
**Changes in the Aroma Composition of Different
Plant Parts in Stevia (*Stevia rebaudiana* Bertoni)
Depending on Various Drying Methods**

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INTRODUCTION

Stevia (*Stevia rebaudiana* Bertoni), a perennial plant belonging to the Asteraceae family, is native to South America and has been used as a natural sweetener for centuries, particularly in Paraguay and Brazil (Gasmalla et al., 2017). Today, this species, which is successfully cultivated in Asia, Europe, and North America, has gained increasing economic importance worldwide due to the steviol glycosides found in its leaves, which are approximately 200-300 times sweeter than sucrose, have low calories, and do not cause a glycemic response (Kinghorn, 2002; Hossain et al., 2017). The European Food Safety Authority (EFSA) and the World Health Organization have also reported that high-purity stevia extracts are safe for human consumption (Hossain et al., 2017). Stevia-specific bioactive compounds, obtained by drying stevia leaves, are used both in pharmacology and as a food additive (Lemus-Mondaca et al., 2012). Stevia leaves, which have high sweetness potential without being high in calories, have been used by the Guarani people for centuries. The steviol glycosides stevioside and rebaudioside A are 150–300 times sweeter than sucrose (Markovic et al., 2008). The main chemical components contained in stevia leaves are diterpene steviol glycosides, phenolic compounds, flavonoids, alkaloids, chlorophylls, fatty acids, and various volatile oil fractions. Extracts obtained from leaves are reported to be rich in flavonoids, alkaloids, chlorophylls, hydroxycinnamic acids (such as caffeic and chlorogenic acids), oligosaccharides, free sugars, amino acids, lipids, and minerals (Gasmalla et al., 2017).

Studies on the volatile compounds of stevia indicate that monoterpenes, sesquiterpenes, and oxygenated volatile compounds are predominant in the plant's leaves. The essential oils found in stevia leaves are particularly rich in mono- and sesquiterpenes, and components such as α -cadinol, caryophyllene oxide, β -guaiene, and spathulenol have been identified as the main components of the plant's essential oil (Markovic et al., 2008). Stevia attracts attention not only for its sweetening

properties but also for its therapeutic potential. Various studies have demonstrated that leaf extracts exhibit antihypertensive, antihyperglycemic, anti-inflammatory, antimicrobial, and antitumor effects (Muanda et al., 2011). A significant portion of these biological activities stems from the phenolic compounds and volatile oil components in the leaves. Studies have shown that *Stevia* leaves contain important biologically active fractions that possess not only sweetening properties but also antioxidant and phytotoxic properties (Nuryandani et al., 2024).

The preservation of the chemical composition of plant material is directly related to the drying method, one of the most critical stages in post-harvest applications. Drying inhibits the growth of microorganisms and prevents certain biochemical events that could alter the organoleptic properties of plants (Hossain et al., 2010). Although drying is necessary to prevent microbial growth and ensure storage stability, high temperatures and long drying times can lead to losses in the color, aroma, volatile oil composition, and biologically active components of plants (Diaz-Maroto et al., 2002; Hossain et al., 2017). The selection of drying technology is important for preserving bioactive plants in stevia plants (Roohinejad et al., 2025). Therefore, the drying method chosen plays a decisive role in preserving volatile components. The aroma composition of the leaves is a decisive quality criterion in the industrial use of the stevia plant. However, the aroma profile is significantly affected by post-harvest processes, particularly drying methods. The drying process can alter the amount and composition of volatile compounds. While high temperatures can cause oxidation and loss of volatile components, low-temperature methods are more suitable for preserving aroma. Although there are numerous studies in the literature on the drying of medicinal and aromatic plants, studies examining how the volatile compound profiles of stevia leaves and different plant parts change depending on drying conditions are quite limited. Previous studies have determined that different drying processes significantly alter the volatile compound composition in stevia leaves, and it has been reported that microwave

drying in particular leads to a more compact and homogeneous structure (Gasmalla et al., 2017). Similarly, freeze-drying has been noted as the most effective approach for preserving both volatile compounds and phenolic content, while hot-air drying has been reported to cause losses of volatile compounds (Periche et al., 2016).

Drying methods not only affect the amount of volatile components but also cause oxidation or esterification in the components and can alter the qualitative structure of the volatile fraction due to exposure to various thermal reactions (Diaz-Maroto et al., 2003; Periche et al., 2016). In this context, the sensitivity of monoterpenes to temperature increases is a key factor explaining why freeze-drying provides higher protection. The volatile compound profile varies across different anatomical parts of the *Stevia* plant (leaves, stems, flowers, etc.). While the leaf portion offers a richer volatile profile, various studies have indicated that flowers may contain more diverse but lower concentrations of compounds (Marković et al., 2002; Muanda et al., 2011). Therefore, evaluating the effects of drying methods separately for different parts of the plant is a critical requirement for industrial applications.

In this context, understanding how the aroma components in different parts of the *stevia* plant (leaves, stems, flowers) change depending on the drying method used is of great importance both for maintaining product quality and for determining the most suitable technological processes for processing raw materials for functional food, cosmetic, and pharmaceutical applications. The sensitivity of *Stevia*'s volatile components to processing conditions necessitates a detailed examination of the effects of drying methods on aroma stability. This study examines how the aroma component composition in different parts of the *stevia* plant changes under various drying methods, based on current scientific findings, and comprehensively evaluates the role of drying processes on aromatic quality. In this regard, the effects of drying techniques on both the qualitative (component diversity) and quantitative (component concentration) properties of volatile compounds have been

evaluated comparatively. Additionally, by determining the aromatic responses of different plant parts to drying processes, the aim is to establish a scientific basis for preserving or enhancing the targeted aroma profile in the industrial processing of the stevia plant.

1. MATERIALS VE METHODS

1.1. Plant Material

The research was conducted at the Experimental Field of the Faculty of Agriculture, Recep Tayyip Erdoğan University (Figure 1). Different plant parts of *Stevia rebaudiana* Bertoni were used as material in the research. After harvesting the stevia plant, the flowers, stems, and leaves were separated. The samples were then dried using two different drying techniques: in an oven and in a lyophilizer (Figure 2).



Figure 1: Images of the *Stevia rebaudiana* Bertoni plant cultivated in the test area



Figure 2: Images related to the drying of Stevia plant samples using a lyophilizer

1.2. Sample Preparation and Aroma Components Analysis

Samples of the collected stevia plant parts were dried in an oven at 40°C for 24 hours, then ground and passed through 2 mm pore size laboratory sieves to prepare them for analysis. Analysis was performed using a GC-MS Device (Shimadzu, Japan) equipped with SPME (Figure 3.a). Ground plant samples weighing 0.2 g were then placed into a 10 mL vial and sealed with a silicone-rubber septum lid (Figure 3.b).

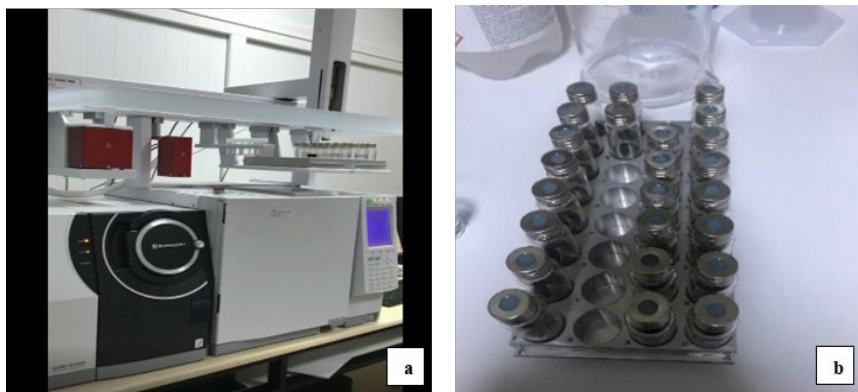


Figure 3: Images of the Gas Chromatography Mass Spectrometer (GCMS) device (a) and samples prepared for analysis (b)

Manufacturer guidelines were followed to precondition the fiber. The fiber was left in the headspace at equilibrium for one minute at room temperature. After sampling, the fiber was placed into the needle and then moved to the injection port of the GC-MS device. The column was a CP 5MS (30 m x 0.25 mm i.d., film thickness 0.25 μ m). The oven temperature was set to isothermal at 220 °C for 20 minutes after being scheduled to rise from 40 °C to 240 °C at 2 °C/min. Helium was used as the carrier gas at a constant flow rate of 1 mL/min. The FFNSC 1.2 databases were used to determine the constituents of essential oils (Seyis et al., 2022).

2. RESULTS AND DISCUSSION

Within the scope of this study, data on the amounts of aroma components in the leaves, flowers, and stems of the stevia plant, depending on different drying methods, are presented in Table 1. The effects of oven drying and freeze-drying (lyophilization) methods applied to samples from different parts of the Stevia (*Stevia rebaudiana* Bertoni) plant (flower, stem, and leaf) on aroma components were determined using a GC–MS device. The results obtained revealed that the volatile component composition showed significant differences depending on both the plant part and the drying method applied.

Table 1. Change in aroma components in stevia plant parts based on drying methods (%)

Chemical Group	R.T.*	R.I.**	Component	O.D. Flower	O.D. Stem	O.D. Leaf	L.D. Flower	L.D. Stem	L.D. Leaf
Monoterpene Hydrocarbons	9.151	933	α -Pinene				0,54		
	10.740	975	β -Pinene	2,33		1,52	10,39	3,34	1,51
			TOPLAM	2,33		1,52	10,93	3,34	1,51
	15.563	1100	Linalool	0,37		0,71	1,07		
Oxygenated Monoterpenes	15.569	1212	Linalyl formate					0,57	1,19
	19.018	1198	α -Terpineol			0,18			
	19.029	1306	α -Terpinyl formate					0,41	0,36
			TOPLAM	0,37		0,89	1,07	0,98	1,55
Sesquiterpene Hydrocarbons	26.051	1382	β -Bourbonene			0,79			0,64
	26.210	1375	α -Copaene			0,28			
	26.275	1390	β -Elemene	0,56	0,53	0,27		0,47	0,47
	26.894	1406	α -Gurjunene	0,28	0,62	0,18	0,33	1,57	
	27.263	1418	β -Caryophyllene	28	8,59	26,39	32,6	26,05	23,2
	27.745	1432	α -trans-Bergamotene	7,33	3,12	7,93	8,99	10,01	7,79
	28.379	1452	(E)- β -Farnesene	22	31,37	21,53	13,16	15,57	23,23
	29.238	1480	Germacrene D	6,11	7,53	5		5,41	5,41
	29.259	1512	γ -Cadinene	1,07	1,51	1,47	4,58	2,55	1,6
	30.570	1518	δ -Cadinene	1,92	2,48	2,23		2,22	2,11
	29.417	1487	β -Selinene		0,6				

Table 1. (Continued)

	29.656	1496	α -Zingiberene	1				
	29.755	1491	Viridiflorene	11,65	5,51			
	29.665	1387	7-epi-Sesquithujene			1,09	1,28	0,67
	29.770	1557	Germacrene B	5,84	7,55			
	29.761	1479	β -Chamigrene		0,5		3,39	6,24
	29.844	1497	α -Muurolene	0,34	0,23			
Sesquiterpene Hydrocarbons	30.578	1423	β -Cedrene			1,62		
	30.814	1459	α -Patchoulene	0,21				
	31.767	1508	β -Bisabolene	2,56	2,24	4,11	5,79	5,61
	33.100	1458	Aromadendrene	9,67		0,55	0,52	0,76
	34.477	1480	α -Curcumene	0,3	0,81	0,48	0,66	0,93
	35.502	1459	Alloaromadendrene	0,45	0,33	0,79		
	34.584	1492	Valencene			0,52		
	TOPLAM			80,67	76,11	75,82	76,04	75,49
	31.755	1562	Nerolidol	3,11		3,26		
Oxygenated Sesquiterpenes	32.115	1688	α -Bisabolol			0,3		0,58
	32.295	1576	Spathulenol	4,15	11,52	5,73	3,01	9,27
	32.395	1610	Cedrol	0,7	1,34	1,09		
	32.480	1587	Caryophyllene oxide	2,25		4,54	2,64	5,93
								5,59

Table 1. (Continued)

Oxygenated Sesquiterpenes	33.220	1632	γ -Eudesmol				0,8			
	33.537	1688	(Z)- α -trans-Bergamotol				1,05	0,19	1,28	0,39
	33.906	1624	epi- γ -Eudesmol				0,27	1,97	2,38	
	34.173	1641	epi- α -Muurolol				1,01	1,74	1,23	0,96
	34.462	1676	α -Santalol				0,62			
	35.700	1760	cis-Lanceol				0,46	5,52	0,29	0,58
	43.778	1594	Viridiflorol				1,68	0,29	0,27	1,11
			TOPLAM				14,68	22,57	18,31	8,99
	10.930	978	Vinyl amyl carbinol							
	15.745	1104	Butyrate (2-methylbutyl)				0,35			
Alcohols, Ketones, Aldehydes, Furans	15.751	1042	2-methylbutyl butyrate				1,06		0,76	0,75
	20.766	1243	3-methyl hexyl butanoate							
	32.600	1573	Tridec-2(E)-enal				0,28			
	39.775	1841	Phytone				0,19	0,65		
	43.766	2016	Civetone				0,56			
	34.084	1647	Amyl cinnamaldehyde				0,88	0,76		
	45.763	1884	Cetyl alcohol				0,61		0,69	
			TOPLAM				1,97	0,28	2,38	2,97
	32.810	1500	Pentadecane				0,32			
	32.819	1600	Hexadecane				0,34			
Arenes	45.748	2100	Heneicosane				0,17			
			TOPLAM				0,32	0,17	0,34	
		GENEL TOPLAM				100,02	100	99,09	100	99,9

According to the analysis results, it was determined that the fraction richest in terms of total volatile compound number and compound concentration was generally found in leaf samples. The major compounds detected in all plant parts, although varying depending on the drying method, were β -Caryophyllene, β -Farnesene, α -trans-Bergamotene, and Spathulenol. At the same time, among the chemical groups, sesquiterpene hydrocarbons have the highest amount, followed by oxygenated sesquiterpenes. An increase in component diversity has been observed in samples where freeze-drying was applied to the flower and stem parts of the plant. However, it has been observed that the concentrations of these components vary depending on the drying method. When drying flower and stem samples in an oven, the amounts of β -pinene, α -trans-Bergamotene, β -Caryophyllene, β -Bisabolene, and Caryophyllene oxide decreased compared to lyophilization, while the amounts of compounds such as Spathulenol, β -Farnesene, and Germacrene D increased. In flower samples dried in an oven, the fact that most components are either found at very low levels or are completely lost indicates that the volatile components in flower tissue are more sensitive to heat. In leaf samples, when freeze-drying (lyophilization) was performed instead of drying in an oven, the amount of β -caryophyllene decreased, but the amounts of important compounds such as β -farnesene, β -chamigrene, β -bisabolene, spathulenol, and caryophyllene oxide increased. In general, freeze-drying has been found to be more effective in preserving both the quality and quantity of volatile aroma components.

The findings of this study reveal that the aroma components in *Stevia rebaudiana* vary significantly depending on both the plant part and the drying method applied. The results of the study are largely consistent with previous studies conducted on stevia and other medicinal aromatic plants.

The study determined that leaf samples have a richer and more concentrated volatile compound profile compared to flower and stem

tissues. This situation is consistent with studies in the literature that define Stevia leaves as the primary source of volatile oils and aroma components. Stevia leaves have been reported to be rich in monoterpenes, sesquiterpenes, and oxygenated terpenes; it has been emphasized that the leaf tissue is the most valuable part of the plant in terms of aromatic quality (Muanda et al., 2011). Tursun et al. (2021) reported that terpenes were detected in the highest concentration in the total volume of aromatic substances as a result of their research. Similarly, caryophyllene oxide, spathulenol, and various terpene derivatives have been reported to be predominant in stevia leaf essential oils (Markovic et al., 2008). In this study, the components identified in the leaves, such as β -pinene, spathulenol, β -farnesene, and β -caryophyllene, demonstrate that the aromatic character of stevia leaves is consistent with the literature.

Freeze-drying has attracted attention in the samples applied, as it preserves volatile components better and yields a more balanced profile in terms of component distribution. This finding is consistent with the results of a study conducted on Stevia leaves (Periche et al., 2016). In the study in question, it was stated that freeze-drying is the most effective method for preserving both phenolic compounds and aroma components, while hot air and oven drying cause losses of volatile compounds. Similarly, Gasmalla et al. (2017) reported that thermal processes such as microwave and hot air drying cause the breakdown of volatile compounds, while drying methods performed at low temperatures better preserve aromatic quality. Compared to other drying methods, vacuum drying has been reported to preserve vitamin (vitamin C and E), polyunsaturated fatty acid, and stevioside content. (Lemus-Mondaca et al., 2016). The reduction or complete loss of some volatile components in oven-dried samples can be explained by the thermal degradation and volatilization mechanisms frequently emphasized in the literature. It has been reported that exposure to high temperatures in aromatic plants leads to the oxidation of monoterpenes and ester hydrolysis, resulting in significant losses in the aroma profile (Diaz-Maroto et al., 2003). In this

study, the decrease in volatile compound diversity following oven drying, particularly in flower and stem tissues, indicates that these tissues are more sensitive to heat.

The limited diversity of volatile compounds in flower samples compared to leaves, but the preservation of some monoterpenes through freeze-drying, suggests that the aromatic potential of *Stevia* flowers is largely dependent on processing conditions. Zygadlo et al. (1997) reported that volatile oil content varies depending on the anatomical part of the plant and that flower tissues generally offer a more delicate volatile profile. The findings of this study support the aforementioned assessments specifically regarding *Stevia*. The low content of volatile compounds in the leaf tissue is consistent with the view in the literature that *Stevia* leaves are generally of secondary importance in terms of aromatic quality. However, the fact that some volatile components can be preserved even in the stem tissue after freeze-drying indicates that this method offers a potential advantage not only for leaves but also for other plant parts. This situation demonstrates that the drying method can modulate the aromatic responsiveness specific to plant tissue.

Overall, the results obtained in this study indicate that low temperature, reduction of oxidative stress, and preservation of cellular structure without damage are critically important for the preservation of aroma components in *Stevia* plants. These findings strongly parallel previous studies emphasizing that freeze-drying should be preferred for quality-focused applications in aromatic and medicinal plants. In conclusion, this study expands the limited information in the literature by detailing the aromatic responses of different parts of the *Stevia* plant to drying methods, providing important scientific contributions, particularly to industrial processing, quality standardization, and target aroma profile development studies.

3. CONCLUSIONS

The findings obtained in this study clearly demonstrate that the aroma composition of *Stevia rebaudiana* is strongly dependent on both the plant part and the drying method applied. Leaves are the richest part of the Stevia plant in terms of aroma components, while flowers have a more limited but selective aroma profile, and the stem tissue has been found to have a relatively low volatile component content. When drying methods are compared, freeze-drying (lyophilization) has emerged as a more successful method than oven drying in preserving Stevia's natural aroma profile.

It has been determined that heat-sensitive compounds, particularly monoterpenes and oxygenated terpenes, decompose or evaporate during oven drying; however, these compounds are largely preserved by freeze-drying. This situation demonstrates that minimizing low temperatures and oxidative stress is critical for aroma stability.

The results obtained indicate that the drying method is a strategic decision for processing stevia in a way that preserves its aromatic quality in the food, functional product, and cosmetics industries. Especially in applications where high aromatic quality is targeted, it is recommended to process the leaf tissue using the freeze-drying method. Furthermore, the fact that different parts of the plant have different aromatic reactivity indicates that the plant part and drying method must be evaluated together according to the intended industrial use. This study addresses drying-based changes in the aroma components of the stevia plant using a holistic approach, filling an important gap in the literature and providing a scientific basis for future quality optimization and process development studies.

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