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Research Article

Volatile Composition of Sweet Passion Fruit (*Passiflora alata* Curtis)

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Passiflora alata Curtis (sweet passion fruit) is a native species grown in South America, especially in Brazil. In addition to being aromatic, its pulp is sweeter and less acidic compared to traditional commercial passion fruits, and this makes it highly appreciated for fresh consumption. Its aroma is also very distinct from other passion fruit species but it has not been characterized so far. In the present study, for the first time, the volatile composition of sweet passion fruit was investigated. Two genotypes (BGM004 and BGM163) were evaluated and two SPME fibers were tested. Forty-five volatile compounds were properly identified and semiquantified. The carboxen-polydimethylsiloxane (CAR/PDMS) fiber presented better performance regarding both number and concentration of compounds. Esters and terpenes were the main volatile classes. Methyl butanoate, methyl (E)-2-butenoate, ethyl butanoate, ethyl (E)-2-butenoate, methyl 2-hexenoate, and ethyl-2-hexenoate were among major compounds. As complementary results, sugar content, titratable acidity, pH, and total soluble solids were evaluated.

1. Introduction

Passion fruits (Passifloraceae family, genus *Passiflora*) are appreciated worldwide. Their intense and exotic aroma and consequently strong flavor derive from a complex volatile composition, including mainly esters, followed by alcohols and terpenes, among other compounds [1–4]. Passion fruits are native of America and grow in the tropical and subtropical regions of the world. In the middle west and northeast regions of Brazil there are near 150 native species, from which about 60 are known to be edible [5–7]. However, only two are currently commercially important, *P. edulis* Sims f. *flavicarpa* Deg. (yellow passion fruit) and *P. edulis* f. *edulis* Sims (purple passion fruit) [4]. Other species hold promising sensory and nutritional characteristics and could be more explored commercially. *P. alata* Curtis (sweet passion fruit) is a native species grown in South America, especially in Brazil. It is also found in Peru, Paraguay, and Argentina [6].

This species holds interesting characteristics. Its aroma is quite distinct from other passion fruits and, in addition to being aromatic, its pulp contains higher sugar and lower organic acids concentrations compared to traditional commercial passion fruit species, which makes it sweeter and less sour. For this reason, sweet passion fruit has been highly appreciated for fresh consumption as a dessert, for example, rather than mainly for juice consumption as with other passion fruit species [6–9]. Consequently, its economic value has grown over the last years, corresponding currently to three to ten times the value of yellow species in Rio de Janeiro, São Paulo, and Minas Gerais, the largest wholesale markets in Brazil [10].

While the volatile composition of other commercial passion fruits has been evaluated in several studies [1, 11–13], to our knowledge, no information on the volatile composition of sweet passion fruit is available in the literature. Therefore, the aim of the present study was to investigate the volatile composition of genotypes of sweet passion fruits grown in the experimental fields of Embrapa, in Northeast Brazil. For this, two types of solid-phase microextraction (SPME) fibers were compared.

2. Materials and Methods

2.1. Samples. Two genotypes of sweet passion fruit belonging to the *Passiflora* germoplasm depository of Embrapa (BGM004 and BGM163) (Figure 1) were grown in the Experimental Fields of Embrapa Cassava and Fruits, Cruz das Almas, BA, Brazil (South latitude 12°48′38″, Greenwich West longitude 39°6′26″, average temperature 22.7°C, and precipitation 4.5 mm H_2O). The fruits were harvested 10–12 months after planting, when about 75% of the peel was yellow (75% ripe) (Figure 1). Two days later, when the peel was 100% yellow (full ripe), fruits were depulped in a horizontal depulper (Bonina 0,25 dF), equipped with a 0.8 mm diameter sieve. Following that, fruits were frozen with liquid nitrogen, stored at −20°C, and transported for immediate analysis.

2.2. Extraction of Volatile Compounds. The extraction of volatile compounds was performed by solid-phase microextraction (SPME). Two SPME fibers (Supelco Inc., Bellefonte, PA, USA) [14, 15] were compared: a 75 μm carboxen-polydimethylsiloxane (CAR/PDMS) (biphasic fiber) and a 50/30 μm divinylbenzene-carboxen-polydimethylsiloxane (DVB/CAR/PDMS) (triphasic fiber). Fibers were activated according to the manufacturer's instructions. For extraction, 4.0 g of fruit pulp was mixed with 5% of NaCl in a sealed 15 mL vial with a magnetic stirring. The vial was placed in a silicone bath at 40°C for 20 min, to achieve the partition equilibrium between sample and headspace. Following that, the SPME fiber was exposed to the headspace for 40 min to adsorb the volatile compounds. The fiber was then introduced into the gas chromatograph injection port for 5 min at 250°C for desorption, followed by a 10 min desorption in a separate GC injection port as cleaning protocol to prevent analyte carryover. Analyses were carried out in duplicate.

2.3. Analyses of Volatile Compounds

2.3.1. Gas Chromatography-Mass Spectrometry. The analyses of volatile compounds were performed in a GC/MS system (Agilent®, Palo Alto, Ca), consisted of a gas chromatographer (model 6890) coupled to a quadrupole mass selective detector (model 5973N). A HP-5 MS capillary column (5% phenyl-methylpolysiloxane) (30 m × 0.25 mm × 0.25 μm film thickness) was used. Helium was used as the carrier gas at a flow rate of 1.0 mL/min. The injector temperature was kept at 250°C in splitless mode; oven temperature gradient program was 40°C for 3 min, rising to 130°C at 3°C/min and to 260°C at 10°C/min, where it was maintained for 3 min. The mass detector was operated at 150°C, in electron impact mode at 70 eV. The ion source temperature was 230°C and the transfer line was kept at 280°C. Scan interval for mass spectral data acquisition was 1.0 s and data were collected over a mass range (m/z) from 35 to 350 u.

2.3.2. Identification and Semiquantification of the Volatile Compounds. Total ion chromatograms (TIC) were processed using the automated data processing software MDS ChemStation (Agilent Technologies, 2008). For compounds identification, the Wiley library (6th edition), linear retention indexes (Kovats indexes), and analytical standards were used. For Kovats index calculation, a standard mixture of n-alkanes (C_8 a C_{26}) (Sigma-Aldrich, Germany) was injected into the CG/MS under the same analysis conditions of samples. Peaks were then identified according to values obtained from Adams [16], Pherobase [17], and NIST Chemistry WebBook [18].

The following analytical standards were purchased from Sigma-Aldrich (Germany): ethyl butanoate, ethyl crotonate, butyl acetate, butyl butanoate, ethyl hexanoate, hexyl acetate, propyl hexanoate, ethyl octanoate, octyl acetate, isoamyl-hexanoate, methyl acetate, hexyl hexanoate, ethyl decanoate, citronellyl acetate, 2-heptenal, nonanal, trans-2-nonenal, decanal, cis-3-hexen-1-ol, trans-3-hexen-1-ol, hexan-1-ol, 1-octanol, linalool, α-pinene, β-pinene, myrcene, limonene, γ-terpinene, α-terpinene, terpinolene, α-ionone, β-ionone, 6-methyl-5-hepten-2-one, rose oxide, and citronellol.

Semiquantification of the identified peaks was performed to compare the amount of volatile compounds obtained for both genotypes as well as to evaluate the effect of the fiber type in adsorption-desorption. The semiquantification was performed using calibration curves made of 5 concentration levels (0.2–60 μg of standard per vial) of 10 representative compounds for the main volatile classes in passion fruit: ethyl butanoate, ethyl hexanoate, hexyl hexanoate, ethyl crotonate, hexan-1-ol, linalool, 6-methyl-5-hepten-2-one, limonene, γ-terpinene, and decanal (Sigma-Aldrich).

2.4. Complementary Physicochemical and Chemical Analyses. Complementary analyses were performed to characterize the sweet passion fruit genotypes. Titratable acidity, expressed in g of citric acid/100 g, was determined by titration with NaOH (0.1 N) up to pH 8.1 with automatic titrator Metrohm 794 Basic Titrino, according to AOAC [19]; pH determination was performed by a potentiometric method according to AOAC [19] using automatic titrator Metrohm 794 Basic Titrino; total soluble solids were determined directly in the fruit pulp using digital refractometer Atago PR-101 (Atago Co. Ltd., Tokyo, Japan). Results were expressed in °Brix, according to AOAC [19]. Analyses of glucose, fructose, and sucrose were determined by HPLC as described by Macrae [20]. For this, a Waters Alliance 2695 liquid chromatographer coupled to a Waters 2410 refractive index detector and amino column (High Performance Carbohydrate) with 4.6 mm × 250 mm at 30°C were used. As mobile phase, 75% acetonitrile in Milli-Q water at a rate of 1.5 mL/min was used and the injection volume was 20 μL.

2.5. Statistical Analysis. Results were analyzed by factorial ANOVA, followed by Fisher or LSD test for means comparison, using the software Statistica®, version 8.0, USA.

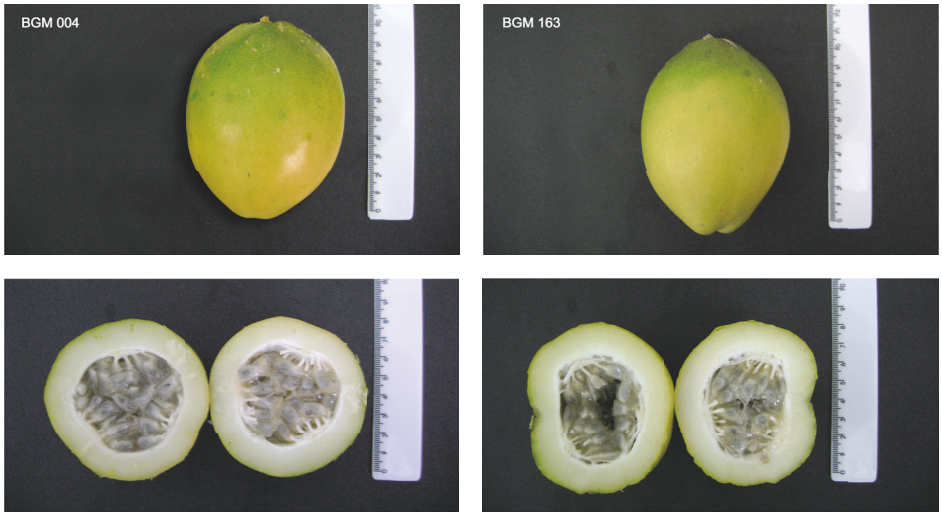

Figure 1: *Passiflora alata* Curtis (sweet passion fruit) genotypes harvested when about 75% of the peel became yellow (75% ripe).

p values < 0.05 were considered significant. Comparisons were performed among genotypes and SPME fibers.

3. Results and Discussion

3.1. Analysis of Volatile Compounds. A hundred and three volatile compounds were detected in both genotypes of passion fruit, by both fibers. From these compounds, 45 (44% of total detected peaks) were properly identified (Table 1). It was not possible to identify the remaining peaks in the chromatograms due to the inexistence of such information in the 6th edition of the Wiley library, in the Adams [16] and in NIST Chemistry WebBook [18]. This could be expected, since this is the first report on sweet passion fruit analysis. The concentrations of volatile compounds in both evaluated genotypes of sweet passion fruits are presented in Table 1.

In relation to the number and identity of compounds, the results of both fibers were similar for both genotypes studied, with only few differences between them: a total of 42 compounds were identified when CAR/PDMS fiber was used, while, using DVB/CAR/PDMS fiber, 41 compounds were identified, in both genotypes. The volatile compounds hexyl hexanoate, hexyl octanoate, dihydro-β-ionone, and 6,10-dimethyl-2-undecanone were identified only when CAR/PDMS was used, while methyl dihydrojasmonate, limonene, and 2-heptanol were identified only when DVB/CAR/PDMS was used. When studying yellow passion fruit, Carasek and Pawliszyn [13] also obtained a better performance with CAR/PDMS fiber, compared to CAR/DVB/PDMS fiber.

Esters comprised the major class of identified compounds in both fibers, corresponding to 60% and 59% of total number of identified compounds, in CAR/PDMS and DVB/CAR/PDMS, respectively. Terpenic hydrocarbons followed, with 24% and 27%, respectively. Together, these two classes correspond to about 85% of all identified compounds (Figures 2(a) and 2(b)). Additional classes were terpenic aldehydes (2.4% and 2.4%, respectively), terpenic ketones (4.8% and 2.4% resp.), alcohols (2.4% and 4.9% resp.), ketones (2.4% and 0.0% resp.), organic acids (2.4% and 2.4% resp.), and aromatic compounds (2.4% and 2.4% resp.) (Figures 2(b) and 2(c)).

Despite the similarity in the number of compounds extracted within each chemical class, CAR/PDMS fiber showed better extraction capacity, about 180% higher for most compounds, when compared to DVB/CAR/PDMS (Figure 2(d)). Exceptions were methyl geranate, octyl butanoate, and bornylene, in BGM004 genotype, with concentrations about 105%, 110%, and 71% higher, respectively, in DVB/CAR/PDMS fiber compared to CAR/PDMS. Another exception was limonene, identified only when DVB/CAR/PDMS fiber was used in both genotypes studied (Table 1).

Thus, when using SPME technique, considering both, the number of extracted compounds and their concentration, CAR/PDMS fiber was shown to be more suitable for volatile compounds extraction in sweet passion fruits. Hence, the discussion will be based only on results from this fiber, but including limonene, which was only extracted by CAR/DVB/PDMS fiber. It is worth mentioning that SPME and other techniques used for extraction do not necessarily fully reflect the compounds distribution and concentration in the fruit headspace. However, they are needed in order to concentrate the volatile compounds and enable the detection of compounds that otherwise would probably not be detected. Perhaps the CAR/DVB/PDMS fiber could reflect more accurately the headspace reality but since there are no studies evaluating the volatile composition of sweet passion fruit, we chose the fiber that presented better performance in terms of number and concentration of compounds.

Although similar chromatographic profiles were observed for both genotypes (Figure 3), higher concentration of total volatile compounds (92.4 mg/100 g of pulp), was observed in BGM004 compared to BGM163 (63.8 mg/100 g of pulp) (Figure 2(d)) (*Note*. both values were obtained using CAR/PDMS fiber). Indeed, BGM004 presented higher concentration of all major volatile compounds, except for methyl butanoate, whose concentration was statistically similar in

Table 1: Concentration of volatile compounds in the pulp of sweet passion fruit genotypes, extracted by two SPME fibers and properly identified and semiquantified (μg/100 g).

	Volatile compounds	KI$^{\alpha}$	KI$^{\beta}$	ID$^{\delta}$	BGM 004		BGM 163	
					CAR/PDMS	DVB/CAR/PDMS	CAR/PDMS	DVB/CAR/PDMS
	Esters							
1	Methyl acetate	<700	515	C	1090.82 Aa	138.86 Ba	683.69 Ab	244.59 Ba
2	Ethyl acetate	<700	609	C	662.35	nd	538.29	96.82
3	Methyl butanoate	727	728	B	8268.60	4639.15	8726.59	3446.35
4	Methyl (E)-2-butenoate*	775	726	B	21329.75	6748.38	19534.15	4967.46
5	Ethy butanoate	808	804	A	9166.85	5515.43	6302.83	2989.42
6	Ethyl (E)-2-butenoate**	853	865	A	11048.18 Aa	3207.06 Ba	5508.82 Ab	1291.36 Bb
7	Methyl-2-pentenoate	873	—	C	133.31	nd	129.12	28.50
8	Methyl 3-hydroxybutanoate	881	858	B	109.22	53.05	185.54	188.91
9	Propyl butanoate	901	896	B	98.56	48.06	44.91	21.11
10	Methyl hexanoate	930	927	B	982.20 Aa	414.11 Ba	488.92 Ab	138.88 Bb
11	Methyl 2-hexenoate	976	—	C	20485.31	6168.59	15317.83	4308.00
12	Butyl butanoate	998	994	A	325.58 Aa	145.04 Ba	102.55 Ab	65.00 Aa
13	Ethyl hexanoate	1002	998	A	1536.22 Aa	779.36 Ba	498.82 Ab	203.74 Bb
14	Ethyl-2-hexenoate	1055	1044	B	12026.88 Aa	5692.67 Ba	3102.64 Ab	1922.25 Ab
15	Methyl benzoate	1093	1090	B	636.45	419.12	760.52	688.96
16	Hexyl butanoate	1193	1192	B	252.31	96.14	325.17	34.00
17	Octyl acetate	1213	1211	A	826.84	962.88	112.22	122.00
18	Hexyl (2E) butanoate	1244	1242	B	219.14 Aa	87.18 Ba	36.85 Ab	67.03 Aa
19	Ethyl (E)-2-octenoate	1249	1249	B	284.23	322.87	31.39	46.28
20	Methyl geranate	1325	1323	B	20.14 Ba	41.32 Aa	6.45 Aa	nd
21	Benzyl butanoate	1346	1345	B	9.88	18.27	tr	8.18
22	(E)-Methyl cinnamate	1382	1379	B	18.40 Aa	5.30 Aa	nd	9.50 Aa
23	Hexyl hexanoate	1386	1383	A	2090.46	nd	1022.14	nd
24	Octyl butanoate	1389	1384	B	93.24 Ba	195.57 Aa	27.86 Aa	TR
25	Hexyl octanoate	1583	1582	B	49.47 Aa	nd	13.87Ab	nd
26	Methyl dihydrojasmonate	1660	—	C	Nd	9.34	nd	nd
	Terpenes							
27	3-δ-Carene	1007	1011	B	19.45	15.26	13.39	15.26
28	p-Cymene	1028	1026	B	19.35Aa	1.04 Ba	15.74 Aa	0.71 Ba
29	Limonene	1029	1029	A	Nd	19.67Aa	nd	10.67Ab
30	Cis-ocimene	1042	1037	B	27.21	19.95	17.34	14.57
31	Trans-β-ocimene	1057	1050	B	76.52	57.14	124.51	77.82
32	γ-Terpinene	1062	1059	A	10.82	5.24	7.54	4.08
33	α-Terpinolene	1083	1088	A	8.47	1.75	3.92	0.38
34	1,3,8-p-Menthatriene	1122	1111	B	8.73	4.26	4.55	3.24
35	Allo-ocimene	1131	1132	B	33.93 Aa	12.64 Ba	16.81 Ab	8.62 Aa
36	Neo-allo-ocimene	1143	1144	B	48.37	15.45	29.03	12.79
37	Bornylene	1379	—	C	1.94 Ba	3.31 Aa	nd	0.28Ab
	Terpene aldehyde							
38	β-Cyclocitral	1218	1219	B	10.75	tr	tr	tr
	Terpene ketone							
39	Dihydro-β-ionone	1442	1436	B	tr	nd	TR	nd
40	β-Ionone	1487	1485	A	1.025	tr	TR	tr
	Alcohol							
41	Hexan-1-ol	875	870	A	387.97	240.26	30.55	tr
42	2-Heptanol	903	—	C	nd	nd	TR	tr
	Acids							
43	Acetic acid	711	—	C	nd	nd	tr	tr

Table 1: Continued.

	Volatile compounds	KI$^{\alpha}$	KI$^{\beta}$	ID$^{\delta}$	BGM 004		BGM 163	
					CAR/PDMS	DVB/CAR/PDMS	CAR/PDMS	DVB/CAR/PDMS
	Ketone							
44	6,10-Dimethyl-2-undecanone	1403	—	C	2.18	nd	tr	nd
	Aromatic compound							
45	m-Cymene	1088	1091	B	tr	tr	tr	tr

*IUPAC name for methyl trans-crotonate; **IUPAC name for ethyl (E)-crotonate; nd: nondetected; tr: unquantifiable traces; different capital letters indicate difference at 95% significance between fibers within the same genotype by ANOVA followed by LSD test; different lower case letters indicate difference at 95% significance between genotypes for the same fiber by ANOVA followed by LSD test; $^{\alpha}$Kovats index value (KI) calculated for the HP-5 MS (5% phenylmethylpolysiloxane) column; $^{\beta}$Kovats index value (KI) using literature data (Adams, 2001; Pherobase, 2012). $^{\delta}$The reliability of the identification proposal is indicated by the following: A: mass spectrum, retention time, and Kovats index agreed with standards; B: mass spectrum agreed with Wiley data and Kovats index agreed with literature data (Adams, 2001; Pherobase, 2012); C: mass spectrum agreed with Wiley virtual library of mass spectral (Kovats index not found in the searched literature).

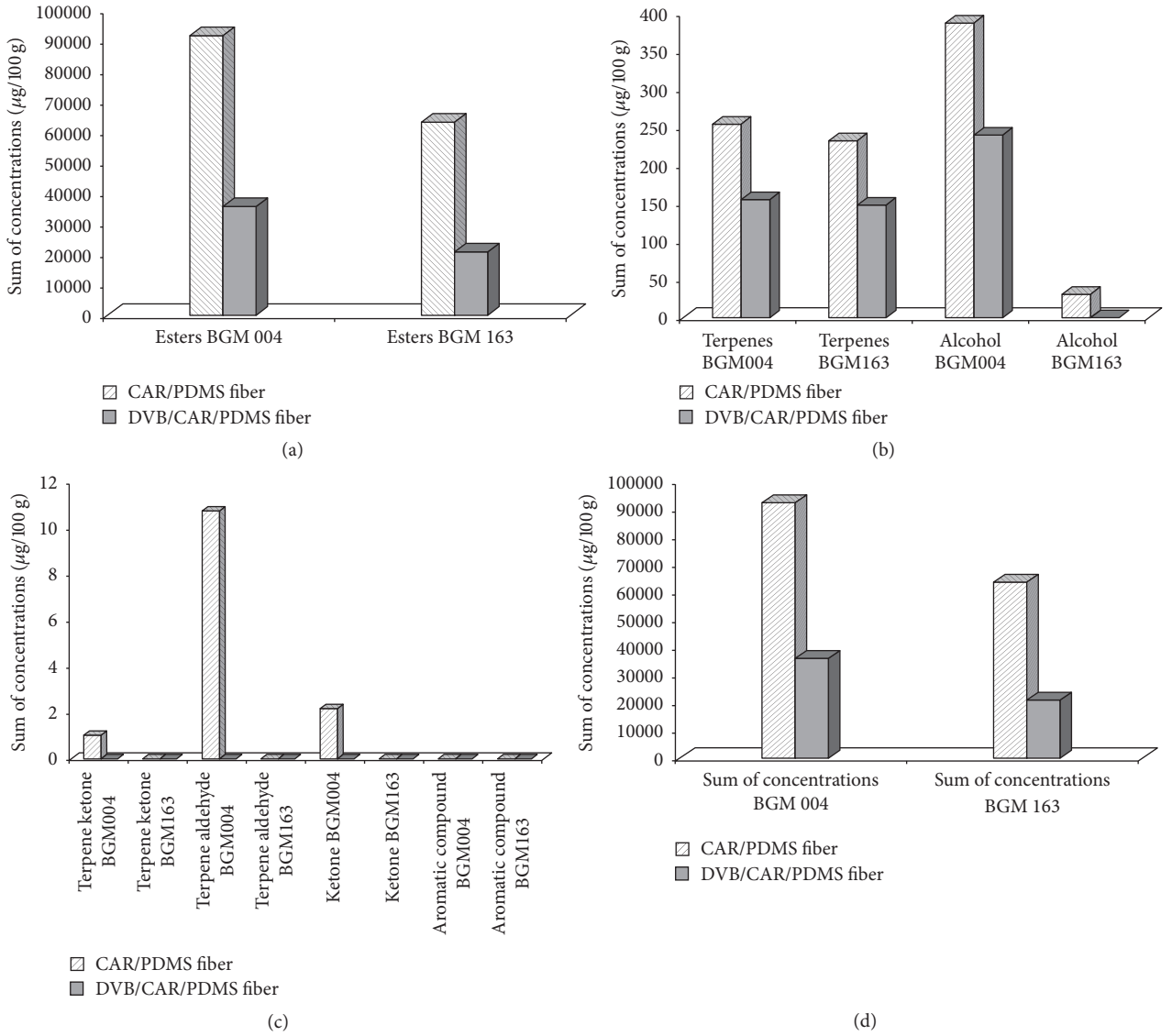

Figure 2: Total concentration (μg/100 g) of esters, terpenes and derivatives, alcohols, ketones, and aromatic compounds semiquantified in passion fruit genotypes.

	Compounds	CAR/PDMS fiber % BGM004	% BGM163
3	Methyl butyrate	8.9	13.7
4	Methyl trans-crotonate	23.1	30.6
5	Ethyl butanoate	9.9	9.9
6	Ethyl (E)-crotonate	12.0	8.6
11	Methyl 2-hexenoate	22.2	24.0
14	Ethyl-2-hexenoate	13.0	4.9

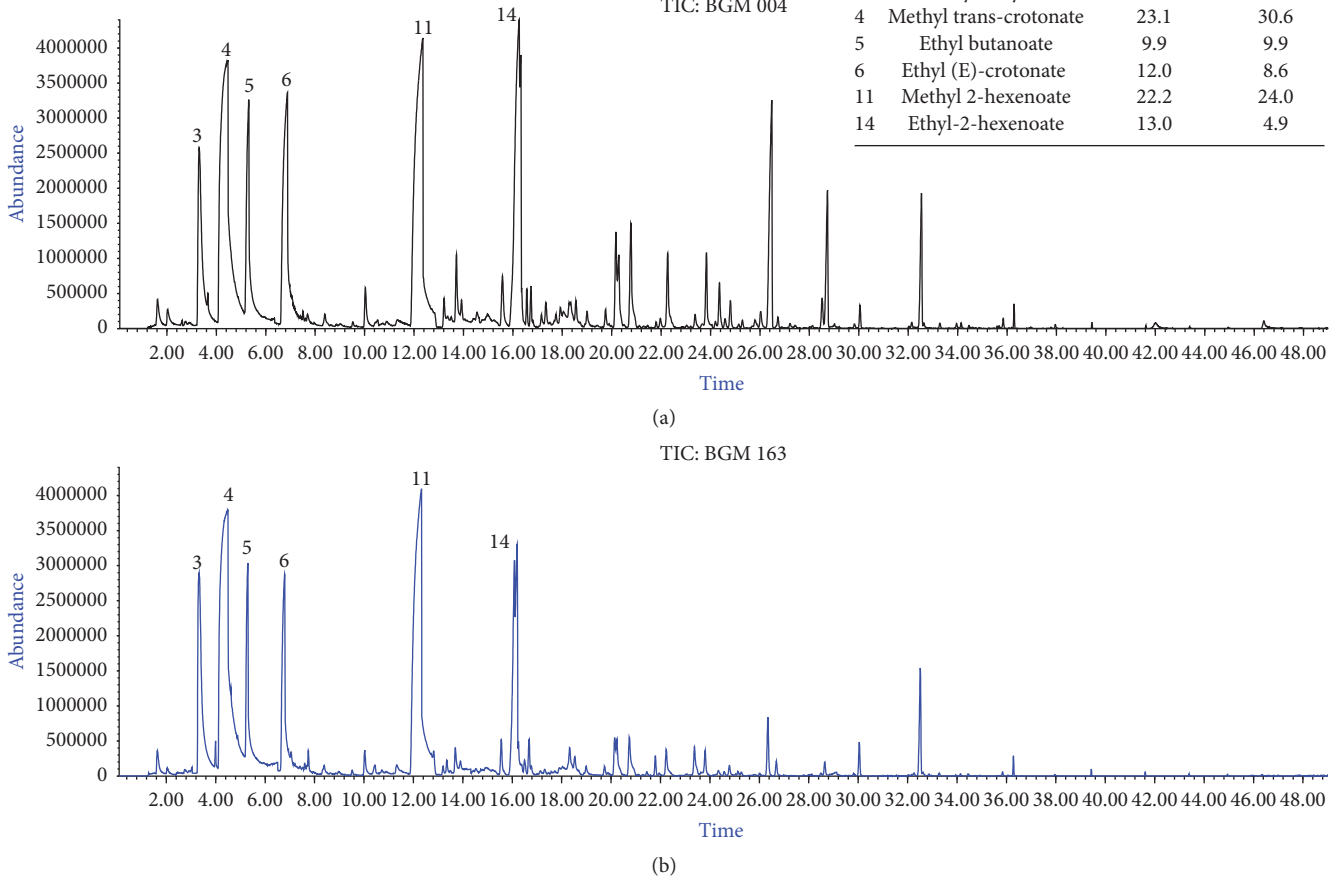

Figure 3: Typical total ions chromatograms and major volatile compounds of sweet passion fruits extracted by a 75 μm carboxen-polydimethylsiloxane (CAR/PDMS) fiber ((a) = genotype BGM004; (b) = genotype BGM163). Figure numbering corresponds to numbering in Table 1. Percentage refers to portion of total concentration of identified peaks.

both genotypes. Such higher concentration was reflected in a stronger aroma and flavor in sensory analysis compared to BGM163 (unpublished data).

The classes of volatile compounds identified in sweet passion fruit genotypes are discussed below.

3.1.1. Esters. As previously mentioned, esters comprised the main class of compounds in sweet passion fruit, both in number and in concentration, as they do for yellow and purple species [1, 2, 4, 12–14, 21–24].

The following major esters quantified in BMG 004 were organized in order of abundance, accounting for 89% of total volatile compounds: methyl (E)-2-butenoate (methyl trans-crotonoate) (23.08% of total), methyl 2-hexenoate (22%), ethyl-2-hexenoate (13%), ethyl (E)-2-butenoate (ethyl trans-crotonoate) (12%), ethyl butanoate (10%), and methyl butanoate (9%). In BMG 163, the most abundant compounds were methyl (E)-2-butenoate (methyl trans-crotonoate) (31%), methyl 2-hexenoate (24%), methyl butanoate (14%), ethyl butanoate (10%), ethyl (E)-2-butenoate (ethyl trans-crotonoate) (8.6%), and ethyl-2-hexenoate (4.9%), accounting for 92% of total volatile compounds.

Esters are well-known as major contributors to the characteristic fruity, floral, and sweet aromas of a wide variety of fruits [25]. The highest concentrations of esters in passion fruit in general were observed in C-2 to C-8 saturated and unsaturated esters. These are produced biosynthetically by β-oxidation of C-2 to C-8 fatty acids in acyl-CoA that react with alcohols, resulting in aliphatic esters [2, 4, 26].

In yellow and purple passion fruits, esters containing two to six carbons (C-2 to C-6) are important for their typical aroma, especially ethyl butanoate and ethyl hexanoate. Other esters including butyl acetate, butyl butanoate, hexyl butanoate, hexyl hexanoate, and 2-methylbutyl hexanoate also contribute to passion fruit characteristic aroma and flavor [4, 11, 22, 24, 27]. However, the esters butyl acetate and 2-methylbutyl hexanoate were not identified in sweet passion fruit, evidencing important differences among the aromas of passion fruit species.

Regarding the impact compounds identified in sweet passion fruits, as there are no previous studies evaluating the volatile composition of this species and no olfatometric techniques were used in the present study, it was not possible

to identify them. However, based on literature data for other passion fruit species [4, 24], ethyl butanoate and ethyl hexanoate could be important compounds responsible for sweet passion fruit aroma and flavor [11, 24, 28]. In addition, ethyl butanoate is known to be an important ester for the aroma of other tropical fruits, like cashew fruit (or cashew apple) and guava [29, 30]. Another possible important impact compound is methyl butanoate, which was a major compound in the present study. According to the literature, this is an important impact compound in other passion fruit species [12, 14, 22, 24], imparting sweet-like, fruity (ripe), flowery, caramel like, greenish, acidic, vinegar, passion fruit, tutti-frutti, and strawberry notes [31].

Ethyl crotonoate, one of the main esters identified in the present study, has also been cited as a high threshold impact compound in yellow passion fruit essence [11], but not for the fresh fruit. It has sweet-like, fruity (ripe), and cashew fruit and pineapple notes [31] and may be an important compound for sweet passion fruit aroma.

Ethyl acetate has a fruity aroma. This compound has been characterized as impact compound in apricot during the fruit maturation [32]. Although it has not been listed as an impact compound in *Passiflora* species [11], its role in sweet passion fruit aroma and sensory profile should be investigated, since its concentration in this species is much higher than in other commercial passion fruit species [4, 11, 21].

Butyl acetate, hexyl acetate, propyl hexanoate, ethyl octanoate, octyl acetate, isoamyl hexanoate, ethyl decanoate, and citronellyl acetate, which have been previously identified in yellow and purple passion fruits [4, 11, 21, 24], were investigated in the present study and not identified in any of the genotypes.

3.1.2. Terpenes and Terpene Derivatives. The chromatographic profiles of terpenes and derivatives were also similar in both genotypes, except for trans-β-ocimene and bornylene, both present in higher concentration in BGM004 genotype (Table 1).

Myrcene, linalool, α-terpineol, limonene, trans-β-ocimene, and cis-β-ocimene are among the terpenes and terpene derivatives commonly reported as contributors to the aroma and flavor of yellow and purple passion fruits [4, 11, 24, 33]. Only limonene and trans-β-ocimene were identified in sweet passion fruit, which shows once more the singularity of this species. These compounds have odor descriptions of citrus/herbal and sweet/almost floral, respectively [4, 11], and may be important for the sweet passion fruit flavor.

The terpenes *cis*-ocimene and terpinolene identified in the present study have been previously identified by Chen et al. [22], Jordán et al. [11], and Carasek and Pawliszyn [13] in yellow and purple passion fruits, although they have not been identified as impact compounds. The terpenes p-cymene, γ-terpinene, and limonene are known as important impact compounds for citrus and citrus peel aroma [34, 35] and could be an impact compound as well in sweet passion fruit.

Low concentrations of the terpene ketones β-ionone and dihydro-β-ionone have been identified in commercial passion fruits [12, 13, 21], where β-ionone is an impact compound with floral notes. These compounds were also identified in apricot and in essential oil of citrus peel [32, 34] and may be important for the sweet passion fruit aroma and flavor.

Low concentrations of the terpene 3-δ-carene have also been previously identified in yellow passion fruit [13, 22]. This compound is also one of the major volatile compounds in mango cultivars, contributing to their aroma and flavor [36, 37]. Therefore, its potential contribution to sweet passion fruit aroma needs to be investigated.

Linalool, α-pinene, β-pinene, myrcene, α-terpinene, α-ionone, rose oxide, and citronellol, which have been previously identified in yellow and purple passion fruits, were investigated and not identified in any of the sweet passion fruit genotypes.

3.1.3. Other Classes of Volatile Compounds. The alcohols 1-hexanol and 2-heptanol, which are among impact compounds in commercial passion fruits aroma [22, 25, 38], were identified in the present study (Table 1) and may be important for sweet passion fruit aroma.

Aldehydes and organic acids have been identified in other passion fruit species [4, 11, 22, 28], but not in the sweet passion fruit, except for very low concentrations of acetic acid (possibly derived from pulp fermentation), identified in BGM163 only [38].

The only ketone identified was 6,10-dimethyl-2-undecanone, which has not been previously identified in passion fruits in general and could possibly derive from terpenes degradation.

According to Werkhoff et al. [21], trace concentrations of sulfur volatiles are associated with the aroma of yellow passion fruit. In the present study, they were not identified, possibly due to the use of SPME technique or due to their inexistence in sweet passion fruit.

The aldehydes, alcohols and ketone 2-heptenal, nonanal, trans-2-nonenal, decanal, cis-3-hexen-1-ol, trans-3-hexen-1-ol, 1-octanol, and 6-methyl-5-hepten-2-one, which have been identified in yellow and purple passion fruits, were investigated and not identified in any of the sweet passion fruit genotypes.

3.2. Analyses of Sugars, pH, and Titratable and Soluble Solids. Complementary analyses for fruits characterization were performed and the results are presented in Table 2. Mean total sugars content (15.4 g/100 g) was considerably higher than the literature values for yellow and purple passion fruits [39–41]. Pruthi and Lal [40] and Ramaiya et al. [42] found averages of 10.0 and 14.3 g/100 g of total sugars, respectively, in purple passion fruits. In yellow passion fruits, Janzantti et al., [24]; Ramaiya et al. [42]; and Macoris et al. [39] found on average 5.25, 5.75, and 6.98 g/100 g, respectively.

The titratable acidity value for sweet passion fruit (1.54 g citric acid/100 g) was about 30% lower than the values obtained by Macoris et al. for yellow passion fruit [39]. Mean pH value (3.71) was about 17% and 5% higher than values found for yellow and purple passion fruits, respectively, by Ramaiya et al. [42].

Table 2: Sugars contents, titratable acidity, pH, and soluble solids determination in the pulp of sweet passion fruit genotypes.

Parameter	BGM 004	BGM 163
pH	3.72 ± 0.04	3.69 ± 0.00
Titratable acidity (g citric acid/100 g)	1.62 ± 0.01[a]	1.46 ± 0.00[b]
Total soluble solids (°Brix)	19.3 ± 0.1[a]	18.2 ± 0.1[b]
Fructose (g fructose/100 g)	5.50 ± 0.06[a]	4.95 ± 0.10[b]
Glucose (g glucose/100 g)	5.13 ± 0.05	5.30 ± 0.13
Sucrose (g sucrose/100 g)	4.57 ± 0.06[b]	5.40 ± 0.07[a]
Total sugar (g/100 g)	15.20 ± 0.10[b]	15.66 ± 0.24[a]

Means of triplicates ± standard deviation. Different letters in the same row indicate significant differences by ANOVA, followed by LSD test at 95% significance.

Mean soluble solids value obtained for sweet passion fruit in the present study was 18.7 °Brix, about 20% higher than the value obtained by Macoris et al. [39] for yellow passion fruit. It is worth mentioning that total soluble solids content is one of the most important parameters required by the fruit juice industry because it gives more body to fresh juices and increases productivity in concentrated juices [41]. A minimum of 13 °Brix was required by Bruckner et al. [41] for production of fruits juices.

4. Conclusion

In the present study, for the first time, the volatile composition of sweet passion fruit genotypes was evaluated, with forty-five peaks being properly identified. The carboxen-polydimethylsiloxane fiber (CAR/PDMS) was more appropriate for aroma analysis in this species. Although both evaluated genotypes presented similar chromatographic profiles, higher total concentration of volatile compounds was observed in BMG004 compared to BMG163. Their aroma profile was very distinct compared to those of yellow and purple species reported in the literature. Special attention should be given to methyl (E)-2-butenoate and ethyl (E)-2-butenoate, which were important compounds in this species and are present in very low concentrations in yellow and purple passion fruits. Although sweet passion fruit has not been as explored as other passion fruit species, this is a flavorful species that can be consumed not only *in natura*, but the high sugar and soluble contents associated with the low acidity create a promising ingredient to integrate blends for the production of naturally sweet passion fruit and mixed fruit juices among other possibilities.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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