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Ultraviolet induced stress response in fresh cut cantaloupe

Olusola Lamikanra*, Olga A. Richard, Alesia Parker

United States Department of Agriculture, Agricultural Research Service, Southern Regional Research Center, 1100 Robert E. Lee Boulevard, New Orleans, LA 70124, USA

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Abstract

Changes in the composition of volatile compounds in cantaloupe melon (*Cucumis melo* L. var. *reticulatus*) as a result of UV induced stress were determined by gas chromatography–mass spectrometry (GC–MS). Several volatile ester compounds were present, of which twenty-seven were identified in fresh cut cantaloupe. Fruit exposure to UV light decreased the concentrations of most of the aliphatic esters by over 60% of the amounts present in the corresponding fresh cut fruit. Cyclic and acyclic terpenoids, including phytoalexin compounds β-ionone, geranylacetone and terpinyl acetate, were also produced as a result of UV exposure for 15 and 60 min, respectively. β-Ionone, when added to crushed cantaloupe (0.01% w/w) completely inhibited microbial growth in the fruit for 24 h at 20 °C. Geranylacetone and terpinyl acetate reduced the microbial population from 6.3×10^8 in the untreated control to 1.2×10^8 and 3.5×10^7 CFU/g respectively. The results indicate the potential use of UV induced stress for screening cantaloupe melon cultivars for disease resistance, and as a minimal processing method to extend the shelf life of fresh cut cantaloupe products. Published by Elsevier Science Ltd.

Keywords: *Cucumis melo*; Cucurbitaceae; Phytoalexins; Cantaloupe; Fruit; Volatiles; Aroma; SPME

1. Introduction

The rapid growth of the fresh cut fruit and vegetable industry has increased interest in physiological and biochemical responses that occur during fresh cut processing and storage (Watada et al., 1996). Cutting induces degradative changes associated with plant tissue senescence and a consequent decrease in shelf life relative to the unprocessed produce. As part of a defense mechanism, plant tissues frequently produce compounds such as phytoalexins that are able to inhibit the growth of micro-organisms. Synthesis of these naturally occurring compounds might be slow and they could be produced at concentrations that are very low relative to other compounds present. These potentially make their stress induced levels difficult to detect. Ultraviolet light has thus been extensively used to simulate biological stress in plants and for determining resistance mechanisms of plant tissues (Mercier, 1997). A number of naturally occurring volatile compounds have also been demonstrated to reduce microbial populations in fruits and vegetables (Hamilton-Kemp et al., 1996; Ntirampemba et al., 1998). Cantaloupe melon is used more than any other fruit in fresh cut processing. The objective of this study is to determine changes in volatile compounds induced by stress conditions in cantaloupe and their possible role in the sensory quality and shelf life of the fresh cut fruit.

2. Results and discussion

The chromatograms obtained are shown in Fig. 1. Incubation of fruit slurry samples at higher temperatures (45 and 65 °C respectively) prior to adsorption of volatile compounds on the SPME fiber generated more volatile compounds but changed the relative amounts of the compounds present (data not shown). The temperature used (30 °C) minimizes changes that could result from heat-induced stress on the fruit tissue and, consequently, better preserves the delicate balance in the relative amounts of aroma compounds in the fruit. This balance is critical in our investigation to determine stress response of cantaloupe melon. Most reports in

* Corresponding author. Tel.: +1-504-286-4278; fax: +1-504-286-4419.

E-mail address: sola@srrc.ars.usda.gov (O. Lamikanra).

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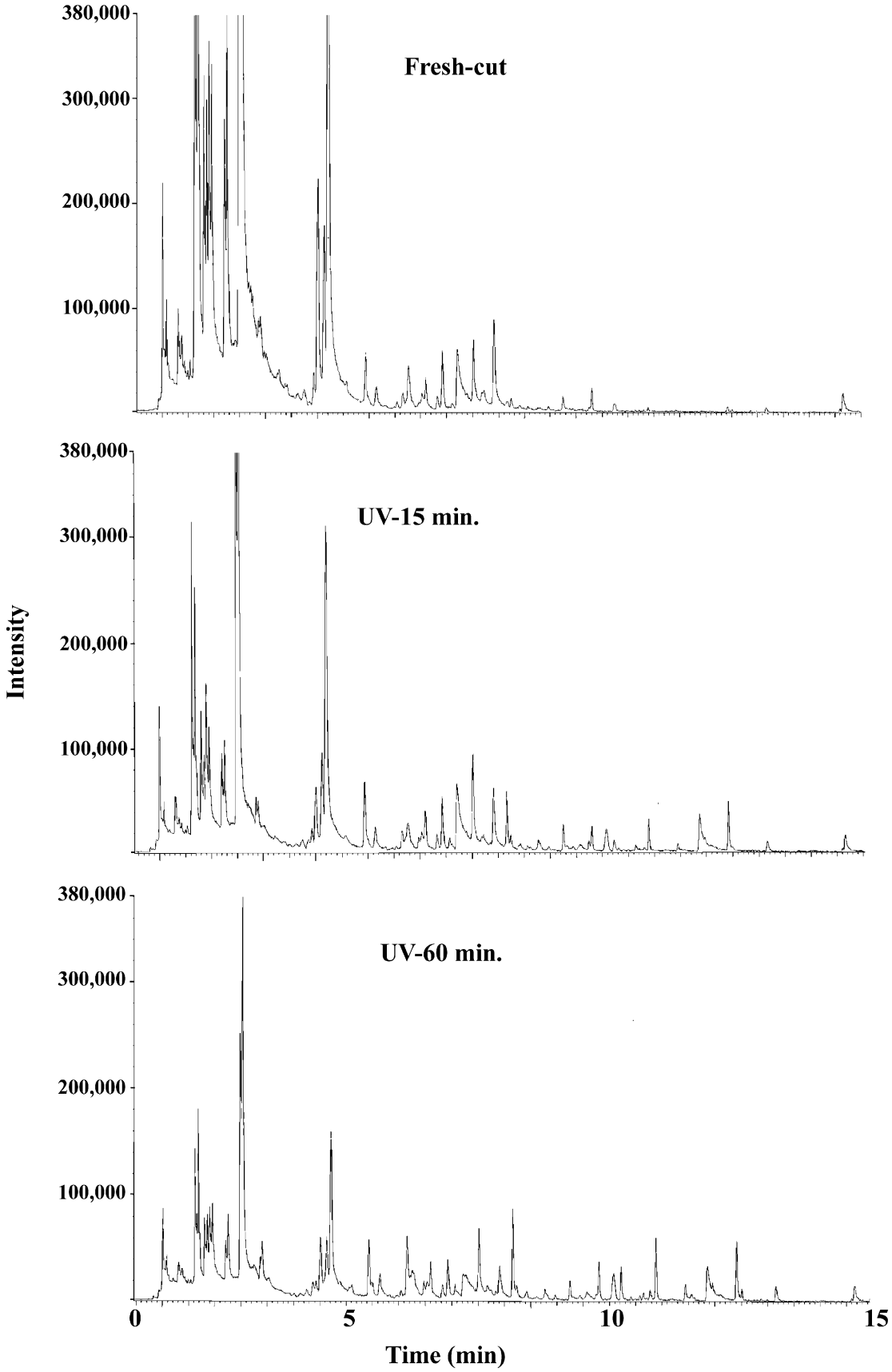

Fig. 1. Total ion chromatogram of aroma compounds in fresh cut cantaloupe melon and the cut fruit exposed to UV light for 15 and 60 min, respectively.

literature are from studies carried out at higher temperatures and over 200 volatile compounds have been reported to be present in cantaloupe melon (Homatidou et al., 1992; Wyllie et al., 1994; Nussbaumer and Hostettler, 1996; Beaulieu and Grimm, 2001). Several volatile ester compounds, of which 27 were identified, were present in the fresh cut cantaloupe (Table 1). The spectrum of esters generated by our method is consistent with previous reports on volatile aroma compounds in cantaloupe melon. The low temperature isolation method, however, precluded extraction of heavier and less volatile compounds. As indicated by Moshonas et al. (1993) and Nussbaumer and Hostettler (1996), methylbutyl acetate and hexyl acetate were the two most prominent volatile compounds in cantaloupe melon (Table 1). The compounds determined by Nussbaumer and Hostettler (1996) to be the most important flavor compounds in *Cucumis melo* L., ethylisobutyrate, methyl 2-methylbutyrate, ethyl butyrate and ethyl 2-methylbutyrate were also isolated by this low temperature extraction procedure.

Exposure of cantaloupe melon slices to UV light for 15 min caused significant decreases in the concentrations of aliphatic esters present in the fruit. In most cases, ester concentrations were reduced by over 60% of the respective amounts present in the corresponding fresh cut fruit. In addition, UV treatment induced the production of the following terpenoids: β-cyclocitral, *cis*- and *trans*- β-ionone, terpinyl acetate, geranylacetone and dihydroactinidiolide. Exposure of cantaloupe slices to UV light for 60 min increased the concentrations of the photo-induced compounds but the volatile profile was similar to that obtained after a 15-min exposure.

The shift in the relative amounts of aliphatic esters appears to be indicative of their involvement in the tissue stress response. Changes in the concentration of esters in some plants have been attributed to their role in plant defense response and resistance (Garcia, 1993; Hildenbrand and Ninnemann, 1994). Terpenoids play important roles as phytoalexins in the disease resistance of a variety of plant families (Elgersma and Liem, 1989; Fulton et al., 1994; Bianchini et al., 1999). β-Ionone, a fragment of β-carotene, is well known for its high antifungal and antibacterial properties in plants (Anzaldi et al., 1999). It has also been reported to inhibit growth of several algal species (French, 1983). This cyclic terpenoid, commonly found in plants from enzymatic oxida-

Table 1
Volatile compounds in fresh-cut cantaloupe melon and cut fruit exposed to UV light for 15 and 60 min, respectively. Peak numbers correspond to those identified in Fig. 1

Peak number	Retention time (min)	Compound	Relative amount[a]			Identification
			Fresh-cut	UV-15 min	UV-60 min	
1	1.51	Ethyl acetate	1.8a	1.3a	1.4a	MS,RT
2	1.81	Isopropyl acetate	1.1a	0.8b	0.8ab	MS,RT
3	1.87	Propyl acetate	1.0a	0.4b	0.7ab	MS,RT
4	2.13	Ethyl isobutyrate	5.7a	2.7b	2.2b	MS,RT
5	2.18	Isobutyl acetate	7.9a	2.5b	1.6b	MS,RT
6	2.31	Ethyl butyrate	2.9a	1.3b	1.3b	MS,RT
7	2.46	Butyl acetate	5.2a	0.2b	2.6ac	MS,RT
8	2.76	Ethyl 2-methylbutyrate	4.8a	1.5b	1.9b	MS,RT
9	2.99	3-Methylbutyl acetate	9.5a	4.6b	3.2b	MS,RT
10	3.03	2-Methylbutyl acetate	22.2a	7.7b	8.8b	MS,RT
11	4.51	Prenyl acetate	3.0a	1.0b	1.3b	MS,RT
12	4.63	*cis*-3-Hexenyl acetate	3.0a	1.2b	1.5b	MS,RT
13	4.71	Hexyl acetate	13.2a	5.5b	4.2b	MS,RT
14	5.44	1,3-Butanediol diacetate	1.0a	1.0a	1.0a	MS,RT
15	5.64	2,3-Butanediol diacetate	0.5a	0.4a	0.7a	MS
16	6.04	Ethyl heptanoate	0.1a	0.0a	0.2a	MS,RT
17	6.48	Methyl caprylate	1.0a	1.6a	0.3b	MS,RT
18	7.21	Benzyl acetate	1.6a	1.8a	0.5b	MS,RT
19	7.39	Ethyl benzoate	0.4a	0.4a	0.4a	MS,RT
20	7.91	Octyl acetate	1.5a	1.0b	1.0b	MS,RT
21	8.17	Ethyl phenyl acetate	0.2a	0.6b	1.3b	MS,RT
22	8.77	β-Cyclocitral	0.0a	5.2b	0.3b	MS,RT
23	10.08	*cis*-β-Ionone	0.0a	0.4b	0.7b	MS
24	10.23	Terpinyl acetate	0.0a	0.1b	0.4b	MS,RT
25	11.87	Geranylacetone	0.0a	0.4b	0.6b	MS,RT
26	12.42	*Trans*-β-ionone	0.0a	0.4b	0.8c	MS,RT
27	13.16	Dihydroactinidiolide	0.0a	0.1b	0.2b	MS

[a] Expressed as amounts relative to concentration of 1,3-butanediol diacetate. Values in each row without the same letters, a, b or c, are significantly different ($P < 0.05$).

tion of β-carotene, imparts woody, dry fruit and raspberry-like flavors (Kotseridis et al., 1998). β-Carotene is the main pigment in cantaloupe melon (Philip and Chen, 1988). The ability of β-ionone to inhibit microorganisms and microtoxins is related to the ease of its biotransformation in the presence of microbial enzymes into hydoxy- and oxo- derivatives. 4,4′-Oxygenase enzymes introduce keto groups in the 4,4′-position while 3,3′-hydroxylase enzyme can introduce hydroxyl groups regardless of prior keto group formation at the 4,4′ position (Fraser et al., 1998). Inhibition of the growth of *Aspergillus parasiticus* and aflatoxin (Wilson and Gueldner, 1984), *Phaffia rhodozyma* (Lewis et al., 1990), *Aspergillus niger* (Larroche et al., 1995), *Aspergillus flavus* (Norton, 1997), Gram-positive and Gram-negative bacteria (Anzaldi et al., 1999) by β-ionone all resulted in the formation of corresponding hydoxy and keto compounds. The potential for β-ionone to undergo this reaction in cantaloupe melon tissue is evidenced by the formation of the lactonic carotenoid, dihydractinidiolide, which is an oxidation product of β-ionone (Etoh and Ina, 1979), in UV treated fresh cut cantaloupe.

The acyclic terpenoid, geranylactone induced by UV in cantaloupe melon also exhibits high antimicrobial activity, usually by way of ω-hydroxylation and epoxidation of the subterminal double bond (Müller et al., 1994). Growth of strains of fungi and bacteria belonging to the genus *Fusarium* spp. are inhibited with a consequent hydration of the inner bond of the molecule (Abraham, 1993). The plant pathogenic fungus *Glomerella cingulata* is also inhibited by geranylacetone. This causes the production of (*E*)-9,10-hydroxy-6,10-dimethyl-5-undecen-2-one and its analogues (Miyazawa et al., 1996), while *Aspergillus niger* inhibition by this terpenoid results in the oxidation of the allylic methyl group (Madyastha and Gururaja, 1993). Terpinyl acetate, a major component of some essential oils, also exhibits antimicrobial properties (Peana et al., 1999). In addition, β-cylocitral, β-ionone and geranylacetone are known insect repellants (Lwande et al., 1999).

The ability of the compounds induced by UV light to act as antimicrobial agents in cantaloupe melon tissue was demonstrated (Table 2). Morphological flora of growth on plates indicated the prevalence of bacteria with minimal fungal growth. No detectable growth occurred on nutrient agar plates when the fruit was suspended in water and transferred to the growth medium immediately after the fruit was cut. Microbial population in the control that was chopped and incubated for 24 h at 20 °C prior to plating was 6.3×10^8 CFU/g. Of the three terpenoid compounds added at 0.01% w/w, β-ionone was the most effective i.e. β-ionone completely inhibited microbial growth in the fruit tissue. Terpinyl acetate was more effective than geranylacetone in inhibiting microbial growth. Addition of geranylacetone and terpinyl acetate to cut cantaloupe melon reduced microbial growth counts to 1.2×10^8 and 3.5×10^7 CFU/g respectively.

Ability of plant tissues to accumulate phytoalexins correlates with their resistance (Noble and Drysdale, 1983; Afek et al., 1999). Phytoalexins have thus been used for screening cultivars of fruits and vegetables for their resistance to pathogen damage (Elgersma and Liem, 1989; Sariq et al., 1997). The UV induced accumulation of phytoalexin compounds in this study demonstrates the potential use of the method to determine resistance potential of cultivars of *Cucumis melo* L. The possible use of UV treatment for extending shelf lives of fresh cut fruits is also indicated by this study. Phytoalexin production improves storage quality of produce (Afek et al., 1995) and UV induced phytoalexins could improve shelf lives of fruits and vegetables during storage (Mercier, 1997).

3. Concluding remarks

The defense response of cantaloupe melon involves a reduction in the concentrations of aliphatic esters in the fruit, and the production of terpenoid phytoalexins. The terpenoid compounds produced in response to biological stress, particularly β-ionone, inhibit microbial growth in the fruit tissue. Our results demonstrate the potential use of UV induced stress for screening cultivars of *Cucumis melo* L. for their resistance to microorganism growth. UV treatment also has a potential use as a minimal processing alternative for fresh cut fruits and further research is needed to determine conditions that would optimize the use of UV induced phytoalexins for extending the shelf life of cut cantaloupe melon products.

4. Experimental

4.1. Sample preparation

Cantaloupe melon (*Cucumis melo* L. var. *reticulatus*) was sliced longitudinally into two halves. The seeds and

Table 2
Effect of terpenoid compounds on total microbial counts expressed in colony forming units (CFU)/g. The fresh cut cantaloupe was prepared for plating immediately after the fruit was cut while the control was chopped and incubated for 24 h at 20 °C. Terpenoid compounds (0.01% w/w) were added to each sample

Sample	Total count (CFU/g)
Fresh-cut	-0-
Control	6.3×10^8 (1.0×10^8)[a]
Geranylacetone	1.2×10^8 (4.2×10^7)[a]
Terpinyl acetate	3.5×10^7 (9.5×10^6)[a]
β-Ionone	-0-

[a] Standard errors are in parentheses.

cavity tissues were removed. One half of the fruit was further cut into two along equatorial lines and several slices (~1 mm thick) were obtained from the exposed cut end. After cutting off approximately 2 mm along the fruit slice edges, they were transferred into petri dishes and placed under ultraviolet light (Fotodyne 3–3000; 254 nm) for 15 and 60 min respectively. Petri dishes containing the samples were placed on a glass beaker such that the samples were approximately 5 cm from the light source. UV treated fruit (3 g) was immediately chopped and transferred into a vial (20 ml) containing NaCl (1 g) and into which a magnetic stirring bar was inserted. The vial was fitted with an aluminum septa cap and sealed. Samples used as control were prepared using a similar procedure without exposure to UV light.

4.2. GC–MS analysis

Volatile components of the fruit were extracted by headspace solid-phase microextraction (SPME) using a fused silica fiber coated with a 100 μm layer of dimethylpolysiloxane. The fiber was conditioned by inserting it into the GC inlet for 2 h prior to use for volatile compound adsorption. The fruit and NaCl mixture was initially stirred in a water bath maintained at 30 °C for 30 min. The SPME fiber was then inserted into the sample headspace for 15 min while stirring continued at the same temperature. Desorption of the fiber took place in the GC inlet at 250 °C for 4 min.

GC–MS analysis was performed on a Hewlett Packard HP-6890 series system utilizing a HP-5 MS Crosslink 5% Phenyl Methyl Siloxane (30 m×0.25 mm×0.25 μm) column. The GC was operated in a splitless mode with helium as the carrier gas. The oven was programmed at an initial temperature of 60 °C ramped to 215 °C at the rate of 8 °C/min, then to 260 °C at °C/min and held for 15 min. The mass spectrometer was operated in a scan mode from 40 to 400 amu, using 70 eV for ionization. Compounds were identified from their retention times using a commercially available library, authentic reference compounds and MS fragmentation patterns. Preliminary experiments conducted to determine concentrations of the volatile compounds using internal standards of compounds similar to those identified were unsuccessful because these compounds coeluted with those present in the fruit. It was determined, using benzothiophene as internal standard, that the concentration of 1,3-butanediol diacetate present in the fruit was unaffected by the different treatments. The standard was dissolved in methanol, injected onto the pulverized fruit (1.55 ng/kg) and mixed thoroughly by agitation prior to the SPME fiber extraction. Thus, 1,3-butanediol diacetate was used as an internal reference compound and concentrations of volatile compounds present were estimated and expressed as their amounts relative to the concentration of this compound.

4.3. Determination of microbial activities

Total microbial counts were carried out aerobically. Nutrient agar (Difco, Detroit, MI) was prepared and used for microbial enumerations. Using a sterile technique, fruit slices (3 g) were finely chopped and separately mixed with *trans* β-ionone, geranylacetone and terpinyl acetate (300 μl), respectively. Replicated samples of the mixture were incubated at 20 °C for 24h after which they were suspended in sterile water (190 ml) by swirling. After a series dilution, 0.1 ml of the fruit suspension was overlaid on the surface of a nutrient agar plate. Duplication was made for each dilution. Bacterial colonies were counted after 24 h of incubation at 30 °C. Colony forming units (CFUs) per gram of melon were calculated. Controls were melon slices that were chopped and incubated for 24 h at 20 °C without addition of the terpenoid compounds and a set that were prepared for plating immediately after cutting, without the 24 h incubation at 20 °C and addition of the terpenoid compounds.

References

Abraham, W.R., 1993. Microbial formation of caparrapidiol and derivatives from *trans*-nerolidol. World Microbiol. Biotechnol. 9, 319–322.

Afek, U., Carmeli, S., Aharoni, N., 1995. Columbianetin, a phytoalexin associated with celery resistance to pathogens during storage. Phytochemistry 39, 1347–1350.

Afek, U., Orenstein, J., Carmeli, S., Rodov, V., Joseph, M.B., 1999. Umbelliferone, a phytoalexin associated with resistance of immature Marsh grapefruit to *Penicillium digitatum*. Phytochemistry 50, 1129–1132.

Anzaldi, M., Sottofattori, R., Granello di Casaleto, B., Balbi, A., 1999. Synthesis and antimicrobial activity of heterocyclic ionone-like derivatives. Eur. J. Med. Chem. 34, 837–842.

Beaulieu, J.C., Grimm, C.C., 2001. Identification of volatile compounds in cantaloupe at various developmental stages using solid phase microextraction. J. Agric. Food Chem. 49, 1345–1532.

Bianchini, G.M., Stipanovic, R.D., Bell, A.A., 1999. Induction of delta-cadinene synthase and sesquiterpenoid phytoalexins in cotton by *Verticillium dahliae*. J. Agric. Food Chem. 47, 4403–4406.

Elgersma, D.M., Liem, J.I., 1989. Accumulation of phytoalexins in susceptible and resistant near-isogenic lines of tomato infected with *Verticillium albo-atrum* or *Fusarium oxysporum* fsp. *lycopersic*i. Physiol. Mol. Plant Pathol. 34, 545–555.

Etoh, H., Ina, K., 1979. Photooxygenation of β-ionone. Agric. Biol. Chem. 43, 2593–2595.

Fraser, P.D., Shimada, H., Misawa, N., 1998. Enzymic confirmation of reactions involved in routes to astaxanthin formation, elucidated using a direct substrate in vitro assay. Eur. J. Biochem. 252, 229–236.

French, R.C., 1983. Germination responses of several species of rust spores to 5-methyl-2-hexanone, isomers of ionone, and other structurally related flavor compounds. J. Agric. Food Chem. 31, 423–427.

Fulton, D.C., Kroon, P.A., Threlfall, D.R., 1994. Enzymological aspects of the redirection of terpenoid biosynthesis in elicitor-treated cultures of *Tabernaemontana divaricata*. Phytochemistry 35, 1183–1186.

Garcia, E.G., 1993. Resistance to *Hemileia vastatrix* in coffee plants. I. Accumulation of phytoalexins. Agronomia-Costarricense 17, 89–93.

Hamilton-Kemp, T.R., Archbold, D.D., Loughrin, J.H., Collins, R.W., Byers, M.E., 1996. Metabolism of natural volatile compounds by strawberry fruit. J. Agric Food Chem. 44, 2802–2805.

Hildenbrand, S., Ninnemann, H., 1994. Kinetics of phytoalexin accumulation in potato tubers of different genotypes infected with *Erwinia carotovora* ssp. *atroseptica*. Physiol. Mol. Plant Pathol. 44, 335–347.

Homatidou, V., I., Karvouni, S., Dourtoglou, V. G., Poulos, C. P., 1992. Determination of total volatile components of *Cucumis melo* L. variety *Cantaloupensis* J. Agric. Food Chem. 40, 1385–1388.

Kotseridis, Y., Baumes, R., Skouroumounis, G.K., 1998. Synthesis of labelled [$^2H_4$] β-damascenone, [$^2H_2$]2-methoxy-3-isobutylpyrazine, [$^2H_3$] α-ionone, and [$^2H_3$]β-ionone, for quantification in grapes, juices and wines. J. Chromatog. A. 824, 71–78.

Larroche, C., Creuly, C., Gros, J.B., 1995. Fed-batch biotransformation of β-ionone by *Aspergillus niger*. Appl. Microbiol. Biotechnol. 43, 222–227.

Lwande, W., Ndakala, A.J., Hassanali, L., 1999. *Gynandropsis gynandra* essential oil and its constituents as tick (*Rhipticephalus appendiculatus*) repellents. Phytochemistry 50, 401–403.

Lewis, M.J., Ragot, N., Berlant, M.C., Miranda, M., 1990. Selection of astaxanthin overproducing mutants of *Phaffia rhodozyma* with β-ionone. Applied and Enviromental Microbiology 56, 2944–2945.

Madyastha, K.M., Gururaja, T.L., 1993. Utility of microbes in organic synthesis: selective transformations of acyclic isoprenoids by *Aspergillus niger*. Indian J. Chem. 32B, 609–614.

Mercier, J., 1997. Role of phytoalexins and other antimicrobial compounds from fruits and vegetables in postharvest disease resistance. In: Thomas-Barberan, F.A., Robins, R.J. (Eds.), Photochemistry of Fruit and Vegetables. C.H.I.P.S, Neimer, TX, pp. 221–241.

Miyazawa, M., Nankai, H., Kameoka, H., 1996. Biotransformation of ayclic terpenoids (+)-trans-nerolidol and geranylacetone, by *Giomerella cingulata*. J. Agric Food Chem. 44, 1543–1547.

Moshonas, M.G., Shaw, P.E., Baldwin, E.A., Yuen, W., 1993. Volatile and nonvolatile components in hami melon (*Cucumis melo* L.). Lebensm.-Wiss. u. -Technol. 26, 557–589.

Muller, A., Abraham, W.R., Kieslich, K., 1994. Microbial oxidation of geranylacetone and geranyloxycoumarin, aurapten. Bull. Soc. Chim. Belg. 103 (7–8), 405–423.

Noble, J.P., Drysdale, R.B., 1983. The role of benzoic acid and phenolic compounds in latency in fruits of two apple cultivars infected with *Pezicula malicorticis* or *Nectria galligena*. Physiol. Plant Pathol. 23, 207–216.

Norton, R.A., 1997. Effect of carotenoids on aflatoxin B_1 synthesis by Aspergillus flavus. Postharv. Path. Mycot. 87, 814–821.

Ntirampemba, G., Langlois, B.E., Archbold, D.D., Hamilton-Kemp, T.R., Barth, M.M., 1998. Microbial populations of *Botrytis cinerea*-inoculated strawberry fruit exposed to four volatile compounds. J. Food Prot. 61, 1352–1357.

Nussbaumer, C., Hostettler, B., 1996. New flavour compounds of *Cucumis melo* L. In: Taylor, A.J., Mottram, D.S. (Eds.), Flavor Science: Recent Developments. Spec. Publ. R. Soc. Chem. Cambridge, UK. 197, 70–73.

Peana, A.T, Moretti, M.D.L., Juliano, C., 1999. Chemical composition and antimicrobial action of the essential oils of *Salvia desoleana* and *S. sclarea*. Planta 65, 752–754.

Philip, T., Chen, T.S., 1998. Development of a method for the quantitative estimation of provitamin A carotenoids in some fruits. J. Food Sci. 53, 1703–1706.

Sarig, P., Zutkhi, Y., Monjauze, A., Lisker, N., Ben Arie, R., 1997. Phytoalexin elicitation in grape berries and their susceptibility to *Rhizopus stolonifer*. Physiol. Mol. Plant Pathol. 50, 337–347.

Watada, A.E., Ko, N.P., Minott, D.A., 1996. Factors affecting quality of fresh-cut horticultural products. Postharvest Biol. Technol. 9, 115–125.

Wilson, Jr, D. M., Gueldner, R., 1984. Control of Mycotoxin Production by Chemically Inhibiting Fungal Growth. United States Patent No. 4,474,816.

Wyllie Grant, S., Leach, D.N., Wang, Y., Shewfelt, R.L., 1994. Sulfur volatiles in *Cucumis melo* cv. Makdimon (muskmelon) aroma. ACS Symp. Ser. 564, 36–48.