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Hazel leaves as novel herbal tea ingredient: Evaluation of functional properties, sensory characteristics, and consumers' acceptability

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PAPER

Abstract

Although hazel leaves have historically been used in traditional medicine, they have not yet been studied as an ingredient in food or beverages. This research investigates the potential use of *Corylus avellana* L. (hazel) leaves in the preparation of herbal teas. The impact of two drying methods, Air Drying (AD) 50°C/3 h and Microwave Drying (MWD) 400 W/4 min, on the phenolic content, volatile aroma compounds, sensory profile, and consumers' acceptability of the resulting herbal teas was evaluated. The results showed that MWD determined a higher total phenolic content (0.78 mg/L GAE) compared to AD (0.70 mg/L GAE), while the DPPH assay showed a similar antioxidant capacity (35.4% AD vs 35.6% MWD). Volatile compound and sensory analyses revealed that MWD enhanced the formation of aldehydes and ketones associated with fruity, citrus, and sweet notes, whereas in AD samples, grassy and herbaceous volatiles such as unsaturated alcohols and aldehydes prevailed. Consumers' acceptability, evaluated through the Hedonic Scale Method, demonstrated a clear preference for MWD herbal teas. Overall, hazel leaf herbal teas represent a promising approach to valorizing agricultural by-products, combining health-promoting potential with sustainability. MWD emerges as the more suitable drying technique to optimize both functional and sensory qualities, highlighting practical applications in the herbal tea industry, in line with current consumer trends and the rapidly growing herbal tea market.

Keywords: consumers' acceptability; drying technologies; hazel leaves; herbal tea; volatile aroma compounds

Introduction

The European hazel (*Corylus avellana* L.) belongs to the genus Corylus, family Betulaceae (Erdogan and Mehlenbacher, 2000); native to the Black Sea region, its cultivation is now widespread in many countries of the Mediterranean basin (Boccacci and Botta, 2009). Turkey is the world's largest producer of European hazel with over 67% of global production, followed by Italy (12 %), Azerbaijan (5 %), and the United States (4 %). In Italy, the main production areas are Campania, Piedmont, Lazio, and Sicily regions (Squara *et al.,* 2022).

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The fruit is the main product of *C. avellana* L., consumed whole as an ingredient in various food products and processed to extract the oil, used in cosmetics and as a food condiment (Alasalvar and Shahidi, 2008). Both the nuts and the oil are known for their chemical composition, which makes these products important for a healthy diet (Maguire *et al.,* 2004; Phillips *et al.,* 2005; Shahidi and Miraliakbari, 2005, 2006; Venkatachalam and Sathe, 2006).

However, hazel by-products, such as the peel, shell, and leaves, are also rich in phytochemicals with recognized antioxidant, free radical scavenging (Alasalvar *et al.,* 2006; Oliver Chen and Blumberg, 2008; Shahidi *et al.* 2007), anticarcinogenic and antimutagenic properties, and positive effects on coronary heart disease, osteoporosis, and diabetes (Jiang *et al.,* 2002).

The possibility of using dried hazel leaves as ingredients results in their inclusion in the diet as substances with human health benefits. This is supported by several studies showing the potential of stems, leaves, and other parts of different plants to produce herbal teas with high bioactive power (Alasalvar and Shahidi, 2008; Huda *et al.,* 2024; Jimenez-Lopez *et al.,* 2020; Pavlić *et al.,* 2023; Tapsell *et al.,* 2004). In this context, hazel leaves have been used in traditional Iranian medicine as a liver tonic (Akbarzadeh *et al.,* 2015). Today, the leaves are also often used in galenic preparations for the treatment of hemorrhoids, varicose veins, phlebitis, edema of the lower limbs (Amaral *et al.,* 2010), and chronic pain (Bottone *et al.,* 2019).

However, to the best of our knowledge, no study has investigated the use of hazel leaves as ingredients in the preparation of food products and beverages, such as herbal teas.

Today, the European herbal tea market is growing rapidly, with an annual growth rate (CAGR) of 5.49% for the period 2024–2032, oriented toward the use of organic and natural ingredients that combine health and sustainability (Euromonitor International, 2023). A majority of people choose herbal teas not only for their varied taste but also for their beneficial effects, preferring them to traditional drinks such as black or green tea. In this context, herbal teas made from alternative natural products, by-products, or agricultural waste are attracting increasing interest (Verified Market Research, 2025). Their use allows the production of herbal teas with a focus on economic and environmental sustainability (Cincotta *et al.,* 2024, 2025).

The drying process is essential for using leaves in herbal tea preparation and to prolong their shelf life. Drying techniques play a key role in the sustainable valorization of plant resources. Recent studies, conducted on leaves from different species, used Air Drying (AD) and Microwave Drying (MWD) as drying systems, demonstrating the effects of different methods on the final product quality (Cincotta *et al.*, 2024, 2025). Moreover, MWD is characterized by its energy efficiency and reduced processing time compared to traditional methods. This approach contributes to lower energy consumption and emissions, making it a more sustainable process (Nowacka *et al.,* 2024).

In this context, the research aims to evaluate the possibility of using hazel leaves to produce functional and sustainable herbal teas appreciated by consumers. The leaves, used for the production of herbal teas, were dried using different drying technologies, such as AD and MWD, and characterized for their volatile aroma compounds, which are responsible for their sensory characteristics and consumers' acceptability. This work provides new insights into the valorization of hazel by-products and contributes to the development of environmentally sustainable, functional herbal beverages.

Materials and Methods

Sample collection and drying processes

Fresh leaves of *C. avellana* L. (1753) were harvested randomly from a hazel grove located in Sicily, Italy, during October 2024, before their natural abscission, and damaged ones were discarded. Following this, the leaves were immediately transported to the laboratory where they were cleaned with cold water to remove surface impurities, split into two batches, and subjected to two different drying treatments: Air Drying (AD) and Microwave Drying (MWD).

The drying protocols were adapted from those reported by Cincotta *et al.* (2025). For the AD process, 10 leaves were placed in a tray dryer (Armfield Ltd., Model UOP8, Hampshire, UK) operating at 50°C for 3 h, with a constant airflow rate of 1.5 m/s. In the MWD process, the leaves were placed on a ceramic plate inside a microwave oven (LG Electronics Inc, Model MH8265DPS. CB1QUESD, Amstelveen, The Netherlands) at 400 W for 4 min.

The drying conditions (temperature, time, and power) were selected based on previous optimization tests (Cincotta *et al.,* 2025) and aimed at achieving optimal sensory characteristics as determined in pretrials by a trained panel. The initial moisture content of the leaves was approximately 73%, and drying was carried out until a moisture reduction of 98% was achieved (final moisture 1.46 %). This was monitored by periodically weighing the samples using an analytical balance (Sartorius, Model

QUINTIX 65-1S, Göttingen, Germany) with a precision of 0.0001 g. All drying experiments were performed in triplicate under the same conditions.

Hazel leaf herbal tea preparation

The preparation of hazel leaf herbal tea followed the same protocol used by Cincotta *et al.* (2025). Briefly, 3 g of finely chopped hazel leaves were infused in 120 mL of mineral water at 95°C for 10 min. The solution was then filtered using standard filter paper (Munktell & Filtrak, Barenstein, Germany) and subsequently cooled to ambient temperature (22°C). All infusions were prepared and analyzed in triplicate to ensure repeatability. The obtained herbal tea was then used for the following analysis.

Total phenolic content and antioxidant capacity

The total polyphenol content (TPC) and antioxidant capacity (AC) of hazel leaf herbal tea were determined through spectrophotometric analysis, employing the Folin–Ciocalteu method and DPPH assay, respectively, following the protocol described by Vinci *et al.* (2022).

Volatile aroma compound analysis

The analysis of volatile aroma compounds in hazel leaf herbal tea was performed following the method by Cincotta *et al.* (2025) using headspace solid-phase microextraction coupled with gas chromatography–mass spectrometry (HS-SPME-GC-MS). An 18 mL aliquot of herbal tea was placed into a 40 mL glass vial to which 4 g of NaCl was added, and equilibrated at 30°C for 30 min. A DVB/CARB/PDMS fiber was then exposed to the vial headspace for 30 min to extract volatile compounds, followed by desorption in the GC injector for 3 min at 260°C.

GC-MS analysis was performed using a Shimadzu GC-2010 Plus gas chromatograph coupled with a TQMS 8040 triple-quadrupole mass spectrometer (Shimadzu, Milan, Italy), equipped with a Vf-Wax-ms capillary column (60 m × 0.25 mm i.d., 0.25 µm film thickness). The chromatographic conditions were as follows: injector temperature of 260°C; splitless injection mode; oven temperature of 45°C (held for 5 min) to 110°C at 5°C/min, and ramped to 260°C at 20°C/min; helium as carrier gas at a constant flow rate of 1 mL/min; and transfer line temperature set at 250°C. Mass spectra were acquired over an m/z range of 40–400 with a scan speed of 1250 amu/s. Compound identification was performed by matching mass spectra with the NIST'24 library (NIST/EPA/NIH Mass Spectra Library, Wiley, Gaithersburg, MD, USA) and the FFNSC 3.0 database, injection of analytical standards, calculation of linear retention indices (LRIs) using the Van den Dool and Kratz equation, and relevant literature. Results were expressed as relative peak area percentages.

Qualitative descriptive analysis

The qualitative descriptive analysis (QDA) of the hazel leaf herbal teas followed the method reported by Cincotta *et al.* (2025). All participants signed an informed consent under the principles outlined by the Helsinki Declaration. The sensory panel underwent a 4-week training program aligned with ISO 8586:2023 standards. During preliminary sessions, a range of sensory descriptors was generated, from which 17 were selected based on frequency of citation.

Each descriptor was clearly defined and explained to avoid ambiguity. The descriptors were subsequently validated using reference standards, enabling panelists to calibrate their sensory perceptions and maintain consistency in descriptor use across different sessions. The intensity of each sensation was rated on a scale from 1 (absence of sensation) to 9 (extremely intense).

Evaluations took place between 10:00 a.m. and 12:00 p.m. in individual booths illuminated with white light. The sample presentation order was randomized across participants and sessions. Water and unsalted crackers were provided between samples for palate cleansing. Data collection was performed using a computerized registration system (FIZZ Byosistemes ver. 2.00 M, Couternon, France).

Consumers' acceptability test

The acceptability test involved 80 participants (41 males and 39 females) aged 24–60 years. Participants were randomly recruited by convenience sampling among students and staff of the Department of Veterinary Sciences at the University of Messina who regularly consumed herbal teas. Participation in the survey was completely voluntary. The samples were evaluated for color, appearance, odor, taste, and overall acceptability using a hedonic scale ranging from 1 (extreme dislike) to 9 (extreme appreciation) (Cincotta *et al.*, 2025). Each participant assessed the samples over four separate sessions.

Statistical analysis

Statistical analyses were performed using XLStat software, version 2024.1 (Addinsoft, New York, NY, USA). A one-way analysis of variance (ANOVA) followed by Duncan's multiple range test was applied to both chemical and sensory data at a 95% confidence level. Principal component analysis (PCA) was used to analyze chemical and sensory data (Tripodi *et al.*, 2025).

Results and Discussions

Total phenolic content and antioxidant activity

Figure 1 reports the TPC (expressed as mg/L gallic acid equivalents) and the percentage of AC in hazel leaf herbal tea, prepared with AD and MWD leaves. The results showed a statistically significant difference between the two drying techniques in terms of TPC, whereas no statistical difference was observed for the AC%.

The TPC was slightly higher in the microwave-dried leaf herbal tea (0.78 mg/L GAE) compared to the air-dried ones (0.70 mg/L GAE). According to other authors, this suggests that MWD is more effective in preserving or extracting phenolic compounds from hazel leaves (Snoussi *et al.,* 2021). In contrast, the antioxidant capacity values were similar (35.4 ± 0.2 % for AD and 35.6 ± 0.1 % for MWD).

These findings are consistent with previous studies highlighting the advantages of MWD in retaining phenolic compounds in plant materials. For example, Sultana *et al.* (2012) and Lasano *et al.* (2018) demonstrated that MWD increased the TPC and antioxidant activity in *Strobilanthes crispus* leaves and in herbal tea from *S. crispus* leaves, respectively, than conventionally dried samples. Similarly, an increase in TPC was observed in herbal teas prepared with MWD leaves of avocado and fig compared to AD leaves, by using the same conditions used in the present study (Cincotta *et al.,* 2024, 2025). This could be attributed to the fact that MWD offers volumetric heating, which facilitates quick moisture removal while minimizing thermal degradation (Ozdemir and Karagoz, 2024; Salehi *et al.,* 2023).

Differently, AD, due to its longer exposure times, may result in partial degradation or transformation of heat-sensitive phenolic compounds. Moreover, faster enzyme inactivation using microwaves helps preserve antioxidant-related molecules that might otherwise be oxidized during slower drying processes (Dhar and Chakraborty, 2024).

In most cases, polyphenols are the main contributors of the AC (Barimah *et al.*, 2017); however, in our samples, the higher polyphenol content observed in MWD samples has not given an appreciable increase in AC. In agreement with several authors, this result could be related to the fact that the antioxidant power of an extract depends not only on the TPC but also on the specific

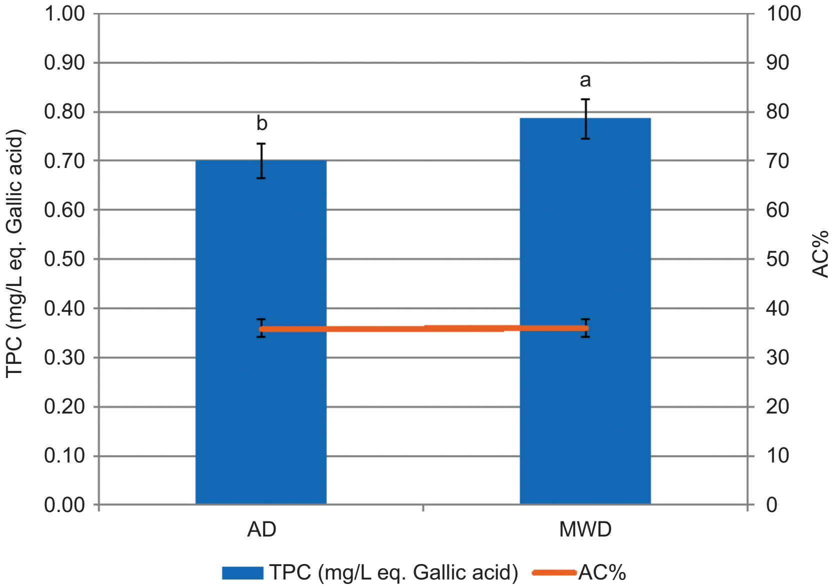

Figure 1. **Total phenolic content and antioxidant activity of hazel leaf herbal teas. Different letters indicate statistically significant differences with P < 0.05.**

composition and structure of the compounds present (She *et al.,* 2024). Furthermore, the similar ACs could suggest that both drying methods preserved the bioactive integrity of key antioxidant compounds, including vitamins or volatiles, which are not included by total phenolic assays, but which can contribute to the AC (El-Gamal *et al.,* 2023; Köksal *et al.*, 2006).

Volatile aroma compounds

The volatile aroma compounds of hazel leaf herbal teas revealed that the drying method has a significant influence, resulting in statistically significant differences ($P < 0.05$) across all major chemical classes (Table 1).

Table 1. Volatile aroma percentage composition of the hazel leaf herbal teas.

Compounds	LRI 1	Odor 2	AD % 3	MWD % 4
Alchools				
1-Penten-3-ol	1164	Vegetable	0.57 ± 0.04^{a}[5]	0.23 ± 0.01^{b}
1-Pentanol	1245	Fermented	$–^{b}$	1.84 ± 0.10^{a}
(*E*)-3-Hexen-1-ol	1356	Grassy, leafy	0.19 ± 0.02^{b}	0.59 ± 0.04^{a}
(*Z*)-3-Hexen-1-ol	1378	Grassy, leafy	10.41 ± 1.10^{a}	$–^{b}$
(*E*)-2-Hexen-1-ol	1397	Fresh, fruity	0.69 ± 0.03^{b}	1.52 ± 0.06^{a}
1-Octen-3-ol	1438	Hearty	$–^{b}$	1.06 ± 0.06^{a}
2-Ethyl-hexanol	1478	Citrus	0.37 ± 0.01^{b}	2.02 ± 0.09^{a}
1-Octanol	1546	Fatty-citrus	0.44 ± 0.02^{b}	1.95 ± 0.07^{a}
∑ Unsaturated			***11.29 ± 0.07^{a}***	***2.11 ± 0.10^{b}***
∑ Saturated			***1.38 ± 1.15^{b}***	***7.10 ± 0.33^{a}***
All			***12.67 ± 1.22^{a}***	***9.20 ± 0.43^{b}***
Aldehydes				
Pentanal	978	Fermented, fruity	0.25 ± 0.01^{b}	6.78 ± 0.31^{a}
2-Ethyl-3-methylbutanal	1063	–	1.08 ± 0.10^{b}	5.04 ± 0.24^{a}
Hexanal	1078	Grassy, leafy, fatty	2.24 ± 0.25^{b}	3.74 ± 0.22^{a}
(*E*)-2-Pentenal	1129	Pungent, fruity	0.76 ± 0.05^{a}	0.23 ± 0.03^{b}
(*Z*)-3-Hexenal	1130	Grassy, leafy	0.41 ± 0.03^{a}	$–^{b}$
Heptanal	1175	Aldehydic, fatty	0.40 ± 0.02^{b}	2.01 ± 0.20^{a}
(*Z*)-2-Hexenal	1198	Grassy, leafy	1.38 ± 0.11^{a}	$–^{b}$
(*E*)-2-Hexenal	1218	Grassy, leafy	51.17 ± 1.51^{a}	$–^{b}$
Octanal	1280	Aldehydic, orange	0.89 ± 0.06^{b}	7.17 ± 0.71^{a}
(*Z*)-2-Heptenal	1321	–	0.29 ± 0.02^{b}	0.98 ± 0.04^{a}
Nonanal	1386	Orange peel	5.99 ± 0.76^{b}	41.09 ± 1.55^{a}
(*E*)-2-Octenal	1427	Fatty	0.28 ± 0.01^{b}	0.48 ± 0.04^{a}
(*E*,*Z*)-2,4-Heptadienal	1465	Fatty	1.25 ± 0.13^{a}	$–^{b}$
Decanal	1493	Aldehydic	1.05 ± 0.09^{b}	5.38 ± 0.63^{a}
(*E*,*E*)-2,4-Heptadienal	1495	Fatty	1.16 ± 0.10^{a}	$–^{b}$
(*E*,*Z*)-2,6-Nonadienal	1586	Green, fatty	0.42 ± 0.03^{a}	$–^{b}$
∑ Unsaturated			***57.12 ± 1.99^{a}***	***1.69 ± 0.11^{b}***
∑ Saturated			***11.90 ± 1.29^{b}***	***71.21 ± 3.86^{a}***
All			***69.03 ± 3.28***	***72.90 ± 3.97***
Esters				
Butyl acetate	1067	Ethereal	0.04 ± 0.01^{b}	1.17 ± 0.09^{a}
(*E*)-3-Hexen-1-ol acetate	1307	Fruity	0.51 ± 0.08^{a}	$–^{b}$
Hexyl formate	1345	Fruity	1.76 ± 0.21^{a}	0.33 ± 0.03^{b}

(*continues*)

Table 1. Continued

Compounds	LRI 1	Odor 2	AD % 3	MWD % 4
All			***2.30 ± 0.30^{a}***	***1.50 ± 0.12^{b}***
Furans				
2-Ethyl-furan	951	Malty	5.71 ± 0.57^{a}	0.50 ± 0.02^{b}
(*E*)-2-Pentenyl-furan	1289	Phenolic	0.26 ± 0.03^{a}	-^{b}
All			***5.97 ± 0.60^{a}***	***0.50 ± 0.02^{b}***
Hydrocarbons				
Styrene	1252	Balsamic	-^{b}	1.45 ± 0.11^{a}
All			***-^{b}***	***1.45 ± 0.11^{a}***
Ketones				
2-Methyl-3-pentanone	996	-	0.03 ± 0.01^{b}	0.61 ± 0.03^{a}
1-Penten-3-one	1020	Spicy	2.39 ± 0.41^{a}	0.21 ± 0.01^{b}
1-Octen-3-one	1294	Earthy	0.15 ± 0.01^{a}	-^{b}
2,6,6-Trimethylcyclohexanone	1311	-	0.36 ± 0.02^{a}	-^{b}
2,5-Octanedione	1315	-	1.18 ± 0.44	1.67 ± 0.16
6-Methyl-5-hepten-2-one	1332	Citrus, fruity	1.14 ± 0.07^{b}	8.11 ± 0.66^{a}
All			***5.25 ± 0.96^{b}***	***10.60 ± 0.86^{a}***
Terpenes				
Limonene	1178	Citrus	0.27 ± 0.01^{b}	0.93 ± 0.04^{a}
Eucalyptol	1197	Eucalyptus	-^{b}	0.81 ± 0.03^{a}
Linalool	1535	Floral	1.19 ± 0.12^{b}	2.12 ± 0.22^{a}
β-Cyclocitral	1625	Hay-like, mild floral	1.31 ± 0.17^{a}	-^{b}
Estragole	1672	Anise	2.00 ± 0.21^{a}	-^{b}
All			***4.78 ± 0.31^{a}***	***3.86 ± 0.29^{b}***

[1]Linear retention indices calculated on a VF-wax-ms 60m capillary column; [2]Odor descriptors were identified by Flavornet Database https://www.flavornet.org/index.html (accessed on 5 May 2025), references Stilo *et al.* (2022) and Squara *et al.* (2022); [3]Air-dried hazel leaf herbal tea; [4]Microwave-dried hazel leaf herbal tea; [5]Different superscript letters in the same row indicate significant differences ($P < 0.05$).
AD, air drying; LRI, linear retention index; MWD, microwave drying.

Alcohols, which contribute to the "grassy" and "leafy" odors, were slightly more abundant in herbal teas produced from AD leaves, with a total concentration of 12.67% compared to 9.20% in MWD.

However, notable differences have been observed between saturated and unsaturated alcohols. In particular, (*Z*)-4-Hexen-1-ol, a grassy and leafy odor compound, was present at high levels in AD (10.41%) and absent in the MWD samples. Conversely, MWD promoted the formation of heavier alcohols such as 1-Octanol and 2-Ethylhexanol, both present in significantly higher amounts than in the AD ones. These differences also stem from the different fatty acids from which they are formed. In fact, (*Z*)-4-Hexen-1-ol, as well as unsaturated aldehydes, is derived from α-linolenic acid degradation, which is very sensitive to heat (Wang *et al.*, 2024). These differences are likely due to the nature of microwave energy, which induces rapid internal heating and can cause evaporation or degradation of volatile compounds during processing (Qin *et al.*, 2022). The increase of saturated alcohols, such as 1-Octanol and 2-Ethylhexanol, reduces the grassy leaf odor in herbal teas and increases the citrus-like notes. Similar effects have been reported in herbs, such as basil, where MWD has been shown to alter volatile compound profiles due to the thermal impacts (Altay *et al.*, 2024; Di Cesare *et al.*, 2003; Imaizumi *et al.*, 2021). A similar trend was also observed for aldehydes, where a significant difference was observed between saturated and unsaturated ones. The most significant difference resulted in nonanal (orange peel) and octanal (aldehydic, orange) contents, which were present at much higher levels in MWD (41.09 and 7.17%, respectively) than in AD (5.99 and 0.89%, respectively). On the other hand, *E*-2-Hexenal, a volatile compound strongly associated with grassy and leafy notes, was present in high concentrations in AD (51.17%) but was absent in MWD samples. These findings suggest that MWD promotes the formation of longer-chain saturated aldehydes while reducing the presence of unsaturated aldehydes typically associated with lipid oxidation pathways. This shift is supported by studies on other vegetal food matrices, such as tea, where convective drying determined the formation of unsaturated aldehydes compared to rapid, high-energy methods such as microwaves (Wang *et al.,* 2022).

Esters, known for their fruity and floral notes, prevailed in AD samples (2.30 %) compared to MWD (1.50 %). The loss of esters during MWD may be attributed to their thermal instability and high volatility, as previously observed in other vegetables such as ginger, garlic, and scallion (Okonkwo *et al.,* 2024).

A notable difference was also observed in the ketone fraction. The samples subjected to MWD exhibited almost twice the total ketone content (10.60 %) compared to the air-dried samples (5.25 %). Among these, 6-Methyl-5-hepten-2-one, a compound with fruity and citrus aroma, was particularly higher in MWD samples (8.11% vs 1.14% in AD). This increase could result from microwave-induced degradation of carotenoids or unsaturated fatty acids, as reported by Fratianni *et al.* (2013).

Terpenes, which contribute significantly to the floral and citrus notes of herbal teas, were better preserved in AD (4.78 %) than in MWD (3.86 %). Estragole and β-Cyclocitral were completely absent in MWD but present in AD samples. These findings confirm the thermal sensitivity of monoterpenes and phenylpropanoids, which are more likely to degrade or volatilize during rapid heating. Eucalyptol and linalool, on the other hand, were higher in MWD samples, suggesting that MWD may favor the liberation of certain bound terpenes due to cell wall rupture (Di Cesare *et al.*, 2003; Wojdyło *et al.,* 2014).

Furans, which arise from Maillard reactions and sugar degradation, were higher in AD (5.97 %) than in MWD (0.50 %), indicating that prolonged thermal exposure in AD conditions likely favors their formation. Meanwhile, MWD samples showed the presence of styrene (1.45 %), absent in AD, likely formed through the degradation of aromatic precursors under microwave energy (e.g., phenylalanine) (Chen *et al.,* 2022). The presence of styrene in MWD samples could raise additional safety considerations, as it has been classified by the IARC as a probable human carcinogen. Therefore, the choice of the drying method can significantly influence the levels of toxicologically relevant compounds. The compositional differences between AD and MWD samples should be carefully evaluated with respect to potential human exposure.

Overall, as shown in several studies, the volatile fraction results demonstrate that quantitative differences are mainly associated with drying treatment time (Cincotta *et al.*, 2024, 2025; Hu *et al.*, 2023; Shivanna and Subban, 2014). Our results show that AD favors the retention of compounds associated with green, leafy, and herbal notes, such as green alcohols and aldehydes, whereas MWD promotes the formation of aldehydes and ketones contributing to fruity, citrus, and waxy aromas.

Sensory analysis

The sensory evaluation of hazel leaf herbal teas revealed significant differences in most of the key attributes, in relation to the drying method used (Figure 2). Regarding the color, a rich orange and golden color was observed by the panel in AD herbal teas, whereas the MWD teas appeared lighter and greener.

Additionally, MWD samples showed stronger fruity, citrus, and floral notes, along with sweeter taste and aftertaste, but lower intensity in bitter, astringent, and woody taste. On the other hand, AD herbal teas were marked by a more pronounced grassy or leafy, balsamic, and honey-like aromas, as well as a woody, bitter, and astringent taste and aftertaste.

The Principal Component Analysis (PCA) biplot (Figure 3) highlights the sensory differences in hazel herbal teas obtained through MWD and AD. The first two principal components (PC1 and PC2) account for 97.05 % of the total variance. A clear separation was observed along the PC1, with MWD samples clustering on the negative side and AD samples on the positive side. This separation demonstrates that the drying method influenced the sensory profile of the herbal teas. MWD samples were closely associated with floral and fruity, citrus odors, which aligned with the higher quantities of 6-methyl-5-hepten-2-one, 1-Octanol, and 2-Ethylhexanol found in these samples (Di Cesare *et al.*, 2003). Furthermore, the MWD samples had a sweet aftertaste and pale yellow color, which suggested that this method better preserved volatile aromatic compounds and limited thermal degradation. In contrast, AD samples exhibited strong grassy or leafy, balsamic, honey-like, hay, and chamomile odors, as well as bitter, astringent, woody tastes, and a deeper golden to orange hue. The odor notes observed in the AD samples could be associated with the high contents of alcohols and unsaturated aldehydes, in particular (*Z*)-4-Hexen-1-ol and (*E*)-2-Hexenal (Wang *et al.*, 2022).

Microwave drying is known to induce rapid heating at the intracellular level, which promotes cell wall rupture and accelerates moisture removal without exposing the matrix to prolonged high temperatures

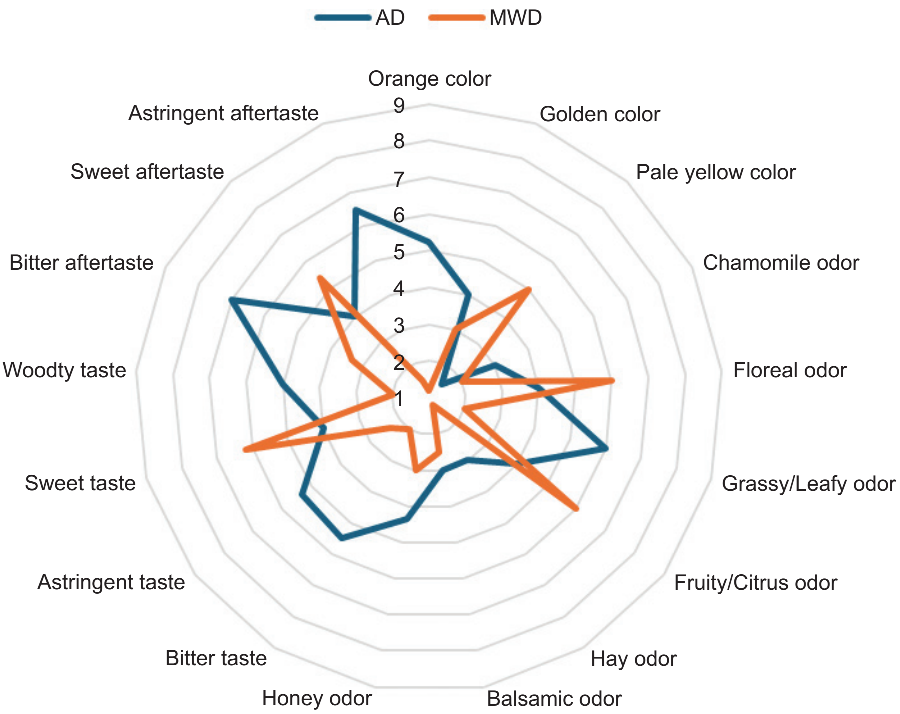

Figure 2. **Graphical representation of the sensory profile of AD and MWD hazel herbal tea.**

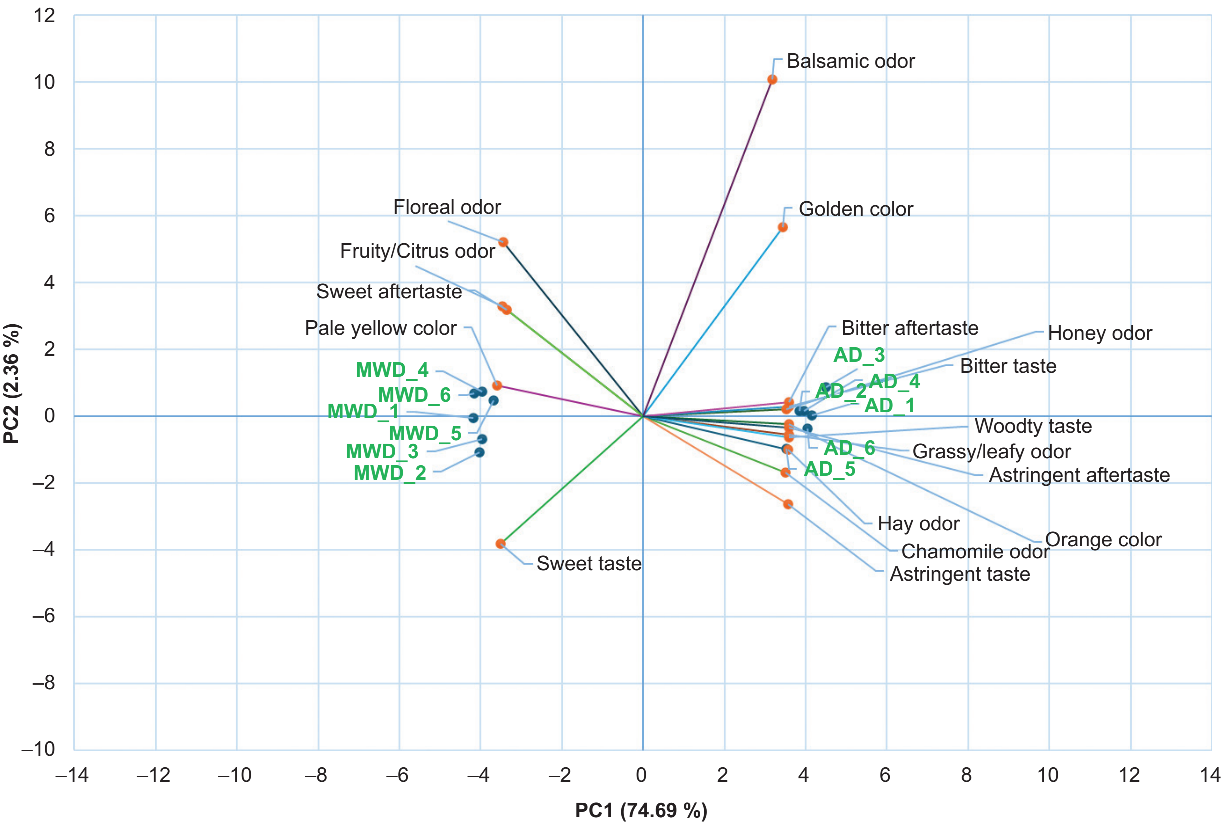

Figure 3. **PCA loading plot of AD and MWD hazel herbal tea sensory data.**

(Joardder and Karim, 2023). This limits oxidative degradation and the formation of thermally derived bitter or burnt compounds, such as furans or phenolic degradation products, which are more likely to form during slower, and high-oxygen exposure of AD. This phenomenon likely explains the lower intensities of astringent and bitter descriptors in the MWD samples. In contrast, the AD herbal teas, subjected to more gradual thermal exposure, showed higher woody and honey-like sensory notes, which may be related to Maillard reactions and lipid oxidation products, such as furans, occurring over longer periods. This is consistent with the literature findings, indicating that conventional roasting or drying can generate a broader profile of nutty, toasted, and caramelized aromas in hazelnut (Manzo *et al.,* 2017).

Moreover, these findings align with the existing literature, which highlights how conventional drying techniques determine the development of an aroma profile driven by Maillard reactions and lipid oxidation occurring over prolonged heat exposure (Kalkan *et al.,* 2015; Manzo *et al.,* 2017).

Figure 4 shows the PCA biplot integrating both volatile aroma compounds and odor sensory descriptors of herbal teas, demonstrating a strong correlation between the volatile profiles and odor sensory descriptors. A clear separation is once again observed between the two drying treatments. MWD samples are positioned on the positive side of PC1, whereas AD samples in the negative side. This spatial distribution reflects distinct chemical and sensory profiles resulting from the drying methods. MWD herbal teas were strongly associated with compounds such as terpenes, ketones, and saturated aldehydes, typically related to floral and fruity notes, which is highlighted by the proximity of these sensory descriptors. Conversely, AD herbal teas show a stronger correlation with unsaturated aldehydes and alcohols related to grassy and herbaceous notes. Accordingly, grassy or leafy, hay, and chamomile odors are the closest sensory attributes. The presence of furan derivatives and aldehydes in AD samples likely reflects thermal degradation pathways, such as lipid oxidation or Maillard reaction, due to prolonged exposure to heat (Kalkan *et al.,* 2015; Manzo *et al.,* 2017). These findings confirm the critical role of drying technique in shaping both chemical and sensory quality of hazel herbal teas.

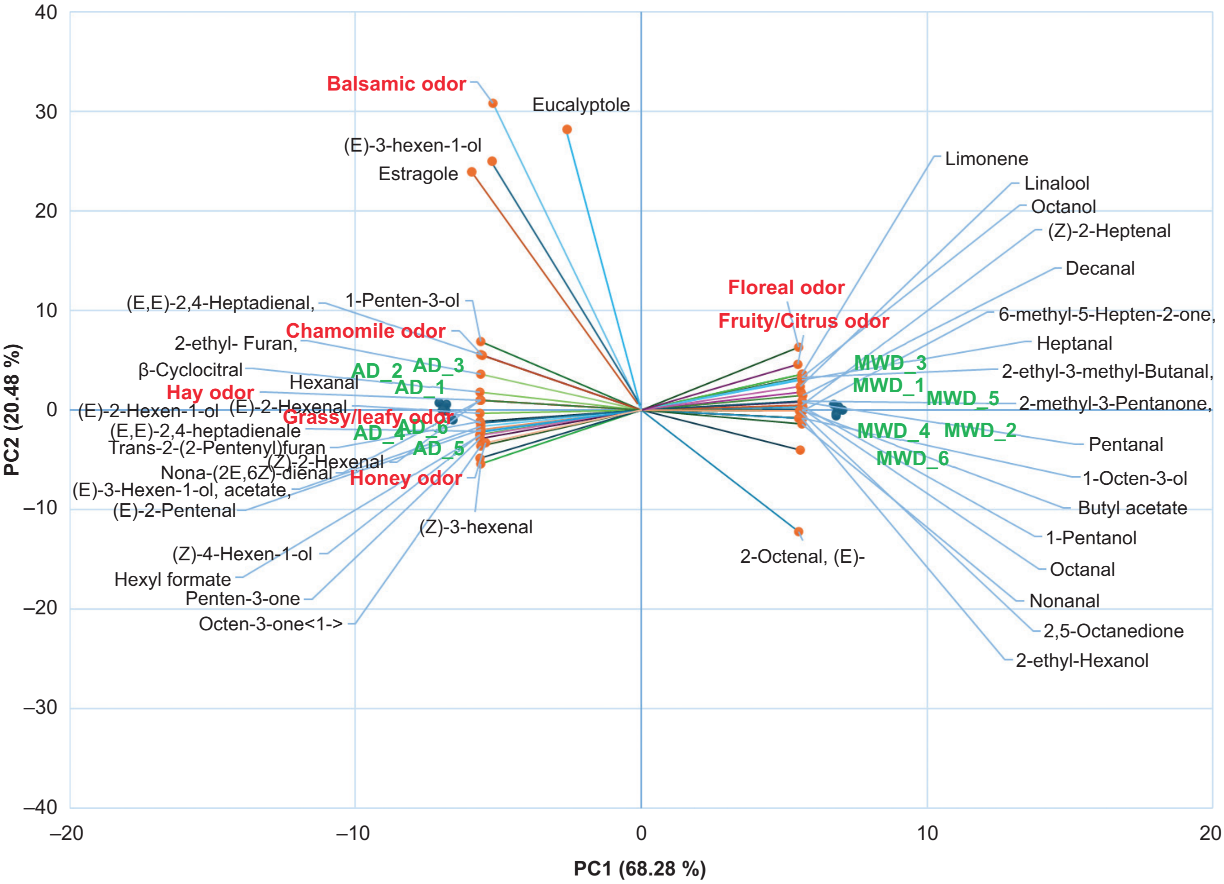

Figure 4. PCA loading plot of AD and MWD hazel herbal tea volatile and odor sensory data.

Consumers' acceptability

Figure 5 shows the consumers' acceptability results of hazel leaf herbal teas. A clear trend emerges, showing consistently higher consumer preference for herbal teas produced from MWD leaves across all sensory attributes. The color attribute received notably higher scores in MWD samples (~7.2) compared to AD (~5.4), suggesting that MWD leads to a more appealing visual aspect. Attributes related to odor, flavor, and taste followed a similar trend, with MWD samples scoring between 6.2 (like slightly) and 6.5 (like slightly/moderately), while AD samples ranged from approximately 4.0 (dislike slightly) to 5.2 (neither like nor dislike) (Lee *et al.*, 2008; Yang and Lee, 2020).

These differences may be attributed to the differences observed for volatile aroma compounds and phytochemicals in MWD herbal teas, which tend to change under prolonged high-temperature exposure in conventional AD. This results in a higher overall acceptability for the MWD herbal teas that was significantly higher than AD ones (6.6 vs 4.8), highlighting the influence of the drying technique on consumer appreciation (Cincotta *et al.*, 2025; Radojčin *et al.*, 2021). These findings suggest that MWD is a more suitable method for preserving and/or generating the desirable sensory qualities of hazel leaves, thus enhancing the market potential and consumer appeal.

Conclusions

The present study provides a comprehensive assessment of *C. avellana* L. leaves as a novel and sustainable raw material for the formulation of herbal teas, with particular attention to the impact of drying technology on their functional, aromatic, and sensory properties. The results demonstrate that MWD is more effective than conventional air drying in preserving total phenolic compounds, without compromising antioxidant capacity. This suggests that MWD may facilitate the retention of specific bioactive molecules while reducing thermal degradation and process time, aligning with sustainability goals in food processing.

From a sensory perspective, the drying method induced significant modifications in the volatile compound profile, which was strongly associated with sensory attributes. MWD samples exhibited higher concentrations of saturated aldehydes and ketones, responsible for fruity and sweet notes and were consistently rated more positively by consumers in terms of color, odor, flavor, and overall acceptability. Conversely, AD samples were characterized by grassy or leafy, balsamic, and astringent descriptors, reflecting the preservation of volatile alcohols and unsaturated aldehydes associated with herbaceous and vegetal notes. These findings underscore the dual role of MWD in enhancing both the functional and hedonic properties of hazel leaf herbal teas.

In conclusion, the development of functional beverages that respond to consumer demands for natural origin, health-promoting properties, and optimized sensory characteristics represents a strategic approach to product differentiation and diversification within the increasingly competitive herbal tea sector. Furthermore, the results obtained can be used as input for the design and optimization of industrial microwave drying systems, enabling the development of new products and better preservation of sensory characteristics and nutraceutical properties. Future research should focus on determining the variation in individual bioactive compounds that affect

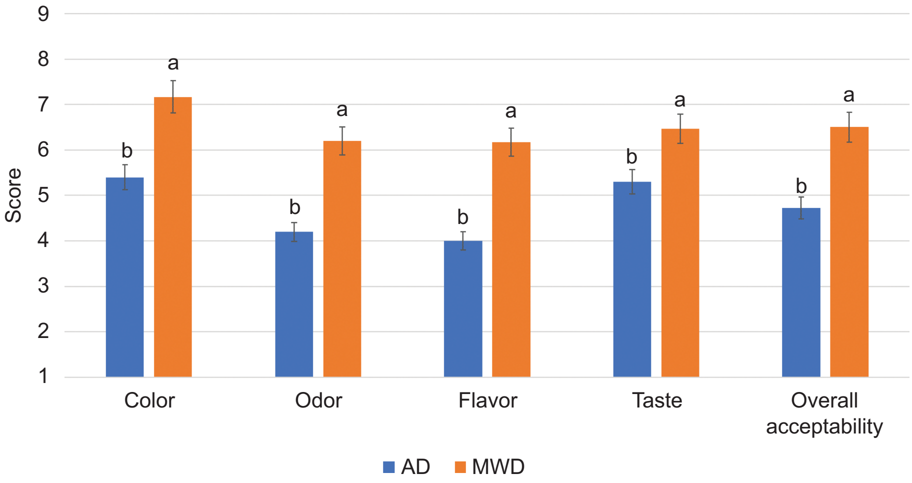

Figure 5. Consumers' acceptability of hazel leaf herbal teas. 1: extreme dislike, 9: extreme appreciation. Different letters for the same attribute indicate statistically significant differences at P < 0.05 by Duncan's test.

the antioxidant activity of hazelnut leaves and validating scalability and long-term quality stability.

Authors Contributions

Conceptualization, Antonella Verzera and Fabrizio Cincotta; methodology, Marco Torre and Fabrizio Cincotta; software, Gianluca Tripodi and Alessio Cappelli; validation, Gianluca Tripodi, Marco Torre and Fabrizio Cincotta; formal analysis, Marco Torre and Fabrizio Cincotta; investigation, Gianluca Tripodi and Alessio Cappelli; resources, Fabrizio Cincotta; data curation, Gianluca Tripodi, Marco Torre and Alessio Cappelli; writing—original draft preparation, Gianluca Tripodi and Fabrizio Cincotta; writing-review and editing, Antonella Verzera; visualization, Fabrizio Cincotta; supervision, Antonella Verzera.

Conflicts of Interest

None.

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None.

References

Akbarzadeh, T., Sabourian, R., Saeedi, M., Rezaeizadeh, H., Khanavi, M. and Ardekani, M.R.S., 2015. Liver tonics: Review of plants used in Iranian traditional medicine. Asian Pacific Journal of Tropical Biomedicine. 5: 170–181. https://doi.org/10.1016/S2221-1691(15)30002-2

Alasalvar, C., Karamac, M., Amarowicz, R. and Shahidi, F., 2006. Antioxidant and antiradical activities in extracts of hazelnut kernel (*Corylus avellana* L.) and hazelnut green leafy cover. Journal of Agricultural and Food Chemistry. 54: 4826–4832. https://doi.org/10.1021/jf0601259

Alasalvar, C. and Shahidi, F., 2008. Tree nuts: Composition, phytochemicals, and health effects: An overview. Boca Raton, FL: CRC press. pp. 15–24. https://doi.org/10.1201/9781420019391

Altay, K., Dirim, S.N. and Hayaloglu, A.A., 2024. Effects of different drying processes on the quality changes in Arapgir purple basil (*Ocimum basilicum* L.) leaves and drying-induced changes in bioactive and volatile compounds and essential oils. Journal of Food Science. 89: 9088–9107. https://doi.org/10.1111/1750-3841.17515

Amaral, J.S., Valentao, P., Andrade, P.B., Martins, R.C. and Seabra, R.M., 2010. Phenolic composition of hazelnut leaves: Influence of cultivar, geographical origin and ripening stage. Scientia. Horticulturae. 126: 306–313. https://doi.org/10.1016/j.scienta.2010.07.026

Barimah, J., Yanney, P., Laryea, D. and Quarcoo, C., 2017. Effect of drying methods on phytochemicals, antioxidant activity and total phenolic content of dandelion leaves. American Journal of Food and Nutrition. 5(4): 136–141. https://doi.org/10.12691/ajfn-5-4-4

Boccacci, P. and Botta, R., 2009. Investigating the origin of hazelnut (*Corylus avellana* L.) cultivars using chloroplast microsatellites. Genetic Resources and Crop Evolution. 56: 851–859. https://doi.org/10.1007/s10722-009-9406-6

Bottone, A., Cerulli, A., D'Urso, G., Masullo, M., Montoro, P., Napolitano, A., et al. 2019. Plant specialized metabolites in hazelnut (*Corylus avellana*) kernel and byproducts: An update on chemistry, biological activity, and analytical aspects. Planta Medica. 85(11/12): 840–855. https://doi.org/10.1055/a-0947-5725

Chen, P., Gong, M., Chen, Y., Zhou, Z., Liu, M., Fang, Y., et al. 2022. Thermal decomposition pathways of phenylalanine and glutamic acid and the interaction mechanism between the two amino acids and glucose. Fuel. 324: 124345. https://doi.org/10.1016/j.fuel.2022.124345

Cincotta, F., Merlino, M., Condurso, C., Miller, A., Torre, M. and Verzera, A., 2024. Avocado leaf-waste management: Drying technology and quality of leaf herbal teas of different varieties cultivated in the Mediterranean area. International Journal of Food Science and Technology. 59(4): 2516–2523. https://doi.org/10.1111/ijfs.16987

Cincotta, F., Torre, M., Merlino, M., Condurso, C., Buda, M. and Verzera, A., 2025. Sustainable herbal teas from fig (*Ficus carica* L.) waste leaves: Volatile fingerprinting, sensory descriptors, and consumer acceptability. Beverages. 11(1): 16. https://doi.org/10.3390/beverages11010016

Dhar, R. and Chakraborty, S., 2024. Effect of continuous microwave processing on enzymes and quality attributes of bael beverage. Food Chemistry. 453: 139621. https://doi.org/10.1016/j.foodchem.2024.139621

Di Cesare, L.F., Forni, E., Viscardi, D. and Nani, R.C., 2003. Changes in the chemical composition of basil caused by different drying procedures. Journal of Agricultural and Food Chemistry. 51(12): 3575–3581. https://doi.org/10.1021/jf021080o

El-Gamal, R., Song, C., Rayan, A.M., Liu, C., Al-Rejaie, S. and El-Masry, G., 2023. Thermal degradation of bioactive compounds during drying process of horticultural and agronomic products: A comprehensive overview. Agronomy. 13(6): 1580. https://doi.org/10.3390/agronomy13061580

Erdogan, V. and Mehlenbacher, S.A., 2000. Interspecific hybridization in hazelnut (*Corylus*). The Journal of the American Society for Horticultural Science. 125: 489–497. https://doi.org/10.21273/JASHS.125.4.489

Euromonitor International, 2023. Tea in Western Europe, February 2023. [cited 2024 Nov 08]. Available from: https://www.euromonitor.com/tea-in-western-europe/report

Fratianni, A., Albanese, D., Mignogna, R., Cinquanta, L., Panfili, G. and Di Matteo, M., 2013. Degradation of carotenoids in apricot (*Prunus armeniaca* L.) during drying process. Plant Foods for Human Nutrition. 68: 241–246. https://doi.org/10.1007/s11130-013-0369-6

Hu, D., Liu, X., Qin, Y., Yan, J., Li R. and Yang, Q., 2023. The impact of different drying methods on the physical properties, bioactive components, antioxidant capacity, volatile components and industrial application of coffee peel. Food Chemistry. 19: 100807. https://doi.org/10.1016/j.fochx.2023.100807

Huda, H.S.A., Majid, N.B.A., Chen, Y., Adnan, M., Ashraf, S.A., Roszko, M., et al. 2024. Exploring the ancient roots and modern global brews of tea and herbal beverages: A comprehensive review of origins, types, health benefits, market dynamics, and future trends. Food Science and Nutrition. 12(10): 6938–6955. https://doi.org/10.1002/fsn3.4346

Imaizumi, T., Jitareerat, P., Laohakunjit, N. and Kaisangsri, N., 2021. Effect of microwave drying on drying characteristics, volatile compounds and color of holy basil (*Ocimum tenuiflorum* L.). Agriculture and Natural Resources. 55: 1–6. https://doi.org/10.34044/j.anres.2021.55.1.01

ISO 8586:2023, 2023. Sensory analysis—Selection and training of sensory assessors. ISO: Geneva, Switzerland, 2023. [cited 2024 Nov 08]. Available from: https://www.iso.org/standard/76667.html

Jiang, R., Manson, J.E., Stampfer, M.J., Liu, S., Willett, W.C. and Hu, F.B., 2002. Nut and peanut butter consumption and risk of type 2 diabetes in women. JAMA. 288: 2554–2560. https://doi:10.1001/jama.288.20.2554

Jimenez-Lopez, C., Fraga-Corral, M., Carpena, M., García-Oliveira, P., Echave, J., Pereira, A.G., et al. 2020. Agriculture waste valorisation as a source of antioxidant phenolic compounds within a circular and sustainable bioeconomy. Food and Functiom. 11(6): 4853–4877. https://doi.org/10.1039/D0FO00937G

Joardder, M.U. and Karim, A., 2023. Pore evolution in cell walls of food tissue during microwave-assisted drying: An in-depth investigation. Foods. 12(13): 2497. https://doi.org/10.3390/foods12132497

Kalkan, F., Kranthi Vanga, S., Gariepy, Y. and Raghavan, V., 2015. Effect of MW-assisted roasting on nutritional and chemical properties of hazelnuts. Food and Nutrition Research. 59(1): 28916. https://doi.org/10.3402/fnr.v59.28916

Köksal, A.İ., Artik, N., Şimşek, A. and Güneş, N., 2006. Nutrient composition of hazelnut (*Corylus avellana* L.) varieties cultivated in Turkey. Food Chemistry. 99(3): 509–515. https://doi.org/10.1016/j.foodchem.2005.08.013

Lasano, N.F., Rahmat, A., Ramli, N.S. and Bakar, M.F.A., 2018. Effect of oven and microwave drying on polyphenols content and antioxidant capacity of herbal tea from *Strobilanthes crispus* leaves. Asian Journal of Pharmaceutical and Clinical Research. 11(6): 363–368. https://doi.org/10.22159/ajpcr.2018.v11i6.24660

Lee, O.H., Lee, H.S., Sung, Y.E., Lee, S.M. and Kim, K.O., 2008. Sensory characteristics and consumer acceptability of various green teas. Food Science and Biotechnology. 17(2): 349–356.

Maguire, L.S., O'Sullivan, S.M., Galvin, K., O'Connor, T.P. and O'Brien, N.M., 2004. Fatty acid profile, tocopherol, squalane and phytosterol content of walnuts, almonds, peanuts, hazelnuts and the macadamia nut. International Journal of Food Science and Nutrition. 3: 171–178. https://doi.org/10.1080/09637480410001725175

Manzo, N., Troise, A.D., Fogliano, V., Pizzolongo, F., Montefusco, I., Cirillo, C., et al. 2017. Impact of traditional and microwave roasting on chemical composition of hazelnut cultivar "Tonda di Giffoni." Quality Assurance and Safety of Crops and Foods. 9(4): 391–399. https://doi.org/10.15586/qas.v9i4.113

Nowacka, M., Matys, A. and Witrowa-Rajchert, D., 2024. Innovative technologies for improving the sustainability of the food drying industry. Current Food Science and Technology Reports. 2: 231–239. https://doi.org/10.1007/s43555-024-00026-8

Okonkwo, C.E., Onyeaka, H., Olaniran, A.F., Isaac-Bamgboye, F.J., Nwaiwu, O., Ukwuru, M., et al. 2024. Changes in flavor profile of vegetable seasonings by innovative drying technologies: A review. Journal of Food Science. 89(11): 6818–6838. https://doi.org/10.1111/1750-3841.17346

Oliver Chen, C.Y. and Blumberg, J., 2008. Phytochemical composition of nuts. Asia Pacific Journal of Clinical Nutriition. 17: 329–332. http://www.healthyeatingclub.org/APJCN/

Ozdemir, M. and Karagoz, S., 2024. Effects of microwave drying on physicochemical characteristics, microstructure, and antioxidant properties of propolis extract. Journal of the Science of Food and Agriculture. 104(4): 2189–2197. https://doi.org/10.1002/jsfa.13106

Pavlić, B., Aćimović, M., Sknepnek, A., Miletić, D., Mrkonjić, Ž., Kljakić, A.C., et al. 2023. Sustainable raw materials for efficient valorization and recovery of bioactive compounds. Industrial Crops and Products. 193: 116167. https://doi.org/10.1016/j.indcrop.2022.116167

Phillips, K.M., Ruggio, D.M. and Ashraf-Khorassani, M., 2005. Phytosterol composition of nuts and seeds commonly consumed in the United States. Journal of Agricultural and Food Chemistry. 53: 9436–9445. https://doi.org/10.1021/jf051505h

Qin, H.W., Yang, T.M., Yang, S.B., Yang, M.Q., Wang, Y.Z. and Zhang, J.Y., 2022. Effects of different pre-drying and drying methods on volatile compounds in the pericarp and kernel of *Amomum tsao-ko*. Frontiers in Plant Science. 13: 803776. https://doi.org/10.3389/fpls.2022.803776

Radojčin, M., Pavkov, I., Bursać Kovačević, D., Putnik, P., Wiktor, A., Stamenković, Z., et al. 2021. Effect of selected drying methods and emerging drying intensification technologies on the quality of dried fruit: A review. Processes. 9: 132. https://doi.org/10.3390/pr9010132

Salehi, F., Inanloodoghouz, M. and Ghazvineh, S., 2023. Influence of microwave pretreatment on the total phenolics, antioxidant activity, moisture diffusivity, and rehydration rate of dried sweet cherry. Food Science and Nutrition. 11(12): 7870–7876. https://doi.org/10.1002/fsn3.3703

Shahidi, F., Alasalvar, F. and Liyana-Pathirana, C.M., 2007. Antioxidant phytochemicals in hazelnut kernel (*Corylus avellana* L.) and hazelnut byproducts. Journal of Agriculture and Food Chemistry. 55: 1212–1220. https://doi.org/10.1021/jf062472o

Shahidi, F. and Miraliakbari, H., 2005. Tree nut oils. In: Shahidi, F., editor. Bailey's industrial oil and fat products, edible oil and fat products: Specialty oils and oil products. Vol. 3, 6th ed. Hoboken, NJ: Wiley Interscience. pp. 175–193. https://doi.org/10.1002/047167849X.bio046.pub2

Shahidi, F. and Miraliakbari, H., 2006. Tree nut oils and byproducts: Compositional characteristics and nutraceutical applications. In: Shahidi, F., editor. Nutraceutical and specialty lipids and their co-products. Boca Raton, FL: CRC Press, Taylor & Francis Group. pp. 159–168. https://doi.org/10.1201/9781420015911

She, J., Li, Q., Cui, M., Zheng, Q., Yang, J., Chen, T., et al. 2024. Profiling of phenolic composition in camellia oil and its correlative antioxidant properties analysis. Frontiers in Nutrition. 11: 1440279. http://10.3389/fnut.2024.1440279

Shivanna, V.B. and Subban, N., 2014. Effect of various drying methods on flavor characteristics and physicochemical properties of dried curry leaves (*Murraya koenigii* L. Spreng). Drying Technology. 32(8): 882–890. https://doi.org/10.1080/07373937.2013.871727

Snoussi, A., Essaidi, I., Ben Haj Koubaier, H., Zrelli, H., Alsafari, I., Živoslav, T., et al. 2021. Drying methodology effect on the phenolic content, antioxidant activity of *Myrtus communis* L. leaves ethanol extracts and soybean oil oxidative stability. BMC Chemistry. 15: 31. https://doi.org/10.1186/s13065-021-00753-2

Squara, S., Stilo, F., Cialiè Rosso, M., Liberto, E., Spigolon, N., Genova, G., et al. 2022. *Corylus avellana* L. aroma blueprint: Potent odorants signatures in the volatilome of high quality hazelnuts. Frontiers in Plant Science. 13: 840028. https://doi.org/10.3389/fpls.2022.840028

Stilo, F., Cialiè Rosso, M., Squara, S., Bicchi, C., Cordero, C. and Cagliero, C., 2022. *Corylus avellana* L. Natural signature: Chiral recognition of selected informative components in the volatilome of high-quality hazelnuts. Frontiers in Plant Science. 13: 844711. https://doi.org/10.3389/fpls.2022.844711

Sultana, B., Anwar, F. and Ashraf, M., 2012. Effect of drying techniques on the total phenolic content and antioxidant activity of selected medicinal plant extracts. Journal of Medicinal Plants Research. 6(1): 104–109. https://doi.org/10.5897/JMPR11.916

Tapsell, L.C., Gillen, L.J., Patch, C.S., Batterham, M., Owen, A., Bare, M., et al. 2004. Including walnuts in a low-fat/modii ed-fat diet improves HDL cholesterol-to-total cholesterol ratios in patients with type 2 diabetes. Diabetes Care. 27: 2777–2783. https://doi.org/10.2337/diacare.27.12.2777

Tripodi, G., Merlino, M., Torre, M., Condurso, C., Verzera, A. and Cincotta, F., 2025. Characterization of aroma, sensory properties, and consumer acceptability of honey from *Capparis spinosa* L. Foods. 14(11): 1978. https://doi.org/10.3390/foods14111978

Venkatachalam, M. and Sathe, S.K., 2006. Chemical composition of selected edible nut seeds. Journal of Agriculture and Food Chemistry. 54: 4705–4714. https://doi.org/10.1021/jf0606959

Verified Market Research, 2025. Global herbal tea market size by product type (instant premixes, liquid, powdered RTD), by raw material type (black, green, and yellow), by geographic scope and forecast. [cited 2025 Nov 19]. Available from: https://www.verifiedmarketresearch.com/product/herbal-tea-market/

Vinci, G., D'Ascenzo, F., Maddaloni, L., Prencipe, S.A. and Tiradritti, M., 2022. The influence of green and black tea infusion parameters on total polyphenol content and antioxidant activity by ABTS and DPPH assays. Beverages. 8: 18. https://doi.org/10.3390/beverages8020018

Wang, H., Chen, L., Xu, A., Zhao, Y., Wang, Y., Liu, Z., et al. 2024. Thermochemical reactions in tea drying shape the flavor of tea: A review. Food Research International. 197: 115188. https://doi.org/10.1016/j.foodres.2024.115188

Wang, H., Ouyang, W., Yu, Y., Wang, J., Yuan, H., Hua, J., et al. 2022. Analysis of non-volatile and volatile metabolites reveals the influence of second-drying heat transfer methods on green tea quality. Food Chemistry. 14: 100354. https://doi.org/10.1016/j.fochx.2022.100354

Wojdyło, A., Figiel, A. and Oszmiański, J., 2014. Effect of drying methods with the application of vacuum microwaves on the bioactive compounds, color, and antioxidant activity of strawberry fruits. Journal of Agriculture and Food Chemistry. 57(4): 1337–1343. https://doi.org/10.1021/jf802944d

Yang, J.E. and Lee, J., 2020. Consumer perception and liking, and sensory characteristics of blended teas. Food Science and Biotechnology. 29: 63–74. https://doi.org/10.1007/s10068-019-00643-3