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Effect of Different Postharvest Methods on Essential Oil Content and Composition of Three *Mentha* Genotypes

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Abstract: *Mentha* sp. is commonly used for essential oil (EO) extraction and incorporated in multiple products of food and pharmaceutical industries. Postharvest management is a key factor in line of production to preserve quality-determining plant ingredients. This study focused on the effects of two different postharvest processes on EO content and the composition of three different *Mentha* genotypes (*Mentha* × *piperita* 'Multimentha', *Mentha* × *piperita* 'Fränkische Blaue' and *Mentha rotundifolia* 'Apfelminze'). They were cultivated under greenhouse conditions. One postharvest treatment consisted of drying *Mentha* as whole plant after harvesting and later separating leaves from stems. In the second treatment, leaves were separated from stems directly after harvesting and then dried. EO content was determined by steam distillation and composition of EO was characterized by GC/MS analysis. Key findings of the study are that the postharvest processing treatments had no significant influence on the content or composition of the EO. Only the genotype 'Fränkische Blaue' showed a significantly higher EO content in the dry separated treatment at the third harvest (2.9 ± 0.15 mL/100 g DM (sD)) than separated fresh (2.4 ± 0.24 mL/100 g DM (sF)). However, genotype selection and harvest time had a clear impact on EO content and composition.

Keywords: biomass drying; essential oils; medicinal plants; *Mentha* × *piperita*; *Mentha rotundifolia*; menthol; postharvest processing; volatile organic compounds; GC/MS

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1. Introduction

The genus *Mentha* belongs to the Lamiaceae family and comprises perennial aromatic herbs, which are spread over large areas around the world [1]. *Mentha* is well known for tea production but is mainly used for the extraction of essential oil (EO). For tea production and EO extraction, mint leaves are used [2]. EOs are applied as flavoring agents and ingredients of various products in the food industry, cosmetics, and pharmaceuticals [3]. EOs possess antimicrobial, antiviral, antioxidant and antitumor activities [2]. Talebi et al. used the EOs of *Mentha* × *piperita* in combination with nanocellulose to produce a biodegradable active polylactide acid composite film. Antibacterial activity was demonstrated in an experiment with ground beef over 12 days of storage [4]. An example of the pharmaceutical or medicinal effect would be the in vitro virucidal activity of peppermint-EO against type 1 and type 2 herpes viruses [5].

EOs in general consist of volatile compounds composed of monoterpenes, sesquiterpenes, their oxygenated derivatives, and phenylpropanoids [6]. Peppermint-EO consists

mainly of monoterpenes [7], specifically menthol (30–55%), moderate proportions of its precursor menthone (14–32%) and low levels of the minor compound pulegone [8]. Preferably, the pulegone content should be as low as possible, since pulegone will be metabolized to menthofuran in the liver, which has shown hepatotoxic effects [9]. Concentrations of pulegone at $\leq$1% are graded as harmless [10]. *Mentha* can be classified into three different groups according to its predominant monoterpenes. The menthol pathway with the production of menthol, menthone and menthofuran, is used by *Mentha* × *piperita* L., *Mentha longifolia* L. and *Mentha arvensis* L., among others. The carvone pathway with carvone, dihydrocarvone and carveol is expressed by *Mentha spicata* L. and *Mentha* × *rotundifolia* L. The third group produces linalool and linalylacetate through the linalool pathway. It includes *Mentha aquatica* var. *citrata* and *Mentha* × *piperita* (L.) *Huds.* [1].

As the content and composition of EO are value determining factors, they need to be optimized to ensure quality and financial return on investment (ROI). Many factors affect EO composition and EO content. As already indicated by the various pathways, genetics and thus the choice of variety plays a role. Approximately 20 to 30 *Mentha* species as well as numerous subspecies, hybrids and other cultivars are known today [11]. Management, e.g., harvest time [12,13] and environmental influences, such as irradiation and nutrient availability [14–16], are of relevance since interactions exist between genetics, environment and management (G × E × M) [17]. Management practices also include postharvest procedures, which begin at the moment of harvest or collection and include drying, shredding, grinding, packaging, storage and EO extraction. Each of these steps may affect the content and composition of the EO [18]. The typical postharvest procedure for peppermint involves first drying the whole plant and then cutting, sieving and separating leaves and stems via wind sifting. After the separation of leaves and stems, the dry leaves are packaged. Cutting, sieving, separating and packaging are also known as primary processing [19].

Drying and its effect on the content and composition of EOs has been well studied. Generally, the type of drying (ambient temperature-dried, oven-dried, freeze-dried) affects the composition of valuable compounds [20]. Not only drying mechanism but, in case of oven drying, the temperature impacts quantity and quality of EOs [21]. Stanisavljević et al. (2010) investigated the impact of three different drying methods (shade drying, laboratory oven at 45 °C, condensation drying oven at 35 °C) on the content and composition of the EO of *Mentha longifolia* (L.) *Huds*. The EO content was determined via hydrodistillation and its composition via GC/MS. The highest EO content (1.1%) and the highest percentage of piperitone (71.7%), the main compound, were found after drying with the condensation drying oven, the second highest in the shade drying process (0.9%), and the lowest after laboratory oven drying (0.6%). After drying with the laboratory oven, the most EO compounds were found (24), the second most in the treatment with the condensation oven (20), and the lowest number after shade drying (18). However, pulegone (1.4%) was identified only in the EO from the *Mentha* dried in the laboratory oven, while in the EO produced in the shade drying experiment, most pharmacologically active compounds, like menthol, were present [22].

Investigations on package type and storage period of *Mentha* × *piperita* were carried out by Mehasen et al. (2009). In addition to different harvesting and handling treatments as well as drying methods, three different packaging types (plastic cases, jute cases and carton boxes) were examined for total microbial count (TMC) and the preservation of the EO content and composition every four months over a period of one year. Carton boxes preserved the highest EO content in *Mentha* and had the least influence on the composition of EOs. In all packaging materials, the EO content decreased and its composition changed with increasing storage time [18]. This was also found by Pandey et al. (2023), who further incorporated the extraction of EOs in a fresh state in their comparison [23].

While there are many studies on drying, packaging and storage, only a few studies focus on the separation step. Aćimović et al. (2021) investigated the impact of a separation method on EO content and composition in chamomile (*Matricaria chamomilla* L.

syn. *Chamomilla recutita* L.). In their experiment, chamomile was dried immediately after harvest or separated between flowers and stems before drying. The study showed that the separation of chamomile in flowers and stems before drying had a significant effect on the content and composition of the EOs [24].

The aim of the present study was to improve the existing primary processing, especially the separation step of leaves and stems in *Mentha* as an example for a high-value medicinal plant. Therefore, three hypotheses were drawn up. First, we hypothesize that the EO content is higher in leaves that have been separated from the stem in the fresh state. Second, the EO composition is of higher quality when leaves and stems are separated prior to drying rather than after drying. Third, genotypic differences are expected for the degree of change in quality and quantity of EOs.

2. Materials and Methods

2.1. Plant Material and Cultivation

Three mint genotypes were selected for this study: *Mentha* × *piperita* 'Multimentha', *Mentha* × *piperita* 'Fränkische Blaue' and *Mentha rotundifolia* 'Apfelminze', which will be called 'Multimentha', 'Fränkische Blaue' and 'Apfelminze', respectively, in this paper. The plant material for this experiment was propagated via cuttings from plants that were cultivated in a greenhouse at Campus Klein-Altendorf since 2021, resulting in 60 genetically identical plants for each genotype. The parent material for these plants originated from a genotype assortment that was installed at Campus Klein-Altendorf in 2016 and cultivated under field conditions since then. The cuttings were grown under greenhouse conditions (16 h light/8 h dark) and were watered every 48 h via an ebb–flow system. After 4 weeks, rooted cuttings were transplanted in pots (0.5 l volume) with 'Einheitserde ED73' (Einheitserde Werkverband, Sinntal-Altengronau, Germany) and were cultivated for a total of five months (February–June 2022) under the same greenhouse conditions (16 h light/8 h dark) with ebb–flow irrigation. Temperature and relative humidity were recorded over the course of the experiment (Table 1). A total of three harvests were performed consecutively, resulting in a triple repetition of the postharvest processing treatments (1st harvest in April, 2nd harvest in May and 3rd harvest in June). For each repetition, a harvest was performed shortly before flowering and followed by pruning the plants.

Table 1. Average temperatures (°C) and relative humidity (%) during the five months (February–June 2022) of the experimental period.

Month	Temperature (°C)	Relative Humidity (%)
February	20.7	49.8
March	20.5	48.6
April	20.7	53.8
May	23.4	52.0
June	25.2	52.9

2.2. Postharvest Processing

In order to investigate the impact of postharvest treatments on EOs (content and composition), plants were divided into two groups (Figure 1). In the first group the separation of leaves and stems was carried out in the fresh state (sF), and afterwards, the biomass was dried. In the second group plants were harvested as whole plants (aerial parts), and leaves and stems were separated after the drying process (sD). The separation was carried out manually. Fresh mass (g/plant) was determined immediately after harvesting. After determining the fresh matter yield (g/plant) of the whole plants (above ground biomass), plant material was dried at 35 °C for 5 days (until weight constancy) in a laboratory drying oven (Venticell 707–Eco Line, MMM Group, Planegg, Germany). A drying temperature of 35 °C was chosen to minimize EO losses during drying, as higher temperatures lead to higher losses [25]. Dry matter content (g/plant) and dry substance (%) were determined, and dried plant material was stored in closed bags at room temperature

until EO extraction. For the sD plants, dry mass was weighed, then the leaves and stems were separated, and subsequently, the dry mass of the leaves and stems was determined individually. For each genotype and treatment, 20 plants were randomly selected from the total of 60 plants.

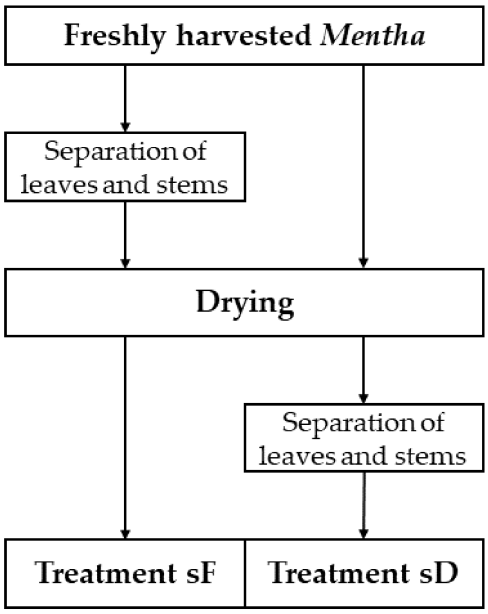


Figure 1. Scheme of the postharvest processing of the freshly harvested *Mentha* material, resulting in the treatments sF (separated fresh) and sD (separated dry).

2.3. Essential Oil Extraction and Analysis

2.3.1. Chemicals

Methanol (HPLC, LC-MS grade) (99.9%) was obtained from VWR International S.A.S (Fontenay-sous-Bois, Ile-de-France, France). Eucalyptol (99.8%), (R)-(+)-Limonene (99.2%), (−)-Menthone (99.0%), Menthofuran (99.3%), (+)-Menthol (99.9%), (−)-Menthol (99.9%), (+)-Dihydrocarvone (99.5%), (−)-Carvone (99.5%), Piperitone (98.3%), (−)-Menthyl acetate (%) and β-Caryophyllene (98.8%) were purchased from Merck GmbH (Darmstadt, Germany).

2.3.2. Extraction and Sample Preparation

The EOs were extracted by steam distillation according to the methodology of the European Pharmacopoeia [8] using apparatus 'KOL' und 'KOL 2' (behr Labor-Technik GmbH, Düsseldorf, Germany). 10 g of leaf samples were coarsely crushed with a pestle and mortar and placed into a 500 mL round flask together with 200 mL of distilled water. After the boiling temperature was reached, distillation was carried out for 2 h. Subsequently, EO volume was determined after a cooling period of 30 min. Collected EO was kept refrigerated at 4 °C in amber glass bottles protected from light. Prior to GC-TOF-MS analysis, EO samples were diluted in Methanol (1/100; v/v).

2.3.3. GC-TOF-MS Analysis

The analysis of the composition of EO was carried out using an Agilent 7890B gas chromatograph (Agilent Technologies, Palo Alto, CA, USA) equipped with a ZEBRON ZB 1 MS (30 m, 0.25 mm i.d. × 0.1 µm df). Helium was used as carrier gas at a constant flow of 1.0 mL/min. The column temperature was initially kept at 50 °C for 2 min, then gradually increased up to 200 °C at an increment of 3 °C/min, and kept at 225 °C for 10 min. Detection was performed on a time-of-flight mass spectrometer (Markes International Ltd., Llantrisant, RCT, UK) operating in the electron-ionization (EI) mode with an ionizing voltage set at −70 eV. The transfer line was set to 250 °C. The ion source temperature was 250 °C. The injector temperature was kept at 250 °C. Mass spectra were collected in full

scan (m/z 45–450). Data analysis was performed using the software TOF-DS Version 2.0 (Markes International Ltd., Llantrisant, RCT, UK). Analytes were identified by comparing the retention times and mass spectra with standard substances and using NIST Mass Spectral Library (National Institute of Standards and Technology, Gaithersburg, MD, USA). Quantitative analysis (in percent) was performed by peak area measurement (TIC) corrected by detector response.

2.4. Statistical Analysis

Data are depicted as tables (with mean and standard deviation) or boxplots, illustrating median, upper and lower quartile as well as standard deviation. Statistical analysis was performed using JMP Pro 17 (SAS Institute GmbH, Heidelberg, Germany). Normal distribution was tested via Shapiro–Wilk test. Not all variables showed to be normally distributed. Still, based on the Central Limit Theorem and the fact that small sample sizes do not always express normal distribution even if the statistical population is normally distributed, statistical analysis was performed via analysis of variance (ANOVA) with Tukey HSD as post hoc procedure to determine homogenous subgroups at a p-value of $p \leq 0.05$, indicated by letters. Differences in the postharvest methods (separation during fresh or dried state) were investigated via Student's t-test ($p \leq 0.05$), with significant differences marked by an asterisk (*). For this experiment, a one year period with a triple repetition (harvests in April, May and June) was chosen. The controlled environment in the greenhouse allowed for stable and reliable data that are generally transferable to other years.

3. Results

3.1. Biomass

Biomass accumulation of different genotypes and two processing procedures are shown in Table 2. The highest fresh mass was found in 'Fränkische Blaue' in both the sF and sD treatments (75.8 ± 19.7 g/plant; 72.5 ± 23.8 g/plant), followed by 'Apfelminze' (58.8 ± 27.5 g/plant; 62.7 ± 26.5 g/plant) and 'Multimentha' (53.6 ± 18.2 g/plant; 47.5 ± 17.9 g/plant). Also, for dry matter, 'Fränkische Blaue' yielded the highest amounts (9.4 ± 3.3 g/plant; 9.3 ± 3.9 g/plant), followed by 'Apfelminze' (7.6 ± 4.8 g/plant; 8.4 ± 5.1 g/plant) and 'Multimentha' (5.8 ± 2.3 g/plant; 5.0 ± 2.2 g/plant). For all three genotypes, the fresh mass of the stems was higher than leafy biomass. While the dry mass proportions of leaves and stems in 'Apfelminze' behaved the same compared to the fresh mass (sD: 3.9 ± 2.3 g/plant (leaf); 4.4 ± 2.9 g/plant (stem)), the peppermints 'Multimentha' (sD: 2.6 ± 1.3 g/plant (leaf); 2.4 ± 1.1 g/plant (stem)) and 'Fränkische Blaue' (sD: 5.3 ± 2.4 g/plant (leaf); 4.0 ± 1.6 g/plant (stem)) showed higher dry biomass yield for the leaves than for the stems.

Table 2. Biomass accumulation (g/plant) of the three *Mentha* genotypes, including fresh matter and dry matter for the processing procedures sF (separated fresh; leaves and stems were removed before drying) and sD (separated dry; separation was carried out after drying). Significant differences calculated by ANOVA and Tukey HSD (n = 60, α = 0.05) are indicated by letters (a–d) for FM and DM separately.

Genotype	Postharvest Processing	Fresh Matter (g/plant)			Dry Matter (g/plant)		
		Whole Plant	Leaf	Stem	Whole Plant	Leaf	Stem
'Multimentha'	sF	53.6 ± 18.2 cd	23.4 ± 8.0 b	30.1 ± 10.9 b	5.8 ± 2.3 bc	3.0 ± 1.2 bc	2.8 ± 1.2 b
	sD	47.5 ± 17.9 d	-	-	5.0 ± 2.2 c	2.6 ± 1.3 c	2.4 ± 1.1 b
'Apfelminze'	sF	58.8 ± 27.5 cd	26.5 ± 13.9 b	32.3 ± 14.0 b	7.6 ± 4.8 ab	3.6 ± 2.3 bc	4.0 ± 2.7 a
	sD	62.7 ± 26.5 bc	-	-	8.4 ± 5.1 a	3.9 ± 2.3 b	4.4 ± 2.9 a
'Fränkische Blaue'	sF	75.8 ± 19.7 a	36.2 ± 10.9 a	39.5 ± 10.1 a	9.4 ± 3.3 a	5.1 ± 1.9 a	4.3 ± 1.4 a
	sD	72.5 ± 23.8 ab	-	-	9.3 ± 3.9 a	5.3 ± 2.4 a	4.0 ± 1.6 a

3.2. Essential Oil Content

The EO content increased for each genotype with time of harvest (April–June) (Figure 2). For example, in April, 'Fränkische Blaue' (treatment sD) had an EO content of 1.8 ± 0.13 mL/100 g, in May 2.5 ± 0.1 mL/100 g, and 2.9 ± 0.15 mL/100 g after the third harvest in June. 'Multimentha' in the sD processing treatment reached the highest EO contents at each harvest date: 2.2 ± 0.14 mL/100 g (April), 2.9 ± 0.7 mL/100 g (May) and 3.5 ± 0.3 mL/100 g (June). In contrast, the lowest EO contents were found in 'Apfelminze'. For both processing treatments (sD and sF), 'Apfelminze' reached an EO content of 1.7 ± 0.08 mL/100 g after the first harvest, 2.1 ± 0.13 mL/100 g (sD) and 2.0 ± 0.03 mL/100 g (sF) after the second harvest, and 2.3 ± 0.05 mL/100 g (sD and sF) after the third harvest. Within the harvest date and genotype, almost no significant differences were found between the processing treatments (except for 'Fränkische Blaue', third harvest, 2.9 ± 0.15 mL/100 g DM (sD) and 2.4 ± 0.24 mL/100 g DM (sF)).

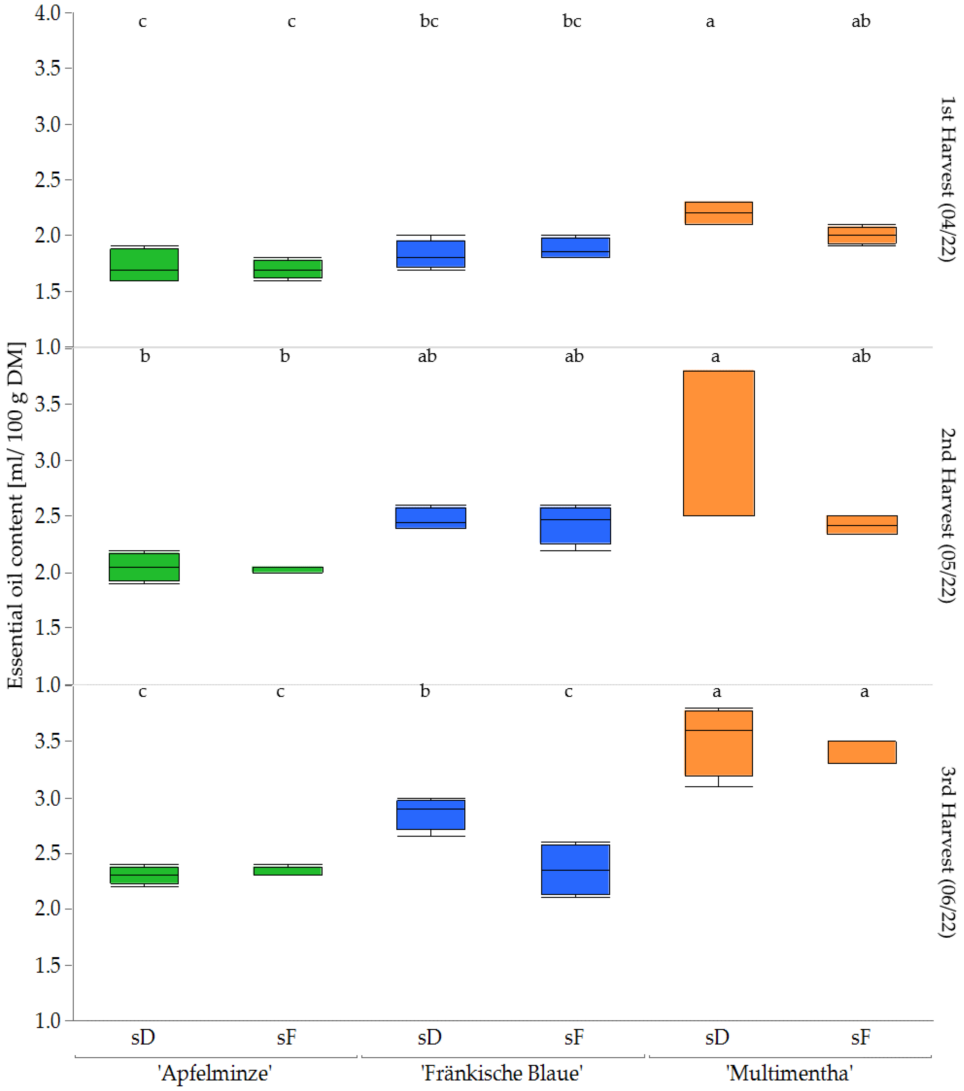


Figure 2. EO contents (mL/100 g) of dry leaves of the three *Mentha* genotypes ('Multimentha' (orange); 'Apfelminze' (green); 'Fränkische Blaue' (blue)) and postharvest processing treatments (separated in dry state (sD); separated in fresh state (sF)) grouped by harvest date (first harvest in April, second harvest in May and third harvest in June). Significant differences calculated by ANOVA and Tukey HSD (n = 4, $\alpha = 0.05$) are indicated by letters (a–c) for each harvest separately.

The pooled EO contents (first–third harvest), shown in Figure 3, differed significantly between the genotypes, with 'Multimentha' exhibiting the highest contents (2.9 ± 0.7 mL/100 g for separation of leaves in the dried state; sD), followed by 'Fränkische Blaue' (2.4 ± 0.5 mL/100 g) and 'Apfelminze' (2.0 ± 0.3 mL/100 g) with equal processing. With regard to the processing method, sD had a slightly higher EO content on average than sF, although the effect within a genotype was not statistically significant.

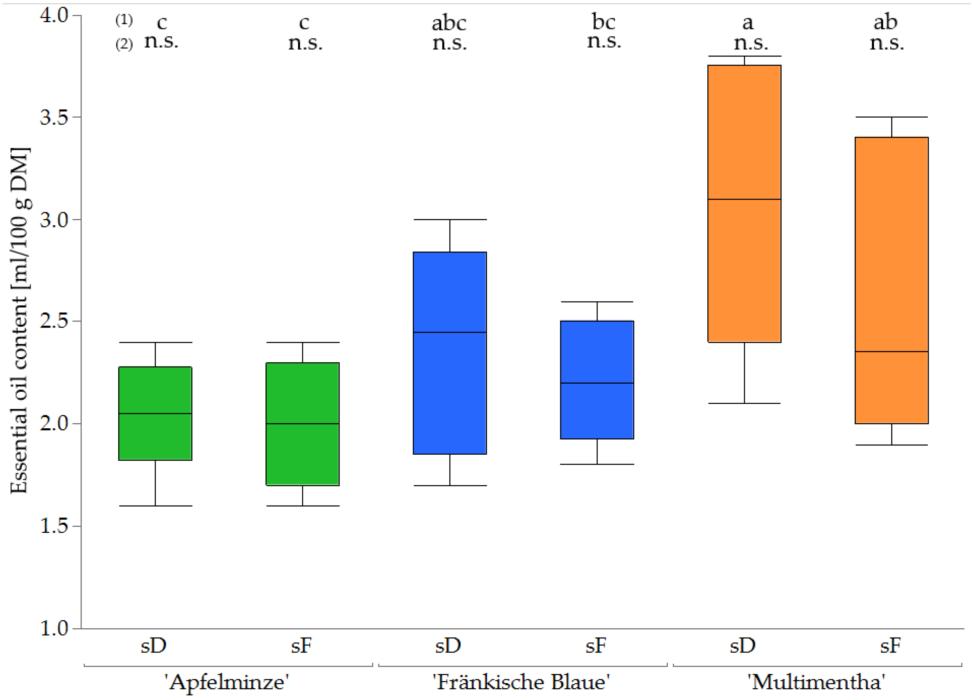


Figure 3. EO contents (mL/100 g) of dry leaves of the three *Mentha* genotypes ('Multimentha' (orange); 'Apfelminze' (green); 'Fränkische Blaue' (blue) and postharvest processing treatments (separated in dry state (sD); separated in fresh state (sF)) for all harvest dates. (1) Significant differences calculated by ANOVA and Tukey HSD (n = 12, α = 0.05) are indicated by letters (a–c). (2) There were no significant differences between treatments within cultivar (n.s.), as revealed by a Student's *t*-test (n = 12, α = 0.05).

3.3. Essential Oil Composition

EO composition varied slightly among both postharvest treatments and different harvests and also genotypes. The EO of 'Apfelminze' had the fewest number of compounds (5–7), whereas EOs of the peppermints 'Multimentha' and 'Fränkische Blaue' showed 9–11 compounds. Most of the compounds could be detected in every harvest. Exceptions were the compounds α-terpinene and *trans*-dihydrocarvone, which were only found in the first harvest, and β-phellandrene, which occurred only in the third harvest. The compounds detected in the first and second harvest were present in both postharvest processing sD and sF in the respective genotypes. In the third harvest, two compounds were only detected in the treatment sF and one compound only in the variant sD. β-phellandrene was found only in 'Apfelminze' (sF), β-caryophyllene only in 'Fränkische Blaue' (sD), and α-dihydroionone only in 'Multimentha' (sF). Total Ion Chromatograms for the first harvest are illustrated in Figures 4–6.

The main compound of the 'Apfelminze' in the first harvest, shown in Table 3, was carvone with 70.13 ± 0.42% (sD) and 69.72 ± 4.97% (sF). In the other two genotypes, carvone was not present. The second most compounds were eucalyptol/limonene with 11.44 ± 0.68% (sD) and 10.41 ± 1.46% (sF). The main compound in the two peppermints was *p*-menthone. It occurred in the 'Fränkische Blaue' with 46.25 ± 1.70% (sD) and 44.03 ± 0.65% (sF) and in the 'Multimentha' with 57.02 ± 1.05% (sD) and 55.90 ± 1.63%

(sF). The second most common compound was menthol isomer B. It was found in both postharvest treatments of the 'Fränkische Blaue' with 24.02 ± 2.03% (sD) and 24.18 ± 0.40% (sF) and in the 'Multimentha' with 19.65 ± 0.82% (sD) and 20.78 ± 1.99% (sF). All other compounds were present at levels below 10%. Compound levels below 1% were not listed.

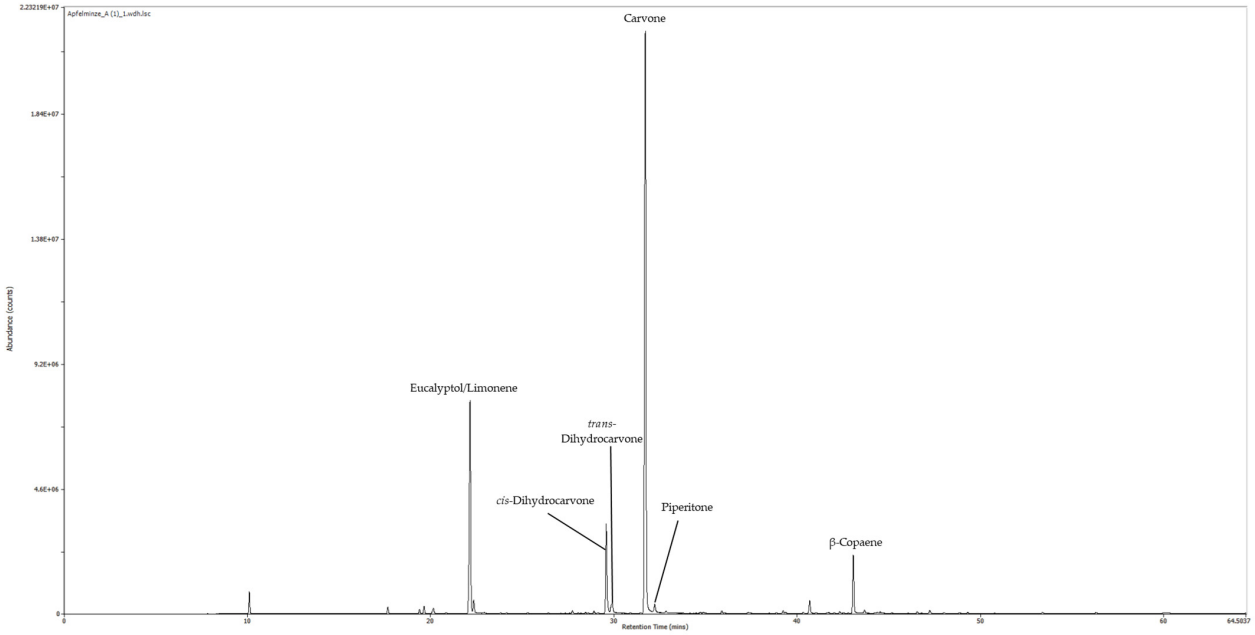


Figure 4. Total Ion Chromatogram of *Mentha rotundifolia* 'Apfelminze' after the first harvest (April).

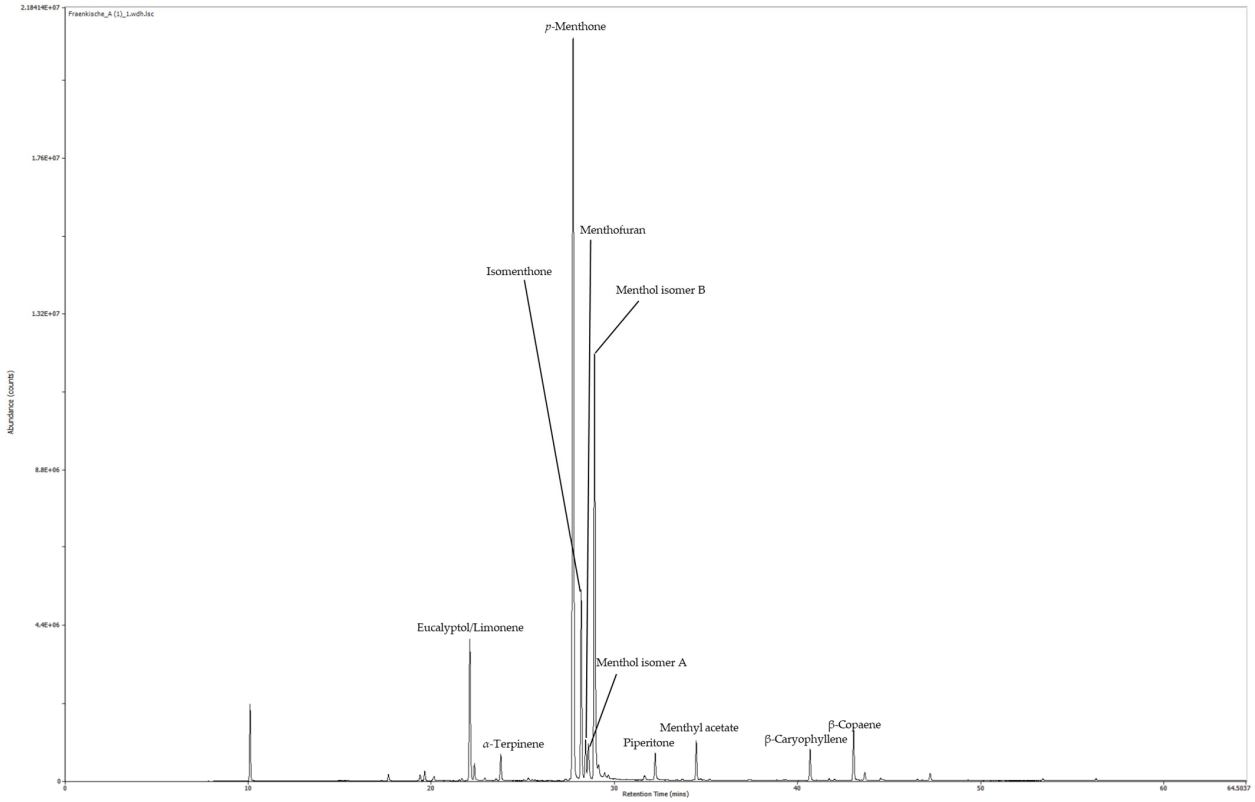


Figure 5. Total Ion Chromatogram of *Mentha* × *piperita* 'Fränkische Blaue' after the first harvest (April).

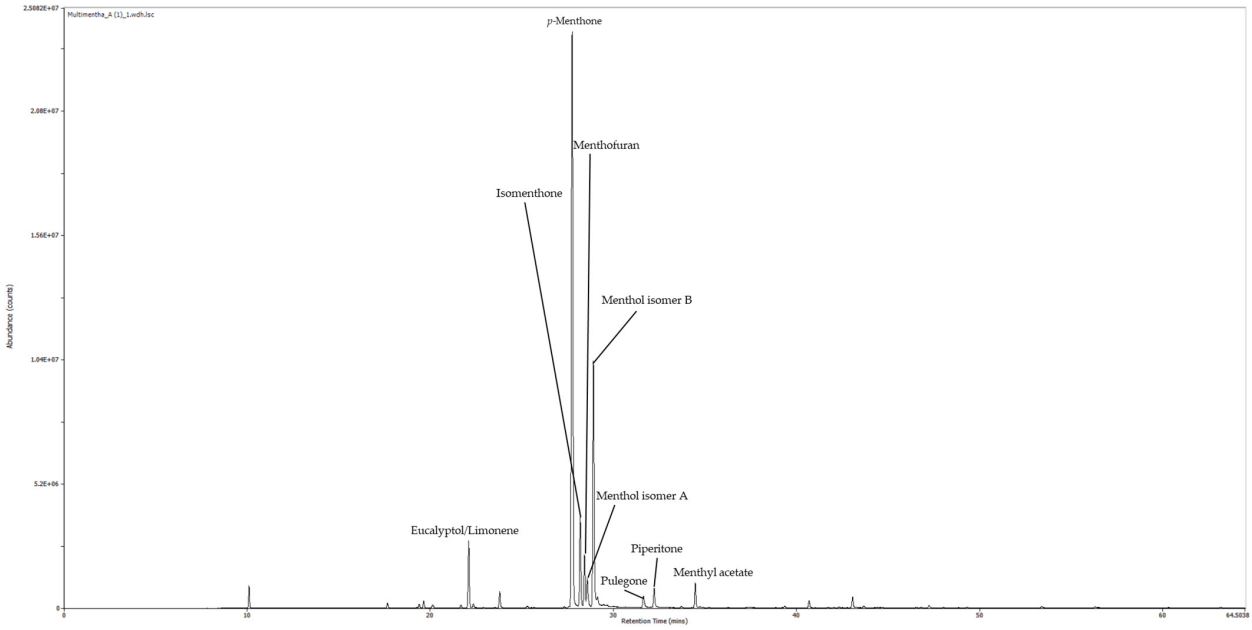


Figure 6. Total Ion Chromatogram of *Mentha* × *piperita* 'Multimentha' after the first harvest (April).

Table 3. EO composition (%) of the three *Mentha* genotypes for the postharvest processing treatments (separated in dry state (sD); separated in fresh state (sF)) after the first harvest (April); not detected (n.d.).

RT (min)	Compound	'Apfelminze' sD (%)	'Apfelminze' sF (%)	'Fränkische Blaue' sD (%)	'Fränkische Blaue' sF (%)	'Multimentha' sD (%)	'Multimentha' sF (%)
22.09	Eucalyptol/ Limonene	11.44 ± 0.68	10.41 ± 1.46	4.45 ± 0.39	4.69 ± 0.12	2.91 ± 0.39	3.17 ± 0.06
23.78	*α*-Terpinene	n.d.	n.d.	1.07 ± 0.07	1.32 ± 0.07	n.d.	n.d.
27.73	*p*-Menthone	n.d.	n.d.	46.25 ± 1.70	44.03 ± 0.65	57.02 ± 1.05	55.90 ± 1.63
28.18	Isomenthone	n.d.	n.d.	9.68 ± 0.14	9.63 ± 0.43	6.71 ± 0.19	6.53 ± 0.21
28.41	Menthofuran	n.d.	n.d.	2.37 ± 0.86	1.98 ± 0.20	2.93 ± 0.30	3.13 ± 0.29
28.57	Menthol isomer A	n.d.	n.d.	1.70 ± 0.22	1.82 ± 0.10	1.97 ± 0.09	2.24 ± 0.24
28.90	Menthol isomer B	n.d.	n.d.	24.02 ± 2.03	24.18 ± 0.40	19.65 ± 0.82	20.78 ± 1.99
29.57	*cis*-Dihydrocarvone	7.66 ± 1.27	8.28 ± 2.39	n.d.	n.d.	n.d.	n.d.
29.89	*trans*-Dihydrocarvone	1.41 ±0.19	1.45 ± 0.64	n.d.	n.d.	n.d.	n.d.
31.69	Pulegone	n.d.	n.d.	n.d.	n.d.	1.25 ± 0.49	n.d.
31.70	Carvone	70.13 ± 0.42	69.72 ± 4.97	n.d.	n.d.	n.d.	n.d.
32.21	Piperitone	1.13 ± 0.10	n.d.	2.02 ± 0.09	2.23 ± 0.11	1.81 ± 1.09	1.14 ± 1.29
34.46	Menthyl acetate	n.d.	n.d.	1.58 ± 0.40	2.00 ± 0.22	1.52 ± 0.09	1.06 ± 0.74
40.67	*β*-Caryophyllene	n.d.	n.d.	1.06 ± 0.19	1.26 ± 0.17	n.d.	n.d.
43.05	*β*-Copaene	3.82 ± 0.48	4.51 ± 0.51	2.07 ± 0.43	2.61 ± 0.48	n.d.	n.d.

In the second harvest (Table 4), carvone was again detected as the main compound of the 'Apfelminze' with 72.84 ± 1.57% in postharvest treatment sD and 70.29 ± 0.72% in treatment sF. Also, the second most abundant compound was eucalyptol/limonene, with 13.63 ± 0.54% (sD) and 13.07 ± 0.57% (sF). *p*-menthone was again the main compound in the peppermints after the second harvest of 'Fränkische Blaue' with 50. 58 ± 1.22% (sD) and 49.52 ± 1.00% (sF) and of 'Multimentha' with 53.96 ± 0.78% (sD) and 52.75 ± 0.05% (sF). The second most compound in the 'Fränkische Blaue' was again the menthol isomer B with 15.93 ± 1.00% (sD) and 17.10 ± 0.34% (sF), and as third highest, isomenthone with 11.32 ± 0.43% (sD) and 11.28 ± 0.28% (sF). 'Multimentha', in contrast to the first harvest, contained pulegone as the second most abundant compound with 18.55 ± 1.93% (sD) and 20.27 ± 1.35% (sF) and then as the third highest fraction menthol isomer B with 9.26 ± 0.22% (sD) and 10.34 ± 0.27% (sF).

Table 4. EO composition of the three *Mentha* genotypes for the postharvest processing treatments (separated in dry state (sD); separated in fresh state (sF)) after the second harvest (May); not detected (n.d.).

RT (min)	Compound	'Apfelminze' sD (%)	'Apfelminze' sF (%)	'Fränkische Blaue' sD (%)	'Fränkische Blaue' sF (%)	'Multimentha' sD (%)	'Multimentha' sF (%)
22.09	Eucalyptol/ Limonene	13.63 ± 0.54	13.07 ± 0.57	4.20 ± 0.18	3.96 ± 0.33	1.91 ± 0.04	1.77 ± 0.09
27.73	*p*-Menthone	n.d.	n.d.	50. 58 ± 1.22	49.52 ± 1.00	53.96 ± 0.78	52.75 ± 0.05
28.18	Isomenthone	n.d.	n.d.	11.32 ± 0.43	11.28 ± 0.28	6.62 ± 0.09	6.17 ± 0.18
28.41	Menthofuran	n.d.	n.d.	4.65 ± 0.54	4.36 ± 0.39	1.08 ± 1.45	1.08 ± 1.45
28.57	Menthol isomer A	n.d.	n.d.	1.46 ± 0.12	1.62 ± 0.06	3.61 ± 0.46	2.0 ± 0.07
28.90	Menthol isomer B	n.d.	n.d.	15.93 ± 1.00	17.10 ± 0.34	9.26 ± 0.22	10.34 ± 0.27
29.12	*α*-Dihydroionone	n.d.	n.d.	n.d.	n.d.	n.d.	1.14 ± 0.04
29.57	*cis*-Dihydrocarvone	3.02 ± 0.47	4.15 ± 0.52	n.d.	n.d.	n.d.	n.d.
31.69	Pulegone	n.d.	n.d.	4.90 ± 0.52	3.50 ± 1.43	18.55 ± 1.93	20.27 ± 1.35
31.70	Carvone	72.84 ± 1.57	70.29 ± 0.72	n.d.	n.d.	n.d.	n.d.
32.21	Piperitone	1.17 ± 0.03	1.26 ± 0.16	1.96 ± 0.16	2.21 ± 0.10	1.79 ± 0.24	1.72 ± 0.06
34.46	Menthyl acetate	n.d.	n.d.	1.16 ± 0.24	1.53 ± 0.19	n.d.	n.d.
40.67	*β*-Caryophyllene	n.d.	n.d.	1.26 ± 0.28	1.09 ± 0.21	n.d.	n.d.
43.05	*β*-Copaene	4.28 ± 0.92	4.87 ± 0.86	n.d.	1.67 ± 0.32	n.d.	n.d.

In the third harvest (Table 5), 'Apfelminze' also showed carvone again as the main compound with 71.13 ± 0.86% (sD) and 69.41 ± 1.11% (sF) and eucalyptol/limonene as the second most compound with 14.38 ± 0.27% (sD) and 14.32 ± 0.35% (sF). Unlike the previous harvests, only the postharvest treatment sF had *β*-phellandrene with 1.10 ± 0.08%. 'Fränkische Blaue' was again mainly composed of *p*-menthone with 48.52 ± 1.02% (sD) and 44.92 ± 0.92% (sF). In contrast to the second harvest, pulegone was now also the second most abundant compound in the third harvest with 14.27 ± 2.18% (sD) and 19.48 ± 2.89% (sF). This was followed by menthol isomer B with 11.10 ± 1.32% (sD) and 12.74 ± 1.87% (sF) and isomenthone with 10.74 ± 0.58% (sD) and 9.81 ± 0.32% (sF). Remarkably, *β*-caryophyllene was found only in the treatment sD with 1.26 ± 0.28%. The major compound

of 'Multimentha' was also the *p*-menthone with 46.11± 3.62% (sD) and 44.23 ± 4.34% (sF). This was again followed by the pulegone with 33.44 ± 4.56% (sD) and 34.06 ± 1.12% (sF). *α*-dihydroionone was detected only in the sF variant with 1.11 ± 0.17%.

Table 5. EO composition of the three *Mentha* genotypes for the postharvest processing treatments (separated in dry state (sD); separated in fresh state (sF)) after the third harvest (June); not detected (n.d.).

RT (min)	Compound	'Apfelminze' sD (%)	'Apfelminze' sF (%)	'Fränkische Blaue' sD (%)	'Fränkische Blaue' sF (%)	'Multimentha' sD (%)	'Multimentha' sF (%)
19.38	*β*-Phellandrene	n.d.	1.10 ± 0.08	n.d.	n.d.	n.d.	n.d.
22.09	Eucalyptol/ Limonene	14.38 ± 0.27	14.32 ± 0.35	4.13 ± 0.34	2.97 ± 1.90	3.00 ± 0.40	3.06 ± 0.52
27.73	*p*-Menthone	n.d.	n.d.	48.52 ± 1.02	44.92 ± 0.92	46.11± 3.62	44.23 ± 4.34
28.18	Isomenthone	n.d.	n.d.	10.74 ± 0.58	9.81 ±0.32	5.56 ± 0.84	5.71 ± 0.21
28.41	Menthofuran	n.d.	n.d.	4.30 ± 0.73	3.14 ± 1.49	1.35 ± 0.40	1.73 ± 0.47
28.57	Menthol isomer A	n.d.	n.d.	1.28 ± 0.07	1.45 ± 0.29	2.61 ± 0.59	2.08 ± 0.84
28.90	Menthol isomer B	n.d.	n.d.	11.10 ± 1.32	12.74 ± 1.87	3.42 ± 0.70	3.44 ± 0.76
29.12	*α*-Dihydroionone	n.d.	n.d.	n.d.	n.d.	n.d.	1.11 ± 0.17
29.57	*cis*-Dihydrocarvone	2.48 ± 0.81	2.69 ± 0.65	n.d.	n.d.	n.d.	n.d.
31.69	Pulegone	n.d.	n.d.	14.27 ± 2.18	19.48 ± 2.89	33.44 ± 4.56	34.06 ± 1.12
31.70	Carvone	71.13 ± 0.86	69.41 ± 1.11	n.d.	n.d.	n.d.	n.d.
32.21	Piperitone	1.59 ± 0.06	1.72 ± 0.22	1.72 ± 0.17	1.03 ± 0.68	0.98 ± 0.14	1.06 ± 0.17
40.67	*β*-Caryophyllene	1.24 ± 0.06	1.04 ± 0.64	1.26 ± 0.28	n.d.	n.d.	n.d.
43.05	*β*-Copaene	5.12 ± 0.17	5.26 ± 0.35	n.d.	n.d.	n.d.	n.d.

4. Discussion

The first hypothesis was that the EO content is higher in leaves that have been separated from the stem in a fresh state (sF) in contrast to separation in a dried state (sD). As oven-drying is generally acknowledged as fast, simple and inexpensive, this type of drying was used in the present study [20]. Because postharvest treatments may lead to yield reduction, especially of volatile compounds, it was suspected that losses of EO would be higher in the sD treatment since the drying process contributes to the depletion of thermolabile EOs [26] and the damage of the trichomes [27]. However, no significant differences in EO contents occurred between the postharvest treatments. Only the sD treatment yielded slightly higher values than the sF treatment in some cases (e.g., 'Fränkische Blaue', third harvest, 2.9 ± 0.15 mL/100 g DM (sD) and 2.4 ± 0.24 mL/100 g DM (sF)). This might be related to a longer period of time between harvest and preservation (drying) and an enlarged surface at the points of injury on the leaf and stem where more volatile EO compounds could possibly be lost [28] than in treatment sF in comparison to sD. However, a prior separation of leaf and stem could preserve a higher EO yield as the drying period is much shorter, when only the leaves are dried and the separated stems would be sorted out beforehand. This could lead to better product quality or at least to saving time and energy, which is also a sustainability aspect, because fewer resources are consumed [29]. Generally, the results indicate that different farming practices do not interfere with product quality, which poses a great potential for farmers as separation does not have negative effects on yield.

Furthermore, it was hypothesized that the EO might be of higher quality when leaves and stems are separated prior to drying than after drying, because this would remove the water from the separated leaves more quickly and there would be less respiration and enzymatic processes [24]. The drying method impacts the phytochemical profile (e.g., in *Lavendula angustifolia* Mill.) [30]. In regard to separation steps of leaves and stems, Aćimović et al. noted that chamomile plant material that was not separated in flowers and stems before drying contained high contents of E-β-farnesene, whereas plant material that was separated (flowers with short stems) before drying contained the pharmacologically valuable α-bisabolol as the main compound [24]. The injury to the plant by the separation of leaf and stem could actually have had the opposite effect with regard to the enzymatic processes, since enzymes and analytes are often spatially separated from each other in the intact material and reactions can only take place when damaged [31]. However, in the study conducted with the *Mentha* genotypes, no significant influence of the postharvest processing treatment on the composition of the EO was detected. Due to this, the second hypothesis must be rejected, again resulting in an important finding for farming practices as yield and quality are not diminished by using a suboptimal separation time.

The choice of genotype had a significant effect on the content and composition of the EO. Thus, the third hypothesis, that genotype specific differences are expected within the degree of change in the quality and quantity of EOs, can be accepted. It is commonly known that menthol and menthone are the major compounds in *Mentha* × *piperita* as well as piperitone oxide and piperitenone oxide in *M. suaveolens* [32]. The results confirm the classification of the genotypes into the three different groups according to their predominant monoterpenes [1]. The peppermints (*Mentha* × *piperita* 'Multimentha', *Mentha* × *piperita* 'Fränkische Blaue') could clearly be assigned to the menthol pathway since the main compound was *p*-menthone, and they also contained menthol and menthofuran. 'Apfelminze' (*Mentha rotundifolia*) belongs to the carvone pathway, because carvone was its main compound of approximately 70%. Besides the genotypic influence, a change in composition depending on the harvest date was observed. The EO content increased on average with each harvest, but the proportion of undesired compounds also increased. This change could have been due to the rising temperature. The average temperature during the first harvest was 20.7 °C in April, 23.4 °C in May, and 25.2 °C in June. For example, the amount of pulegone in both 'Multimentha' and 'Fränkische Blaue' increased with each harvest. In the first harvest, this was 1.25% (sD) and not detected in the sF treatment of 'Multimentha' and 33.44% (sD) and 34.06% (sF) in the third harvest. Pulegone can be converted to menthone by biosynthetic reactions but is also a precursor of menthofuran [33], which has shown hepatotoxic effects [9]. Grulova et al. also found an influence of temperature on EO composition [34]. It could be concluded that EO of the highest quality is obtained from the first harvest and this can act as a sales argument for farmers.

In summary, the postharvest processing treatments studied here (separated in dry state (sD) or in fresh state (sF)) did not significantly affect the EO content and composition of the three *Mentha* genotypes. In order to preserve the quality-determining plant ingredients, influences at other points in the production chain are more important, such as genotype selection, harvest frequency, drying and storage. There is already a broad research base on drying and storage of *Mentha*. Therefore, further studies should be conducted with a focus on genotype selection, harvesting dates and frequency. Additionally, comparisons in regard to EO content as well as composition should be made between drying of stem and leaves and drying only the leaves.

5. Conclusions

- Postharvest processing treatments (separated in dry state (sD); separated in fresh state (sF)) did not significantly affect the EO content and composition of the three *Mentha* genotypes;

- There was a genotype effect, as significant differences in EO content and composition were detected between the peppermints ('Multimentha' and 'Fränkische Blaue') and the 'Apfelminze';
- There was an increase in EO content on average with each harvest but also an increase in undesired compounds, such as pulegone;
- Further studies should be conducted, for example, on harvesting times and frequency and comparisons between a drying of stem and leaves and leaves only in regard to EO content and composition.

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References

1. Saric-Kundalic, B.; Fialova, S.; Dobes, C.; Ölzant, S.; Tekelova, D.; Grancai, D.; Reznicek, G.; Saukel, J. Multivariate Numerical Taxonomy of Mentha Species, Hybrids, Varieties and Cultivars. *Sci. Pharm.* **2009**, *77*, 851–876. [CrossRef]
2. McKay, D.L.; Blumberg, J.B. A review of the bioactivity and potential health benefits of peppermint tea (*Mentha piperita* L.). *Phytother. Res.* **2006**, *20*, 619–633. [CrossRef]
3. Anwar, F.; Abbas, A.; Mehmood, T.; Gilani, A.-H.; Rehman, N.-U. Mentha: A genus rich in vital nutra-pharmaceuticals—A review. *Phytother. Res.* **2019**, *33*, 2548–2570. [CrossRef]
4. Talebi, F.; Misaghi, A.; Khanjari, A.; Kamkar, A.; Gandomi, H.; Rezaeigolestani, M. Incorporation of spice essential oils into poly-lactic acid film matrix with the aim of extending microbiological and sensorial shelf life of ground beef. *LWT* **2018**, *96*, 482–490. [CrossRef]
5. Schuhmacher, A.; Reichling, J.; Schnitzler, P. Virucidal effect of peppermint oil on the enveloped viruses herpes simplex virus type 1 and type 2 in vitro. *Phytomedicine* **2003**, *10*, 504–510. [CrossRef] [PubMed]
6. Saad, N.Y.; Muller, C.D.; Lobstein, A. Major bioactivities and mechanism of action of essential oils and their components. *Flavour Fragr. J.* **2013**, *28*, 269–279. [CrossRef]
7. Maffei, M.; Chialva, F.; Sacco, T. Glandular trichomes and essential oils in developing peppermint leaves. *New Phytol.* **1989**, *111*, 707–716. [CrossRef]
8. Deutscher Apotheker Verlag. *Pharmacopoeia Europaea—Europäisches Arzneibuch*; Amtliche Deutsche Ausgabe; Deutscher Apotheker Verlag: Stuttgart, Germany, 2020; ISBN 978-3-7692-7515-5.
9. Gordon, W.P.; Huitric, A.C.; Seth, C.L.; McClanahan, R.H.; Nelson, S.D. The metabolism of the abortifacient terpene, (R)-(+)-pulegone, to a proximate toxin, menthofuran. *Drug Metab. Dispos.* **1987**, *15*, 589–594. [PubMed]
10. Nair, B. Final report on the safety assessment of Mentha Piperita (Peppermint) Oil, Mentha Piperita (Peppermint) Leaf Extract, Mentha Piperita (Peppermint) Leaf, and Mentha Piperita (Peppermint) Leaf Water. *Int. J. Toxicol.* **2001**, *20*, 61–73. [PubMed]
11. Lawrence, B.M. (Ed.) *Mint: The Genus Mentha*; CRC Press, Taylor & Francis Group: Boca Raton, FL, USA, 2006.
12. Kizil, S.; Tonçer, Ö. Influence of different harvest times on the yield and oil composition of spearmint (*Mentha spicata* L. var. *spicata*). *J. Food Agric. Environ.* **2006**, *4*, 135–137.
13. Rohloff, J.; Dragland, S.; Mordal, R.; Iversen, T.-H. Effect of harvest time and drying method on biomass production, essential oil yield, and quality of peppermint (*Mentha* × *piperita* L.). *J. Agric. Food Chem.* **2005**, *53*, 4143–4148. [CrossRef]
14. Duriyaprapan, S.; Britten, E.J. The Effects of Solar Radiation on Plant Growth, Oil Yield and Oil Quality of Japanese Mint. *J. Exp. Biol.* **1982**, *33*, 1319–1324. [CrossRef]

15. Maffei, M.; Scannerini, S. UV-B Effect on Photomorphogenesis and Essential Oil Composition in Peppermint (*Mentha piperita* L.). *J. Essent. Oil Res.* **2000**, *12*, 523–529. [CrossRef]
16. Maffei, M.; Canova, D.; Bertea, C.M.; Scannerini, S. UV-A effects on photomorphogenesis and essential-oil composition in *Mentha piperita*. *J. Photochem. Photobiol. B Biol.* **1999**, *52*, 105–110. [CrossRef]
17. Hatfield, J.L.; Walthall, C.L. Meeting Global Food Needs: Realizing the Potential via Genetics × Environment × Management Interactions. *Agron. J.* **2015**, *107*, 1215–1226. [CrossRef]
18. Mehasen, H.E.D.; Hamouda, A.A.; Soliman, S. Effect of some postharvest treatments on peppermint quality. *J. Product. Dev.* **2009**, *14*, 375–390. [CrossRef]
19. Leibniz Institute for Agicultural Engineering and Bioeconomy. *Leitfaden Trocknung von Arznei-und Gewürzpflanzen*; Leibniz Institute for Agicultural Engineering and Bioeconomy: Potsdam, Germany, 2017.
20. Díaz-Maroto, M.C.; Pérez-Coello, M.S.; Vinas, M.A.G.; Cabezudo, M.D. Influence of Drying on the Flavor Quality of Spearmint (*Mentha spicata* L.). *J. Agric. Food Chem.* **2023**, *51*, 1265–1269. [CrossRef]
21. Shittu, S.K.; Shehu, M.I.; Suleiman, J. Effect of the drying method on the quality and drying characteristic of mint leaves. *FJS* **2021**, *5*, 72–78. [CrossRef]
22. Stanisavljević, D.M.; Đorđević, S.M.; Ristić, M.S.; Veličković, D.T.; Ranđelović, N.V. Effects of different drying methods on the yield and the composition of essential oil from herb *Mentha longifolia* (L.) Hudson. *Biol. Nyssana* **2010**, *1*, 89–93.
23. Pandey, P.; Upadhyay, R.K.; Padalia, R.C.; Venkatesha, K.T.; Kumar, D.; Chauhan, A.; Tiwari, A.K.; Singh, V.R. Standardization of post-harvest practices for best quality essential oil production of *Mentha arvensis* L. *Environ. Conserv. J.* **2023**, *24*, 232–237. [CrossRef]
24. Aćimović, M.; Lončar, B.; Kiprovski, B.; Stanković Jeremić, J.; Todosijević, M. Chamomile essential oil quality after postharvest separation treatments. *Ratar. Povrt.* **2021**, *58*, 72–78. [CrossRef]
25. Guo, H.L.; Chen, Y.; Xu, W.; Xu, M.-T.; Sun, Y.; Wang, X.-C.; Wang, X.-Y.; Luo, J.; Zhang, H.; Xiong, Y.-K. Assessment of Drying Kinetics, Textural and Aroma Attributes of Mentha haplocalyx Leaves during the Hot Air Thin-Layer Drying Process. *Foods* **2022**, *11*, 784. [CrossRef]
26. Mahanta, B.P.; Bora, P.K.; Kemprai, P.; Borah, G.; Lal, M.; Haldar, S. Thermolabile essential oils, aromas and flavours: Degradation pathways, effect of thermal processing and alteration of sensory quality. *Food Res. Int.* **2021**, *145*, 110404. [CrossRef] [PubMed]
27. Mokhtarikhah, G.; Ebadi, M.-T.; Ayyari, M. Qualitative changes of spearmint essential oil as affected by drying methods. *Ind. Crops Prod.* **2020**, *153*, 112492. [CrossRef]
28. Tanko, H.; Carrier, D.J.; Duan, L.; Clausen, E. Pre- and post-harvest processing of medicinal plants. *Plant Genet. Resour.* **2005**, *3*, 304–313. [CrossRef]
29. Acar, C.; Dincer, I.; Mujumdar, A. A comprehensive review of recent advances in renewable-based drying technologies for a sustainable future. *Dry. Technol.* **2022**, *40*, 1029–1050. [CrossRef]
30. Caser, M.; Falla, N.M.; Demasi, S.; Scariot, V. From Fresh to Dried Lavender Flower: Changes in Phytochemical Profile According to Drying Method. *Horticulturae* **2023**, *9*, 700. [CrossRef]
31. Taranto, F.; Pasqualone, A.; Mangini, G.; Tripodi, P.; Miazzi, M.M.; Pavan, S.; Montemurro, C. Polyphenol Oxidases in Crops: Biochemical, Physiological and Genetic Aspects. *Int. J. Mol. Sci.* **2017**, *18*, 377. [CrossRef]
32. Giménez-Santamarina, S.; Llorens-Molina, J.A.; Sempere-Ferre, F.; Santamarina, C.; Roselló, J.; Santamarina, M.P. Chemical composition of essential oils of three Mentha species and their antifungal activity against selected phytopathogenic and post-harvest fungi. *Life* **2022**, *15*, 64–73. [CrossRef]
33. Lawrence, B.M. *A Study of the Monoterpene Interrelationships in the Genus Mentha with Special Reference to the Origin of Pulegone and Menthofuran*; Print Three Inc.: Toronto, ON, Canada, 1978.
34. Grulova, D.; de Martino, L.; Mancini, E.; Salamon, I.; de Feo, V. Seasonal variability of the main components in essential oil of *Mentha* × *piperita* L. *J. Sci. Food Agric.* **2015**, *95*, 621–627. [CrossRef]

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