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Essential Oil Composition of Cilantro

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Leaf oil was isolated from two commercial samples of cilantro (*Coriandrum sativum* L.) and from growth-chamber-grown plants at five different stages of growth. The oils were analyzed by GC/MS. They were found to be composed mainly of $C_{10}-C_{16}$ aldehydes. (*E*)-2-Alkenals predominated. Substantial quantitative differences were observed between the two cilantro samples and in the leaf oils isolated at different growth stages. The data indicate that cilantro oil may exhibit significant variation in composition due to ontogenic factors. The data also suggest a possible link among growth stage, oil composition, and consumer preference.

Keywords: *Cilantro; Coriandrum sativuum; essential oil; ontogeny*

INTRODUCTION

The green leaves of immature *Coriandrum sativum* L. are one of the most widely used fresh herbs. It is featured in the cuisines of China, Southeast Asia, India, and South and Central America. The tradition of its use in these cultures has contributed to its current popularity in the United States. It is a common ingredient in products such as salsa and appears on the menus of gourmet restaurants in poultry and seafood dishes. In the United States and the Spanish-speaking world the herb is most commonly known as cilantro. Other names used are coriander and Chinese parsley.

In a prior work, we reported on the composition of leaf oil isolated from *C. sativum* L. at the blooming stage (Potter and Fagerson, 1990). The leaf oil was composed mainly of (*E*)-2-decenal (46.6%). Other principal constituents were (*E*)-2-dodecanal, decanal, (*E*)-2-undecanal, (*E*)-2-tetradecanal, 1-decanol, and 2-decen-1-ol. Other research groups have reported similar results (Carlbolm, 1936; Mookherjee et al., 1989). Few if any studies have reported the composition of leaf oil from plants at a less mature stage of development (vegetative). *C. sativum* L. is typically harvested at this stage (prior to blooming) for use as cilantro. It is also notable that Lawrence (1986) reported that the composition of oils isolated from whole coriander plants exhibited significant ontogenic variation. He studied plants from the blooming stage to the development of fully mature fruit.

In this work, we report on the essential oil composition of two commercial cilantro samples and on the leaf oil composition of *C. sativum* L. plants sampled at five different stages of growth (vegetative to fruit set). We believe this a first report of cilantro oil composition. Substantial quantitative differences in the leaf oil composition of the two commercial samples was observed. Large quantitative differences were also observed when the oils isolated from *C. sativum* L. plants at differing growth stages were compared. Results emphasize ontogenic factors as determinants in the cilantro oil composition.

MATERIALS AND METHODS

Plant Material. *C. sativum* L. plants were grown from dried fruits (Johnny's Selected Seeds, Albion, ME) in growth chambers. A commercial potting mix was used (Pro Mix BX) with plants thinned after sprouting to one plant per pot. The illumination period was 12 h with temperature at 25 °C. Whole plants were harvested at five different stages of growth: 1, vegetative; 2, change in leaf morphology; 3, blossom initiation; 4, full bloom; and 5, green fruit set. After harvest, plants were immediately subjected to steam codistillation with pentane to isolate leaf oil volatiles. The two commercial cilantro samples were purchased at local (Amherst, MA) markets.

Isolation of Leaf Oil. Fresh leaves (10 g) were clipped from the plants using solvent-rinsed stainless steel scissors and tweezers. Leaves were transferred to a 500 mL distillation flask containing 250 mL of distilled deionized water. The flask was spiked with 90 μg of naphthalene-d_8 as an internal standard and was connected to a modified Likens–Nickerson steam codistillation apparatus (J&W Scientific, Folsom, CA). After extraction with *n*-pentane for 2 h, the pentane was recovered and concentrated to 1.0 mL under a stream of dry nitrogen. The extract was stored at −20 °C prior to analysis. The standard and solvents were obtained from Aldrich Chemical Co. (Milwaukee, WI) and were used without further purification.

GC/MS Analysis. A 30 m × 0.25 mm HP-5 (Hewlett-Packard, Avondale, PA) fused silica capillary column was directly coupled to the ion source of a Hewlett-Packard Model 5989A GC/mass spectrometer. The GC oven temperature was programmed as follows: 40 °C (hold for 1 min), increase at 2 °C/min to 240 °C. Helium carrier gas head pressure was fixed at 100 kPa with injection at 250 °C in the splitless mode. Mass spectral data were obtained in the electron impact (33–300 Da) and chemical ionization (CI) modes. Isobutane at 0.5 Torr was used as the CI reagent gas. The source temperature under CI conditions was 150 °C.

Standards. Reference compounds were purchased from Aldrich or were donated by Bedoukian Fine Chemicals and Takasago, Inc.

RESULTS AND DISCUSSION

Total ion current chromatograms (TIC) obtained from the commercial cilantro samples are shown in Figure 1. Compounds for which structural assignments were made are presented in Table 1. Compounds positively identified by GC/MS analysis of standards accounted for >70% of the TIC of both samples.

Qualitatively, the cilantro samples were very similar, being composed mainly of C_9-C_{16} alkanals and alkenals. The 2-alkenals were most prominent, comprising more than 50% of the TIC of both samples. Their composition

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Table 1. Essential Oil Composition of Two Commercially Grown Cilantro Samples

RRT[a]	compound	MW[b]	ID[c]	% TIC[d] A	% TIC[d] B
0.255	unknown[e]	104		0.10	0.12
0.317	nonane	128	S	0.36	1.28
0.508	5-methyltetrahydrofurfuryl alcohol	116		0.07	0.06
0.532	2,4,6-trimethylheptane	142		0.10	0.12
0.541	octanal	128	S	0.47	<0.03
0.595	limonene	136	S	0.03	0.19
0.637	phenylacetaldehyde	120	S	0.03	0.17
0.799	undecane	156	S	0.04	0.06
0.812	nonanal	142	S	0.27	0.07
1.071	(*E*)-4-decenal	154	S	0.16	<0.03
1.086	(*E*)-9-decenal	154	S	0.46	<0.03
1.118	decanal	156	S	9.25	9.45
1.230	decenal isomer	154		0.68	<0.03
1.284	(*E*)-2-decenal	154	S	12.1	0.87
1.293	2-decen-1-ol	156		8.18	<0.03
1.305	1-decanol	158	S	2.09	0.89
1.313	undecenal isomer	168		1.93	0.09
1.321	undecenal isomer	168		0.06	<0.03
1.376	undecenal isomer	168		0.10	<0.03
1.405	undecanal	170	S	2.31	2.14
1.516	undecenal isomer	168		0.17	0.09
1.565	(*E*)-2-undecenal	168	S	5.32	1.18
1.577	2-undecen-1-ol	170		0.21	<0.03
1.587	1-undecanol	172	S	0.07	<0.03
1.643	dodecenal isomer	182		0.13	0.08
1.655	dodecenal isomer	182		0.34	0.31
1.690	dodecanal	184	S	4.96	10.3
1.735	germacrene B	204		0.10	0.18
1.795	dodecenal isomer	182		0.51	0.47
1.855	(*E*)-2-dodecenal	182	S	15.6	21.6
1.858	2-dodecen-1-ol	184		0.58	0.82
1.862	1-dodecanol	186	S	0.09	0.18
1.955	tridecanal	198	S	1.44	1.43
2.019	Tridecenal isomer	196		0.05	0.09
2.058	tridecenal isomer	196		0.05	0.08
2.102	(*E*)-2-tridecanal	196	S	2.53	1.83
2.110	2-tridecen-1-ol	238		0.04	<0.03
2.172	tetradecenal isomer	210	S	0.09	0.07
2.181	tetradecenal isomer	210		0.27	0.26
2.211	tetradecanal	212	S	1.69	2.22
2.250	diallylfumerate	196		<0.03	0.25
2.312	tetradecenal isomer	210		0.36	0.37
2.368	(*E*)-2-tetradecenal	210	S	12.7	20.2
2.428	pentadecenal isomer	224		0.09	<0.03
2.454	pentadecanal	226		0.47	0.61
2.466	unknown[f]	194		0.47	5.57
2.552	pentadecenal isomer	224		0.10	0.07
2.598	(*E*)-2-pentadecenal	224		4.77	5.12
2.671	hexadecanal	240		0.05	0.10
2.705	unknown[g]	238		<0.03	0.04
2.735	hexadecenal isomer	238		<0.03	<0.03
2.748	(*E*)-2-hexadecenal	238		0.94	1.58
2.848	unknown[h]	306		0.05	0.36
2.922	phytol	296		2.79	3.46
	methyl stearate	298	S	0.06	0.13
3.005	1-eicosanol	298		1.48	0.40
3.009	unknown[i]	298		0.14	0.08
3.092	1-docosanol	326		1.38	2.41
3.111	unknown[j]	310		0.13	0.21
3.202	1-tetracosanol	354		0.42	0.35

[a] Retention time relative to that of the internal standard, naphthalene-d_8. [b] Molecular weight based on isobutane CI spectra. [c] S indicates identification confirmed by analysis of a standard. The other structural assignments are based on MS interpretation and comparison with the NIST database (NIST, 1994). [d] Percent total ion current. [e] EI-MS data: 45 (100), 43 (94), 41 (3), 71 (24), 55 (24), 104 (2). [f] EI-MS data: 108 (100), 79 (32), 80 (25), 109 (13), 81 (8), 77 (7). [g] EI-MS data: 95 (100), 82 (97), 68 (91), 57 (83), 43 (78), 69 (70). [h] EI-MS data: 83 (100), 55 (62), 224 (26), 84 (5). [i] EI-MS data: 221 (100), 276 (46), 243 (42), 233 (32), 43 (29), 215 (24). [j] EI-MS data: 57 (100), 43 (88), 83 (82), 55 (81), 97 (79), 69 (76).

was similar to published reports of leaf oil composition isolated from *C. sativum* L. plants at the blooming stage (Carlbolm, 1936; Lawrence, 1986; Mookherjee et al., 1989; Potter and Fagerson, 1990).

In a quantitative sense, there were substantial differences between the two cilantro samples and published results for the blooming stage leaf oils. Some of the more prominent differences are shown in Figure 2. This figure compares the (*E*)-2-alkenal contents by carbon number. Sample B was enriched in the higher carbon number homologs, C_{12}−C_{16}, whereas sample A had much higher concentrations of the C_{10} and C_{11} homologs. Sample A also had a much higher (*E*)-2-decen-1-ol content. It accounted for 8.2% of the TIC in

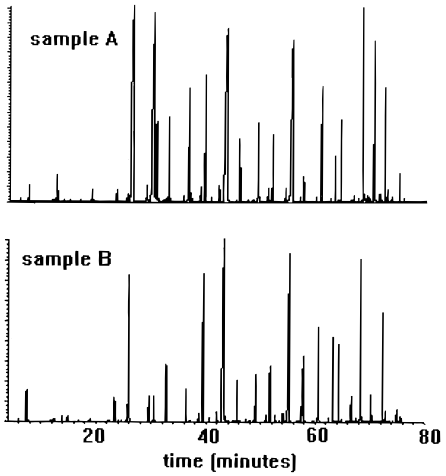

Figure 1. TIC chromatograms of cilantro essential oil samples.

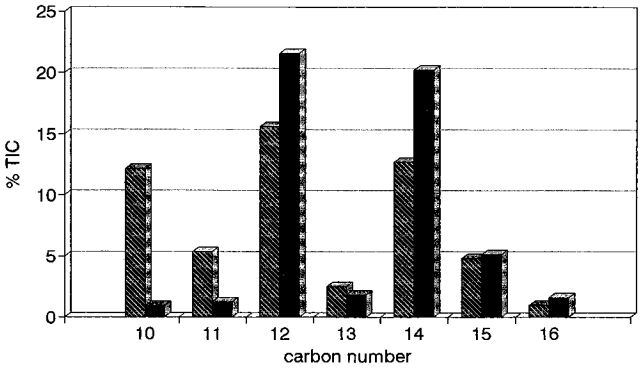

Figure 2. (*E*)-2-Alkenal concentration in cilantro essential oil.

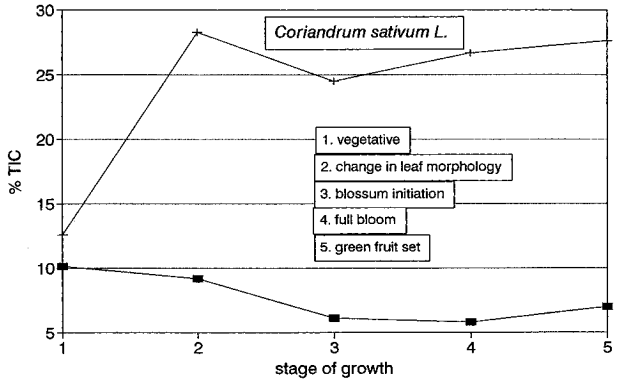

Figure 3. Change in (*E*)-2-decenal (■) and decanal (+) concentration with stage of growth.

this sample. This compound was not detected in sample B.

Even greater differences were observed when the published data for *C. sativum* L. leaf oil harvested at the blooming stage and the cilantro data were compared. The (*E*)-2-decenal content in blooming stage samples was reported to be in the 40−50% range (Potter and Fagerson, 1990; Mookherjee et al., 1989) more than 4−40 times greater than observed in the cilantro samples.

Results obtained from the analysis of coriander plants harvested at five stages of growth indicate that these differences may be attributable to ontogenic factors. (*E*)-2-Decenal and decanal concentration data with stage of growth are summarized in Figure 3. From the vegetative to the stage where leaf morphology changed and buds formed (*E*)-2-decenal concentration increased by a factor of nearly 3, while the decanal content decreased ca. 10%. After blooming, the concentration of these compounds in the leaf oils remained relatively constant.

Lawrence (1986) also isolated oils from coriander plants at different stages of growth: from blooming to development of mature fruit. His data showed that the composition of oils isolated from coriander plants may change significantly as they develop. Among his reported results, (*E*)-2-decenal first increased and then decreased, linalool showed a steady increase, and decanal exhibited a steady decrease.

The sharp increase in (*E*)-2-decenal content at the bud formation and blooming stages may at least partly explain why cilantro is typically harvested prior to this stage of development. (*E*)-2-Decenal is a potent irritant (Sax and Lewis, 1989) and is found in the defensive secretion of insects (Jacobs et al., 1989). From this, it may be inferred that it may be objectionable to humans. The data reported in this study indicate that harvesting plants at earlier stages of growth may be a means of producing cilantro with low (*E*)-2-decenal content. A positive link to consumer preference is likely.

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