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Aroma-Active Components in Fermented Bamboo Shoots

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Bamboo shoots (*Phyllostachys pubescens*) were fermented and prepared in a traditional Taiwanese manner. Static and dynamic headspace extractions of volatile compounds were conducted by solid phase microextraction (SPME) and by cryogenic focusing purge and trap, respectively. Volatile analysis was conducted with gas chromatography and mass spectrometry. Gas chromatography−olfactometry (GCO) was conducted utilizing the Osme time−intensity method. Of 70 volatile compounds detected, 29 possessed aroma activity, and the most odor active included *p*-cresol (barn-like), 2-heptanol (mushroom), acetic acid (vinegar), and 1-octen-3-ol (mushroom). SPME extracted 66 compounds, purge and trap extracted 14 compounds, and 12 compounds were common to both methods. The Osme GCO technique coupled with SPME is an effective tool for the extraction and evaluation of aroma-active headspace volatiles.

KEYWORDS: GCO; Osme; fermented bamboo shoot; aroma-active volatiles; SPME; purge and trap

INTRODUCTION

For centuries, fermented bamboo shoots (*Phyllostachys pubescens*) have lent unique flavors and a distinctive crunchy-chewy texture to traditional Asian dishes. They are often combined with other ingredients such as ginger, garlic, bell pepper, white sesame, and red chili and then stir fried or mixed with leak, scallions, poultry stock, and anise to make soup.

In the Republic of China (Taiwan), bamboo shoots remain one of the most abundantly produced vegetables, as evidenced by the 1999 agriculture figures: >358000 metric tons was harvested. Natural fermentation is a tradition arguably as old as is the consumption of bamboo shoots and remains a popular processing technique because it results in the production of compounds that add distinctive flavors. Natural fermentation relies on the environment to supply microorganisms needed to generate flavorful products.

Fermentation in foods is a biotransformation of substrates by bacteria, yeasts, and/or molds (*1*, *2*) that yield, among other compounds, unique and diverse flavors important in many popular foods. Fermented vegetables are very popular in many ethnic cultures (*3*, *4*) and contain, among others, the odorous sulfur compounds dimethyl trisulfide, diallyl disulfide, diallyl trisulfide, methylallyl disulfide, and 3-(methylthio)propanal. Additionally, (*E*,*Z*)-2,6-nonadienal (cucumber-like), phenylacetaldehyde (honeysuckle-like), linalool (floral), (*E*,*E*)-2,4-decadienal (fatty), and 2,3-butanedione (buttery) were determined to be important aroma contributors. The most potent odor-active components responsible for the aroma of fermented cucumbers (*5*) are *trans*-4-hexenoic acid and *cis*-4-hexenoic acid. The volatile compounds produced from Japanese-style fermented vegetables, called Nukadoko, (*6*) include short-chain fatty acids, various alcohols, and esters.

Gas chromatography−olfactometry (GCO) techniques include CharmAnalysis (*7*), aroma extraction dilution analysis (AEDA; *8*), and Osme (*9*). Both CharmAnalysis and AEDA are bioassays for determining the odor activity of compounds by sniffing GC effluent from a series of diluted extracts. Olfactometry dilution analysis techniques have proven to be valuable in identifying aroma-active components in foods, and they provide an understanding of the contributions aromas make to the overall flavor of the food (*10*).

Unlike GCO dilution analysis techniques, with Osme, only one concentration of extract is required, and this may be the naturally occurring concentration of headspace volatiles present at equilibrium conditions in a sealed vial [ideally suited for use with solid phase microextraction (SPME)], or, like AEDA and CharmAnalysis, it may utilize a liquid extract. Osme is based on sensory analysis principals. It utilizes a cross-modal matching technique, a concept based on Stevens's power law (*11*). Cross-modal matching refers to matching the intensity of one attribute, such as aroma intensity, to that of another attribute, such as the perception of visual length. The matching of perceived sensory attribute intensities to the perception of visual length led to the common use of line scales in sensory analysis (*12*). For Osme analysis, panelists are trained to utilize a 0−15 point scale to rate the intensities of eluting aroma-active components in a manner consistent with line scales and consistent descriptive analysis, a popular and frequently utilized sensory evaluation method. Osme is also a time−intensity approach (*13*), for example, it measures time of aroma component elution from the GC versus aroma intensity with T_{max}, I_{max}, and AUC denoting time of maximum aroma intensity, maximum intensity, and area under the curve, respectively. Osme analysis has been

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successfully coupled with SPME and used to identify differences in the aroma profiles of unheated and excessively heated orange juices (*14*). Additionally, it has been successfully utilized to identify the odorants and odorant contributions in Pinot Noir wines (*15*), a corn-based snack (*16*), Gala apples (*17*−*19*), grapefruit juice (*20*), and cooked mussels (*21*). Osme has also been utilized to measure the aroma activity of vanillin in citrus juices (*22*).

The purpose of this study was to identify important aroma-active compounds and to assess their relative contributions to the unique flavor of bamboo shoots fermented in steps outlined in a traditional Taiwanese recipe. Additionally, we sought to compare static headspace extraction using SPME with dynamic headspace extraction using a cryogenic purge and trap system.

MATERIALS AND METHODS

Processing. Fresh bamboo shoots were harvested from Meinon, Kaoshiung County, Taiwan, in May 2000. The outer layer was removed by hand-peeling, and the shoot was cut into cubes. Cubes were placed in a boiling water bath for 15 min and then placed in cheesecloth bags. Pressure was applied to the cheesecloth bags by placing bags on cut stone flooring and covering them with pine planks. Approximately 20 kg of stones was placed atop the pine planks. This apparatus was stored under a protective cover but exposed to ambient temperatures and humidity. Pressing lasted 5 days. At that time, a sour, barn-like, or medicine-like odor was produced from the bamboo, due to fermentation by endogenous microorganisms. Sodium chloride (from sea salt) was mixed with bamboo shoot cubes, and then the cubes were manually cut into smaller pieces and put into a clean cheesecloth bag. Additional sodium chloride was added, and pressing was again conducted for an additional 7 days. The pressed, fermented, salted product was stored in glass bottles and sealed with a plug of cheesecloth. In our study, bamboo had been stored for 2 weeks before it was placed in a sealable, polyethylene bag (720 g in 1 qt size) and transported to the United States (stored for 2 days at ambient temperature during transportation). Shoots were refrigerated at 4 °C for 60 days prior to odor and chemical analyses. An additional sample of bamboo was prepared in the identical manner and shipped in glass containers instead of polyethylene containers. This step was conducted to determine if the polyethylene containers had absorbed volatile compounds from the original bamboo to the point that flavor intensity was reduced.

Static Headspace Analysis by SPME. Bamboo (10 g) was placed in a 22 mL glass vial with an open center screw cap with a PTFE/Teflon septum (Supelco Co., Bellefonte, PA) for 12 h at 4 °C. Each vial was removed from refrigerated storage and remained at ambient temperature for 15 min before it was placed in a 37 °C water bath for 30 min prior to volatile sampling. An SPME fiber, 2 cm, 50/30 μm DVB/Carboxen/PDMS (Supelco Co.) was baked overnight at 250 °C prior to sampling. The SPME fiber was exposed to the headspace volatiles for 60 min prior to chromatographic analyses.

Gas Chromatography—Mass Spectrometry (GC-MS). GC-MS consisted of an HP 5890 series II GC/HP 5972 mass selective detector (MSD, Hewlett-Packard Co., Palo Alto, CA) equipped with a DB-Wax capillary column (J&W Scientific, Folsom, CA), 30 m × 0.25 mm i.d., 0.25 μm film thickness. Temperatures were as follows: injection port, 225 °C; oven, programmed at 40 °C for 5 min, then raised at 8 °C/min to 250 °C, and held for 5 min. MSD conditions were as follows: capillary direct interface temperature, 280 °C; ionization energy, 70 eV; mass range, 33−350 amu; EM voltage (Atune +200 V); scan rate, 2.2 scans/s. Helium was used as carrier gas at a constant flow rate of 0.96 mL/min.

Dynamic Headspace Sampling—Gas Chromatography—Mass Spectrometry (DHS-GC-MS). A Tekmar 3000 purge and trap concentrator/cryofocusing module (Tekmar Co., Cincinnati, OH) coupled with an HP 5890 series II GC was employed for DHS-GC-MS. Ten grams of bamboo in a 25 mL purge tube was prepurged with helium (40 mL/min) for 2 min. The sample was then preheated to 40 °C for 5 min, and the volatiles were purged at 60 °C for 30 min onto a VOCARB 3000 trap (Supelco Co.) maintained at 0 °C. After sampling, the trap was dry purged for 5 min, and then the volatiles were desorbed (180 °C for 1 min) and subsequently cryofocused (−120 °C) onto a 15 cm section of 0.53 mm i.d. deactivated fused silica capillary column. Transfer lines and valves were maintained at a temperature of 150 °C. Trap pressure control was set at 4 psi. Helium flow during thermal adsorption of the VOCARB 3000 trap (20 mL/min) and cryofocusing trap (1.4 mL/min) was controlled by the split/splitless electronic pressure control pneumatics of the GC. Cryofocused volatiles were thermally desorbed (180 °C for 1 min) directly into the analytical GC column. All other GC and mass spectrometry conditions were the same as previously described. Between analyses, the system was purged, clean glassware was installed, and the VOCARB 3000 trap was baked (225 °C for 20 min).

SPME—Gas Chromatography—Olfactometry (SPME-GCO). Three males, aged 32−39, served as panelists. For training, separate standard solutions for each of the following compounds in ethanol were prepared at 200 ppm (w/w) and at 1000 ppm (w/w): dimethyl sulfide, hexanal, 2-heptanol, 1-octen-3-ol, allyl disulfide, benzaldehyde, and *p*-cresol. Panelists sniffed the vials containing standards. The 200 ppm standards served as anchors for a medium aroma intensity standard (7 on the 0−15 point scale), whereas the 1000 ppm standards served as anchors for the extreme aroma intensity (15 on the 0−15 point scale). Additional standards were prepared for training and contained all seven compounds listed above, each at a concentration of 200 and 1000 ppm in methanol. Each standard was injected into the GC, and resultant effluents were evaluated a total of five times per panelist. The latter training step proved to be valuable in that panelists became familiar with the Osme aroma intensity scale, proper breathing techniques, and diverse verbal descriptors. In the final training step panelists evaluated headspace extracts of bamboo samples four times each. These final four practice runs indicated panelists could replicate analyses in a precise manner.

Osme Analysis. Consensus aromagrams (Osmegrams) were developed by first identifying which aroma-active peaks were detected by each panel member in two of three replications. Aroma peaks that met this criterion were then compared with peaks detected by other panelists. Only aroma peaks detected by two of three panelists were included in the consensus osmegram (**Table 1**). Identification of aroma-active components was determined by a comparison of retention indices (Kovats) for aroma peaks (Osme analysis) with retention indicies from GC-FID and retention indices from mass spectrometry (GC-MS). Additionally, mass spectra were identified by comparison with spectra obtained in the Wiley library (version B00.00; Wiley, New York, 1990). Authentic standards were analyzed and confirmed earlier identification efforts (**Table 1**).

The GCO system consisted of Varian 3400 GC (Varian Instrument Group, Walnut Creek, CA) equipped with a sniff port. The capillary column present in the GC oven extended all the way through the heated, stainless steel sniff port to a glass funnel fitted to the end. Heated, humidified air (air flow rate was 30 mL/min) was introduced into the sniff port upstream near the point where the capillary column first entered (the sniff port). Air engulfed the capillary column effluent and carried it into the glass funnel where Osme evaluation was conducted. The GC oven contained a DB-Wax column, 30 m × 0.32 mm i.d., 0.25 μm d_f (J&W Scientific). GC conditions were identical to those listed for GC-MS. All bamboo GCO analyses were conducted with SPME.

Components were separated in the capillary column and passed through the sniffing port to the seated panelist, who rated the intensity of the volatiles on a 16-point sliding scale using a variable resistor in the manner reported earlier (*14*). The aroma intensity scale ranged from no aroma perceived = 0, to moderate = 7, to extreme = 15. The sliding scale was interfaced with a personal computer (Osme software, Starkville, MS) allowing time−intensity data recordings. At the time of aroma perception, the panelist verbally described the aroma to the experimenter. Retention times and verbal descriptions were recorded to permit aroma descriptors to be coupled with computerized aroma time−intensity plots. Retention times of alkane standards were analyzed by GC-FID prior to olfactometry analysis. This enabled the conversion

Table 1. Volatile Components of Fermented Bamboo Shoots

no.	component	aroma descriptor	KI DB-Wax	KI DB-5ms	ID	Osme[f] I_{max}	Osme[f] AUC
1	acetaldehyde	ND[g]	677		*d*		
2	dimethyl sulfide	stinky/sulfury	904	724	*a*, *d*	4.1	4.1
3	acetic acid, methyl ester	ND	909		*a*, *d*		
4	acetic acid, ethyl ester	ND	921		*a*, *d*		
5	dichloromethane	ND	933		*b*		
6	ethanol	ND	937	726	*b*, *d*		
7	pentanal	ND	953	741	*a*, *d*		
8	2-butanol	ND	988		*a*, *d*		
9	ethyl 2-methylbutanoate	fruity	1047		*a*	2.8	4.4
10	hexanal	green	1076	771	*a*, *d*	6.4	7.9
11	cyclopentanone	ND	1154	767	*a*, *d*		
12	heptanal	ND	1162		*a*		
13	*d*,*l*-limonene	ND	1169	1017	*a*		
14	unknown	garlic	1204		*e*	2.8	6.2
15	2-pentylfuran	ND	1215		*b*		
16	unknown	herbal, sour	1257		*e*	4.6	5.5
17	octanal	ND	1279		*a*		
18	cyclopentanol	ND	1300		*b*, *d*		
19	(*Z*)-2-heptenal	ND	1319		*a*		
20	**2-heptanol**[h]	**mushroom/earthy**	**1321**		***a***	**13.2**	**28.2**
21	6-methyl-5-hepten-2-one	ND	1329		*b*		
22	1-hexanol	ND	1354	821	*a*		
23	nonanal	ND	1386	1117	*a*		
24	3-octanol	ND	1396		*a*		
25	**unknown**	**savory**	**1397**		***e***	**11.4**	**18.8**
26	cyclohexanol	ND	1403		*b*		
27	2-octanol	ND	1421		*a*		
28	1-octen-3-ol	mushroom/plastic	1429		*a*	3.6	3.7
29	**acetic acid**	**vinegar**	**1433**	**734**	***a*, *d***	**13.2**	**16.7**
30	heptanol	ND	1453		*a*		
31	allyl disulfide	ND	1465		*a*		
32	**methional**	**potato/fermented**	**1474**		***a***	**13.9**	**83.3**
33	unknown	earthy/barn-like	1490		*e*	2.7	2.9
34	2-ethyl-1-hexanol	ND	1491		*a*		
35	benzaldehyde	musty	1503	937	*a*	5.3	10.4
36	4-ethylbenzaldehyde	ND	1521		*d*		
37	propanoic acid	ND	1525		*b*		
38	(*Z*)-2-nonenal	ND	1532		*a*		
39	unknown	bell pepper/spicy	1538		*e*	4.3	6.2
40	unknown	plastic	1541		*e*	7.4	10.1
41	**linalool**	**floral/perfume**	**1552**	**1098**	***a*, *d***	**9.1**	**12.3**
42	1-octanol	ND	1558		*a*		
43	2(3*H*)-furanone, dihydro	ND	1608		*b*		
44	**(*E*,*Z*)-2,6-nonadienal**[c]	**cucumber/green**	**1611**	**994**	***a***	**9.3**	**15.5**
45	1-phenyl ethanol	ND	1628		*a*		
46	2-furan methanol	ND	1640	808	*a*		
47	benzene, 1-methoxy-4(2-propenyl)	ND	1647	1199	*b*		
48	unknown	savory/corn chip	1691		*e*	6.1	13.6
49	naphthalene	ND	1706	1179	*b*		
50	pentanoic acid	ND	1712		*a*		
51	unknown	minty	1734		*e*	5.0	12.7
52	benzoic acid, 2-hydroxy-, methyl ester	ND	1743		*b*		
53	benzaldehyde, 2-hydroxy-5-methyl	ND	1750		*b*		
54	hexanoic acid	ND	1814		*a*		
55	unknown	acrid/sharp/metallic	1820		*e*	7.1	8.2
56	**unknown**	**honey/sweet/floral**	**1834**		***e***	**8.3**	**12.5**
57	benzene methanol	ND	1844	1608	*a*		
58	unknown	garlicky	1872		*e*	7.3	10.7
59	benzeneethanol	ND	1878		*a*		
60	3-methoxy-2-butanol	ND	1903		*b*		
61	2-methoxy-4-cresol	sweet	1915	1191	*a*	9.0	12.6
62	**phenyl acetaldehyde**	**rosy/perfume/floral**	**1932**		***a***	**9.0**	**12.6**
63	**phenol**	**stale**	**1955**	**973**	***a***	**7.7**	**13.2**
64	unknown	bubble gum/vanillin	1975		*e*	5.6	11.8
65	4-ethylguaiacol	ND	1989		*b*		
66	unknown	pepper	2029		*e*	3.8	11.0
67	unknown	anise/medicine	2037		*e*	8.1	15.0.7
68	**unknown**	**stale**	**2085**		***e***	**9.0**	**17.8**
69	*p*-cresol	barn-like/medicine	2096	1103	*a*, *d*	14.9	139.3
70	3-ethylphenol	ND		1173	*b*		

[a] Peak identified by SPME extraction, GC-MS analysis on a DB-Wax column or on a DB-5 column. Peak was verified by analysis of a standard. [b] Peak identified by SPME extraction, GC-MS analysis on a DB-Wax column or on a DB-5 column. [c] Stereochemistry not determined. [d] Peak found with purge and trap GC-MS with DB-Wax capillary column. [e] Odor detected with GCO with DB-Wax capillary column. [f] I_{max} is the maximum peak intensity (0–15), and AUC is the area under the peak curve. [g] ND indicates not detected. [h] Compounds in bold font are the 10 most aroma-active compounds from fermented bamboo shoot headspace.

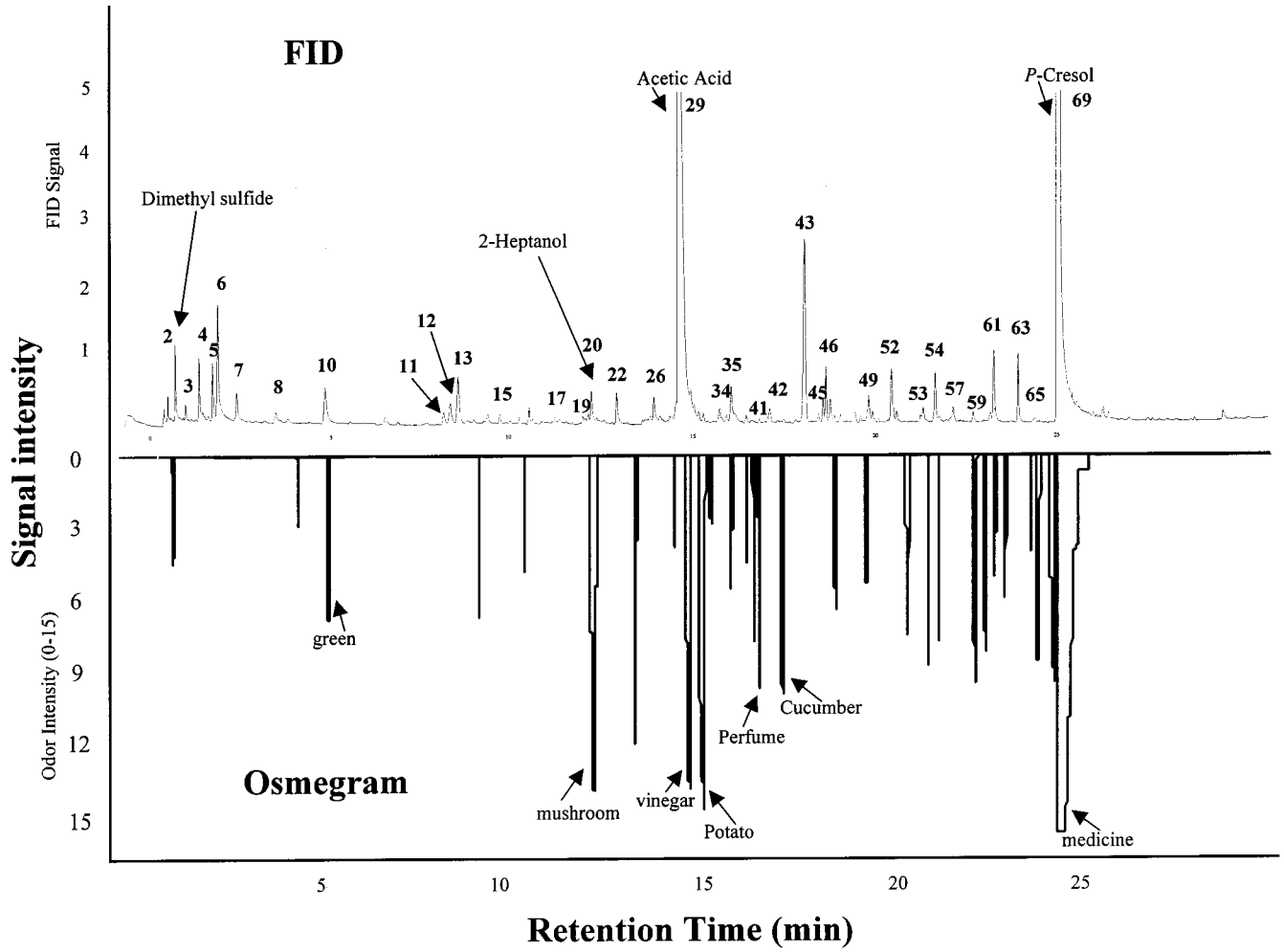

Figure 1. Fermented bamboo shoot headspace FID chromatogram coupled with Osmegram.

of aroma-active peak retention times to standard Kovats index values. Standard values could then be related to indices from GC-MS sample analysis and compared with published values from compounds of known identity.

Aroma Compound Identification. MS and FID analyses were conducted on DB-5 and DB-Wax capillary columns (J&W Scientific). Aroma compounds were identified by matching mass spectra with spectra in a Wiley 138K Mass Spectral Database (version B00.00; Wiley, New York, 1990; purchased from Hewlett-Packard Co., Palo Alto, CA.). Additionally, Kovats retention indices and component aroma characteristics were verified by analysis of aroma standards (Aldrich Chemical Co., Milwaukee, WI) and FlavorNet (*23*).

Sensory Panel Testing. Triangle tests were conducted to determine the effect of bamboo storage in polyethylene bags on aroma intensity. Younger bamboo shoots (aged 1 month) were sealed in glass jars with screw lids and shipped from Taiwan to our laboratory. Samples were stored at 4° C for 7 days prior to sensory analysis. Thirty panelists were presented with three samples coded with random three-digit numbers. Two of the samples were either bamboo stored in glass or bamboo stored in polyethylene or visa versa. Panelists were asked to evaluate bamboo aroma and determine which one of the three samples presented differed from the other two (*12*).

RESULTS AND DISCUSSION

Aroma-Active Volatiles. A total of 29 aroma-active peaks were detected in bamboo headspace (**Table 1**). The 10 most important aroma-active components (based on aroma peak area) were *p*-cresol, methional, 2-heptanol, acetic acid, (*E,Z*)-2,6-nonadienal, linalool, phenyl acetaldehyde, and three unknowns.

p-Cresol imparted a barn-like/medicine-like odor to bamboo. The large GCO *p*-cresol peak indicated that it was the most important aroma-active compound in bamboo. Selmer and Andrei (*24*) reported *p*-cresol was the main fermentation byproduct of tyrosine, the major free amino acid in bamboo shoots (*25*). During initial GCO training, panelists evaluated the odor of a sample of bamboo in a glass vial and reported a pungent, intense *p*-cresol-like odor. According to panelists, the 1000 ppm sample of *p*-cresol sniffed for intensity training was much less intense than this odor-active compound in bamboo headspace. Although the *p*-cresol GC peak was very large (**Figure 1**), the odor threshold for *p*-cresol is also high, 55 μg/kg in water (*26*). A possible explanation for the overpowering *p*-cresol odor in bamboo headspace may be that a combination of *p*-cresol and acetic acid enhances the odor intensity of both components in a synergistic manner that is more pronounced than the odors of either component perceived individually.

Methional did not exhibit a large GC peak, but it was an important aroma-active compound apparently because of its low odor threshold (0.2 μg/kg; *34*). Methional, 3-(methylthio)-propanal, is the Strecker degradation compound of methionine (*26*) and has been identified in boiled crayfish (*27*), cooked mussels (*21*), and hand-squeezed grapefruit juice (*28*). Also, a Strecker degradation compound of methionine, dimethyl sulfide exhibits a low odor threshold (1.0 μg/kg) and was an aroma contributor in bamboo headspace.

Table 2. Results from SPME/GC Analysis: Three Replications of Integrated FID Peak Areas of Components

			statistical analysis		
no.	component	aroma descriptor	mean	SD	% RSD
10	hexanal	green	65.33	6.81	10.42
20	2-heptanol	mushroom	63.00	6.31	10.02
29	acetic acid	vinegar	1825.25	194.11	10.63
35	benzaldehyde	musty	157.25	64.23	40.85
63	phenol	stale	62.75	3.30	5.26
69	*p*-cresol	barn-like/medicine	71981.80	1994.45	2.77

The GC peak area for acetic acid was also large, and it possessed a large GCO peak area. Acetic acid imparted a sharp, sour, vinegar-like odor. Panelists did not perceive ethanol by GCO; however, this component was identified in bamboo when extraction and analyses were conducted with DHS-GC-MS.

Additional aroma-active compounds, 2-heptanol and linalool (odor threshold is 6 μg/L; *26*), were among the 10 most aroma-active components. 2-Heptanol and linalool were identified as volatile components in fermented cucumber (*5*), and 2-heptanol was reported as one of the most important aroma-active components of Gorgonzola cheese (*29*).

Comparison of Results from SPME with Results from Purge and Trap Extraction. A total of 70 volatile components were identified in the headspace of bamboo. Results from static headspace SPME sampling of volatile extracts and dynamic headspace purge and trap sampling of volatile extracts are shown in **Table 1**. Fifteen unknown components were detected only by GCO. These components may have been below the detection limit of GC and MS. Compounds were identified by matching Kovats retention indices (*30*) of unknowns, on two types of capillary columns, with Kovats retention indices of authentic standards or by matching mass spectra with spectra in a Wiley 138 database. Also, literature retention index values (*14*, *24*, *31*) were used to help in compound identification.

Purge and trap, a dynamic headspace sampling technique, is reported to be effective in extracting and concentrating trace headspace food volatiles (*32*). Acetaldehyde is a highly volatile, relatively low molecular weight component. Purge and trap seemed more adapt at extracting acetaldehyde and certain alcohols such as ethanol. Two compounds, acetaldehyde and 4-ethylbenzaldehyde, were identified exclusively by the DHS-GC-MS method. Fifty-six compounds were extracted only with SPME, and 12 compounds were extracted by both techniques. The number of peaks identified with purge and trap seems rather low, and this may be attributed to the fact that the Vocarb 3000 is not the most appropriate trap (100% Carboxen).

Several compounds identified in bamboo, including phenethyl alcohol, 4-ethylguaiacol, 2-methoxy-4-cresol, 3-ethylphenol, ethyl acetate, ethanol, acetic acid, benzaldehyde, and phenyl acetaldehyde, were previously reported as aroma compounds present in a Japanese fermented vegetable product (*6*, *33*). Hexanal was previously reported as an undesirable flavor volatile generated during the fermentation of cucumber (*34*). Benzaldehyde, noted for imparting bitter almond and cherry flavors, has been identified as a secondary metabolite from microbial fermentation by *Pseudomonas putida* (*35*).

Reproducibility of headspace extracts by SPME utilizing the divinyl benzene/Carboxen/poly(dimethylsiloxane) fiber ranged from <5 to 40% (**Table 2**). Bazemore et al. (*14*) utilized a Carboxen/poly(dimethylsiloxane) fiber and reported similar results.

Effect of Storage in Polyethylene Bags and Sensory Panel Testing. Flavor scalping of polyethylene (absorption of flavor compounds by polyethylene) has previously been documented by Marin et al. (*36*). Because initial bamboo samples were shipped in polyethylene bags, the scalping effect on the aroma profile and on the aroma intensity was unknown. Subsequent experiments indicated that panelists were unable to distinguish between the odor of bamboo samples stored in polyethylene bags and samples stored in glass jars. The number of correct responses (10 of 30) was not statistically different from what would be expected purely by chance ($p \sim 0.41$).

In conclusion, the Osme GCO technique coupled with SPME provided an effective means for extraction and evaluation of aroma-active headspace volatiles. SPME (DVB/Carboxen/PDMS fiber) extracted many more volatiles than the purge and trap system (66 compared to 14), but purge and trap may be slightly more effective at extracting the highly volatile, low molecular weight compounds such as acetaldehyde.

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