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Discovery and Analysis of Antioxidant-Packed Compounds from Ginger

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KEYWORDS

Ginger, Antioxidant Activity, Drying Methods, Ethanol Extraction, Total Antioxidant Activity (TAA)

ABSTRACT:

Introduction: The Southeast Asian perennial ginger (Zingiber officinale Roscoe) is rich in bioactive substances including zingerone, which have antibacterial, anticancer, anti-inflammatory, and antioxidant qualities. The medicinal potential of gingerone is supported by its phenolic structure, which makes it a less risky and less side effect-prone treatment than traditional methods. This study investigates the pharmacological characteristics of zingerone, providing information for the creation of plant-based treatments. **Objective:** This study aims to explore the effects of various extraction solvents and drying techniques on the antioxidant characteristics of bentong ginger (Zingiber officinale). The study evaluates extracts made by sun, oven, freeze, and vacuum drying with ethanol, aqueous ethanol, and hot water as solvents. It also evaluates the radical scavenging abilities of DPPH• and ABTS•+ and the Ferric Reducing Antioxidant Power (FRAP).

Methods: This study investigates how Bentong ginger's (Zingiber officinale) antioxidant qualities are affected by drying techniques and extraction solvents. We measured the Total Antioxidant Activity (TAA), the DPPH• and ABTS•+ radical scavenging, the Ferric Reducing Antioxidant Power (FRAP), and the ethanol, aqueous ethanol, and hot water solvents in extracts that were dried in the sun, oven, freeze, and hoover.

Results: The result demonstrate that sun-drying and freeze-drying enhance antioxidant activity, with ethanol and aqueous ethanol being the most effective solvents. Strong positive correlations were found between Stronger associations were seen between total phenolic content (TPC) and total flavonoid content (TFC) and FRAP and TAA, but not with radical scavenging capabilities.These findings highlight the effectiveness of sun-drying and freeze-drying combined with ethanol extraction for maximizing ginger's antioxidant potential**.**

Conclusion: Research on Zingiberaceae medicinal plants reveals significant antioxidant properties, with high levels of flavonoids, phenolics, and terpenoids contributing to their effectiveness. These findings support their traditional medicinal uses and suggest potential for modern pharmaceutical and nutraceutical applications. Future studies should explore in vivo effects and clinical trials to further validate their antioxidant potential and develop natural therapies.

1. Introduction

The perennial herb ginger (*Zingiber officinale* Roscoe) is used extensively as a spice, in cooking, and in traditional medicine. Ginger is a native of Southeast Asia and is grown all over the world. It has been used as a medicine to treat conditions like nausea, vomiting, digestive disorders, and respiratory disorders. The rhizome of the ginger plant contains bioactive compounds, notably zingerone, which is a phenolic compound responsible for ginger's pungent flavor and aroma. Zingerone belongs to the gingerol family, which includes other bioactive compounds like gingerol, shogaol, and paradol. Its chemical structure, characterized by a phenolic ring with a hydroxyl group and a hydroxymethyl side chain, underlies its significant bioactivity and pharmacological properties (1–3).

Numerous pharmacological characteristics, including as antioxidant, anti-inflammatory, anticancer, and antibacterial effects, are displayed by gingerone. Its capacity to suppress prostaglandin synthesis and NF-κB activation, two processes connected to inflammation and immunological responses, is responsible for these characteristics. In addition, zingerone has the ability to stop the growth and spread of cancer cells because of its antioxidant action, which guards against oxidative stress and cellular damage. These pathways point to zingerone's potential for treatment even though its particular modes of action are yet unclear (4,5).The study

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of zingerone is important as it offers a natural and safe alternative to conventional treatments for various diseases and conditions. Current treatments, such as NSAIDs, antioxidant supplements, and chemotherapy drugs, often come with significant side effects like gastrointestinal upset, allergic reactions, and increased risk of cardiovascular disease. In contrast, zingerone, being a natural compound found in the commonly consumed spice ginger, presents a safer option with its antioxidant, anti-inflammatory, and anticancer activities. This research aims to explore zingerone's pharmacological properties and mechanisms of action, contributing valuable insights into developing new plant-based treatments for various health conditions (6,7).

2. Methods

Sample Preparation: Because ginger is so popular, it was chosen for this investigation. One kilogram of fresh, uniformly sized, and matured ginger rhizomes was collected. The ginger was cut into pieces thinner than 5 mm, cleaned, and subjected to various drying methods. Uniform heat distribution was ensured during drying. Fresh ginger served as the control sample (8,9).

Drying of Ginger: Ginger was dried for three days at 60 °C under vacuum and convection ovens, following method. It was also sun-dried on rattan trays. Moisture content was reduced to below 10-20% for microbial stability. After drying, the ginger was ground into powder, packed in airtight containers, and stored at 4 °C until analysis (10).

Antioxidant Analysis

Ginger Bioactive Compound Extraction Using Various Solvents

Three solvents—hot water, 80% aqueous ethanol, and 100% ethanol—were used to extract fresh and dried ginger at a 1:10 ratio. In conical flasks, the maceration was carried out for 24 hours at room temperature at 150 rpm. Fioroni Grade 601 paper was used to filter the extracts, and the procedure was repeated to guarantee full extraction (11). To obtain dry solids, the extracts were subsequently evaporated at 4 °C. Equation (1) was used to compute yield.

Yield % = (Weight of dry extract / Weight taken for extraction) × 100.

The dried extracts were made as stock solutions containing 1 mg/mL in the proper solvents and kept cold, at 4 °C.

Calculating the Phenolic Content in Total (TPC)

Ginger extracts were tested for total phenolic content (TPC) using the Folin-Ciocalteu method. 0.5 mL of 1:1 diluted Folin-Ciocalteu reagent and 2.5 mL of 20% sodium carbonate were added to a 100 µL extract sample that had been diluted to 1 mL with distilled water. The mixture was incubated at room temperature in the dark for forty minutes. After the incubation period, a reference blank reagent was used to detect absorbance at 725 nm. The TPC values were expressed in milligrammes of gallic acid equivalents (GAE) per gramme of dry extract (12,13) in accordance with previous studies.

Total Flavonoid Concentration (TFC) Determination

Utilising a modified aluminium chloride method as previously described, Ginger extracts' total flavonoid content (TFC) was calculated. Two millilitres of distilled water were used to dilute a 100 µL extract sample. The mixture was mixed with 0.15 mL of a 5% sodium nitrite solution and left for six minutes. A 10% aluminium chloride solution was added, and the mixture was then allowed to incubate for an additional 6 minutes. The ultimate volume of 5 millilitres was then achieved by adding enough distilled water and 2 millilitres of 4% sodium hydroxide. After 15 minutes of dark storage, the mixture's absorbance at 510 nm was determined. The number of flavonoids in each gramme of dry extract was expressed as milligrams of rutin equivalents (RE).

Identifying the AA Content

The ascorbic acid (AA) content was strongminded by applying Klein and Perry's method. After 45 minutes of re-extraction with 10 mL of 1% metaphosphoric acid, a 150 mg sample of dried ginger extract was filtered using Whatman No. 4 paper. After combining one millilitre of the filtrate with nine millilitres of 0.005% 2,6-dichlorophenolindophenol (DCPIP) solution, the absorbance at 515 nm was measured in comparison to a blank. Using a standard L-ascorbic acid calibration curve, the AA concentration was determined and

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represented as milligrams of AA per gramme of ginger extract (16).

FRAP Assay: Ferric Reducing Antioxidant Power
The ferric reducing antioxidant power (FRAP) of ginger extracts was evaluated using Pulido's method. The FRAP reagent was prepared by mixing $FeCl_3 \cdot 6H_2O$ (20 mM), acetate buffer (300 mM, pH 3.6), and TPTZ (20 mM in 40 mM HCl) in a 10:1:1 ratio. Following the combination of 30 µL of ginger extract sample and 900 µL of FRAP reagent, 1 mL of the mixture was obtained by diluting it with distilled water. The mixture was incubated at 37°C for 30 minutes, and the absorbance at 593 nm was recorded. A calibration curve was made using FeSO4 solutions ranging in concentration from 10 to 100 µM. Millimoles of Fe (II) equivalents per gramme of dry extract were used to present the results (17, 18).

To determine Total Antioxidant Activity (TAA), the Phosphomolybdenum Assay was utilised.

Utilising the green phosphomolybdenum complex method, ginger extracts' total antioxidant activity (TAA) was determined. In this procedure, 100 µL of the extract was mixed with a solution containing 4 mM ammonium molybdate, 0.6 M sulphuric acid, and 28 mM sodium phosphate in test tubes. The tubes were sealed and then incubated at 95°C for 30 minutes, or until they cooled to room temperature. Absorbance was measured at 695 nm using a reference reagent blank. To create the calibration curve, ascorbic acid (AA) solutions with concentrations ranging from 10 to 100 µg/mL were employed. Grammes of AA equivalents per gramme of dry extract, or TAA, was stated (19).

We evaluated the scavenging capacity of ginger extract against free radicals using the ABTS radical cation decolorisation test. 2.45 mM potassium persulfate was reacted with a 7 mM ABTS solution to produce the ABTS radical cation (ABTS•+). After that, it was left to incubate for 12 to 16 hours in the dark at ambient temperature. The solution was diluted with ethanol to achieve an absorbance of 0.70 ± 0.02 at 734 nm before testing. In order to perform the antioxidant assay, 100 µL of the extract and 0.9 mL of the diluted ABTS•+ solution were combined, and the combination was let to stand at room temperature in the dark for 30 minutes. The findings were shown as millimoles of TEAC (trollox equivalent antioxidant capacity) per trolox (0 to 15 µM) that were used for calibration.

Evaluating 1,1-Diphenyl-2-picrylhydrazyl's Radical Scavenging Activity (DPPH)

DPPH radical scavenging ability of the ginger extract was assessed by applying the approach outlined by Sowndhararajan et al. [59]. 50 µL of methanol was used to dilute different amounts of ginger extract, which were then mixed with 950 µL of a methanolic solution that contained 0.1 mM DPPH. The solutions were allowed to sit at room temperature in the dark for 20 minutes in order to facilitate consistent absorption. The DPPH radical decrease at 517 nm was measured after incubation (21, 22). The scavenging activity was calculated using the formula below.

$$\textbf{DPPH inhibition} = \frac{\text{Control absorbance} - \text{Sample absorbance}}{\text{Control absorbance}} X\ 100$$

Where:

- In the event that the sample is not present, the absorbance of the DPPH solution is denoted as the "control absorbance."
- The absorbance of the DPPH solution containing the sample is referred to as sample absorbance.

Plotting the inhibition % against concentration and doing a linear regression analysis yielded the IC50 value, or the concentration required to inhibit 50% of free radicals. Stronger antioxidant activity is indicated by lower IC50 values.

Results

Sample collection, drying and preparation

The ginger rhizomes were collected and dried at 60°C and then powdered.

Anti-oxidant analysis

In order to maximise the benefits of each method while minimising its drawbacks, this study used a range of antioxidant assays, which increased the precision of results pertaining to antioxidant activity. "F" represents the control sample, which was fresh ginger. The following four methods of drying were tested: freeze-drying (Z), vacuum oven-drying (V), oven-drying (O) and sun-drying (S). Furthermore, a number of solvents were used in the extraction process, which are denoted by the acronyms "H," "A," and "E," respectively: hot water (H), 80% aqueous ethanol (A), and pure ethanol (E). For example, "Z-E" denotes freeze-dried ginger

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extracted with pure ethanol, and "F-H" denotes fresh ginger extracted with hot water.

The Yield of Different Extraction Methods

Figure 1 illustrates how various drying techniques significantly affect the amount of Bentong ginger that can be extracted ($p < 0.05$). The best yield was obtained when sun-drying and aqueous ethanol extraction were combined. Particularly, sun-dried ginger produced a yield that was 6.20 times higher than fresh ginger, surpassing the results of freeze-drying (5.73 times), vacuum-drying (5.34 times), and oven-drying (2.85 times). Similar to this, sun-drying produced the most increase (3.04-fold) in ethanol extractions, with vacuum-drying (2.52-fold), freeze-drying (2.70-fold), and oven-drying (1.46-fold) following suit. Vacuum-drying (4.41-fold) yielded the highest yield among the hot water extracts; freeze- and sun-drying (3.69-fold) also yielded good results. In conclusion, the best technique for maximising extraction yield was sun-drying combined with aqueous ethanol extraction.

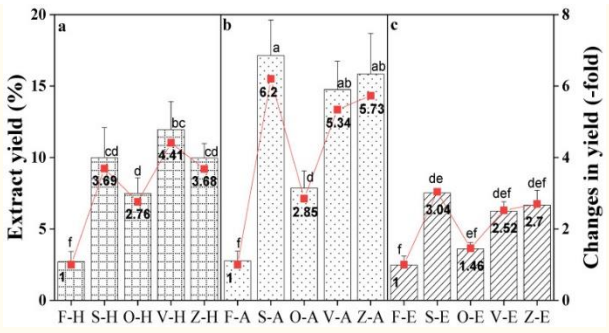

Figure 1 illustrates the ginger extraction yield using sun (S), oven (O), hoover (V) and freeze (Z) drying methods. Three distinct solvents were used in the procedures: ethanol (E), aqueous ethanol (A), and hot water (H). Variations were evaluated in relation to the fresh ginger samples, with fresh ginger (F) acting as the control for comparison. Bars with distinct letter labels indicate statistically significant differences. For example, sample Z-E is freeze-dried ginger extracted with ethanol, and sample F-H is fresh ginger extracted with hot water as a control.

Comparing the TPC, TFC, and AA Content of the Samples

When compared to fresh ginger, dried ginger has higher total phenolic content (TPC) and TFC, or total flavonoid content, is displayed in Figure 2. The freeze-dried ginger extracted with ethanol (Z-E) showed the highest TPC, with a TPC of 20.91 mg GAE/g extract, 2.60 times higher than fresh ginger. Freeze-drying was particularly effective in preserving phenolic chemicals. Additionally, there was a noticeable increase in the TPC of sun-dried ginger (S-E), rising 2.44 times to 19.57 mg GAE/g extract. Conversely, however, TPC increases were less in ethanolic extracts from vacuum- and oven-dried samples, indicating that phenolic chemicals may be degraded at higher temperatures.

The highest values of TFC were obtained by sun-drying (651.5% TFC/100 g extract) and freeze-drying (1041.5 g RE/100 g extract; 10.18-fold increase). The high TFC associated with sun-drying may be the result of increased UV-B radiation exposure and stress-induced flavonoid synthesis. The fact that TFC increased only slightly with hot water extraction as compared to other drying methods suggests that flavonoids may be degraded by enzymatic activity and the presence of water.

The content of ascorbic acid (AA) was not considerably affected by the drying techniques used. Because AA is intrinsically fragile, longer drying durations probably added to its depletion. Who reported minimal or nonexistent AA in ginger samples? This is consistent.

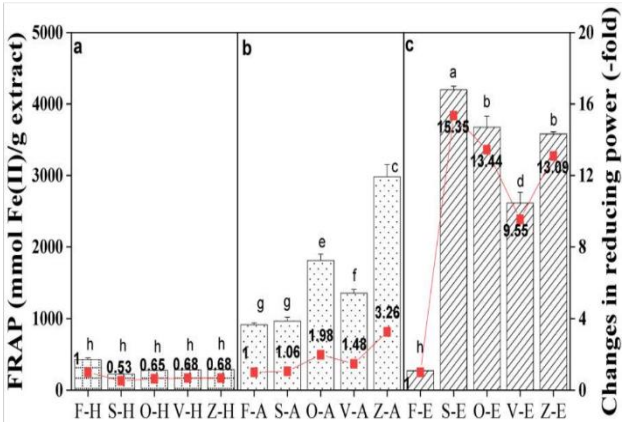

Figure 2: The reduction power of bentong ginger was evaluated using various extraction solvents and drying techniquesinclude the use of solvents such as hot water (H), aqueous (A), and ethanol (E) in conjunction with drying techniques including sun (S), oven (O), hoover (V), and freeze (Z). In this comparison, fresh ginger (F) was used as the control group. Calculations were made on changes in reduction power in relation to the

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corresponding fresh ginger samples. Significant differences between groups are indicated by bars with different letter labels. Sample Z-E shows ethanol-based freeze-drying, while Sample F-H shows the extraction of fresh ginger using hot water.

FTAA Value Comparison between Samples

The antioxidant capacity of the various samples is displayed in Figure 3, where ethanol extracts exhibited the highest Total Antioxidant Activity (TAA), followed by extracts made of aqueous ethanol and hot water. The ethanol extracts that increased TAA the most were those that were sun-dried (6.82 times), oven-dried (6.77 times), freeze-dried (6.71 times), and vacuum-dried (6.06 times). The most notable increase in TAA (2.97-fold) for aqueous ethanol extracts was obtained by freeze-drying; minor improvements were obtained by oven-drying (1.74-fold), vacuum-drying (1.61-fold), and sun-drying (1.21-fold). In comparison, hot water extracts decreased TAA by 0.82 times, with the exception of sun-drying, which resulted in a marginal improvement.

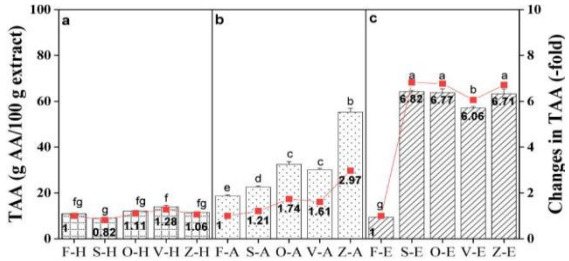

Figure 3 shows the Total Antioxidant Activity (TAA) of Bentong ginger was extracted using four distinct drying methods: sun-drying (S), oven-drying (O), vacuum-drying (V), and freeze-drying. The three solvents used were hot water (H), aqueous ethanol (A), and ethanol (E),(Z). The control was fresh ginger (F). The adjustments were computed in relation to the matching fresh ginger samples. Bars with different lettering denote statistically significant differences. For instance, Z-E is freeze-dried ginger extracted using ethanol, and F-H is fresh ginger extracted using hot water, the control, which resulted in a 0.82-fold reduction.

A comparison of the scavenging activity of ABTS•+ in the samples

As a percentage of radical cation inhibition, Figure 4 shows Bentong ginger's ability to scavenge ABTS•+ in relation to various extraction solvents and drying techniques. As a positive control, the vitamin E analogue trolox demonstrated a dose-dependent suppression of radical cations. Ethanol extracts had the highest ABTS•+ scavenging activity of all the extracts. Sun-dried extracts had the highest antioxidant activity, increasing it by 3.51 times, followed by oven-dried extracts (3.1 times), vacuum-dried extracts (2.9 times), and freeze-dried extracts (2.7 times). The greatest increase in ABTS•+ scavenging activity for aqueous ethanol extracts was produced by freeze-drying (1.48-fold), which was followed by oven-drying (1.18-fold). Vacuum and sun-drying produced lower increases (0.93-fold each). Conversely, the antioxidant activity of hot water extracts decreased, with values falling below one-fold increase.

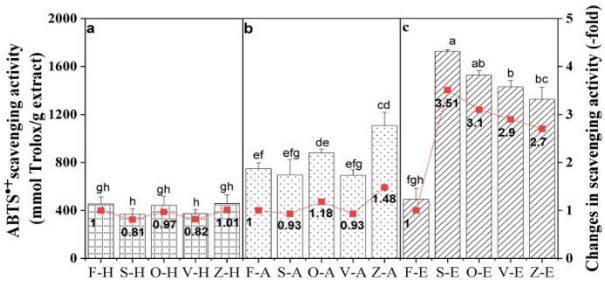

Figure 4: Using hot water (H), aqueous (A), and ethanol (E) solvents in conjunction with sun (S), oven (O), hoover (V), and freeze (Z) drying techniques, the ABTS•+ scavenging activity of bentong ginger was evaluated. Utilising fresh ginger (F) as the control group for comparison, and changes were assessed in respect to the matching fresh ginger samples. Bars with distinct letter labels denote significant variations across groups. Sample F-H displays the extraction of fresh ginger using hot water, while Sample Z-E demonstrates freeze-drying based on ethanol.

Comparing the Samples' DPPH and Scavenging Activity

In the DPPH experiment, a lower IC50 value denotes more antioxidant activity and scavenging capacity. which calculates the IC50 value to quantify the extracts' capacity as antioxidants. The investigation's findings showed that after drying, ginger samples significantly increased their capacity to scavenge DPPH•, especially when using ethanol and aqueous solvents. Figure 5 illustrates the percentage of DPPH• scavenging activity for dried ginger relative to fresh ginger.

Except for the samples that were extracted with hot water, every dried sample showed strong DPPH inhibition. Ethanol extracts demonstrated the highest

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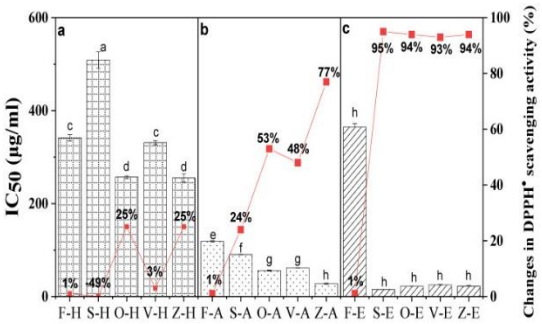
ability to scavenge free radicals. With an IC50 value of only 15.23 µg/mL, sun-dried ginger samples in particular demonstrated the highest amount of radical inhibition. The next techniques were oven (IC50 = 22.10 µg/mL), freeze (IC50 = 22.25 µg/mL), and vacuum (IC50 = 24.89 µg/mL) drying. Dried ginger extracted with ethanol showed a considerable improvement in DPPH• scavenging activity, going from 93% to 95%.They discovered that DPPH radicals were 90.1% inhibited by alcohol extracts of Vietnamese ginger.

Aqueous extracts of dried ginger showed a significant increase in DPPH scavenging activity; freeze-dried samples showed much higher activity ($p < 0.05$) than fresh ginger. For aqueous ethanol extracts, the following sequence of DPPH• scavenging activity was noted: freeze-dried (77%) > oven-dried (53%) > vacuum-dried (48%) > sun-dried (24%) > fresh (control). However, the least degree of DPPH scavenging activity was shown by hot water extracts; their IC50 values varied from 509.14 to 255.06 µg/mL, indicating a decreased capability for antioxidants.



The DPPH test results for Bentong ginger extracts prepared by sun (S), oven (O), hoover (V) and freeze-drying (Z) techniques are shown in Figure 5. Three different solvents were used to prepare the extracts: a) hot water (H), b) aqueous ethanol (A), and c) ethanol (E). Variations were compared to equivalent fresh ginger samples (F), which acted as the control. Bars with different letter labels denote significant variations between groups. For instance, Z-E stands for freeze-dried ginger extracted with ethanol, and F-H stands for fresh ginger extracted with hot water.

5. Discussion

Because of its secondary metabolites, gingerols and shogaols, which give ginger its unique flavour and medicinal qualities, ginger is widely recognised for having potent antioxidant qualities. This study uses many assays to explore the intricate interaction between antioxidant components and their activity as it looks at the effects of different drying methods and extraction solvents on the antioxidant activity of bentong ginger.

Impact of Drying Methods on Antioxidant Activity

Drying ginger enhances its antioxidant properties by increasing the extractable phytochemicals through several mechanisms. The drying process breaks down the cell structures in the ginger tissue, making it more brittle and allowing intracellular chemicals to be released into solvents (8). Sun-drying, in particular, emerged as the most effective method, significantly boosting Total Antioxidant Activity (TAA) and reducing the IC50 values for DPPH• scavenging (8,23). This can be attributed to the gradual moisture loss during sun-drying, which concentrates the antioxidants and stimulates stress-induced synthesis of additional antioxidant compounds (24,25).

Freeze-drying also demonstrated superior antioxidant activity compared to other methods, likely due to its ability to preserve antioxidant compounds through lyophilization, which avoids high-temperature degradation. However, oven-drying and vacuum-drying, while effective revealed somewhat lower levels of antioxidant activity when compared to freeze- and sun-drying. This implies that the conditions and procedure employed during drying have a significant impact on the retention of antioxidants. (26,27).

Extraction Solvents and Their Effectiveness

Ginger extracts' potential as antioxidants is greatly influenced by the extraction solvent used.. Ethanol and aqueous ethanol (80%, v/v) were found to be the most effective solvents, likely due to their ability to solubilize a broader range of antioxidant compounds, including phenolics and flavonoids. Ethanol extracts consistently exhibited the highest levels of antioxidant activity across various assays, reinforcing its efficacy as a solvent for extracting antioxidant components from ginger (28).

Conversely, hot water extracts showed minimal improvement in antioxidant activity, which could be attributed to high surface tension washing away hydrophilic compounds or high enzymatic activity affecting antioxidant stability. The varying effectiveness of different solvents highlights the the significance of

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choosing the appropriate solvent to optimise antioxidant component extraction and preservation (29–31).

Antioxidant Content and Activity Correlation

Strong positive connections were found by Pearson's correlation analysis between antioxidant substances such ferric reducing antioxidant power (FRAP), total phenolic content (TPC), and total flavonoid content (TFC).This implies that greater concentrations of these substances are linked to improved antioxidant and reductive capacities. Likewise, a robust association was noted between Total Antioxidant Activity (TAA) and TPC and TFC, suggesting that these substances have a substantial impact on ginger's antioxidant potential (32, 33).

Nevertheless, there was less of a link between antioxidant concentration and DPPH and ABTS, two activities that scavenge free radicals [76, 78]. This suggests that although phenolic content plays a significant role in antioxidant activity, other parameters that are as important include molecular weight, the presence of particular functional groups, and the overall structure of antioxidant compounds. Tannic acid, for instance, is a high molecular weight phenolic that is more effective at neutralising radicals (34, 35).

Overall Implications

The study emphasises how drying and extraction techniques might improve ginger's antioxidant qualities. It was shown that the best techniques for maintaining and boosting antioxidant content and activity were sun- and freeze-drying. Ethanol and aqueous ethanol were the most effective solvents for extracting these antioxidants. The correlation analysis further supports that while TPC and TFC contribute significantly to antioxidant activity, the specific characteristics and molecular properties of the compounds also influence their effectiveness.

In conclusion, optimizing drying methods and extraction solvents is vital for maximizing the antioxidant potential of ginger. The findings highlight that both the choice of drying technique and solvent, as well as the inherent characteristics of antioxidant compounds, play integral roles in determining the overall antioxidant capacity of ginger.

Reference

1. Kumari M, Kumar M, Solankey SS. Zingiber officinale Roscoe: Ginger BT - Medicinal, Aromatic and Stimulant Plants. In: Novak J, Blüthner WD, editors. Cham: Springer International Publishing; 2020. p. 605–21. Available from: https://doi.org/10.1007/978-3-030-38792-1_20
2. Mao QQ, Xu XY, Cao SY, Gan RY, Corke H, Beta T, et al. Bioactive Compounds and Bioactivities of Ginger (Zingiber officinale Roscoe). Foods (Basel, Switzerland). 2019 May;8(6).
3. Mohamad Hesam Shahrajabian WS, Cheng Q. Clinical aspects and health benefits of ginger (Zingiber officinale) in both traditional Chinese medicine and modern industry. Acta Agric Scand Sect B — Soil \& Plant Sci [Internet]. 2019;69(6):546–56. Available from: https://doi.org/10.1080/09064710.2019.1606930
4. Bashir N, Ahmad SB, Rehman MU, Muzamil S, Bhat RR, Mir MUR, et al. Zingerone (4-(four-hydroxy-3-methylphenyl) butane-two-1) modulates adjuvant-induced rheumatoid arthritis by regulating inflammatory cytokines and antioxidants. Redox Rep. 2021 Dec;26(1):62–70.
5. Ahmad B, Rehman MU, Amin I, Arif A, Rasool S, Bhat SA, et al. A Review on Pharmacological Properties of Zingerone (4-(4-Hydroxy-3-methoxyphenyl)-2-butanone). ScientificWorldJournal. 2015;2015:816364.
6. Anh NH, Kim SJ, Long NP, Min JE, Yoon YC, Lee EG, et al. Ginger on Human Health: A Comprehensive Systematic Review of 109 Randomized Controlled Trials. Nutrients [Internet]. 2020;12(1). Available from: https://www.mdpi.com/2072-6643/12/1/157
7. Ballester P, Cerdá B, Arcusa R, Marhuenda J, Yamedjeu K, Zafrilla P. Effect of Ginger on Inflammatory Diseases. Molecules [Internet]. 2022;27(21). Available from: https://www.mdpi.com/1420-3049/27/21/7223
8. Mustafa I, Chin NL. Antioxidant Properties of Dried Ginger (Zingiber officinale Roscoe) var. Bentong. Foods [Internet]. 2023;12(1). Available from: https://www.mdpi.com/2304-8158/12/1/178
9. E J, R V, T JZ. Quality of dry ginger (Zingiber officinale) by different drying methods. J Food Sci Technol. 2014 Nov;51(11):3190–8.
10. Depiver JA, Mallik S. An Empirical Study on Convective Drying of Ginger Rhizomes Leveraging Environmental Stress Chambers and Linear Heat Conduction Methodology. Agriculture [Internet]. 2023;13(7). Available from: https://www.mdpi.com/2077-0472/13/7/1322
11. Kumar A, P N, Kumar M, Jose A, Tomer V, Oz E, et al. Major Phytochemicals: Recent Advances in Health Benefits and Extraction Method. Molecules [Internet]. 2023;28(2). Available from:

Journal of Chemical Health Risks

www.jchr.org

JCHR (2024) 14(5), 1744-1752 | ISSN:2251-6727

https://www.mdpi.com/1420-3049/28/2/887

12. Idris NA, Yasin HM, Usman A. Voltammetric and spectroscopic determination of polyphenols and antioxidants in ginger (Zingiber officinale Roscoe). Heliyon [Internet]. 2019;5(5):e01717. Available from: https://www.sciencedirect.com/science/article/pii/S2405844018377879
13. Ali AMA, El-Nour MEM, Yagi SM. Total phenolic and flavonoid contents and antioxidant activity of ginger (Zingiber officinale Rosc.) rhizome, callus and callus treated with some elicitors. J Genet Eng Biotechnol. 2018 Dec;16(2):677–82.
14. Akullo JO, Kiage-Mokua BN, Nakimbugwe D, Ng'ang'a J, Kinyuru J. Phytochemical profile and antioxidant activity of various solvent extracts of two varieties of ginger and garlic. Heliyon [Internet]. 2023;9(8):e18806. Available from: https://www.sciencedirect.com/science/article/pii/S2405844023060140
15. Fattahi S, Zabihi E, Abedian Z, Pourbagher R, Motevalizadeh Ardekani A, Mostafazadeh A, et al. Total Phenolic and Flavonoid Contents of Aqueous Extract of Stinging Nettle and In Vitro Antiproliferative Effect on Hela and BT-474 Cell Lines. Int J Mol Cell Med. 2014;3(2):102–7.
16. Amjad E, Sokouti B, Asnaashari S. A hybrid systems biology and systems pharmacology investigation of Zingerone's effects on reconstructed human epidermal tissues. Egypt J Med Hum Genet [Internet]. 2021;22(1):90. Available from: https://doi.org/10.1186/s43042-021-00204-6
17. Arora DS, Chandra P. Antioxidant Activity of Aspergillus fumigatus. ISRN Pharmacol. 2011;2011:619395.
18. Fernandes RPP, Trindade MA, Tonin FG, Lima CG, Pugine SMP, Munekata PES, et al. Evaluation of antioxidant capacity of 13 plant extracts by three different methods: cluster analyses applied for selection of the natural extracts with higher antioxidant capacity to replace synthetic antioxidant in lamb burgers. J Food Sci Technol. 2016 Jan;53(1):451–60.
19. Wan C, Yu Y, Zhou S, Liu W, Tian S, Cao S. Antioxidant activity and free radical-scavenging capacity of Gynura divaricata leaf extracts at different temperatures. Pharmacogn Mag. 2011 Jan;7(25):40–5.
20. Ilyasov IR, Beloborodov VL, Selivanova IA, Terekhov RP. ABTS/PP Decolorization Assay of Antioxidant Capacity Reaction Pathways. Int J Mol Sci. 2020 Feb;21(3).
21. Hinneburg I, Damien Dorman HJ, Hiltunen R. Antioxidant activities of extracts from selected culinary herbs and spices. Food Chem [Internet]. 2006;97(1):122–9. Available from: https://www.sciencedirect.com/science/article/pii/S0308814605002840
22. Mošovská S, Nováková D, Kaliňák M. Antioxidant activity of ginger extract and identification of its active components. Acta Chim Slovaca [Internet]. 2015;8(2):115–9. Available from: https://doi.org/10.1515/acs-2015-0020
23. Rahman NFA, Shamsudin R, Ismail A, Shah NNAK, Varith J. Effects of drying methods on total phenolic contents and antioxidant capacity of the pomelo (Citrus grandis (L.) Osbeck) peels. Innov Food Sci Emerg Technol [Internet]. 2018;50:217–25. Available from: https://www.sciencedirect.com/science/article/pii/S1466856417300139
24. Roshanak S, Rahimmalek M, Goli SAH. Evaluation of seven different drying treatments in respect to total flavonoid, phenolic, vitamin C content, chlorophyll, antioxidant activity and color of green tea (Camellia sinensis or C. assamica) leaves. J Food Sci Technol. 2016 Jan;53(1):721–9.
25. Toydemir G, Gultekin Subasi B, Hall RD, Beekwilder J, Boyacioglu D, Capanoglu E. Effect of food processing on antioxidants, their bioavailability and potential relevance to human health. Food Chem X [Internet]. 2022;14:100334. Available from: https://www.sciencedirect.com/science/article/pii/S2590157522001328
26. Bhatta S, Stevanovic Janezic T, Ratti C. Freeze-Drying of Plant-Based Foods. Foods (Basel, Switzerland). 2020 Jan;9(1).
27. Silva GV da, Machado BAS, Oliveira WP de, Silva CFG da, Quadros CP de, Druzian JI, et al. Effect of Drying Methods on Bioactive Compounds and Antioxidant Capacity in Grape Skin Residues from the New Hybrid Variety "BRS Magna". Molecules. 2020 Aug;25(16).
28. Zhang QW, Lin LG, Ye WC. Techniques for extraction and isolation of natural products: a comprehensive review. Chin Med. 2018;13:20.
29. Spigno G, Tramelli L, De Faveri DM. Effects of extraction time, temperature and solvent on concentration and antioxidant activity of grape marc phenolics. J Food Eng [Internet]. 2007;81(1):200–8. Available from: https://www.sciencedirect.com/science/article/pii/S0260877406006649
30. Kim IS, Yang MR, Lee OH, Kang SN. Antioxidant Activities of Hot Water Extracts from Various Spices. Int J Mol Sci [Internet]. 2011;12(6):4120–31. Available from: https://www.mdpi.com/1422-0067/12/6/4120
31. Dong CH, Yao YJ. In vitro evaluation of antioxidant activities of aqueous extracts from natural and

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cultured mycelia of Cordyceps sinensis. Leb + [i.e und] Technol Food Sci + Technol Sci + Technol Aliment. 2008 May;41(4):669–77.

32. Priyanthi C, Sivakanesan R. The Total Antioxidant Capacity and the Total Phenolic Content of Rice Using Water as a Solvent. Int J food Sci. 2021;2021:5268584.
33. Muflihah YM, Gollavelli G, Ling YC. Correlation Study of Antioxidant Activity with Phenolic and Flavonoid Compounds in 12 Indonesian Indigenous Herbs. Antioxidants (Basel, Switzerland). 2021 Sep;10(10).
34. Wang J, Hu S, Nie S, Yu Q, Xie M. Reviews on Mechanisms of In Vitro Antioxidant Activity of Polysaccharides. Oxid Med Cell Longev. 2016;2016:5692852.
35. Bibi Sadeer N, Montesano D, Albrizio S, Zengin G, Mahomoodally MF. The Versatility of Antioxidant Assays in Food Science and Safety-Chemistry, Applications, Strengths, and Limitations. Antioxidants (Basel, Switzerland). 2020 Aug;9(8).