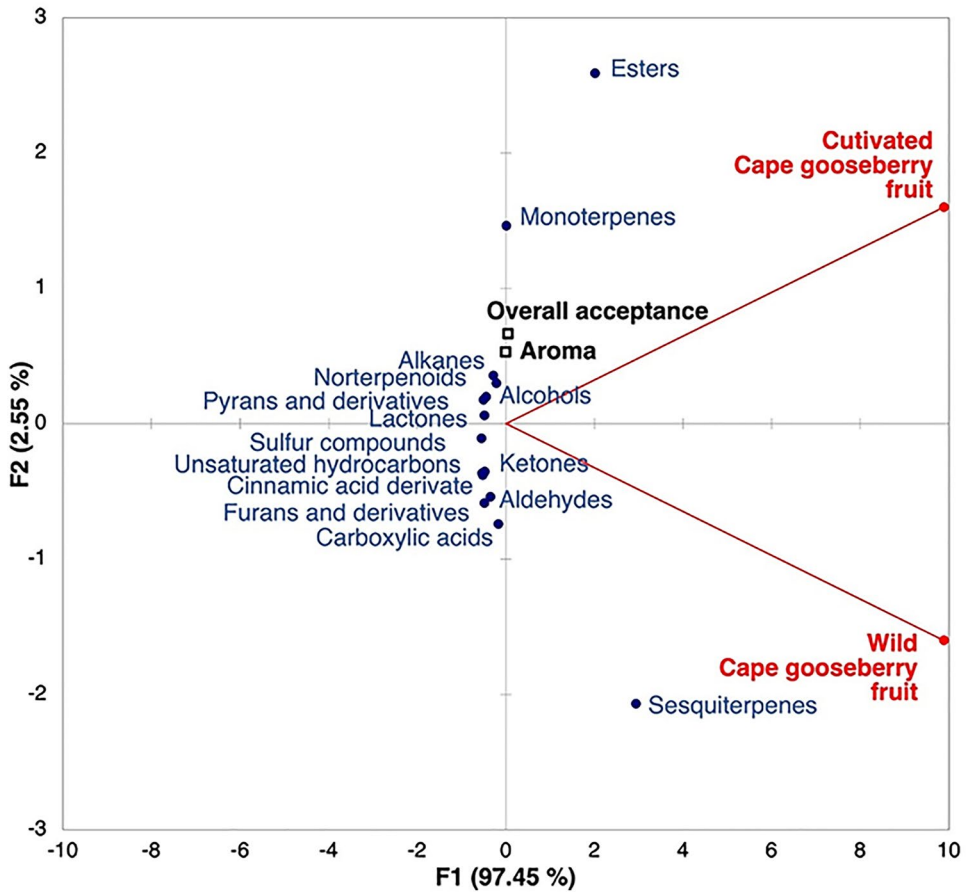

Fig. 2 PCA of volatile compounds in cultivated and wild cape gooseberry fruits

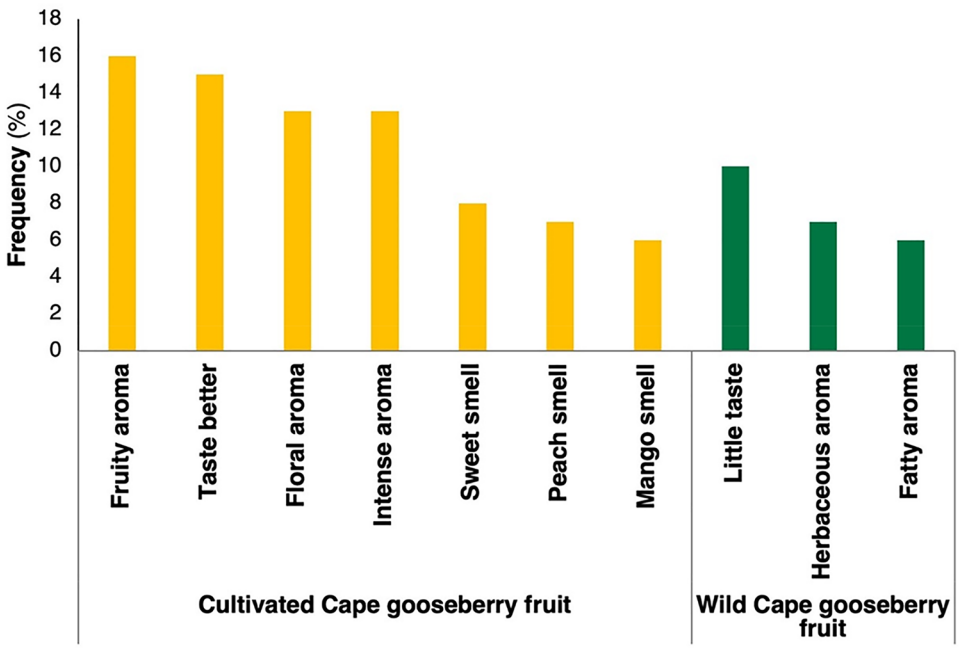

Fig. 3 Frequency of panelist comments in sensory evaluation in cape gooseberry fruits

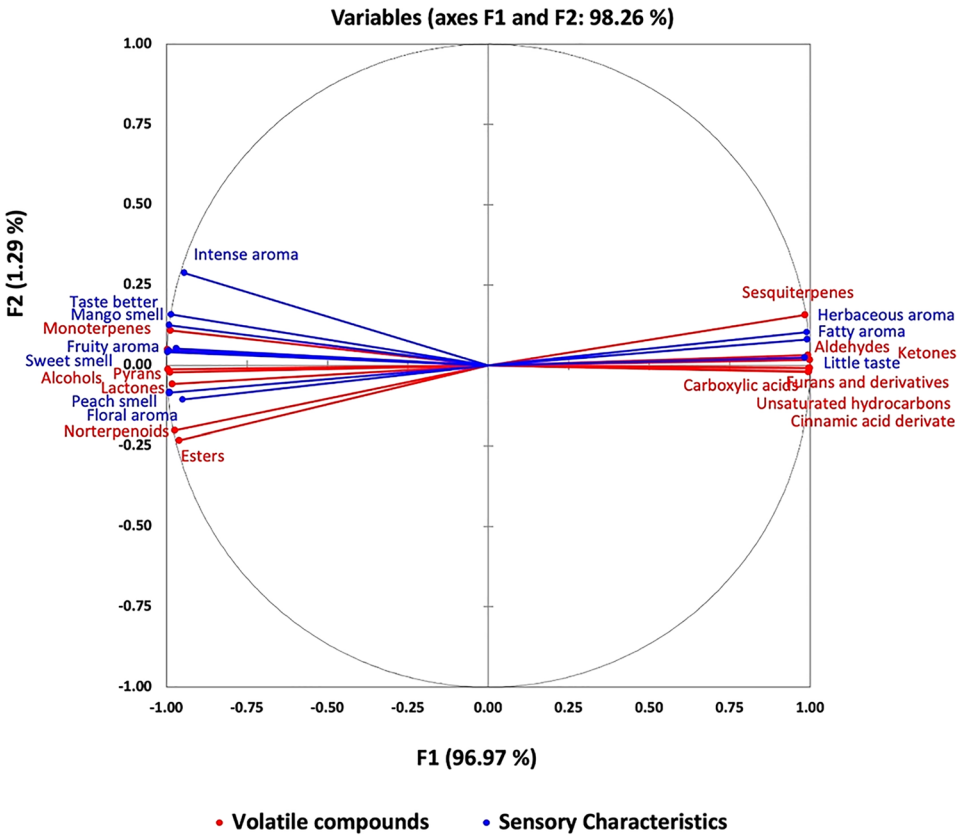

Fig. 4 Representation of sensory characteristics and volatile compounds based on the MFA in cape gooseberry fruits

compounds, pyrans and derivatives, alcohols, alkanes, lactones, norterpenoids and esters are associated with "floral aroma", "peach smell", "sweet smell", "fruity aroma", "mango smell", "taste better" and "intense aroma".

The herbaceous aroma is mainly associated with sesquiterpenes (Fig. 4), which according to the PCA (Fig. 2) characterize wild fruits. Sesquiterpenes have a very low odor threshold, in the ppb range [34]; therefore, it is presumable that many of the identified sesquiterpenes contributed to the detected aroma. Sesquiterpenes are considered important fruit odorants due to their sensory properties described as green, herbaceous, citrus, resinous and woody aromas, the aromatic character being green/herbaceous not only due to sesquiterpenes but also aldehydes and ketones [35]. In this context, the higher amount of sesquiterpenes together with that of aldehydes and ketones in wild fruits, compared to cultivated fruits, could help to enhance the herbaceous aroma perceived by the panelists in wild fruits.

The fatty aroma is mainly associated with aldehydes (Fig. 4). All detected aldehydes have more than 6 carbon atoms. According to Guichard [30], as the chain length increases beyond C_6, aldehydes have an increasingly fatty odor. This odorant characteristic of the aldehydes may be related to the fatty aroma that the panelist perceived in the wild fruits (Fig. 3).

Overall, Fig. 4 clearly shows that a sensory characteristic is associated with more than one class of volatile compound. Regarding the esters, these are related to floral and fruity aromas [17, 32]. According to the PCA (Fig. 2), it is the esters that mainly characterize the cultivated fruits, so the fruity and floral aromas that were perceived with higher intensity in the cultivated fruits may be related to the presence of these volatile compounds. Although the cultivated fruits present a higher relative abundance of esters than the wild ones (34.14 and 26.77%, respectively), they are the lower molecular weight esters that are mostly found only in the cultivated fruits, responsible for the fruity and floral character. Such is the case of ethyl hexanoate, ethyl benzoate, ethyl octanoate, ethyl nonanoate and methyl decanoate, which although they were found in low percentages of relative area, are considered volatile compounds responsible for the floral-fruity character with significant effects on flavor due to their low odor-threshold values [17, 32]. Ethyl decanoate, the ester with the highest relative area in cultivated fruits, has also a low threshold value and contributes to the fruity, floral, and sweet aroma [7].

Figure 4 shows that the floral aroma is associated with norterpenoids and esters. The floral aroma was mainly perceived by the panelists in the cultivated fruits (Fig. 3). This aroma perceived could be favored by the norterpenoids

β-damascenone and geranyl acetone, which were detected only in cultivated fruits, as well as by *β*-ionone. These volatile compounds have a characteristic rose and violet-like aroma and due to their low odor detection thresholds, they have been suggested as key odorants in the aroma of several fruits [7, 35].

The peach aroma perceived by the panelists, mainly in the cultivated fruits, is associated with the composition of lactones (Fig. 4). The very low odor thresholds for lactones allow them to be detected in the olfactory system even in small amounts [8, 17]. Lactones have characteristics aromas that are attributable to peach and have been reported as character-impacted compounds in this fruit, being the main responsible for the peach aroma: γ-hexalactone, γ-decalactone and γ-dodecalactone [7, 17], which are present in the cultivated fruits of cape gooseberry.

According to Fig. 4, mango aroma is associated with monoterpenes. Mango was another of the fruits related to the cultivated cape gooseberry fruits aroma, being the most important compounds that contribute to mango flavor with active odor values (low odor-threshold values) the following monoterpenes, esters and lactones: α-pinene, myrcene, α-phellandrene, *p*-cymene, limonene, terpinolene, terpinen-4-ol, methyl benzoate, ethyl decanoate, ethyl dodecanoate, γ-hexalactone, γ-octalactone and γ-decalactone, as well as (E)-2-nonenal, (E)-β-ionone and 2,5-dimethyl-4-methoxy-3(2H)-furanone [17]. The mentioned compounds were found mostly in the cultivated cape gooseberry fruits, in some cases as α-pinene, myrcene, terpinen-4-ol, γ-hexalactone and γ-octalactone were present only in cultivated fruits, while limonene, terpinolene, methyl benzoate, ethyl decanoate, ethyl dodecanoate, γ-decalactone, (E)-β-ionone and 2,5-dimethyl-4-methoxy-3(2H)-furanone were found in both cultivated and wild fruits.

Finally, although the description and comments of the sensory characteristics of both fruits were made by an untrained panel of regular consumers of fruits who did not know the fruit under study, the results obtained from the PCA and MFA showed relationships between the percentage distribution of volatile compounds and the evaluation and comments of the panelists. All these allowed defining characteristics and sensory attributes that characterized and differentiated each fruit.

Conclusion

The volatile compound profiles of cape gooseberry fruits determined by HS–SPME–GC–MS allowed the identification of 170 volatile compounds in CGB and 108 in WGB. From the total volatile compounds identified, only 67 ones were found in common in both fruits and 144 are here reported for the first time in cape gooseberry fruits. A PCA plot showed the aroma profile could be related mainly to the ester composition in cultivated fruits and to the sesquiterpene composition in wild fruits. Multiple factor analysis showed that the sensory characteristics defined by potential consumers were associated with more than one class of volatile compound. Consumers associated wild fruits with herbaceous and fatty aromas while cultivated fruits were associated with fruity and floral aromas. The sensory characteristics of both fruits defined by an untrained panel and the composition of volatile compounds allowed us to define characteristics and sensory attributes that characterized and differentiated each fruit.

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Data availability The data that support the findings of this study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors declare that there is no conflict of interest.

Compliance with ethics requirements This article does not contain any studies with human or animal subjects.

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