Profiling of Aroma Compounds Released from Cooking *Dendrocalamus latiflorus* Shoots

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Volatile aroma compounds in *Dendrocalamus latiflorus* shoots were extracted using solid-phase microextraction (SPME) and then heated at various temperatures and for various durations. Gas chromatography-mass spectrometry (GC-MS) analyses showed that frozen *D. latiflorus* shoots at ambient temperature contain 18 volatile aroma compounds, with limonene and 2-pentyl furan being the major components. Limonene has the fragrance of lemon and citrus fruits, while 2-pentyl furan gives off the scent of flowers and fruits. Additionally, heating temperature had a significant influence on the volatile aroma compounds. Some, including limonene, 2-pentyl furan and *n*-hexanal, showed marked decrement in content and vaporized almost completely at 100 °C, while others, including *n*-heneicosane and 4-hydroxybenzaldehyde, showed pronounced increase in relative contents. Furthermore, there was a positive relationship between *n*-heneicosane content and heating duration but a negative relationship between 4-hydroxybenzaldehyde content and heating duration, revealing substantial effects of heating duration on the volatile aroma compounds of *D. latiflorus* shoots.

Keywords: Bamboo shoots; Dendrocalamus latiflorus; Aroma compounds; Solid-phase microextraction (SPME); Gas chromatography-mass spectrometry (GC-MS)

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INTRODUCTION

Bamboo is an important forest resource of high economic value (Liese 1987). Bamboo shoot, which is the budding sprout wrapped inside its sheath (Lu 2001), is often used in Oriental cuisines. Asians have a long history and preference for eating bamboo shoot because of its crispy texture and delicious taste in addition to its high dietary fiber, low fat, and rich mineral content. In Taiwan, there are many different bamboo species cultivated, including *Dendrocalamus latiflorus* Munro, *Phyllostachys pubescens* Mazel, *P. makinoi* Hayata, *Leleba oldhamii* Nakai, and *L. edulis* Odashimo (Huang *et al*. 2016). These bamboo species have been used in local cuisines according to their distinctive smell, taste, and texture (Tsai 2002). Of the above-mentioned species, *D. latiflorus*, *L. oldhamii*, and *L. edulis* shoots constitute the main income of bamboo farmers. In Taiwan and Chinese Mainland, *D. latiflorus* shoots are a popular summer food. *D. latiflorus* shoots are consumed fresh as well as dried, processed, and canned for exports. Satya *et al*. (2010) reported Japan's high annual demand for bamboo shoots, importing thousands of tons of fresh and processed *P. pubescens* shoots from Taiwan. The high economic value of bamboo shoots for dietary consumption warrants more attention (Luo 2009).

Previous studies on bamboo shoots have focused on their nutritional value and nutrient contents, which include carbohydrates, protein, vitamins, and various amino acids and trace elements (Chen *et al*. 1999; Kumbhare and Bhargava 2007; Nirmala *et al*. 2007; 2008, Satya *et al*. 2010). Recent studies have emphasized bamboo shoot's beneficial effects on health. *D. latiflorus* possesses an antifungal protein, known as dendrocinin or dendrocin, which is a natural source for producing phenolic antioxidants (Wang and Ng 2003; Park and Jhon 2010). Moreover, unsaturated fatty acids and phytosterol in bamboo shoots contribute to reduced serum cholesterol, restrained inflammation, and they help to prevent prostate diseases (Lu *et al*. 2011). The aroma-active components in fermented bamboo shoots have also been studied (Fu *et al*. 2002). Profiling volatile compounds of *P. pubescens* shoots showed that spring *P. pubescens* shoots at ambient temperature contain *epi*-cedrol and methyl salicylate, which have protective properties against insects, while winter *P. pubescens* shoots contain 1-octen-3-ol with a characteristic mushroom smell. A 60-min heat treatment at 100 °C revealed *n*-heneicosane as the major compound in winter *P. pubescens* shoots (Chung *et al*. 2012).

Current approaches to the extraction of volatile organic compounds and essential oils are numerous and diverse, and the most widely used method is solid-phase microextraction (SPME) (Yang and Peppard 1994; Hsu *et al*. 2006; Chung *et al*. 2008). When applying SPME, a fiber coating is employed to extract both volatile and non-volatile components from different media in the liquid or gas phase. Without the need for solvents, SPME is simple and inexpensive (Alexandra and Pawliszyn 1996; Chen *et al*. 2010; Chung *et al*. 2012). Considering its ease of implementation and wide application, this study used SPME to extract volatile aroma components from *D. latiflorus* shoots. Gas chromatography-mass spectrometry (GC-MS) was employed to determine the volatile compounds at ambient temperature. This is the first investigation on the effects of heating temperatures and durations on volatile aroma compounds in *D. latiflorus* shoots. Findings on the characteristics of *D. latiflorus* shoots would enhance understanding of its aroma compounds released from cooking and promote its use in cuisines.

EXPERIMENTAL

Materials

Shoots of ma bamboo (*Dendrocalamus latiflorus* Munro) were obtained from the Experimental Forest of National Taiwan University located in Shuili. Harvested in July of 2018, the bamboo shoot samples had base diameters ranging from 15 to 20 cm and were grown to a height of 45 to 60 cm above the ground. Prior to analysis, the freshly harvested bamboo shoots were first washed and then stored in a sealed bag at -80 °C without exposure to light.

Methods

Treatment conditions

To examine how heating temperatures and durations affect compositional changes and relative contents of aroma constituents, volatile compounds present in *D. latiflorus* shoots were extracted using SPME at an ambient temperature (25 °C), then steam-cooked at 40 °C, 60 °C, and 100 °C. Steam cooking at 100 °C was conducted for 5 min, 30 min, and 60 min.

Extraction of volatile compounds by SPME

A manual SPME device (Supelco Co., Bellefonte, PA, USA) was used with a 65-μm polydimethylsiloxane-divinylbenzene (PDMS/DVB) fiber. The PDMS/DVB fiber was conditioned as recommended by the manufacturer prior to extraction. Frozen *D. latiflorus* shoots, 3 g in weight, were placed in a 20 mL vial closed by a PTFE/silicone septum, and then heated in water baths of 25 °C, 40 °C, 60 °C, and 100 °C for 30 min. Each extraction was held for 30 min at different temperatures, followed by 5-min desorption at a gas chromatography (GC) inlet at 230 °C. Similarly, the samples were steam-cooked at 100 °C for various durations before SPME extraction for further analysis.

GC-mass spectroscopy (MS) and GC-FID analyses

An analysis of volatile compounds present in *D. latiflorus* shoots was conducted using a Trace GC PoLaris Q mass (ion source temperature 230 °C, 70 eV) detector (Thermo Electron Corporation, Waltham, MA, USA) equipped with a DB-5ms capillary column (Crossbond 5% phenyl methylpolysiloxane with a length of 30 m, diameter of 0.25 mm, and film thickness of 0.25 μm). The oven temperature was held at 40 °C for 4 min, then programmed to increase from 40 to 230 °C at a rate of 4 °C/min and held for 5 min. Other parameters included an injector temperature at 230 °C; carrier gas, helium at a flow rate of 1 mL/min; split ratio of 1:30; and a scan range of 50 to 400 amu. Each extraction takes about 46.67 min.

The major components of *D. latiflorus* shoots identified were confirmed through comparing against standards and according to their mass spectral fragmentation with reference to the Wiley 7.0 and National Institute of Standards and Technology (NIST) V2.0 (Adams 2007). The percentage peak area was calculated using the GC-FID. In addition, the Kovats index (KI) was also calculated (Eq. 1),

$$KI = 100N + 100\,\frac{\log t'_{\mathrm{R(X)}} - \log t'_{\mathrm{R}(N)}}{\log t'_{\mathrm{R}(N+1)} - \log t'_{\mathrm{R}(N)}} \tag{1}$$

where $t'_{\mathrm{R}(N)}$ and $t'_{\mathrm{R}(N+1)}$ are the adjusted retention times for N and $N + 1$ carbon atoms, respectively, in *n*-alkanes, and $t'_{\mathrm{R(X)}}$ is the adjusted retention time for an unknown compound X; $t'_{\mathrm{R(X)}}$ should fall between $t'_{\mathrm{R}(N)}$ and $t'_{\mathrm{R}(N+1)}$.

RESULTS AND DISCUSSION

Volatile Aroma Compounds Present in *D. latiflorus* Shoots at Ambient Temperature

Figure 1 shows the GC-MS spectra of volatile aroma compounds present in *D. latiflorus* shoots at ambient temperature, and Table 1 lists their relative contents. At ambient temperature, *D. latiflorus* shoot is comprised of 18 volatile compounds, categorized under monoterpenes (35.99%) and furan (20.41%), followed by aliphatic aldehydes (13.30%), benzenoids (9.83%), and aliphatic alcohols (4.55%). The major volatile aroma compounds include limonene (25.11%) and 2-pentyl furan (20.41%), followed by *n*-hexanal (9.80%), *α*-pinene (6.64%), and benzaldehyde (6.14%).

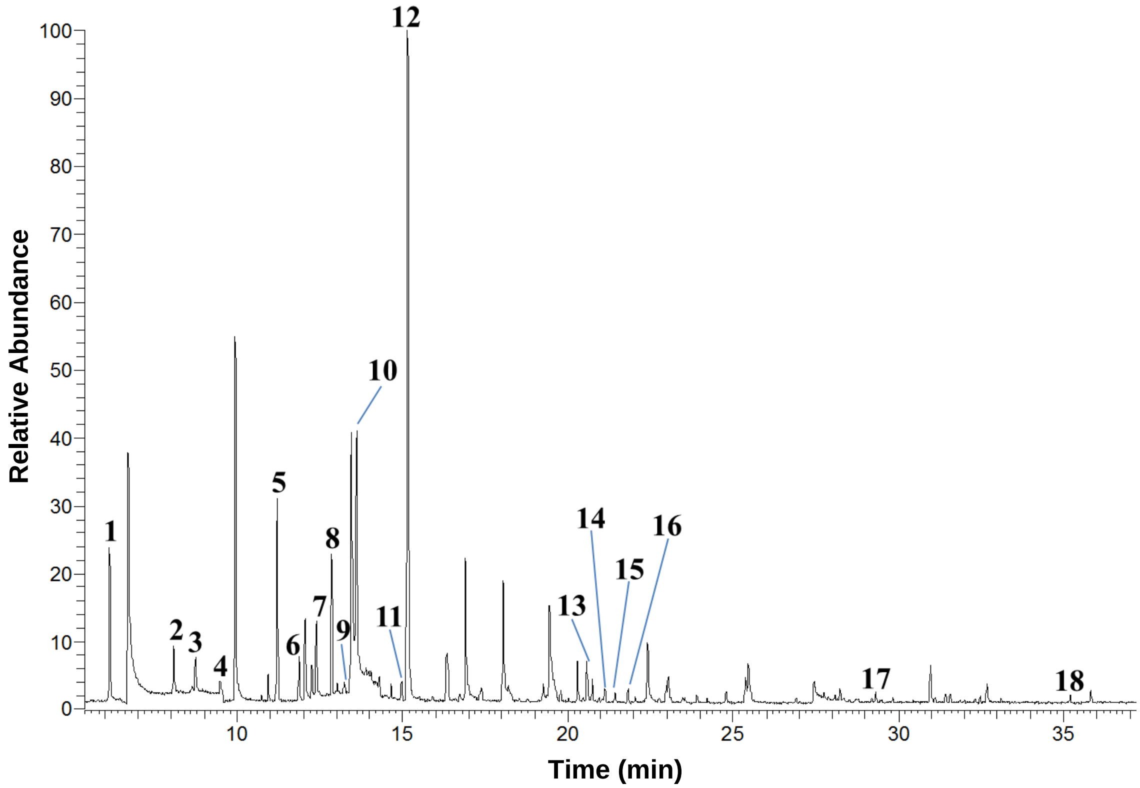

Fig. 1. GC-MS spectra of volatile aroma compounds present in *D. latiflorus* shoots at 25 °C. Peak number: (1) *n*-hexanal; (2) *trans*-2-hexen-1-al; (3) *n*-hexanol; (4) styrene; (5) *α*-pinene; (6) camphene; (7) benzaldehyde; (8) sabinene; (9) *β*-pinene; (10) 2-pentyl furan; (11) *p*-cymene; (12) limonene; (13) *n*-nonanol; (14) naphthalene; (15) methyl salicylate; (16) *n*-dodecane; (17) *trans-β*-caryophyllene; and (18) cedrol.

Table 2 lists the characteristic aroma of the volatile compounds released by *D. latiflorus* shoots at 25 °C according to the results surveyed from related literature. Limonene and 2-pentyl furan are the main aroma compounds found in *D. latiflorus* shoots. The former possesses the fresh, fruit-floral fragrance of lemon and citrus characteristics (Tu *et al*. 2002; Choi 2006; Gürbüz *et al*. 2006; Costa *et al*. 2008), while the latter has the scent of flowers and fruits (Yang *et al*. 2008. Klensporf and Henryk 2008; Thompson *et al*. 2009; Olivares *et al*. 2011). Limonene and 2-pentyl furan are often used as aromatic food additives. As for the minor volatile aroma compounds, *n*-hexanal has a grass and herbal fragrance (Gocmen *et al.* 2004; Klensporf and Henryk 2008; Wang *et al*. 2008), *α*-pinene gives the scent of pinewood and fresh herbs (Tu *et al*. 2002; Choi 2006; Costa *et al*. 2008), and benzaldehyde smells nutty like almond and sweet candy (Gocmen *et al*. 2004; Costa *et al*. 2008; Yang *et al*. 2008).

In addition to being added to food for its aroma, limonene has also been used as a pesticide. Ibrahim *et al*. (2001) reviewed the suitability of limonene for the control of insect pests and found that not only is it phytotoxic, it also shows insecticidal, repellent, antimicrobial activities, making it a natural ingredient for pesticides. At ambient temperature, *P. pubescens* shoots contain methyl salicylate (Chung *et al*. 2012). Jayasekara *et al*. (2002) researched the methanolic extract of *Securidaca longepedunculata* (Polygalaceae) root bark, commonly used as a pesticide by the Africans, and found methyl salicylate as its principal volatile component.

Table 1. Relative Contents of Volatile Aroma Compounds Present in *D. latiflorus* Shoots at 25 °C

R.t. (min)	KI[a]	rKI[b]	Compounds	MF	Relative content (%)[c]	Identification[d]
6.15	801	801	*n*-Hexanal	$C_6H_{12}O$	9.80	KI, MS, ST
8.07	857	855	*trans*-2-Hexen-1-al	$C_6H_{10}O$	3.50	KI, MS
8.74	874	870	*n*-Hexanol	$C_6H_{14}O$	2.14	KI, MS, ST
9.50	890	-	Styrene	C_8H_8	1.89	KI, MS, ST
11.21	934	939	*α*-Pinene	$C_{10}H_{16}$	6.64	KI, MS, ST
11.87	951	954	Camphene	$C_{10}H_{16}$	0.96	KI, MS, ST
12.40	964	960	Benzaldehyde	C_7H_6O	6.14	KI, MS, ST
12.85	974	975	Sabinene	$C_{10}H_{16}$	2.42	KI, MS, ST
13.02	978	979	*β*-Pinene	$C_{10}H_{16}$	0.10	KI, MS, ST
13.62	991	988	2-Pentyl furan	$C_9H_{14}O$	20.41	KI, MS, ST
14.97	1025	1025	*p*-Cymene	$C_{10}H_{14}$	0.77	KI, MS, ST
15.21	1031	1029	Limonene	$C_{10}H_{16}$	25.11	KI, MS, ST
20.59	1169	1169	*n*-Nonanol	$C_9H_{20}O$	2.41	KI, MS, ST
21.11	1182	1181	Naphthalene	$C_{10}H_8$	0.85	KI, MS, ST
21.42	1190	1192	Methyl salicylate	$C_8H_8O_3$	0.95	KI, MS, ST
21.81	1199	1200	*n*-Dodecane	$C_{12}H_{26}$	0.47	KI, MS, ST
29.32	1417	1419	*trans*-*β*-Caryophyllene	$C_{15}H_{24}$	0.65	KI, MS, ST
35.21	1607	1600	Cedrol	$C_{15}H_{26}O$	1.98	KI, MS, ST
Monoterpenes					35.99	
n-Alkanes					0.47	
Sesquiterpenes					0.65	
Oxygenated sesquiterpenes					1.98	
Aliphatic alcohols					4.55	
Aliphatic aldehydes					13.30	
Benzenoid					9.83	
Furan					20.41	
Identified					87.18	

a: Kovats index relative to C_8–C_{22} *n*-alkanes on the DB-5ms column
b: Identification based on comparison of the mass spectrum, Kovats index on a DB-5ms column in Adams (2007) and co-injection with authentic compounds
c: Relative content of compound less than 0.1%, was not shown in the table
d: KI, Kovats index; MS, mass spectroscopy; ST, co-injection with authentic standard compounds

Table 2. Aroma of Volatile Compounds Present in *D. latiflorus* Shoots at 25 °C

No.	Volatile compounds	Aroma	References
1	*n*-Hexanal	Grassy, Green	Gocmen *et al*. 2004; Klensporf and Henryk 2008; Wang *et al*. 2008
2	*trans*-2-Hexen-1-al	Fragrant, Sweet, Fruity	Wang *et al*. 2008
3	*n*-Hexanol	Cut grass, Sweet, Resinous, Green	Gürbüz *et al*. 2006; Costa *et al*. 2008
4	Styrene	Plastic, PVC, Solvent	Garruti *et al*. 2006
5	*α*-Pinene	Resinous, Pine-like, Herbaceous, Fresh	Tu *et al*. 2002; Costa *et al*. 2008; Choi 2006
6	Camphene	Warm, Herbaceous, Green	Tu *et al.* 2002; Choi 2006
7	Benzaldehyde	Almond, Sweet, Candy, Fruity, Nutty, Fragrant	Gocmen *et al*. 2004; Costa *et al*. 2008; Wang *et al*. 2008; Yang *et al.* 2008
8	Sabinene	Green, Spicy, Warm, Woody	Tu *et al.* 2002; Choi 2006; Costa *et al*. 2008
9	*β*-Pinene	Fresh, Pine-like, Resinous, Green, Waxy	Tu *et al.* 2002; Choi 2006; Costa *et al.* 2008
10	2-Pentyl furan	Floral, Fruit, Cucumber, Hay, Licorice, Fatty (very faint), Meat broth, Savory, Metallic	Klensporf and Henryk 2008; Yang *et al*. 2008; Thompson *et al*. 2009; Olivares *et al*. 2011
11	*p*-Cymene	Green, Citric	Tu *et al.* 2002; Choi 2006; Costa *et al*. 2008
12	Limonene	Citrus-like, Pungent green, Lemon-like, Citric, Fresh	Tu *et al.* 2002; Choi 2006 ; Gürbüz *et al*. 2006; Costa *et al.* 2008
14	Naphthalene	Naphthalene, Old house	Gocmen *et al*. 2004; Yang *et al*. 2008
15	Methyl salicylate	Sweet, Spicy, Minty	Wang *et al*. 2008
16	*trans*-*β*-Caryophyllene	Spicy, Woody	Sant'Anna *et al*. 2007
17	Cedrol	Herbaceous	Tu *et al*. 2002; Choi 2006

Freshly harvested *D. latiflorus* shoots have fragrances attributable to their two main volatile aroma components, limonene and 2-pentyl furan. In addition, limonene also offers protection against insect and pest attack. Hence, although both *D. latiflorus* shoots and spring *P. pubescens* shoots have high carbohydrate contents and are grown above the ground, their hard sheath and chemical composition, especially limonene, contribute to self-defense against attack from insects and other microorganisms.

Effect of Heating Temperature on Volatile Compounds of *D. latiflorus* Shoots

Table 3 shows the changes in composition of *D. latiflorus* shoots when heated at different temperatures and lists the changes in relative contents (%) of its volatile aroma constituents after heat treatment. The contents of monoterpenes, furan, and aliphatic aldehydes decrease from 35.99%, 20.41%, and 13.30% at ambient temperature, to 15.05%, 17.64%, and 3.76% at 40 °C, and finally to 0.42%, 1.43%, and 0.70% at 100 °C, respectively. Such marked decline in contents evidenced the obvious influence of heating temperature on the composition of *D. latiflorus* shoots. The same trend was observed for limonene, 2-pentyl furan, and *n*-hexanal, which are the major monoterpenoids, furan, and aliphatic aldehyde compounds, respectively. Their relative contents dropped markedly from 25.11%, 20.41%, and 9.80% at ambient temperature to 0.42%, 1.43%, and 0.41% at 100 °C, respectively. In other words, these volatile aroma compounds almost vaporized completely. As reported by Ibrahim *et al*. (2001), while limonene has shown deterrent and insecticidal properties, it is volatile under high temperature, thus accounting for the decline in relative content with an increase in heating temperature. In the analysis conducted by Lehtinen and Laakso (2004) on the quality of oat products, 2-pentyl furan and linoleic acid were produced under lipid oxidation and their relative contents decreased with increasing processing temperature. Apart from these major volatile aroma components, other minor ones also show obvious reductions in relative contents at higher heating temperatures. As shown in Table 3, the relative contents of *α*-pinene and benzaldehyde at ambient temperature were 6.64% and 6.14%, respectively. At 100 °C, the content of benzaldehyde dropped to 0.16% while *α*-pinene could no longer be detected, thus revealing the obvious effects of heating temperature on these two aromatic constituents.

Table 3. Changes in Relative Contents (%) of Volatile Compounds Present in *D. latiflorus* Shoots after Heating at Different Temperatures for 30 min

R.t. (min)	KI[a]	rKI[b]	Compounds	MF	Heating Temperatures (°C)			
					25*	40*	60*	100*
6.13	801	801	*n*-Hexanal	$C_6H_{12}O$	9.80	1.31	0.69	0.41
11.21	934	939	*α*-Pinene	$C_{10}H_{16}$	6.64	1.76	1.41	-
12.41	964	960	Benzaldehyde	C_7H_6O	6.14	5.21	1.99	0.16
13.62	991	988	2-Pentyl furan	$C_9H_{14}O$	20.41	17.64	6.90	1.43
15.21	1031	1029	Limonene	$C_{10}H_{16}$	25.11	11.98	4.12	0.42
27.42	1360	1355	4-Hydroxybenzaldehyde	$C_7H_6O_2$	-	11.58	10.50	45.33
44.12	2097	2100	*n*-Heneicosane	$C_{21}H_{44}$	-	1.18	14.64	33.45
45.59	2200	2200	*n*-Docosane	$C_{22}H_{46}$	-	-	0.29	2.66
Monoterpenes					35.99	15.05	5.53	0.42
n-Alkanes					0.47	2.13	16.32	36.40
Sesquiterpenes					0.65	1.14	5.09	0.01
Oxygenated sesquiterpenes					1.98	1.25	2.10	0.16
Aliphatic alcohols					4.55	10.50	10.46	0.36
Aliphatic aldehydes					13.30	3.76	1.94	0.70
Benzenoids					9.83	18.79	17.17	45.80
Furan					20.41	17.64	6.90	1.43
Identified					87.18	70.27	65.50	84.86

a: Kovats index relative to C_8–C_{22} *n*-alkanes on the DB-5ms column
b: Identification based on comparison of the mass spectrum, Kovats index on a DB-5ms column in Adams (2007) and co-injection with authentic compounds
* Relative content of compound less than 0.1%, was not shown in the table

In contrast, some volatile compounds of *D. latiflorus* shoots increased in content with higher heating temperatures (Chung *et al*. 2012). As seen in Table 3, *n*-alkanes showed the most obvious increase, from a trace amount of 0.47% at ambient temperature, to 2.13% at 40 °C, 16.32% at 60 °C, and 36.40% at 100 °C. The same trend was observed for *n*-heneicosane, the major constituent of *n*-alkane, which was hardly detectable at ambient temperature but became the second major component (33.45%) after being heated at 100 °C. Similarly, the relative content of benzenoid, as shown in Table 3, also increased markedly from 9.83% at ambient temperature to 45.80% at 100 °C. Its major constituents, *n*-heneicosane and 4-hydroxybenzaldehyde, also showed comparable increases in relative contents, as can be seen in Table 3, from barely detectable at ambient temperature to 33.45% and 45.33%, respectively, at 100 °C. Similar findings were obtained for spring and winter *P. pubescens* shoots when heated at 100 °C with *n*-heneicosane becoming the major constituent (Chung *et al*. 2012).

When assessing the antidepressant effect of water extract of *Gastrodia elata* B1, Chen *et al.* (2008) found that 4-hydroxybenzaldehyde is one of the main constituents of monoamine oxidase (MAO) inhibitors. Kaunzinger *et al*. (1997) detected 4-hydroxybenzaldehyde of considerably higher proportion than any vanilla extract. Ha *et al*. (2000) also found evidence in rat brains that antioxidation and GABAergic neuromodulation of 4-hydroxybenzaldehyde partially contribute to an antiepileptic and anticonvulsive activity of *G. elata* B1.

Effect of Heating Duration on Volatile Compounds of *D. latiflorus* Shoot

Table 4 shows the changes in composition of *D. latiflorus* shoots heated at 100 °C for different durations. The *n*-alkanes and benzenoids showed opposite changes in relative content with heating duration. The relative content of *n*-alkanes increased with heating duration, from 35.84% after 5 min, to 36.40% after 30 min, finally reaching 43.39% after 60 min, while the relative content of benzenoids decreased with heating duration, from 54.30% after 5 min, to 45.80% after 30 min, and finally reaching 35.24% after 60 min. In other words, there exists a positive (negative) relationship between the relative content of *n*-alkanes (benzenoids) with heating duration. Such trends can be accounted for by the changes in the relative content of volatile compounds present in *D. latiflorus* shoots, shown in Table 3.

As mentioned above, *n*-alkanes comprise mainly *n*-heneicosane, whose relative content increases from 33.07% after 5 min, to 33.45% after 30 min, and ultimately reaching 39.54% after 60 min, as can be seen in Table 4. This positive relationship between *n*-heneicosane content and heating duration in *D. latiflorus* shoots echoes the results obtained by Chung *et al.* (2012) for winter *P. pubescens* shoots. On the other hand, benzenoids are mainly comprised of 4-hydroxybenzaldehyde, whose relative content decreases from 53.89% after 5 min, to 45.33% after 30 min, finally reaching 34.64% after 60 min, as can be seen in Table 4. This negative relationship between 4-hydroxybenzaldehyde content and heating duration in *D. latiflorus* shoots is also consistent with the findings obtained by Chung *et al*. (2012) for spring *P. pubescens* shoots. Other minor fatty acid and ester compounds, including dodecanoic acid, methyl linoleate, and linoleic acid, also showed increases in relative content with prolonged heating duration, implying a positive relationship of fatty acid and ester compounds in *D. latiflorus* shoots with heating duration.

Table 4. Changes in Relative Contents of Volatile Compounds Present in *D. latiflorus* Shoots Heated at 100 °C for Different Durations

R.t. (min)	KI[a]	rKI[b]	Compounds	MF	Duration time (min)		
					5*	30*	60*
27.42	1360	1355	4-Hydroxybenzaldehyde	C_7H_6O	53.89	45.33	34.64
33.83	1562	1569	Dodecanoic acid	$C_{13}H_{26}O_2$	0.93	1.16	1.41
44.01	2088	2091	Methyl linoleate	$C_{19}H_{34}O_2$	0.38	2.37	2.14
44.12	2097	2100	*n*-Heneicosane	$C_{21}H_{44}$	33.07	33.45	39.54
44.52	2125	2129	Linoleic acid	$C_{18}H_{32}O_2$	0.45	5.58	8.78
45.59	2200	2200	*n*-Docosane	$C_{22}H_{46}$	2.26	2.66	3.37
Monoterpenes[c]					0.40	0.42	0.40
n-Alkanes					35.84	36.40	43.39
Fatty acids & esters					1.76	9.12	12.34
Sesquiterpenes[c]					0.05	0.01	0.04
Oxygenated sesquiterpenes					0.16	0.16	0.15
Aliphatic alcohols					0.56	0.36	0.53
Aliphatic aldehydes					0.66	0.70	0.76
Benzenoids					54.30	45.80	35.24
Furan					0.75	1.43	1.73
Identified					94.48	94.40	94.58

a: Kovats index relative to C_8–C_{22} *n*-alkanes on the DB-5ms column
b: Identification based on comparison of the mass spectrum, Kovats index on a DB-5ms column in Adams (2007) and co-injection with authentic compounds
* Relative content of compound less than 0.1% was not shown in the table

CONCLUSIONS

1. The effects of heating temperature and duration on the volatile compounds of *D. latiflorus* shoots were examined. Extraction using SPME followed by GC-MS analyses showed that frozen *D. latiflorus* shoots at ambient temperature contain 18 volatile compounds, with limonene and 2-pentyl furan constituting the majority.
2. Limonene has the aroma of lemon and citrus fruits, while 2-pentyl furan is redolent of flowers and fruits. Moreover, heating temperature was found to have an obvious impact on the volatile aroma compounds.
3. Limonene, 2-pentyl furan, and *n*-hexanal, showed a marked decline in content and became almost vaporized completely at 100 °C, while others compounds, including *n*-heneicosane and 4-hydroxybenzaldehyde, showed a pronounced increase in relative contents.
4. There existed a positive relationship between *n*-heneicosane content and heating duration but a negative relationship between 4-hydroxybenzaldehyde content and heating duration, revealing the substantial effects of heating duration on volatile aroma compounds of *D. latiflorus* shoots.

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