Jurnal Crystal: Publikasi Penelitian Kimia dan Terapannya
Vol. 6, No. 2, Page. 72 - 161, 2024
e-ISSN 2685-7065

THE EFFECT OF TEMPERATURE AND ROCK SUGAR PERCENTAGE ON POLYPHENOL CONTENT IN PROCESSED RED GINGER (*Zingiber officinale* var. Rubrum) PRODUCTS

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Riwayat Article
Received: 27 March 2024; Received in Revision: 06 July 204; Accepted: 24 July 2024

Abstract

The aim of this study was to determine the effect of evaporation-crystallization operating conditions on the polyphenolic content of red ginger extract (*Zingiber officinale* var. Rubrum), a medicinal plant known for its multiple health benefits in traditional Asian medicine. Polyphenolic compounds found in red ginger, such as gingerol and shogaol, are potent antioxidants with a variety of therapeutic effects, including antiviral, anticancer, and anti-inflammatory properties. The extraction and crystallization processes are essential to maximizing the bioavailability of these compounds. This study investigated the variation of crystallizer (rock sugar) content and temperature during both processes on the polyphenol content of the samples. In this study, the evaporation-crystallization method was applied to red ginger raw materials to determine the optimal conditions for maintaining polyphenol content. The results showed that red ginger extract before treatment (sample P) had the highest polyphenol content, recorded at about 3150 mg gallic acid/g. Sample SB treated at 80°C with 100% sugar content had a significant polyphenol content of about 2300 mg gallic acid/g. In contrast, increasing the treatment temperature by 10°C (SD sample) resulted in the lowest content measured, indicating a temperature-sensitive condition in the maintenance of polyphenols during the process. Further analysis showed that sugar content had a significant effect on polyphenol stability. This finding contradicts previous studies suggesting that sugar can cause polyphenol degradation. This study suggested that the presence of crystallizing agents may affect the Folin–Ciocalteu reagent used for polyphenol content analysis, leading to higher readings. In addition, this study investigated the polyphenol content in liquid-phase samples (after brewing and dissolution in hot water). The results showed a decrease compared to the solid-phase samples. The decrease in polyphenol content during steeping is consistent with the idea that hot water immersion can dissolve and thus reduce phenolic content. This study highlights the importance of extraction-crystallization parameters on the quality of red ginger extracts and suggests that control of temperature and sugar concentration can significantly improve polyphenol stability, thereby optimizing the therapeutic potential of red ginger products. Comparisons with commercial products highlight the superior polyphenol content of the study samples, supporting tailored extraction methods to maximize health benefits.

Keywords: evaporation-crystallization, gallic acid, polyphenol content, red ginger extract, rock sugar.

Abstrak

Penelitian ini bertujuan untuk mengetahui pengaruh kondisi operasi evaporasi-kristalisasi terhadap kandungan polifenol pada ekstrak jahe merah (*Zingiber officinale* var. Rubrum), sebuah tanaman obat yang terkenal dalam pengobatan tradisional Asia karena beragam manfaat kesehatannya. Senyawa polifenolik yang terdapat dalam jahe merah, seperti gingerol dan shogaol, adalah antioksidan kuat yang menawarkan berbagai efek terapeutik, termasuk antiviral, antikanker, dan antiinflamasi. Proses ekstraksi dan kristalisasi sangat penting untuk memaksimalkan bioavailabilitas senyawa ini. Penelitian ini mengkaji tentang variasi persentase agen kristalisasi (gula batu) dan suhu selama kedua proses tersebut terhadap kandungan polifenol sampel. Penelitian ini menggunakan metode evaporasi-kristalisasi pada bahan baku jahe merah untuk menentukan kondisi optimal dalam mempertahankan kadar polifenolnya. Hasil menunjukkan bahwa ekstrak jahe merah sebelum perlakuan (sampel P) memiliki kandungan polifenol tertinggi, tercatat sekitar 3150 mg asam galat/g. Sampel SB yang diperlakukan dengan kandungan gula 100% pada 80°C memiliki kandungan polifenol signifikan sekitar 2300 mg asam galat/g. Sebaliknya, peningkatan suhu perlakuan sebesar 10°C (sampel SD) menghasilkan kandungan terendah yang diukur, menunjukkan kondisi yang sensitif terhadap suhu dalam menjaga polifenol selama proses berlangsung. Analisis lebih lanjut menunjukkan bahwa kandungan gula berdampak signifikan terhadap stabilitas polifenol. Sebuah temuan yang bertentangan dengan studi sebelumnya yang menyarankan gula dapat menyebabkan degradasi polifenol. Penelitian ini mengemukakan bahwa keberadaan agen kristalisasi dapat mempengaruhi reagen Folin-Ciocalteu yang digunakan untuk analisis kandungan polifenol, menyebabkan nilai yang diukur lebih tinggi. Selain itu, penelitian ini mengeksplorasi kandungan polifenol dalam sampel fase cair (pasca penyeduhan – pelarutan ke dalam air panas). Hasilnya menunjukkan penurunan dibandingkan dengan sampel fase padat. Penurunan tingkat polifenol selama penyeduhan sesuai dengan gagasan bahwa perendaman air panas dapat melarutkan dan dengan demikian mengurangi kandungan fenolik. Penelitian ini menekankan pentingnya parameter ekstraksi-kristalisasi terhadap kualitas ekstrak jahe merah dan menyarankan bahwa kontrol suhu dan konsentrasi gula dapat meningkatkan stabilitas polifenol secara signifikan, sehingga mengoptimalkan potensi terapeutik produk jahe merah. Perbandingan dengan produk komersial menonjolkan kandungan polifenol yang superior dari sampel penelitian, mendukung metode ekstraksi yang disesuaikan untuk memaksimalkan manfaat kesehatan.

Kata kunci: asam galat, ekstrak jahe merah, evaporasi-kristalisasi, gula batu, kadar polifenol.

1. Introduction

The herb red ginger (*Zingiber officinale* var. rubrum) is widely used in traditional medicine in Asia. Red ginger acts as an immunomodulator and is considered safe because it has few side effects (Zhang et al., 2022). Compared to other types of ginger, red ginger has the highest essential oil content, which is 2.58–3.90%, so people often use it as a medicine (Hidayati et al., 2015). Active compounds such as gingerol, zingeron, shogaol, and zingiberen in red ginger provide various health benefits such as antiviral, anticancer, anti-inflammatory, antifungal, antioxidant, antibacterial, analgesic, and diuretic (Dewi & Riyandari, 2020). The chemical content of red ginger is presented in Table 1 below.

Table 1. Quantitative chemical content of red ginger (Saptiwi et al., 2019)

Compound	Percentage/Content
Gingerol	
6 Gingerol	0.5-1.5% of dry weight
8 Gingerol	0.1-0.5% of dry weight
10-Gingerol	0.05-0.2% of dry weight
Shogaol	
6-Shogaol	0.1-0.5% of dry weight
Zingiberene	25-30 of essential oil
Beta-Bisabolene	10-15% of essential oil
Beta-Sesquiphellandrene	5-10% pf essential oil
Curcumene	1-5% of essential oil
Farnesene	1-5% of essential oil
Neral	0.5-1.0% of essential oil
Geranial	1-2% of essential oil
Linalool	0.1-0.5% of essential oil
Zingibain	0.5-1.0% of dry weight
Vitamin and Minerals	
Vitamin C	5-10 mg per 100 g of fresh ginger
Vitamin B6	0.1-0.2 mg per 100 g of fresh ginger
Magnesium	40-50 mg per 100 g of fresh ginger
Potassium	400-500 mg per 100 g of fresh ginger

The gingerol content of red ginger can reduce high blood cholesterol levels (SNF Bulfiah, 2021). Antioxidants, one of the compounds in red ginger, can inhibit diseases caused by free radicals (Munadi, 2020). However, to maximize the benefits of red ginger, an extraction process is needed to separate its active compounds. This extraction process requires the right techniques and methods so that the red ginger extract produced is of higher quality (Tritanti & Pranita, 2019). One of the advanced methods used is crystallization

The quality of red ginger extract can be measured by its phenolic content, a quantitative measure of phenolic compounds in materials. Phenolic compounds are aromatic compounds with one hydroxyl group directly attached to an aromatic carbocyclic nucleus (Badriyah et al., 2017; Smith & Tatchell, 1969), C_6H_5OH as a phenolic formula. According to (Luhurningtyas et al., 2021), the crude extract of red ginger has a phenolic content of 338.568 mg GAE/g. Polyphenols, one of the groups of phenolic compounds, have abundant biological activities such as antioxidant, antihypertensive, and α-glucosidase inhibitory activities (U Ghani, 2020).

Polyphenol contents in red ginger extract can be affected by factors such as the addition of crystallizers and temperature. The addition of crystallizers can improve product stability, and shelf life (Sari & Hadiyanto, 2013) but may affect polyphenol contents (Andriani et al., 2012). Some studies show that high temperatures can reduce polyphenol contents in foods, and heating at high temperatures can cause polyphenol degradation, making products less stable (Asfaw & Tefera, 2020). This study aims to determine the conditions that can maintain polyphenol contents in red ginger extract with variations in concentration and temperature. In addition, different sources of crystallization agents may also affect the polyphenol content of red ginger extract.

2.Methodology

Materials

The equipment used is an evaporator-crystallizer with a stirrer (Iqbal et al., 2024; Sari et al., 2020; Sari et al., 2023), and a size reducer for the main raw material. The ingredients used are red ginger, rock sugar (Aprillia & Sari, 2024), distilled water, and natural spices as a spicy flavor enhancer.

Preparation Sample

The preparation of research samples includes the preparation of raw materials and processed extracts of red ginger. The process includes the initial handling of raw materials (sorting and washing), extraction, filtration, and sedimentation. The all of process showed in Figure 1.

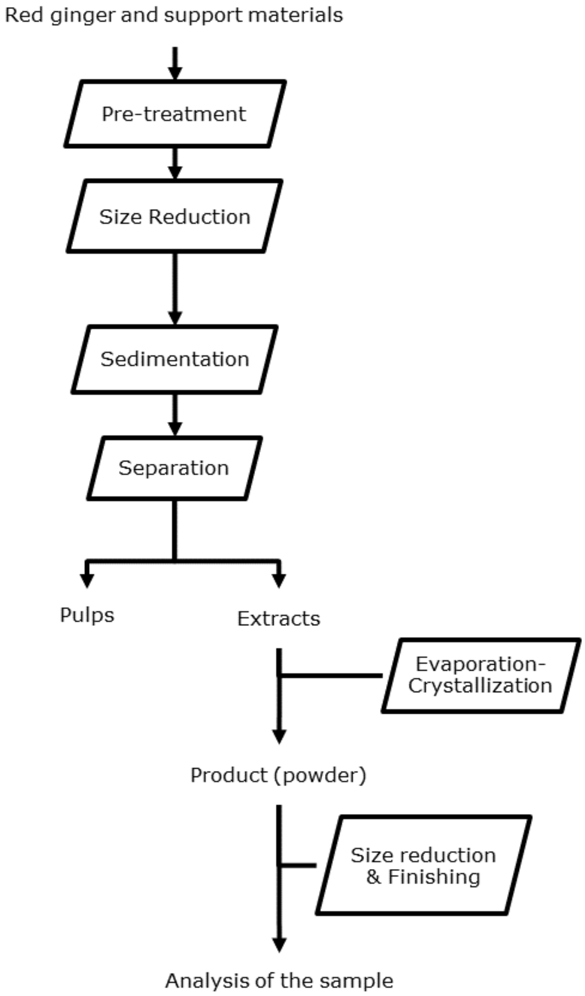

Figure 1. The research process to produce red ginger powder

The samples were subjected to temperature treatment (T = 80 and 90°C), and the percentage of new sugar (60 and 100%) underwent evaporation and crystallization processes. Fresh material in process is given SA until SD code. Pulp is fed as raw materials (Sari et al., 2024) in Figure 1, then given SE until SH code. The product underwent size uniformity (Sari et al., 2023) and product packaging (Fardiansyah et al., 2023; Fauzia et al., 2023; Ulfa et al., 2022). The samples were stored at room temperature and analyzed in the laboratory for polyphenol content (Table 1).

Table 1. Research sample variables with red ginger

No	Sample	Code	Temperature, °C	Rock Sugar, %
1	Fresh red ginger	P	-	-
2	Commercial product	SK and SL	-	-
3	Red ginger	SA	80	60
		SB	80	100
		SC	90	60
		SD	90	100
4	Residue red ginger	SE	80	60
		SF	80	100
		SG	90	60
		SH	90	100

Analysis of Polyphenol Contents

The total polyphenol test procedure used is based on the method of (Chatatikun & Chiabchalard, 2013) through UV-Visible 1800 Shimadzu equipment in Figure 2. The testing process starts with the sample being dissolved in distilled water and prepared at a concentration of 10,000 ppm. A total of 1 ml of sample was added to 2 ml of distilled water. Then 1 ml of 10% Folin solution and 1 ml of bicarbonate solution (60 g/L) were added. The sample was then incubated for 60 minutes at room temperature. The absorbance was read on a spectrophotometer at a wavelength of 725 nm. Gallic acid standards were prepared by dissolving gallic acid in distilled water and were prepared at concentrations of 100, 250, 500, and 1000 g/ml. Distilled water was also used as a blank. The standards and blanks were analyzed in the same way as the samples. Total polyphenols were calibrated against the gallic acid standard and expressed as mg gallic acid equivalent (G.A.E.) g^{-1}D.W. Gallic acid was used as a standard because gallic acid is a type of natural antioxidant that is very stable (Rahayu & Inanda, 2015).

Figure 2. Analysis of polyphenol contents through spectrophotometer device

3. Results and Discussion

The use of the evaporation-crystallization process with red ginger raw materials gave the results shown in Figure 3. Sample P (pure red ginger without processing) had the highest polyphenol content, which was about 3000 mg gallic acid/g, compared to the other samples. It is possible that the high polyphenol content in sample P was due to the lack of temperature treatment and the sugar content in the sample. Meanwhile, the red ginger sample with the highest polyphenol content was sample SB, which had a sugar content of 100% and a temperature of 80°C and a polyphenol content of about 2300 mg gallic acid/g. On the other hand, sample SD, with 100% sugar content and a temperature of 90°C, had the lowest polyphenol content, which was about 1900 mg gallic acid/g. Similar findings (Asyafa & Sari, 2023) about the functional group intensity are higher at the evaporation-crystallization process temperature of 90 compared to 80°C and (Iqbal et al., 2024) used another agent crystallization.

The effect of temperature and sugar content on the polyphenol content of red ginger extract was significant. The SB sample with the same sugar content had a higher polyphenol content than the SD sample. The study by (Antony & Farid, 2022) showed that temperature had a significant effect on polyphenol content. On the other hand, (Dewata et al., 2017) study showed that samples treated at 100°C had a lower phenolic content than other samples. High temperatures are likely to cause phenolic compounds to dissolve in the solvent, resulting in lower polyphenol levels (Ibrahim et al., 2015).

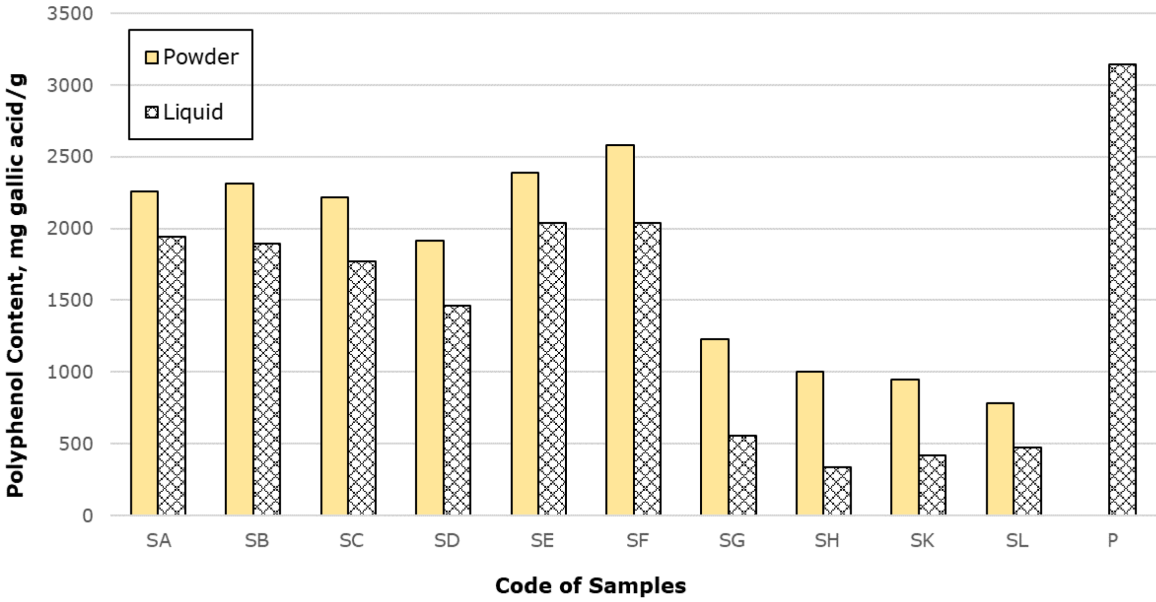

Figure 3. Quantification of polyphenols in processed red ginger products: evaporation-crystallization

A comparison between SB and SA samples in the same temperature treatment showed that SB samples had a higher polyphenol content. In a study by (Loncaric et al., 2014), it was stated that sugar can cause degradation of the polyphenol content in the sample, making it lower than the pure sample. However, the results of this study showed that the sample with 100% sugar content, namely sample SB, had the highest polyphenol content. This may be due to the effect of the Folin-Ciocalteu reagent on the polyphenol content analysis process. Research by (Prastianti et al., 2016) found that sugars have hydroxyl groups, which can reduce the Folin-Ciocalteu reagent and increase the analysis of total polyphenol content. In general, phenolic compound or sugar with Folin-Ciocalteu will produce a product with blue color indicator.

In the liquid phase, additional treatment in the form of a brewing process using hot water results in lower polyphenol levels than solid phase samples. According to a study by (Aisyah et al., 2014), steeping with water causes the phenolic content of the sample to dissolve in the water. This is because during the brewing process, the red ginger extract powder is in direct contact with hot water, which makes it easier for water to enter the cell wall and dissolve phenolic compounds (Dhurhania & Novianto, 2018). In addition, the porosity of this red ginger powder product (68.03 and 76.48% in 90°C and 90% agent crystallization, indicated mesopores and macropores) improves the dissolving process through hot water media (Kurniyanto & Sari, 2023) from previous measurement treatments (delicacy) (Sari et al., 2021; Sinabutar & Sari, 2024).

Figure 3 also shows that the polyphenol content in the study samples was higher than in commercial products. Similarly, the findings (Nuramalia & Sari, 2024) involve carotenoids ($C_{40}H_X$, *x* depends on specific type of carotenoid) and post-evaporation-crystallization glucose processes in red ginger extracts. This difference may be due to factors such as the materials used, processing, and different extraction methods. Carotenoids are tetraterpenoids with hydrophobic properties (difficult to dissolve in water); easily degraded because they are sensitive to light, heat and oxygen; and exhibit antioxidant properties by quenching singlet oxygen and scavenging free radicals (Crupi et al., 2012; Fernandes et al., 2018). A study by (Putri et al., 2022) showed differences in polyphenol levels between two different methods, while a study by (Susanty & Bachmid, 2016) showed that the reflux method produced higher phenolic levels compared to the maceration method. In conclusion, different methods can produce different levels of polyphenols.

4. Conclusion

The study of polyphenol content during the evaporation-crystallization of red ginger preparations was carried out. The results showed that:

a. Polyphenol content influenced by temperature and sugar
   1) The polyphenol content in red ginger is significantly affected by the temperature and sugar content during the extraction process.
   2) Samples with 100% sugar content and 80°C temperature had the highest polyphenol content, ranging from 2315 to 2579 mg gallic acid/g.
   3) Samples processed at high temperatures with lower sugar content exhibited lower polyphenol levels, between 1230 and 2218 mg gallic acid/g.

b. Phase comparison in hot water brewing
   1) The liquid phase of the hot water brewing process resulted in lower polyphenol levels compared to the solid phase samples.
   2) This indicates that more polyphenols remain in the solid residue during brewing.

c. Use of residual raw materials
   1) Utilizing residual raw materials from fresh red ginger is competitive in terms of residual polyphenol content during the evaporation-crystallization process at 80°C.
   2) This approach can be advantageous in maximizing the polyphenol content in the final product.

d. Comparison with commercial samples
   1) Processed products from this study showed higher polyphenol content compared to commercial red ginger products.
   2) Differences in the materials used, the presence or absence of crystallization agents, processing methods, and extraction techniques contribute to these variations.

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