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Aroma Extract Dilution Analysis of Cv. Marion (*Rubus* spp. *hyb*) and Cv. Evergreen (*R. laciniatus* L.) Blackberries

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Cultivar Marion and Evergreen blackberry aromas were analyzed by aroma extract dilution analysis. Sixty-three aromas were identified (some tentatively) by mass spectrometry and gas chromatography−retention time; 48 were common to both cultivars, and 27 have not been previously reported in blackberry fruit. A comparison of cultivars shows that both have comparable compound types and numbers but with widely differing aroma impacts, as measured by flavor dilution (FD) factors. Ethyl 2-methylbutanoate, ethyl 2-methylpropanoate, hexanal, furanones (2,5-dimethyl-4-hydroxy-3-(2*H*)-furanone, 2-ethyl-4-hydroxy-5-methyl-3-(2*H*)-furanone, 4-hydroxy-5-methyl-3-(2*H*)-furanone, 4,5-dimethyl-3-hydroxy-2-(5*H*)-furanone, and 5-ethyl-3-hydroxy-4-methyl-2-(5*H*)-furanone), and sulfur compounds (thiophene, dimethyl sulfide, dimethyl disulfide, dimethyl trisulfide, 2-methylthiophene, and methional) were prominent in Evergreen (FD 512−2048). Except for ethyl 2-methylpropanoate, these same compounds were also prominent in Marion, but the FD factors varied significantly (FD 8−256) from Evergreen. The aroma profile of blackberry is complex, as no single volatile was unanimously described as characteristically blackberry.

KEYWORDS: **Marion; Evergreen; blackberry aroma; AEDA; GC/O; GC-MS**

INTRODUCTION

Blackberries are popular fruits because of their flavor and nutritional content; they have been used as food and medicine for hundreds of years (*1*). Used fresh and processed into a variety of food products, blackberries are extensively cultivated; yet, their aroma compositions have not been detailed as compared to the aromas of other small fruits such as raspberry and strawberry (*2*−*6*). Independent analyses of blackberries examined anthocyanins (*1*), sugars and acids (*7*, *8*), and volatile and bound volatile compounds in fresh or processed blackberries (*9*−*17*). Most of the studies investigated volatile compounds (*9*−*14*) in the Evergreen cultivar. A total of 147 volatiles have been reported in fresh blackberries (*18*), but very few studies were about aroma active compounds, and few compounds were specifically described as "blackberry-like".

The Marion cultivar blackberry (*Rubus* spp. hyb) has a flavor greatly preferred by consumers; consequently, it has replaced cv. Thornless Evergreen (*Rubus laciniatus* Willd.) as the predominant cultivar planted in the Pacific Northwest (*19*, *20*). Consumer preference for the Marion has stimulated research to correlate quantifiable blackberry flavor characteristics to berry genetic makeup, to breed new thornless blackberry cultivars with Marion flavor. Because the aroma differences between Marion and Evergreen have been only subjectively described (*20*), the purpose of this investigation was to identify, rank, and compare the odor active compounds in the two cultivars using aroma extract dilution analysis (AEDA) and gas chromatography−mass spectrometry (GC-MS).

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MATERIALS AND METHODS

Chemicals. Authentic aroma standards were obtained as follows: butyl acetate, limonene, octyl acetate, octyl formate, 2-heptanone, and 2-undecanone were from K&K Laboratories (Jamaica, NY). Methyl hexanoate and octanol were from Eastman (Rochester, NY). Acetaldehyde, acetic acid, β-ionone, butanoic acid, *l*-carvone, 2,5-dimethyl-4-hydroxy-3-(2*H*)-furanone, dimethyl disulfide, dimethyltrisulfide, ethyl acetate, ethyl butanonate, ethyl hexanoate, ethyl 2-methylbutanoate, ethyl 3-methylbutanoate, ethyl 2-methylpropanonate, eugenol, 2-heptanol, hexanal, hexanoic acid, *t*-2-hexenal, linalool, *p*-methylacetophenone, 3-methylbutanal, methyl butanoate, 2-methylbutanoic acid, nonanal, *t*-2-nonenal, octanol, 1-octen-3-ol, 1-octen-3-one, and phenethyl alcohol were from Aldrich Chemical Co. Inc. (Milwaukee, WI). Diacetyl and methional were from Sigma Chemical Co. (St. Louis, MO).

Blackberry Samples. Marion and Evergreen blackberries were grown in Woodburn, OR, from 5 to 10 year old plants. The fruits (both machine and hand-harvested) were washed, graded, individually quick frozen (IQF), and stored at −18 °C. One box of each cultivar (13.6 kg, frozen for 5 months) was transported on ice to the laboratory, where they were stored at −23 °C. Samples had been frozen for 9 months when analyzed.

Extraction of Volatile Compounds. For each cultivar, 1 kg of IQF blackberries was thawed at room temperature in a single layer for 3 h. The berries were combined with 100 g of NaCl and 10 g of $CaCl_2$ in a commercial blender and blended by pulsing for a total of 3 min at

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Table 1. AEDA of Cv. Marion and Evergreen Blackberries (Stabilwax Column)

				FD factors	
RI	compd[a]	aroma descriptors this study	basis of identification[b]	Marion	Evergreen
811	ethyl acetate[r]	floral, fruity	MS, RI	16	2
910	3-methylbutanal	fresh grass, fruity, leaf	MS, RI		4
935	dimethyl sulfide[*,T]	garlic bologna, cabbage	RIL	16	128
965	ethyl 2-methylpropanoate[*]	sweet, fruity, berry, floral	RI		256
973	methyl butanoate	fruity, sweet	RI	4	
998	2,3-butanedione (diacetyl)[*,r]	buttery	MS, RI	2	2
1030	thiophene[*,T]	garlic bologna, sulfury	RIL	8	128
1038	ethyl butanoate	fruity, banana	MS, RI	4	
1053	ethyl 2-methylbutanoate[r]	fruity	MS, RI	4	
1065	ethyl 3-methylbutanoate	fruit, sweet, banana	RI		64
1082	butyl acetate	fruity, juicy	MS, RI	2	
1103	dimethyl disulfide[*]	vegetal	MS, RI	2	
1106	hexanal[r]	green, fresh	MS, RI		4
1161	**unk**	plastic, fatty, waxy		32	
1191	2-heptanone[r]	fruity, banana, sweet, floral	MS, RI	16	32
1202	methyl hexanoate[r]	fruity, green, sweet	MS, RI	8	4
1251	ethyl hexanoate[r]	fruity, floral	MS, RI	8	
1326	1-octen-3-one[*,r]	mushroom, earthy	RI	8	16
1333	2-heptanol[r]	woody, earthy, vegetal, minty	MS, RI	4	512
1369	hexanol[r,T]	floral, spice	MS, RIL	4	
1383	dimethyl trisulfide[*]	vegetal, garlic	MS, RI	2	16
1402	nonanal[r]	floral, fruity	MS, RI	2	
1467	acetic acid[r]	acid, sour	MS, RI	16	32
1476	1-octen-3-ol	mushroom	RI	4	
1490	methional[*]	potato, earthy, onion	RI	32	512
1491	octyl acetate	floral, sweet	MS, RI	4	
1508	theaspirane A[*,r,T]	floral, earthy, tea, green	MS, RIL	4	
1550	theaspirane B[*,r,T]	earthy, fruity, sweet	MS, RIL	4	
1560	linalool[r]	sweet, floral, berry, green	MS, RI	4	128
1574	octanol[r]	waxy, fruity	MS, RI	2	
1622	2-undecanone[r]	floral, grn, pine, citrus	MS, RI	8	128
1634	**unk**	roasted peanuts		2	
1650	butanoic acid[*,r]	rancid cheese, sour, pungent	MS, RI	32	
1693	2-methylbutanoic acid[*,r]	rancid cheese, sour, acid	MS, RI	32	128
1724	**unk**	plastic curtain, waxy			32
1749	*l*-carvone	peppermint, fresh leaf	MS, RI	8	4
1794	*p*-methylacetophenone	fresh, green, floral, fruity	MS, RI		32
1851	β-damascenone[r,T]	sweet, floral, grape, blackberry	MS, RIL	4	32
1868	hexanoic acid[*,r]	pungent, sour	MS, RI	2	128
1875	**unk**	waxy citrus, lemon, woody			32
1905	benzyl alcohol[r,T]	sweet, citrus, grass	MS, RIL	2	2
1952	phenethyl alcohol[r]	floral, perfume, peach	MS, RI	8	64
1967	**unk**	grass, pungent, green, floral			8
2017	cinnamic aldehyde[T]	sweet, spice, cinnamon	MS, RIL	4	
2018	**unk**	floral, grass, green			8
2053	2,5-dimethyl-4-hydroxy-3-(2*H*)-furanone[*,r]	fruity, sweet, caramel	RI	8	1024
2078	2-ethyl-4-hydroxy-5-methyl-3-(2*H*)-furanone[*,T]	cooked bramble, sweet caramel	RIL	32	16
2114	4-hydroxy-5-methyl-3-(2*H*)-furanone[*,T]	caramel, strawberry, cooked bramble	RIL	32	8
2211	4,5-dimethyl-3-hydroxy-2-(5*H*)-furanone[*,T]	spice, curry, fruity	RIL	4	128
2246	5-ethyl-3-hydroxy-4-methyl-2-(5*H*)-furanone[*,T]	roasted meat, cumin, maple syrup	RIL	4	256
2294	cinnamic alcohol[r,T]	floral, tea, sweet, fruity	RIL	8	32

[a] *, not previously reported in blackberry; r, reported in red raspberry; T, tentative identification. [b] MS, mass spectral data; RIL, retention index from literature; RI, retention index from standards.

high speed. Calcium chloride was added to inhibit enzyme activity as described by Buttery and others (*21*). The puréed fruit was passed through a commercial stainless steel food mill to remove seeds. The seed pulp was batch-extracted three times with freshly distilled pentane: diethyl ether (1:1 v/v) while the seedless purée was extracted three times in a separatory funnel. The extracts were combined to yield a total volume of 880 mL. Nonvolatiles were removed from the organic extract using solvent-assisted flavor extraction (SAFE) at 50 °C under vacuum according to the method proposed by Engel and others (*22*). The organic SAFE extract was dried with anhydrous Na_2SO_4, concentrated to 1 mL by solvent distillation, and reduced to its final volume of 0.1 mL with a flow of nitrogen.

GC/O Analysis. The analysis was performed using a Hewlett-Packard 5890 gas chromatograph equipped with a flame ionization detector (FID) and an olfactometer. Samples were analyzed on a Stabilwax column (30 m × 0.32 mm i.d. cross-linked poly(ethylene glycol), 1 μm film thickness, Restek Corp., Bellefonte, PA) and a DB-5 column (30 m × 0.32 mm i.d., cross-linked phenyl-methyl polysiloxane, 1 μm film thickness, J&W Scientific, Folsom, CA). The column effluent was split 1:1 (by volume) into the FID and a heated sniffing port with a fused silica outlet splitter (Alltech Associates, Inc., Deerfield, IL). Injector and detector temperatures were 250 °C. The helium column flow rate was 2.0 mL/min, and the 2 μL sample injections were splitless. The oven temperature was programmed for a 2 min hold at 40 °C,

Table 2. AEDA of Cv. Marion and Evergreen Blackberries (DB5 Column)

				FD factors	
RI	compd[a]	aroma descriptors this study	basis of identification[b]	Marion	Evergreen
<500	acetaldehyde[*,r]	grass, green	MS, RI	1	8
516	dimethyl sulfide[*,T]	garlic, onion	RIL	16	8
557	2-methylpropanal[*,T]	wood, grass	MS, RIL	1	
579	2,3-butanedione (diacetyl)[*,r]	buttery	MS, RI	2	2
599	acetic acid[r]	acetic acid, vinegar	RI		16
609	methylethyl sulfide[*,T]	alliaceous, pungent	RIL	16	8
610	ethyl acetate[r]	fruity	RI	1	
621	**unk**	pungent		8	4
649	3-methylbutanal	vegetal, earthy	MS, RI	1	1
661	thiophene[*,T]	sour, green, earthy, onion	RIL	4	2048
727	dimethyl disulfide[*]	pungent, garlic, sulfury	MS, RI	32	2048
753	ethyl 2-methylpropanoate[*]	fruity	RI		2048
758	2-methylthiophene[*,T]	earthy, pungent	RIL	32	512
770	ethyl butanoate	fruity	MS, RI	2	
791	hexanal[r]	green, fresh	MS, RI	64	1024
808	butanoic acid[*,r]	cheesy, pungent	RI	1	2
848	ethyl 2-methyl/3-methylbutanoate[r]	fruity, sweet, berry, banana	RI	128	1024
854	2-methylbutanoic acid[*,r,T]	cheesy, sour, smelly	RIL	32	16
874	*t*-2-hexenal[r]	fruity, orange, green	MS, RI	1	4
897	methional[*]	baked potato	RI	256	2048
906	2-heptanol[r]	peppermint, green, woody	MS, RI	8	2
957	**unk**	woody, floral, green			128
959	benzaldehyde[r,T]	fruity, berry, juicy	MS, RIL	64	256
971	1-octen-3-one[*,r]	mushroom, earthy	MS, RI	2	16
979	dimethyl trisulfide[*]	green veggie, garlic	RI	16	
980	1-octen-3-ol	woody, earthy, mushroom	RI		64
999	hexyl acetate[r]	fruity	MS, RI	1	1
1002	ethyl hexanoate[r]	floral, fruity	MS, RI	32	1
1033	limonene[r]	overripe melon, green, tea	MS, RI	4	2
1042	*t*-β-ocimene[*,T]	sweet, floral, woody, perfume	RIL	8	2
1045	benzyl alcohol[r,T]	floral, fruity, rose	MS, RIL	1	2
1072	2,5-dimethyl-4-hydroxy-3-(2*H*)-furanone[*,r]	caramel, strawberry	RI	32	
1087	4-hydroxy-5-methyl-3-(2*H*)-furanone[*,T]	cotton candy, sweet	RIL	4	
1096	linalool[r]	fruity, green, sweet, watermelon	MS, RI	16	8
1099	α-terpinolene[r,T]	woody, sweet, earthy	MS, RIL	1	64
1100	nonanal[r]	watermelon, citrus, floral	MS, RI	8	8
1104	octyl formate[*]	fruity	RI	1	
1112	phenethyl alcohol[r]	fruity, floral, rose, sweet	MS, RI		32
1131	4,5-dimethyl-3-hydroxy-2-(5*H*)-furanone[*,T]	roasted vegetables, sweet, caramel	RIL	32	4
1136	2-ethyl-4-hydroxy-5-methyl-3-(2*H*)-furanone[*,T]	floral, sweet, caramel	RIL	2	2
1149	neo-allo-ocimene[*,T]	citrus, vegetal, cucumber	MS, RIL	16	4
1161	*t*-2-nonenal[*]	watermelon, fresh vegetable, green	MS, RI	1	64
1179	*p*-methylacetophenone	floral, hot candy, sweet	RI	2	8
1234	*l*-carvone	anise, fennel	RI	2	
1255	5-ethyl-3-hydroxy-4-methyl-2-(5*H*)-furanone[*,T]	caramel, smoky	RIL	1	
1290	2-undecanone[r]	wet grass, tea, floral, green	MS, RI	4	16
1305	theaspirane A[*,r,T]	warm spices, vegetal, pungent	MS, RIL	2	1
1321	**unk**	caramel, fruity, tea, green			16
1324	4-vinylguaiacol[*,r,T]	BBQ rub, spicy	RIL	1	
1370	eugenol[r]	woody, citrus, spicy	RI	4	4
1392	β-damascenone[r,T]	floral, berry, sweet, grape	MS, RIL	8	4
1433	**unk**	sweet, fruity, herbal, tea		2	
1451	**unk**	floral, spice, perfume, fruit, juicy		4	
1496	β-ionone[r]	floral, perfume, woody, spicy	MS, RI	2	16
1543	elemicin[T]	green tea, spicy, perfume	RIL	1	

[a] *, not previously reported in blackberry; r, reported in red raspberry; T, tentative identification. [b] MS, mass spectral data; RIL, retention index from literature; RI, retention index from standards.

then 40−100 °C at 5 °C/min, then 100−230 °C at 4 °C/min (10 min hold). Retention indices (RI) were estimated in accordance with a modified Kovats method (*23*).

AEDA. Flavor dilution (FD) factors for the odor active compounds in each cultivar were determined using AEDA (*24*). Concentrated samples were serially diluted with 1:1 (v/v) pentane:diethyl ether (1 + 1). GC/O with two experienced panelists was then performed with 2 μL injections of original samples and diluted extracts.

GC-MS Analysis. Analysis of the original concentrated AEDA samples was performed using an Agilent 6890 gas chromatograph equipped with an Agilent 5973 mass selective detector. System software control and data management/analysis were performed through Enhanced ChemStation Software, G1701CA v. C.00.01.08 (Agilent Technologies, Inc., Wilmington, DE). Volatile separation was achieved with two fused silica capillary columns: a 30 m × 0.32 mm i.d. Stabilwax (cross-linked poly(ethylene glycol)) column with a 1 μm

Table 3. AEDA Summary of Cv. Marion and Evergreen Blackberries

cultivar	compd[a]	cultivar	compd[a]
	Acids		
both	acetic acid[r]	both	hexanoic acid[*,r]
both	butanoic acid[*,r]	both	2-methylbutanoic acid[*,r]
	Alcohols		
both	benzyl alcohol[r]	both	linalool[r]
both	cinnamic alcohol[r]	Marion	octanol[r]
Evergreen	heptanol[r]	both	1-octen-3-ol
both	2-heptanol[r]	both	phenethyl alcohol[r]
Marion	hexanol[r]		
	Aldehydes		
both	acetaldehyde[*,r]	both	methional[*]
both	benzaldehyde[r]	both	3-methylbutanal
Marion	cinnamic aldehyde	Marion	2-methylpropanal[*]
both	hexanal[r]	both	nonanal[r]
both	*t*-2-hexenal[r]	both	*t*-2-nonenal[*]
	Esters		
Marion	butyl acetate	Evergreen	ethyl 2-methylpropanoate[*]
both	ethyl acetate[r]	both	hexyl acetate[r]
Marion	ethyl butanoate	Marion	methyl butanoate
both	ethyl hexanoate[r]	both	methyl hexanoate[r]
both	ethyl 2-methylbutanoate[r]	Marion	octyl acetate
Evergreen	ethyl 3-methylbutanoate	Marion	octyl formate[*]
	Furanones		
both	2,5-dimethyl-4-hydroxy-3-(2*H*)-furanone[*,r]	both	5-ethyl-3-hydroxy-4-methyl-2-(5*H*)-furanone[*]
both	4,5-dimethyl-3-hydroxy-2-(5*H*)-furanone[*]	both	4-hydroxy-5-methyl-3-(2*H*)-furanone[*]
both	2-ethyl-4-hydroxy-5-methyl-3-(2*H*)-furanone[*]		
	Hydrocarbons		
both	limonene[r]	both	*t*-β-ocimene[*]
both	neo-allo-ocimene[*]	both	α-terpinolene[r]
	Ketones		
both	2,3-butanedione (diacetyl)[*,r]	both	β-ionone[r]
both	*l*-carvone	both	*p*-methylacetophenone
both	β-damascenone[r]	both	1-octen-3-one[*,r]
both	2-heptanone[r]	both	2-undecanone[r]
	Phenols		
Marion	elemicin	Marion	4-vinylguaiacol[*,r]
both	eugenol[r]		
	Sulfur		
both	dimethyl disulfide[*]	both	methylethyl sulfide[*]
both	dimethyl sulfide[*]	both	2-methylthiophene[*]
both	dimethyl trisulfide[*]	both	thiophene[*]
	Theaspiranes		
both	theaspirane A[*,r]	Marion	theaspirane B[*,r]

[a] *, not previously reported in blackberry; r, reported in red raspberry.

film thickness (Restek) and the other a 30 m × 0.25 mm i.d. DB-5 (cross-linked phenyl-methyl polysiloxane) column with a 0.25 μm film thickness (J&W Scientific). The helium column flow rate was 2.0 mL/min, and the 2 μL sample injections were splitless. The oven temperature was programmed as for the GC/O analysis. Injector, detector transfer line, and ion source temperatures were 250, 280, and 230 °C, respectively. Electron impact mass spectrometric data from *m*/*z* 35−300 was collected at 5.27 scans/s, at an ionization voltage of 70 eV. RI were estimated in accordance with a modified Kovats method (*23*). Compound identifications were made by comparing aromas with authentic standards and Kovats RI, RI reported in the literature (*25*, among others), and/or mass spectral data from the Wiley 275.L (G1035) Database (Agilent Technologies, Inc.).

Further Identification of Some Aroma Compounds by GC-MS Analysis. To further clarify AEDA volatile composition, for each cultivar, 5 kg of IQF blackberries was thawed at room temperature in a single layer for 3 h. The berries were blended by pulsing for a total of 3 min at high speed in a commercial blender, and the purée was poured into a stainless steel pan. Concentrated pectolytic enzyme (Vinozym FCE G, Novo Nordisk, Franklinton, NC) was prepared and thoroughly mixed into the purée. A total of 0.15 g of enzyme were added to the Marion purée, and 1.0 g was added to the more viscous Evergreen purée. The mixture was covered with aluminum foil and left to stand at room temperature overnight (15 h). Five hundred grams of NaCl was blended in, and the mixture was strained and extracted as for the GC/O analysis using CH_2Cl_2 (total volume 2400 mL). The extraction produced an emulsion that was broken with centrifugation for 20 min (1800 rpm, approximately 1000 g). The organic extract was then further prepared as for the GC/O analysis and reduced to its final volume of 0.2 mL with a flow of nitrogen. Analysis conditions and methods were identical to those used for the 1 kg samples, except that 5 μL of sample was injected, and the oven temperature was programmed for a 2 min hold at 40 °C, then 40−230 °C at 1 °C/min (2 min hold).

RESULTS AND DISCUSSION

Tables 1 and **2** list Marion and Evergreen blackberry volatiles separated with polar and nonpolar columns. On the polar column, a total of 51 aroma compounds were detected, with 45 of them identified. On the nonpolar column, 55 aromas were detected, and 51 of them were identified. Among these identified aromas, 12 were detected on the polar column only, while 17 were detected on the nonpolar column only. Combined data (**Table 3**) show that 63 odor active volatiles were detected and 48 were common to both cultivars. Marion contained 60 of 63 volatiles, and Evergreen contained 51.

The most significant (FD ≥ 16) odor active volatiles in Marion determined on the nonpolar (DB-5) column were methional (FD = 256); ethyl 2-methylbutanoate (FD = 128); benzaldehyde and hexanal (FD = 64); 2-methylbutanoic acid, 2,5-dimethyl-4-hydroxy-3-(2*H*)-furanone, 4,5-dimethyl-3-hydroxy-2-(5*H*)-furanone, ethyl hexanoate, dimethyl disulfide, and 2-methylthiophene (FD = 32); and linalool, neo-allo-ocimene, dimethyl sulfide, dimethyl trisulfide, and methylethyl sulfide (FD = 16). In addition, 2-ethyl-4-hydroxy-5-methyl-3-(2*H*)-furanone, 4-hydroxy-5-methyl-3-(2*H*)-furanone, and butanoic acid (FD = 32), ethyl acetate, acetic acid, and 2-heptanone (FD = 16) may also be important to Marion blackberry flavor, as they had high FD factors as determined on the polar (Stabilwax) column.

Many significant (FD ≥ 16) odor active volatiles in Evergreen were identified on the DB-5 column. The most important aroma compounds included methional, ethyl 2-methylpropanoate, thiophene, and dimethyl disulfide (FD = 2048); hexanal and ethyl 2-methylbutanoate (FD = 1024); 2-methylthiophene (FD = 512); benzaldehyde (FD = 256); heptanol (FD = 128); 1-octen-3-ol, *t*-2-nonenal, and α-terpinolene (FD = 64); phenethyl alcohol (FD = 32); and 1-octen-3-one, 2-undecanone, acetic acid, 2-methylbutanoic acid, and *β*-ionone (FD = 16).

In addition, as determined on the polar (Stabilwax) column, 2,5-dimethyl-4-hydroxy-3-(2*H*)-furanone (FD = 1024); 2-heptanol (FD = 512); ethyl 2-methylpropanoate and 5-ethyl-3-hydroxy-4-methyl-2-(5*H*)-furanone (FD = 256); thiophene, linalool, 2-undecanone, hexanoic acid, 4,5-dimethyl-3-hydroxy-2-(5*H*)-furanone and dimethyl sulfide (FD = 128); ethyl 3-methylbutanonate (FD = 64); cinnamic alcohol, 2-heptanone, *p*-methylacetophenone, and *β*-damascenone (FD = 32); and 2-ethyl-4-hydroxy-5-methyl-3-(2*H*)-furanone, 1-octen-3-one, and dimethyl trisulfide (FD = 16) may also be important to Evergreen blackberry flavor.

The cultivars have comparable compound types and numbers but with widely differing aroma impacts, as measured by FD factors. Fresh Marion blackberry aroma has been described as floral, fruity, sweet, caramel-fruity, and woody, while fresh Evergreen aroma is spicy, green, herbaceous, fruity, and sweet. However, there are no prominent corresponding compositional differences between the cultivars within a volatile class. Both cultivars contain the same numbers of odor active acids, furanones, hydrocarbons, ketones, and sulfur compounds. The Marion contains one more theaspirane (theaspirane B); two more alcohols (hexanol, octanol), aldehydes (cinnamic, 2-methylpropanal), and phenols (elemicin, 4-vinylquaiacol); and five more esters (methyl butanoate, ethyl butanoate, butyl acetate, octyl acetate, and octyl formate) than Evergreen. The Evergreen has one alcohol (heptanol) and two esters (ethyl 2-methylpropanoate, ethyl 3-methylbutanoate) not present in Marion. Of 27 newly reported volatiles, three organic acids, two aldehydes, five furanones, two hydrocarbons, two ketones, six sulfur compounds, and one theaspirane are shared by the cultivars. This relatively large number of new volatiles is probably due to the extraction and analytical methods used. It is thought that some portion of Marion aroma is due to its hybrid pedigree, which contains at least five bramble species, including raspberry (*20*). However, although 35 volatiles in this study have been previously reported in red raspberry (*12*, *18*, *26*, *27*), 30 of them are common to both Marion and Evergreen; only four are unique to Marion. Five volatiles out of 63 were described with aroma descriptors specific to bramble fruit (berry, blackberry); no single compound was unanimously described as characteristically blackberry.

AEDA is a suitable method to screen potent odorants in blackberry, and results indicate that characteristic blackberry aroma is apparently a complex formulation of volatiles. Marion and Evergreen blackberries have many potent odorants in common, but qualitative aroma comparisons consistently note the more floral, caramel-fruity, sweet aroma of Marion as compared to the spicy, herbaceous, less fruity aroma of Evergreen. Because a FD factor is the ratio of an odorant's concentration in an initial GC/O extract to its concentration in the most dilute extract that still allows detection, the value is a relative measure (*28*) and does not conclusively determine that one cultivar contains more of a given aroma compound than another. Because the aroma profile of a food is, among others, a function of volatile concentrations and odor thresholds, the next step in identifying specific aroma differences between Marion and Evergreen is the quantification of each aroma with a high FD factor and calculation of its odor activity value (OAV), the ratio of the aroma concentration to its odor threshold in air. OAVs are better measures of which aroma compounds contribute to a cultivar's aroma and of the differences in cultivar aroma profiles.

ACKNOWLEDGMENT

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