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Phytochemical Profile and Antioxidant Activity of Torch Ginger Flower Tea at Various Drying Temperatures

Yusnita Wahyuni Silitonga[1*], Rafiqah Amanda Lubis[1], Nurmaini Ginting[2], Fatma Suryani Harahap[3], Muhammad Nizar Hanafiah Nasution[4], Muttaqin Kholis Ali[5]

[1] Agrotechnology Study Program, Faculty of Science and Technology, Universitas Muhammadiyah, Tapanuli Selatan, Indonesia.
[2] Biology Study Program, Faculty of Teacher Training and Education, Universitas Muhammadiyah, Tapanuli Selatan, Indonesia.
[3] Chemistry Study Program, Faculty of Teacher Training and Education, Universitas Muhammadiyah, Tapanuli Selatan, Indonesia.
[4] Agrotechnology Study Program, Faculty of Agriculture, Universita Graha Nusantara, Tapanuli Selatan, Indonesia.
[5] Senior High School SMAN 1 Tambangan, Kabupaten Mandailing Natal, Sumatera Utara, Indonesia.

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Corresponding Author*:
Yusnita Wahyuni Silitonga
yusnita.wahyuni@um-tapsel.ac.id

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Abstract: Kecombrang can be categorized as a functional plant because it contains phytochemical compounds and antioxidants that can be further developed into herbal tea products. The objective of this study was to determine the phytochemical constituents and antioxidant activity of kecombrang tea processed at three different drying temperatures: 60, 70, and 80 °C. Phytochemical profiling was conducted using both qualitative and quantitative approaches. The qualitative analysis included the identification of alkaloids, flavonoids, tannins, saponins, steroids, glycosides, and triterpenoids, while the quantitative analysis focused on total flavonoids and total phenolics. The results revealed that all tested phytochemical compounds were present in the kecombrang tea extracts except saponins. The highest total flavonoid content was observed at the drying temperature of 60 °C, reaching 32.21 mg QE/g extract, whereas the lowest was recorded at 80 °C with 8.61 mg QE/g extract. Interestingly, the extract processed at 80 °C exhibited the highest total phenolic content at 11.60 mg GAE/g extract, while the lowest phenolic content was found at 60 °C with 2.72 mg GAE/g extract. The strongest antioxidant activity was also observed at 80 °C, with an IC_{50} value of 34.92 ppm. Overall, increasing the drying temperature tended to decrease most phytochemical constituents.

Keywords: Antioxidant; Phytochemical; Tea; Torch ginger

Introduction

Torch ginger is a plant belonging to the Zingiberaceae family that is widely used as a food ingredient, aromatic spice, and traditional medicine in various regions of Southeast Asia (Srivastava et al., 2019; Rachkeeree et al., 2018). Its flowers are known to be rich in secondary metabolites such as flavonoids, phenols, tannins, saponins, and anthocyanins, which play an important role as natural antioxidants (Devi & Barooah, 2025; Naufalin et al., 2021). The presence of these bioactive compounds makes torch ginger flowers highly potential for development as a raw material for functional food products and herbal drinks with high health value (Purwoko et al., 2019; Pamela et al., 2021). In recent years, the trend of consuming flower-based herbal drinks has increased, making the need for scientific characterization of the phytochemical potential of torch ginger increasingly relevant (Edo et al., 2025). The antioxidant activity of natural ingredients is strongly influenced by the content and stability of phytochemical compounds (Akullo et al., 2023; Roby et al., 2025). However, the phytochemical characteristics of plants are sensitive to post-harvest treatments, particularly the drying process (Marchioni et al., 2022). Drying is a crucial step in herbal tea production because

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it reduces water content, inhibits enzyme activity, and extends shelf life (Topal & Şahïn, 2025; Rumicha et al., 2025). However, drying temperature can alter the chemical structure, reduce phenolic compound content, or even trigger the formation of certain bioactive compounds (ElGamal et al., 2023).

Therefore, selecting the appropriate drying temperature is crucial to maintain the chemical quality and functional activity of torch ginger flowers (Bai et al., 2023). Several previous studies have reported that variations in drying temperature for herbal materials can cause significant differences in total phenols, total flavonoids, and antioxidant capacity (Hu et al., 2023; Ismanto et al., 2020). However, specific scientific information regarding the effect of drying temperature on the phytochemical profile and antioxidant activity of torch ginger flowers in tea is still very limited.

The aim of this study was to determine the phytochemical compound content and antioxidant activity of torch ginger tea at each drying temperature of 60, 70, and 80 ^{0}C.

Method

Making Torch Ginger Flower Tea

Torch ginger flowers are thoroughly washed. Afterward, the petals are removed one by one from the unused parts. The removed petals are sliced into small pieces and then air-dried. They are then dried in an oven at varying temperatures of 60, 70, and 80°C for 5 hours.

Torch Ginger Tea Extraction

The torch ginger tea powder sample is placed in a maceration container, and 70% ethanol is added until the powder is submerged. Extraction is then carried out using the maceration method for 3 x 24 hours. After extraction, the filtrate was separated using filter paper and then evaporated with a rotary evaporator to obtain a thick extract (Sari et al., 2022).

Qualitative Analysis of Phytochemical Compounds

The qualitative analysis of phytochemical compounds conducted included testing for alkaloids, flavonoids, glycosides, tannins, saponins, and steroids.

Determination of Total Flavonoid Content

A total of 100 mg of torch ginger tea extract was dissolved in 10 mL of methanol. To 1 mL of the extract, 3 mL of methanol, 0.2 mL of 10% $AlCl_3$, 0.2 mL of potassium acetate were added, and the volume was made up to 10 mL with distilled water. The extract was stored for 40 minutes in the dark (room temperature). Absorbance was measured using UV-Vis spectrophotometry at a wavelength of 438 nm. Quercetin concentrations of 10–60 mg/L were used as a standard. The total flavonoid content of torch ginger fruit extract is expressed as mg quercetin equivalents (QE) per gram of dry weight extract.

Determination of Total Phenolic Content

1 mL of torch ginger tea extract was pipetted. 0.4 mL of Folin-Ciocalteau reagent was added to the sample, shaken and allowed to stand for 4-8 minutes. Then, 4.0 mL of 7% Na_2CO_3 solution was added and shaken until homogeneous. Add distilled water to 10 mL and let stand for 2 hours at room temperature. Absorbance was measured at a maximum absorption wavelength of 744.8 nm. Total phenolic content was expressed as mg gallic acid equivalents (GAE) per g of extract.

Antioxidant Activity Analysis

0.10 g of torch ginger tea extract was weighed, then methanol was added to reach 10 ml. The solution was filtered and made into several concentrations (1, 0.5, and 0.25%) to calculate the IC_{50}. A total of 1 ml of snake fruit extract solution was added with 1 ml of 2,2-diphenyl-1-picrylhydrazyl/DPPH solution (0.004%) and then left in a dark room for 30 minutes. The absorbance of the sample was measured using a spectrophotometer at a wavelength of 517 nm. Ascorbic acid was used for the calibration curve. The antioxidant activity of snake fruit extract was expressed in mg of ascorbic acid equivalents per 100 grams of extract.

Results and Discussion

Overview of Torch Ginger Tea

Torch ginger can be classified as a functional plant. Numerous studies have shown that torch ginger contains bioactive compounds that function as antioxidants, antibacterials, and anticancer agents (Naziruddin et al., 2023). The presence of these bioactive compounds makes torch ginger suitable for use in herbal or health drinks. The drying process is one factor that influences the quality of torch ginger flower tea. Drying aims to reduce the water content. According to the National Standardization Agency (BSN) (2013), the recommended water content for dry tea is no more than 8%.

Figure 1 shows that torch ginger tea processed at lower temperatures exhibits better or brighter color quality. Kerch ginger tea processed at 80 °C is more brown or darker. The drying process causes pigments or dyes to oxidize to brown, a process known as browning. High temperatures cause carotenoid degradation, which leads to color changes in the tea. During the drying process, enzymatic degradation of chlorophyll can occur, with chlorophyll degradation products, such as

pheophytin, appearing dark brown (Mao et al., 2024). During the drying process, catechins also undergo oxidation, producing theaflavins, which produce a yellow color, and thearubigins, which produce a red color. Thearubigin compounds increase with increasing oxidation time as the polyphenol concentration decreases, resulting in a darker tea color (Zeng et al., 2017).

Figure 1. Drying at several temperatures A. 60 ^{0}C, B. 70 ^{0}C, C. 80 ^{0}C

Qualitative Analysis of Phytochemical Compounds

Phytochemical identification includes initial tests for determining the secondary metabolite content of bioactive compounds in plants. Qualitative testing results (Table 1) indicate that torch ginger tea extract contains bioactive compounds, including alkaloids, flavonoids, glycosides, tannins, and steroids. These identification results align with research by Uddin et al. (2024), which found that torch ginger flowers contain flavonoids, alkaloids, glycosides, tannins, steroids, and terpenoids. Qualitatively, no saponins were found in the torch ginger tea extract. The failure to identify saponins is likely due to the drying temperature, as high temperatures can damage the saponin structure (Shi et al., 2019).

Tannins are polyphenolic compounds that impart color to plants. Tannins are the most abundant pigment in torch ginger flower extract, at 2.65 mg/100 ml, followed by anthocyanins, chlorophyll, and carotene. Tannins possess antibacterial properties by precipitating proteins, as they are thought to have a similar effect to phenolic compounds (Das et al., 2020; Cosme et al., 2025). Tannins also possess astringency and contribute to the bitter taste of tea. However, excessive use of tannins can cause adverse side effects, such as digestive disorders, decreased iron levels, or interactions with certain medications (Salama-Müller & Roese, 2023). Glycosides are organic compounds consisting of two molecules: a sugar and a non-sugar. Many plant glycosides are used medicinally (Amen et al., 2021). Biologically, glycosides play a crucial role in plants, involving regulatory, protective, and salinity-resistant functions (Kytidou et al., 2020).

Table 1. Bioactive phytocemicals of torch ginger tea extract

Phytochemical Components	Testing Method/Reagents	Drying Temperature		
		60 ^{0}C	70 ^{0}C	80^{0}C
Alkaloid	Dragendroff, Bouchardat, Meyer	-	+	+
Flavonoid	Serbuk Mg + Amil, Alkohol + HCl_p	+	+	+
Glikosida	Molish + H_2SO_4	+	+	+
Saponin	Air/Dikocok	-	-	-
Tanin	$FeCl_3$	+	+	+
Steroid/	Lieberman-Bourchat	-	+	+

Quantitative Analysis of Flavonoids and Phenolics

The results of the total flavonoid measurements of torch ginger tea extract are shown in Table 2. Torch ginger tea extract at a drying temperature of 600 °C contained the highest total flavonoid content, at 32.21 mg QE/g extract, followed by 17.38 mg QE/g extract at a drying temperature of 700 °C, and the lowest at a drying temperature of 800 °C, at 8.61 mg QE/g extract. This is because the flavonoids contained in torch ginger tea samples are active compounds that are sensitive to temperature, so the drying process with heat tends to reduce flavonoid levels. This is consistent with research by Peristiowati et al. (2025), which states that the optimal drying temperature for green tea powder is 400 °C; drying at higher temperatures leads to a decrease in flavonoids. Flavonoids are commonly found in plants that contain dyes. In plants, flavonoids act as natural antioxidants, protecting plant cells from damage caused by free radicals produced by UV exposure or other environmental stressors. Furthermore, flavonoids serve as a defense mechanism against pathogens, such as bacteria, fungi, and viruses, and help increase plant resistance to unfavorable environmental conditions (Patil et al., 2024). Flavonoids are a group of polyphenols with a basic phenol structure (Mutha et al., 2021). These compounds are easily oxidized and sensitive to heat treatment. Higher temperatures increase the rate of flavonoid degradation (Liu et al., 2022). Flavonoid

degradation occurs due to the cleavage of the molecular chain and an oxidation reaction that causes the hydroxyl group to oxidize, forming other, more volatile compounds (Lin et al., 2023).

Table 2. Total flavonoids and phenolics in torch ginger tea

Drying Temperature (^{0}C)	Total Flavonoids (mg QE/g extract)	Total Phenolic Acid (mg GAE/g extract)
60	32.21	2.72
70	17.38	9.35
80	8.61	11.60

The results of total phenolic measurements (Table 2) show that the torch ginger tea extract at a drying temperature of 80 °C contained the highest total phenolic content, at 11.60 mg GAE/g extract, followed by the drying temperature of 70 °C, at 9.35 mg GAE/g extract. The lowest total phenolic content of the torch ginger tea extract was at a drying temperature of 60 °C, at 2.72 mg GAE/g extract. These data indicate that the higher the drying temperature, the higher the total phenolic content identified. The higher total phenolic content is due to the release of phenolic compounds from cell walls. Patrón-Vázquez et al. (2019) stated that higher temperatures can increase the solubility of phenolic compounds, causing the breakdown of cell structures and increasing the release of phenolic compounds such as phenolic acids (ferulic acid, gallic acid, and vanillic acid) previously bound to cell wall macromolecules. Phenol compounds are commonly found in plants, where phenolic compounds are known to play a role in antioxidant activity. The higher the phenolic compound content, the greater the antioxidant activity. Phenolic compounds in plants share a common characteristic: an aromatic ring containing one or two hydroxyl groups.

Phenol compounds tend to dissolve in polar solvents and are typically found in cell vacuoles (Minatel et al., 2017). Torch ginger flower extract also has antibacterial properties because it can inhibit bacteria. GSMS analysis results indicate that the antibacterial compound is a phenol. Bioactive phenols are antibacterial because they can cause cell lysis, protein denaturation, inhibit protein formation, and dissolve fats in cell walls (Minatel et al., 2017). Phenolic compounds are known for their powerful antioxidant activity, which helps fight free radicals in the body (Rudrapal et al., 2022). Free radicals can cause oxidative stress, which contributes to various degenerative diseases such as cancer, diabetes, and cardiovascular disease. In addition, phenolics have anti-inflammatory and antimicrobial properties (Sarankar et al., 2023).

Antioxidant Content

The results of antioxidant activity measurements (Table 3) show that torch ginger tea extract at a drying temperature of 60 °C contained the highest antioxidant content, at 78.71 ppm/µg/µg, followed by 39.66 ppm/µg at 70 °C, and the lowest at 80 °C, at 34.92 ppm/µg. These data indicate that the higher the drying temperature, the stronger the identified antioxidant activity.

Table 3. Antioxidant activity of torch ginger tea

	IC_{50}(ppm)		
Test Type	60 ^{0}C	70 ^{0}C	80 ^{0}C
Antioxidant activity	78.71	39.66	34.92

Based on Table 3, the IC_{50} values of torch ginger flower tea at 60, 70, and 80 ^{0}C drying temperatures range from 34.92 to 78.71 ppm. Kerch ginger flower tea at 60 ^{0}C drying temperatures had the highest IC_{50} value, while 80 ^{0}C drying temperatures had the lowest. The IC_{50} value of 34.92 ppm for torch ginger flower tea at 80 ^{0}C indicates that drying at higher temperatures results in stronger antioxidant activity (Zagórska et al., 2023). Drying temperature affects the concentration of bioactive compounds; excessively high drying temperatures can cause degradation of the active compounds (Gąsecka et al., 2020) but moderate temperatures can provide optimal antioxidant activity. Drying at a certain level causes cell walls and cell membranes to soften, dehydrate, and disintegrate, thus facilitating the release of bioactive compounds, especially phenolic and flavonoid groups, into the solvent during the extraction process. This makes extraction during tea making more efficient, thus increasing antioxidant activity (Narra et al., 2024). Furthermore, heating at optimal levels inactivates oxidative enzymes such as polyphenol oxidase and peroxidase, which typically trigger phenolic degradation during the drying process. This deactivation of these enzymes contributes to increased stability of antioxidant compounds during processing (Li et al., 2023a, 2023b).

Conclusion

The results showed that all tested phytochemical compounds were found in torch ginger tea except saponins. The highest total flavonoids were found at a drying temperature of 60 ^{0}C, amounting to 32.21 mg QE/g extract, and the lowest was at a drying temperature of 80 ^{0}C at 8.61 mg QE/g extract. Torch ginger tea extract at a drying temperature of 80 ^{0}C contained the highest total phenolics of 11.60 mg GAE/g extract and the lowest at a drying temperature of 60 ^{0}C at 2.72 mg GAE/g extract. The strongest antioxidant activity was found at a temperature of 80 ^{0}C, namely

34.92 Concentration (ppm)/IC_{50}. The higher the drying temperature, the more phytochemical compounds decreased. In contrast to the total phenolics which actually increased at high temperatures, the total amount of phenols increased because high temperatures can release phenolic compounds in the cell wall. The increasing amounts of phenols causes antioxidant activity to also increase.

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Conceptualization, methodology, Y.W.S.; validation, R.A.L.; formal analysis, N.G.; investigation, F.S.H.; resources, data curation, M.K.A.; writing—original draft preparation, writing—review and editing, visualization, M.N.H.N. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
The authors declare no conflict of interest.

References

Akullo, J. O., Kiage-Mokua, B. N., Nakimbugwe, D., Ng'ang'a, J., & Kinyuru, J. (2023). Phytochemical Profile and Antioxidant Activity of Various Solvent Extracts of Two Varieties of Ginger and Garlic. *Heliyon*, *9*(8), e18806. https://doi.org/10.1016/j.heliyon.2023.e18806

Amen, Y., Elsbaey, M., Othman, A., Sallam, M., & Shimizu, K. (2021). Naturally Occurring Chromone Glycosides: Sources, Bioactivities, and Spectroscopic Features. *Molecules*, *26*(24), 7646. https://doi.org/10.3390/molecules26247646

Bai, R., Sun, J., Qiao, X., Zheng, Z., Li, M., & Zhang, B. (2023). Hot Air Convective Drying of Ginger Slices: Drying Behaviour, Quality Characteristics, Optimisation of Parameters, and Volatile Fingerprints Analysis. *Foods*, *12*(6), 1283. https://doi.org/10.3390/foods12061283

Cosme, F., Aires, A., Pinto, T., Oliveira, I., Vilela, A., & Gonçalves, B. (2025). A Comprehensive Review of Bioactive Tannins in Foods and Beverages: Functional Properties, Health Benefits, and Sensory Qualities. *Molecules*, *30*(4), 800. https://doi.org/10.3390/molecules30040800

Das, A. K., Islam, Md. N., Faruk, Md. O., Ashaduzzaman, Md., & Dungani, R. (2020). Review on Tannins: Extraction Processes, Applications and Possibilities. *South African Journal of Botany*, *135*, 58–70. https://doi.org/10.1016/j.sajb.2020.08.008

Devi, O. A., & Barooah, M. S. (2025). Antioxidant Properties of Natural Bioactive Compounds. In M. Kamran Khan (Ed.), *Biochemistry* (Vol. 64). IntechOpen. https://doi.org/10.5772/intechopen.1007127

Edo, G. I., Igbuku, U. A., Makia, R. S., Isoje, E. F., Gaaz, T. S., Yousif, E., Jikah, A. N., Zainulabdeen, K., Akpoghelie, P. O., Opiti, R. A., Essaghah, A. E. A., Ahmed, D. S., & Umar, H. (2025). Phytochemical Profile, Therapeutic Potentials, Nutritional Composition, and Food Applications of Ginger: A Comprehensive Review. *Discover Food*, *5*(1), 25. https://doi.org/10.1007/s44187-025-00280-2

ElGamal, R., Song, C., Rayan, A. M., Liu, C., Al-Rejaie, S., & ElMasry, 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

Gąsecka, M., Siwulski, M., Magdziak, Z., Budzyńska, S., Stuper-Szablewska, K., Niedzielski, P., & Mleczek, M. (2020). The Effect of Drying Temperature on Bioactive Compounds and Antioxidant Activity of Leccinum scabrum (Bull.) Gray and Hericium erinaceus (Bull.) Pers. *Journal of Food Science and Technology*, *57*(2), 513–525. https://doi.org/10.1007/s13197-019-04081-1

Hu, D., Liu, X., Qin, Y., Yan, J., Li, R., & 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: X*, *19*, 100807. https://doi.org/10.1016/j.fochx.2023.100807

Ismanto, S., Rahmi, I., & Febrian, A. (2020). The Influence of Drying Temperature on Chemical Components of Herbal Tea Leaves (Spondiasdulcis soland). *IOP Conference Series: Earth and Environmental Science*, *583*(1), 012030. https://doi.org/10.1088/1755-1315/583/1/012030

Kytidou, K., Artola, M., Overkleeft, H. S., & Aerts, J. M. F. G. (2020). Plant Glycosides and Glycosidases: A Treasure-Trove for Therapeutics. *Frontiers in Plant Science*, *11*, 357. https://doi.org/10.3389/fpls.2020.00357

Li, D., Zhu, L., Wu, Q., Chen, Y., Wu, G., & Zhang, H. (2023a). Effects of Enzyme Deactivation Conditions on the Structure, Bound Phenol Content and Antioxidant Property of Phenol Modified Tartary Buckwheat Protein Hydrolysate. *Food Bioscience*, *54*, 102794. https://doi.org/10.1016/j.fbio.2023.102794

Lin, S., Simal-Gandara, J., Cao, H., & Xiao, J. (2023b). The Stability and Degradation Products of Polyhydroxy Flavonols in Boiling Water. *Current Research in Food Science*, *6*, 100509. https://doi.org/10.1016/j.crfs.2023.100509

Liu, X., Liu, Y., Shan, C., Yang, X., Zhang, Q., Xu, N., Xu, L., & Song, W. (2022). Effects of Five Extraction Methods on Total Content, Composition, and Stability of Flavonoids in Jujube. *Food Chemistry: X*, *14*, 100287. https://doi.org/10.1016/j.fochx.2022.100287

Mao, Y.-L., Wang, J.-Q., Wang, F., Cao, Q.-Q., Yin, J.-F., & Xu, Y.-Q. (2024). Effect of Different Drying Temperature Settings on the Color Characteristics of Tencha. *Food Chemistry: X*, *24*, 101963. https://doi.org/10.1016/j.fochx.2024.101963

Marchioni, I., Taglieri, I., Dimita, R., Ruffoni, B., Zinnai, A., Venturi, F., Sanmartin, C., & Pistelli, L. (2022). Postharvest Treatments on Sensorial and Biochemical Characteristics of Begonia cucullata Willd Edible Flowers. *Foods*, *11*(10), 1481. https://doi.org/10.3390/foods11101481

Minatel, I. O., Borges, C. V., Ferreira, M. I., Gomez, H. A. G., Chen, C.-Y. O., & Lima, G. P. P. (2017). Phenolic Compounds: Functional Properties, Impact of Processing and Bioavailability. In M. Soto-Hernndez, M. Palma-Tenango, & M. D. R. Garcia-Mateos (Eds.), *Phenolic Compounds – Biological Activity*. InTech. https://doi.org/10.5772/66368

Mutha, R. E., Tatiya, A. U., & Surana, S. J. (2021). Flavonoids as Natural Phenolic Compounds and Their Role in Therapeutics: An Overview. *Future Journal of Pharmaceutical Sciences*, *7*(1), 25. https://doi.org/10.1186/s43094-020-00161-8

Narra, F., Piragine, E., Benedetti, G., Ceccanti, C., Florio, M., Spezzini, J., Troisi, F., Giovannoni, R., Martelli, A., & Guidi, L. (2024). Impact of Thermal Processing on Polyphenols, Carotenoids, Glucosinolates, and Ascorbic Acid in Fruit and Vegetables and Their Cardiovascular Benefits. *Comprehensive Reviews in Food Science and Food Safety*, *23*(6), e13426. https://doi.org/10.1111/1541-4337.13426

Naufalin, R., Sutrisna, E., & Wicaksono, R. (2021). Antioxidant Potential Ingredient of Kecombrang Plants (Etlingera elatior). *IOP Conference Series: Earth and Environmental Science*, *653*(1), 012130. https://doi.org/10.1088/1755-1315/653/1/012130

Naziruddin, M. A., Jawaid, M., Elais, R., Sanny, M., Fouad, H., Yusof, N. L., & Abdul-Mutalib, N. A. (2023). Supercritical Fluid Extraction of Torch Ginger: Encapsulation, Metabolite Profiling, and Antioxidant Activity. *Journal of King Saud University - Science*, *35*(5), 102700. https://doi.org/10.1016/j.jksus.2023.102700

Pamela, V. Y., Kusumasari, S., & Meindrawan, B. (2021). Development of Functional Beverages from Herbs: Aspect of Nutrition, Processing and Safety. *IOP Conference Series: Earth and Environmental Science*, *715*(1), 012067. https://doi.org/10.1088/1755-1315/715/1/012067

Patil, J. R., Mhatre, K. J., Yadav, K., Yadav, L. S., Srivastava, S., & Nikalje, G. C. (2024). Flavonoids in Plant-Environment Interactions and Stress Responses. *Discover Plants*, *1*(1), 68. https://doi.org/10.1007/s44372-024-00063-6

Patrón-Vázquez, J., Baas-Dzul, L., Medina-Torres, N., Ayora-Talavera, T., Sánchez-Contreras, Á., García-Cruz, U., & Pacheco, N. (2019). The Effect of Drying Temperature on the Phenolic Content and Functional Behavior of Flours Obtained from Lemon Wastes. *Agronomy*, *9*(9), 474. https://doi.org/10.3390/agronomy9090474

Peristiowati, Y., Kusnul, Z., & Hariyono. (2025). The Effect of Drying Process Temperature and Milling Duration on Total Flavonoid Levels in Dry Green Tea (Camellia sinensis) Powder. *International Journal of Innovative Research and Scientific Studies*, *8*(2), 560–568. https://doi.org/10.53894/ijirss.v8i2.5208

Purwoko, A., Turnip, H., & Maser, W. H. (2019). The Pattern of Etlingera elatior Cultivation in Agroforestry Systems and Its Use as Traditional Medicines and Food by Local People of Kabanjahe, North Sumatra, Indonesia. *Biodiversitas Journal of Biological Diversity*, *20*(7). https://doi.org/10.13057/biodiv/d200728

Rachkeeree, A., Kantadoung, K., Suksathan, R., Puangpradab, R., Page, P. A., & Sommano, S. R. (2018). Nutritional Compositions and Phytochemical Properties of the Edible Flowers from Selected Zingiberaceae Found in Thailand. *Frontiers in Nutrition*, *5*, 3. https://doi.org/10.3389/fnut.2018.00003

Roby, M. H. H., Alsulami, T., Mohamed, A. S., & Aljawish, A. (2025). Harnessing Natural Antioxidants from Herbs to Enhance the Oxidative Stability and Shelf Life of Cottonseed Oil. *Journal of Food Processing and Preservation*, *2025*(1), 7239254. https://doi.org/10.1155/jfpp/7239254

Rudrapal, M., Khairnar, S. J., Khan, J., Dukhyil, A. B., Ansari, M. A., Alomary, M. N., Alshabrmi, F. M., Palai, S., Deb, P. K., & Devi, R. (2022). Dietary Polyphenols and Their Role in Oxidative Stress-Induced Human Diseases: Insights into Protective Effects, Antioxidant Potentials and Mechanism(s) of Action. *Frontiers in Pharmacology*, *13*, 806470. https://doi.org/10.3389/fphar.2022.806470

Rumicha, T. D., Hirko, F., Forsido, S. F., Tola, Y. B., Yimer, A., Kuyu, C. G., Teka, T. A., & Hailu, A.

(2025). Drying Temperature and Storage Duration for the Retention of Bioactive Compounds of Selected Wild Edible Plants from Ethiopia. *Food Science & Nutrition*, *13*(8), e70782. https://doi.org/10.1002/fsn3.70782

Salama-Müller, A., & Roese, N. (2023). Antidiarrheal Properties of the Combination of Tannin Albuminate and Ethacridine Lactate—A Narrative Review. *Natural Product Communications*, *18*(5), 1934578X231170998. https://doi.org/10.1177/1934578X231170998

Sarankar, S. K., Rajak, B., Ojha, S., & Somkuwar, S. (2023). Exploring the Utilization of Phenolic Compounds in Pharmaceuticals and Healthcare. *GSC Biological and Pharmaceutical Sciences*, *24*(3), 095–102. https://doi.org/10.30574/gscbps.2023.24.3.0372

Sari, D. K., Maulana, J., & Sismulyanto, S. (2022). The Effect of Keroncong Music Therapy on Reducing Agitation in the Elderly with Dementia. *Journal of Global Research in Public Health*, *7*(2), 94–101. https://doi.org/10.30994/jgrph.v7i2.397

Shi, L., Gu, Y., Wu, D., Wu, X., Grierson, D., Tu, Y., & Wu, Y. (2019). Hot Air Drying of Tea Flowers: Effect of Experimental Temperatures on Drying Kinetics, Bioactive Compounds and Quality Attributes. *International Journal of Food Science & Technology*, *54*(2), 526–535. https://doi.org/10.1111/ijfs.13967

Srivastava, N., Ranjana, R., Singh, S., Gupta, A. C., Shanker, K., Bawankule, D. U., & Luqman, S. (2019). Aromatic Ginger (Kaempferia galanga L.) Extracts with Ameliorative and Protective Potential as a Functional Food, Beyond Its Flavor and Nutritional Benefits. *Toxicology Reports*, *6*, 521–528. https://doi.org/10.1016/j.toxrep.2019.05.014

Topal, M. E., & Şahïn, B. (2025). Effects of Different Drying Methods on Camellia sinensis: Investigation of Quality Parameters and Drying Kinetics Using Artificial Neural Networks. *LWT*, *229*, 118172. https://doi.org/10.1016/j.lwt.2025.118172

Uddin, M. R., Akhter, F., Abedin, M. J., Shaikh, M. A. A., Mansur, M. A. A., Rahman, M. S., Jamal, A. S. I. M., Akbor, M. A., Hossain, M. H., Sharmin, S., Idris, A. M., & Khandaker, M. U. (2024). Comprehensive Analysis of Phytochemical Profiling, Cytotoxic and Antioxidant Potentials, and Identification of Bioactive Constituents in Methanoic Extracts of Sonneratia apetala Fruit. *Heliyon*, *10*(13), e33507. https://doi.org/10.1016/j.heliyon.2024.e33507

Zagórska, J., Czernicka-Boś, L., Kukula-Koch, W., Iłowiecka, K., & Koch, W. (2023). Impact of Thermal Processing on the Selected Biological Activities of Ginger Rhizome—A Review. *Molecules*, *28*(1), 412. https://doi.org/10.3390/molecules28010412

Zeng, L., Ma, M., Li, C., & Luo, L. (2017). Stability of Tea Polyphenols Solution with Different pH at Different Temperatures. *International Journal of Food Properties*, *20*(1), 1–18. https://doi.org/10.1080/10942912.2014.983605