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Data Descriptor

Volatiles Emitted by Three Genovese Basil Cultivars in Different Growing Systems and Successive Harvests

Michele Ciriello, Luigi Formisano, Youssef Rouphael and Giandomenico Corrado *

Department of Agricultural Sciences, University of Naples Federico II, 80055 Portici, Italy
* Correspondence: giandomenico.corrado@unina.it

Abstract: The Genovese basil (*Ocimum basilicum* L.) is the essential ingredient in "pesto" sauce, and it has always had ample use in Mediterranean gastronomy. This horticultural type of basil is grown in the open field and harvested more than once during its cultivation cycle, but in recent decades it is increasingly grown using alternative cultivation methods (e.g., soilless cultivation) that guarantee higher and more uniform production. The dataset presented in this contribution refers to the analysis of the aroma profile by solid-phase microextraction and gas chromatography coupled with a mass spectrometer, of three different cultivars of Genovese basil (Aroma 2, Eleonora, and Italiano Classico) grown in the open field or floating raft system in two successive harvests. The data are a record of the variability of volatile organic compounds due to key agronomic factors, such as the genotype, the cultivation method, and the cut. They may be of interest for those concerned about the impact of different technical factors on the aroma and flavor of basil plants.

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Keywords: *Ocimum basilicum*; pre-harvest factors; successive cuts; genotype; floating system; open field; VOCs; SPME; GC/MS

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1. Summary

Sweet basil (*Ocimum basilicum* L.) is universally recognized as one of the most important species among the aromatic plants belonging to the vast botanical family Lamiaceae [1]. Although plants of the genus *Ocimum* were historically used for medicinal purposes [2], they have become crucial ingredients in world gastronomic traditions over time. The use of basil as spice and fresh herb made this leafy vegetable ideal for seasoning and enriching different types of dishes, such as meat, fish, soups, and salads [3]. In Italian cuisine, the cradle of the renowned Mediterranean diet, basil plays an important role. In addition to being an ever-present garnishing element in iconic Italian food dishes (spaghetti with cherry tomatoes, pizza Margherita, and Caprese salad), Genovese basil, which is known for its unique aromatic and sensory properties, is the star ingredient in the famous green sauce known as "pesto" [4].

Basil flavor is conferred by aromatic molecules that are biosynthesized and stored in specific structures (glandular trichomes) [5]. Totally dependent on genotype, the most representative fraction of the aromatic profile is represented by monoterpenes (e.g., eucalyptol and linalool) followed by sesquiterpenes (e.g., caryophyllene and α-bergamotene) and phenylpropanoids (e.g., eugenol, estragole, and methyl-eugenol) [6–9]. The well-recognized antimicrobial, antioxidant, and insecticidal activities of basil's aromatic molecules have attracted interest from sectors other than gastronomy, increasing the economic value of this multifaceted leafy vegetable [10–12]. However, aromatic composition and other qualitative traits are affected by preharvest factors such as genetics, environmental conditions, and their mutual interactions [13,14].

To meet the increased demand for fresh produce, growers increasingly rely on alternative growing systems to the open field, such as hydroponics [15]. Hydroponics is a technique for growing plants in aqueous nutrient solutions, in the presence or absence of artificial substrates that act as support for the root system. In addition to reducing the incidence of harmful telluric pathogens, these systems provide higher yields than open fields due to the potential to deseasonalize production and the short crop cycle [16]. Not least, meticulous monitoring of environmental conditions would increase organoleptic quality while standardizing the bioaccumulation of sought-after aroma compounds. Unlike open-field cultivation, hydroponic basil destined for the agro-industrial sector is cut several times during the crop cycle [3,17,18]. The floating raft system (FRS), also known as floating panel culture, involves placing seedlings in perforated polystyrene trays or pots in panels of the same material. Polystyrene panels are placed in tanks filled with a nutrient solution that has been adequately oxygenated to prevent root anoxia. This hydroponic system, due to its cost effectiveness and management friendliness, is one of the most widely adopted and used techniques in hydroponics for intensive basil cultivation [4]. Similar to other preharvest factors, mechanical stress induced by cutting can alter the qualitative–quantitative attributes of basil by affecting the metabolic pathways involved in the biosynthesis of aromatic compounds [19]. In this paper, we present a dataset derived from gas chromatographic analysis coupled with a mass spectrometer (GC/MS) of Genovese basil genotypes (*Ocimum basilicum* L.) generally used for the production of "pesto", grown both in the open field and in hydroponics with two successive cuts (Figure 1). In particular, three Genovese basil cultivars were used: (1) Aroma 2 F1 (Fenix, Belpasso, Italy; shiny, slightly serrated, dark green leaves, with medium-long internodes, suitable for greenhouse and open-field cultivation, with intermediate resistance to Fusarium wilt); (2) Eleonora F1 (Enza Zaden, Enkhuizen, Noord-Holland, Holland; large, slightly serrated leaves, suitable for open field cultivation); (3) Italiano Classico (La Semiorto Sementi, Sarno, Italy; slightly blistered, bright green "spoon" leaves with medium height). In our opinion, the importance of this dataset lies in the possibility of analyzing and highlighting potential differences in the flavor profile of Genovese basil genotypes grown in open field and hydroponic systems. The agroin–dustrial sector is increasingly interested in hydroponic basil production, as it would allow for deseasonalization of production. However, it is crucial to understand how different hydroponic growing conditions can affect the flavor profile of Genovese basil cultivars. This aspect is of essential importance because, for pesto sauce producers, standardization of production processes and product quality is the primary quality attribute. Detailed analysis of the differences between field and hydroponic cultivation could be helpful for both the agro–industrial sector and the scientific community, which is increasingly interested in aspects related to secondary plant metabolism. Second, the qualitative changes in the aroma profile found after cutting could be a cue for interesting research insights to better understand the influence of this preharvest factor.

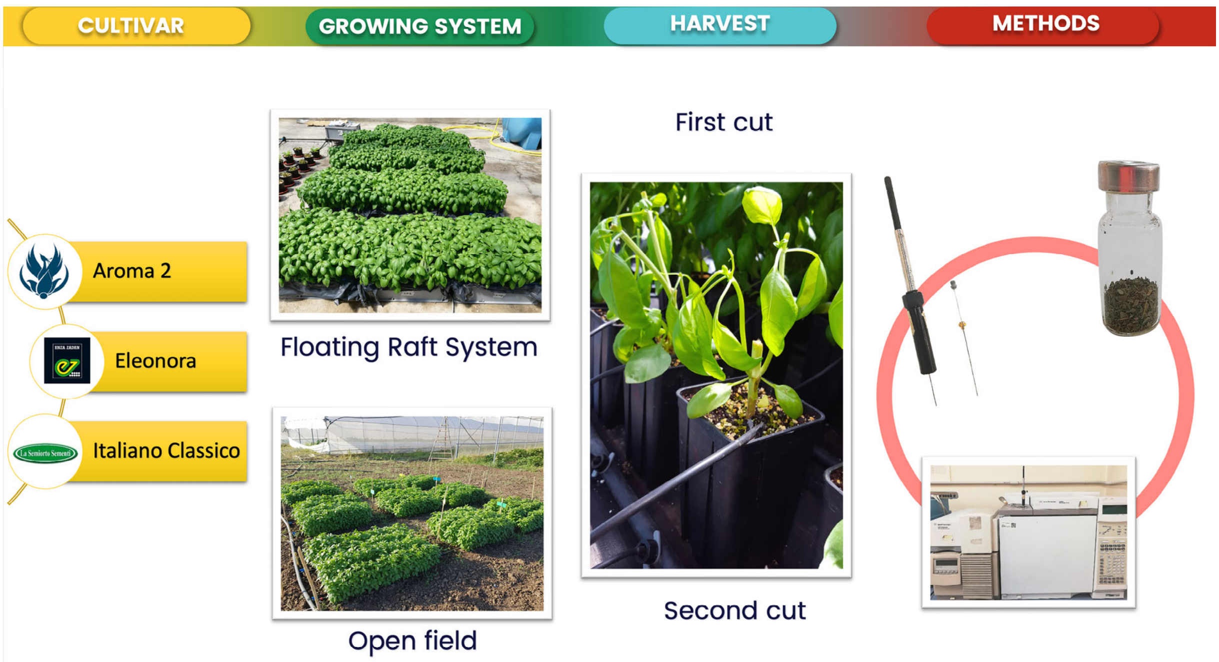

Figure 1. Graphical workflow summarizing present experiments.

2. Data Description

The dataset is composed of two spreadsheets named "FRS" (Floating Raft System) and "OF" (Open Field) that correspond, respectively, to the complete flavor profile of the three Genovese basil cultivars grown in the floating raft system and open field (Tables S1 and S2). The same data arrangement was adopted for both spreadsheets, distributed in 9 columns (A to I) and 35 rows (1 to 35). Specifically, the first, second, and third columns (column A, B, and C) report the retention time, compound, and chemical class of the VOCs, respectively. From column D to column F, the relative abundances (expressed as percentages) of each aromatic compound of the cultivars Eleonora, Aroma 2, and Italiano Classico at first cut (CT1), respectively, are reported. Similarly, from column G to I, the relative abundances (expressed as percentages) of each individual aromatic compound of the cultivars Eleonora, Aroma 2, and Italiano Classico in the second cut (CT2) are reported. Aromatic compounds in which the ratio of the relative peak height to that of the background noise was equal to or less than 3 were labeled "not detected" (nd).

3. Methods

3.1. Experimental Station, Growing System, and Plant Material

Two experimental trials were carried out in spring 2019 at the "Torre Lama" farm of the University of Naples Federico II (Department of Agricultural Sciences) located in Bellizzi (43°10′ N, 14°58′ E, alt. 60 m a.s.l., Salerno, Italy). The research aimed to evaluate the quality performance of three basil cultivars (*Ocimum basilicum* L. var. basilicum) grown under two different growing systems (floating raft system and open field, henceforth FRS and OF, respectively) in two successive harvests (first and second cut, henceforth CT1 and CT2, respectively). For both trials, Genovese basil 'Eleonora' seedlings (Enza Zaden, Enkhuizen, The Netherlands), 'Aroma 2′ (Fenix, Belpasso, Italy), and 'Italiano Classico' (La Semiorto, Sarno, Italy) transplanted 18 days after sowing at two true-leaves were used.

3.2. Experiment 1

The first experiment was carried out in a passive ventilation glass greenhouse, 10 m wide, 30 m long, and 3 and 4.5 m high at the eaves and ridge, respectively, where plastic tanks for the hydroponic cultivation of basil in FRS were arranged. The experimental design was full factorial in which the three basil cultivars (Eleonora, Aroma 2, and Italiano Classico) and two successive cuts (CT1 and CT2) were considered as factors. Each experimental unit was replicated three times and consisted of a single plastic tank filled with 35 L of Hoagland's nutrient solution (NS; modified as needed to meet cultural requirements) containing a 54-hole polystyrene tray with basil seedlings (54 pt/replicate). Hoagland's NS had the following composition of nutrient elements: 14 mM N-NO^-, 1.75 mM S, 1.5 mM P, 3.0 mM K, 4.5 mM Ca, 1.5 mM Mg, 1.0 m NH^{4+}, 15 μM Fe, 9 μM Mn, 0.3 μM Cu, 1.6 μM Zn, 20 μM B, and 0.3 μM Mo. To prevent root anoxia, continuous oxygenation was ensured using Aquaball 60 immersion pumps (Eheim, Stuttgart, Germany). The pH of NS was monitored daily and maintained at 6.0 ± 0.3, while the electrical conductivity was 2.0 ± 0.1 dS m^{-1}. The mean air temperature was 25 °C (min: 15 °C; max: 32 °C), while relative humidity was 55% during day and 79% during night.

3.3. Experiment 2

The second experiment was carried out in the open field in clay soil (46% sand, 24% silt, and 30% clay) having the following physicochemical characteristics: organic matter (*w/w*) 1.21%, total N 0.11%, extractable phosphorus 88 ppm and exchangeable potassium 980 ppm in the first layer of 0–30 cm, pH 7.7, and electrical conductivity 0.16 dS m^{-1}. The experimental design was factorial, in which we considered the same factors as described in experiment 1. Unlike experiment 1, the 250 plants per replication were used. Before transplanting, the soil was plucked and fertilized with 2 kg m^{-2} of mature manure. At the same time, during the experiment, the seedlings are fertigated with a ternary 8-12-24 (10) NPK (SO_3) fertilizer through a drip fertigation system. The latter consisted of a polyethylene main pipe (32 mm) equipped with a series of semi-compensating drippers (Ø 16 mm, 200 μm of thickness, 1.5 L h^{-1}, and 10 cm of spacing).

3.4. Harvesting and Storage of Plant Material

For both experiments, plants were harvested when they reached the pre-flowering phenological stage at the level of the first "true" internode (internode above the cotyledons). Specifically, plants grown in hydroponics were harvested at 18 and 32 days after transplanting, while plants grown in open field were harvested at 34 and 55 days after transplanting. The leaves were separated from the stems. A representative pool of leaves from ten plants per replicate was selected and immediately frozen at −20 °C for successive analysis of volatile compounds.

3.5. Determination of Volatile Organic Compounds

After extraction and concentration by the SPME technique, VOCs were determined using an Agilent 6890N Network Gas Chromatograph (Agilent Technologies Italia, Milan, Italy) coupled with an Agilent HP 5973 Mass Spectrometer (Agilent).

3.5.1. Sample Preparation and SPME Analysis

An aliquot of 500 mg of fresh sample frozen at −20 °C was placed in a 20 mL borosilicate glass vial (Sigma Aldrich, Milan, Italy) and used for SPME analysis. The vial was sealed with specific caps (Push-On Caps) equipped with a PTFE septum and placed at 30 °C under stirring (ARE® magnetic stirrer; Velp® Scientifica, Usmate Velate, Monza Brianza, Italy) for 10 min to facilitate migration of VOCs into the headspace. Through an SPME fiberholder (Supelco®, Bellefonte, PA, USA), a divinylbenzene/carbophane/polydimethylsiloxane fiber (1 cm long and 50/30 μm thick; Supelco®, Bellefonte, PA, USA) was introduced into the vial for VOC adsorption (for 10 min at 30 °C). Each treatment was analyzed in triplicate.

3.5.2. Identification of Volatile Organic Compounds

The fiber laden with VOCs was introduced into the split–splitless injection system of the GC/MS, and maintained at 250 °C with a pressure of 7.64 PSI and a total flow of 24 mL min^{-1}. The desorption phase lasted 10 min, after which the fiber was removed. The GC was equipped with a capillary column coated with a 0.25 μm film of 5% phenyl/95%

dimethylpolysiloxane and 30 m long and 0.250 mm thick (Supelco®, Bellefonte, PA, USA). Chromatographic analysis was performed in temperature gradient mode according to the following schedule: 50 °C for two min; 50 °C to 150 °C with an increase of 10 °C/min; 150 °C to 280 °C with an increase of 15 °C/min; 280 °C for 10 min. The run lasted 30 min and 67 s. The ion source temperature was 230 °C, while helium was used as a carrier gas, setting a flow rate at 1 mL min^{-1}. The mass spectrometer was set at 70 eV. Based on the acquired chromatograms (Figures 2–4), VOCs were identified by comparing the mass spectra with the NIST mass spectral database. Each treatment was analyzed in triplicate and the results were expressed as % normalization of the total area.

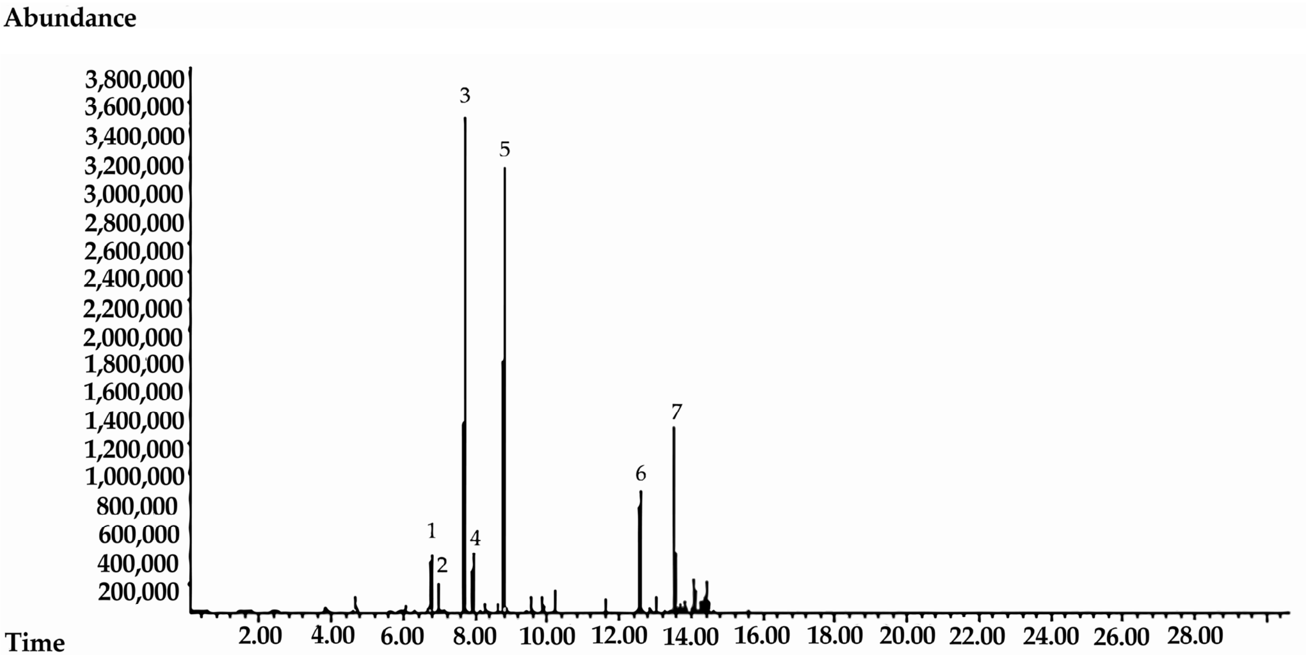

Figure 2. Chromatograms of volatile organic compounds in Eleonora extract by GC/MS at first cut (CT1) with separation of 1-octen-3-ol (1), β-myrcene (2), eucalyptol (3), β-cis-ocimene (4), linalool (5), eugenol (6), α-bergamotene (7).

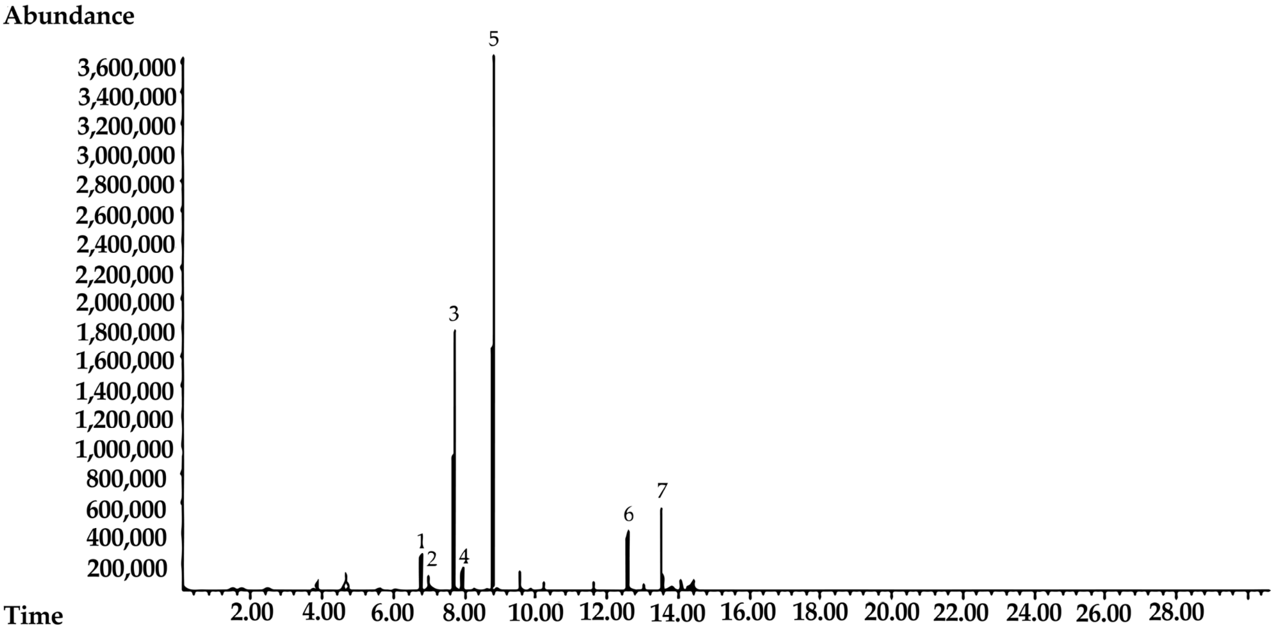

Figure 3. Chromatograms of volatile organic compounds in Aroma 2 extract by GC/MS at first cut (CT1) with separation of 1-octen-3-ol (1), β-myrcene (2), eucalyptol (3), β-cis-ocimene (4), linalool (5), eugenol (6), α-bergamotene (7).

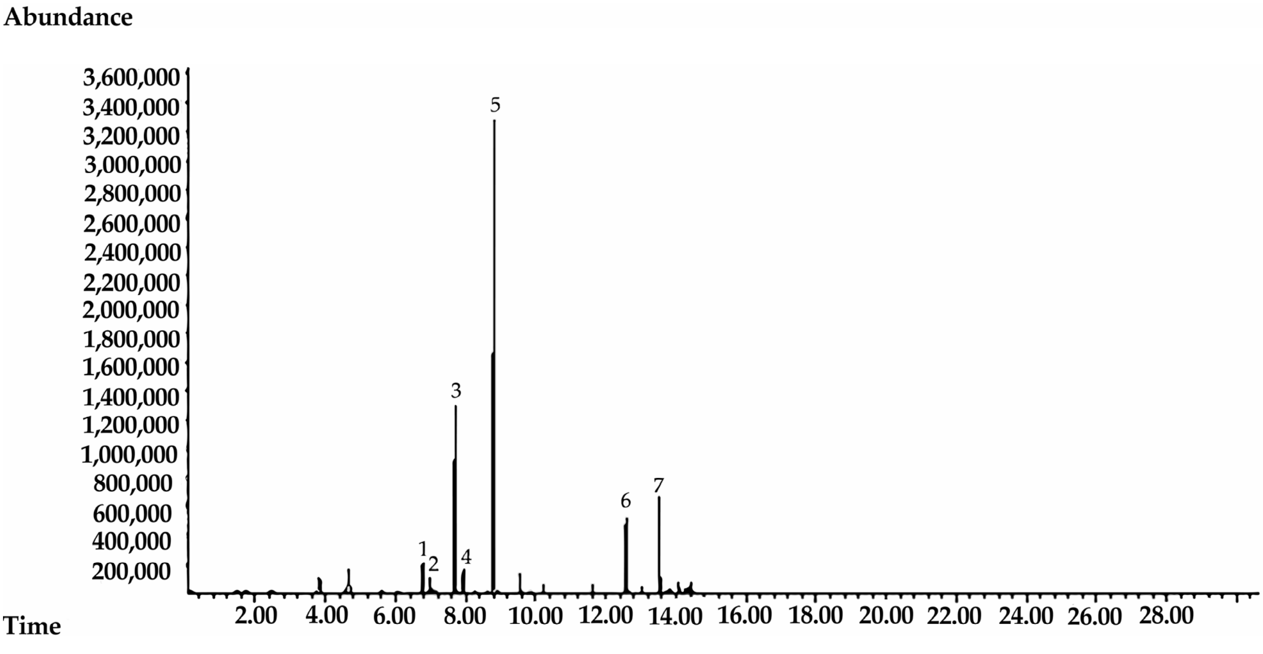

Figure 4. Chromatograms of volatile organic compounds in Italiano Classico extract by GC/MS at first cut (CT1) with separation of 1-octen-3-ol (1), β-myrcene (2), eucalyptol (3), β-cis-ocimene (4), linalool (5), eugenol (6), α-bergamotene (7).

4. Conclusions

For the Genovese basil for manufacturing "pesto" sauce, aroma is one of the most crucial quality attributes, as it influences its flavor [20]. The unmistakable intense aroma of mint-free Genovese basil is due to an aroma profile consisting mainly of monoterpenes, aromatic compounds, and sesquiterpenes [7]. SPME GC/MS analysis of VOCs showed that, regardless of the cut and genetic material, the percentage content of limonene averaged

0.928% in the open field and 0.854% in the floating raft system. The aroma profile of open-field plants did not have methyl eugenol, a highly studied compound because of its insecticidal properties [21]. In the FRS, this compound had an average percentage of 0.276%. Regardless of the growing system and mechanical stress of the cut, the three cultivars had eucalyptol and linalool as the main aromatic compounds, the sum of which accounted for approximately 68.674% of the total aromatic profile. In the open field, the cut increased the linalool content in all cultivars, while an opposite trend was observed in the floating raft system. This result underscores how growing conditions and agronomic practices markedly influence the expression of individual aroma compounds [1], aspects that the processing industry must consider, as they affect the quality of the product.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/data8020033/s1, Table S1: Dataset of the volatile profiles in Floating Raft System (FRS); Table S2: Dataset of the volatile profiles in Open Field (OF).

Author Contributions: Conceptualization, M.C., L.F. and Y.R.; methodology, M.C. and L.F.; software, M.C. and L.F.; validation, M.C. and L.F.; formal analysis, M.C. and L.F.; investigation, M.C. and L.F.; resources, M.C. and L.F.; data curation, M.C. and L.F.; writing—original draft preparation, M.C. and L.F.; writing—review and editing, M.C., L.F., Y.R. and G.C.; visualization, Y.R. and G.C.; supervision, Y.R. and G.C.; project administration, Y.R.; funding acquisition, G.C. All authors have read and agreed to the published version of the manuscript.

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Abbreviations

SPME	Solid-Phase Microextraction
GC/MS	Mass Spectrometer
VOCs	Volatile Organic Compounds
FRS	Floating Raft System
NS	Nutrient Solution
PTFE	Polytetrafluoroethylene
NIST	National Institute of Standards and Technology

References

1. Ciriello, M.; Kyriacou, M.C.; De Pascale, S.; Rouphael, Y. An Appraisal of Critical Factors Configuring the Composition of Basil in Minerals, Bioactive Secondary Metabolites, Micronutrients and Volatile Aromatic Compounds. *J. Food Compos. Anal.* **2022**, *111*, 104582. [CrossRef]
2. Shahrajabian, M.H.; Sun, W.; Cheng, Q. Chemical components and pharmacological benefits of Basil (*Ocimum basilicum*): A review. *Int. J. Food Prop.* **2020**, *23*, 1961–1970. [CrossRef]
3. Corrado, G.; Chiaiese, P.; Lucini, L.; Miras-Moreno, B.; Colla, G.; Rouphael, Y. Successive harvests affect yield, quality and metabolic profile of sweet basil (*Ocimum basilicum* L.). *Agronomy* **2020**, *10*, 830. [CrossRef]
4. Ciriello, M.; Formisano, L.; El-Nakhel, C.; Corrado, G.; Pannico, A.; De Pascale, S.; Rouphael, Y. Morpho-physiological responses and secondary metabolites modulation by preharvest factors of three hydroponically grown genovese basil cultivars. *Front. Plant Sci.* **2021**, *12*, 671026. [CrossRef]
5. Marotti, M.; Piccaglia, R.; Giovanelli, E. Differences in essential oil composition of basil (*Ocimum basilicum* L.) Italian cultivars related to morphological characteristics. *J. Agric. Food Chem.* **1996**, *44*, 3926–3929. [CrossRef]
6. Bekhradi, F.; Delshad, M.; Marín, A.; Luna, M.C.; Garrido, Y.; Kashi, A.; Babalar, M.; Gil, M.I. Effects of salt stress on physiological and postharvest quality characteristics of different Iranian genotypes of basil. *Hortic. Environ. Biotechnol.* **2015**, *56*, 777–785. [CrossRef]

7. De Masi, L.; Siviero, P.; Esposito, C.; Castaldo, D.; Siano, F.; Laratta, B. Assessment of agronomic, chemical and genetic variability in common basil (*Ocimum basilicum* L.). *Eur. Food Res. Technol.* **2006**, *223*, 273–281. [CrossRef]
8. Filip, S. Basil (*Ocimum basilicum* L.) a source of valuable phytonutrients. *Int. J. Clin. Nutr. Diet.* **2017**, *3*, 118. [CrossRef] [PubMed]
9. Makri, O.; Kintzios, S. Ocimum sp.(basil): Botany, cultivation, pharmaceutical properties, and biotechnology. *J. Herbs Spices Med. Plants* **2008**, *13*, 123–150. [CrossRef]
10. Ciriello, M.; Formisano, L.; El-Nakhel, C.; Kyriacou, M.C.; Soteriou, G.A.; Pizzolongo, F.; Romano, R.; De Pascale, S.; Rouphael, Y. Genotype and successive harvests interaction affects phenolic acids and aroma profile of genovese basil for pesto sauce production. *Foods* **2021**, *10*, 278. [CrossRef] [PubMed]
11. Skrypnik, L.; Novikova, A.; Tokupova, E. Improvement of phenolic compounds, essential oil content and antioxidant properties of sweet basil (*Ocimum basilicum* L.) depending on type and concentration of selenium application. *Plants* **2019**, *8*, 458. [CrossRef] [PubMed]
12. Wogiatzi, E.; Papachatzis, A.; Kalorizou, H.; Chouliara, A.; Chouliaras, N. Evaluation of essential oil yield and chemical components of selected basil cultivars. *Biotechnol. Biotechnol. Equip.* **2011**, *25*, 2525–2527. [CrossRef]
13. Siddiqui, M.W. *Preharvest Modulation of Postharvest Fruit and Vegetable Quality*, 1st ed.; Siddiqui, M.W., Ed.; Academic Press: Cambridge, MA, USA, 2017.
14. Tyagi, S.; Sahay, S.; Imran, M.; Rashmi, K.; Mahesh, S.S. Pre-harvest factors influencing the postharvest quality of fruits: A review. *Curr. J. Appl. Sci. Technol.* **2017**, *23*, 12. [CrossRef]
15. Salachas, G.; Savvas, D.; Argyropoulou, K.; Tarantillis, P.A.; Kapotis, G. Yield and nutritional quality of aeroponically cultivated basil as affected by the available root-zone volume. *Emir. J. Food Agric.* **2015**, *27*, 911–918. [CrossRef]
16. Walters, K.J.; Currey, C.J. Hydroponic greenhouse basil production: Comparing systems and cultivars. *HortTechnology* **2015**, *25*, 645–650. [CrossRef]
17. Nicoletto, C.; Santagata, S.; Bona, S.; Sambo, P. Influence of cut number on qualitative traits in different cultivars of sweet basil. *Ind. Crops Prod.* **2013**, *44*, 465–472.
18. Tsasi, G.; Mailis, T.; Daskalaki, A.; Sakadani, E.; Razis, P.; Samaras, Y.; Skaltsa, H. The effect of harvesting on the composition of essential oils from five varieties of *Ocimum basilicum* L. cultivated in the Island of Kefalonia, Greece. *Plants* **2017**, *6*, 41. [CrossRef] [PubMed]
19. Ceccanti, C.; Landi, M.; Rocchetti, G.; Miras Moreno, M.B.; Lucini, L.; Incrocci, L.; Pardossi, A.; Guidi, L. Hydroponically grown Sanguisorba minor Scop.: Effects of cut and storage on fresh-cut produce. *Antioxidants* **2019**, *8*, 631. [CrossRef] [PubMed]
20. Salvadeo, P.; Boggia, R.; Evangelisti, F.; Zunin, P. Analysis of the volatile fraction of "Pesto Genovese" by headspace sorptive extraction (HSSE). *Food Chem.* **2007**, *105*, 1228–1235. [CrossRef]
21. Xu, H.X.; Zheng, X.S.; Yang, Y.J.; Tian, J.C.; Lu, Y.H.; Tan, K.H.; Lu, Z.X. Methyl eugenol bioactivities as a new potential botanical insecticide against major insect pests and their natural enemies on rice (Oriza sativa). *Crop Prot.* **2015**, *72*, 144–149. [CrossRef]