EFFECTS OF EXTRACTION CONDITIONS AND FORMULATION ON THE QUALITY OF CANNED RAMBUTAN TEA

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ABSTRACT:

This study investigates the effects of extraction conditions and formulation parameters on the quality of canned rambutan tea. Tea was extracted at temperatures ranging from 70 to 90°C for 5 - 15 minutes, while formulation variables included syrup concentration (35 - 45%), kumquat juice addition (2–6%), and the rambutan-to-tea ratio (2:8 - 4:6, w/w). The results indicate that increasing extraction temperature and time enhances total dissolved solids and phenolic content. Kumquat juice primarily influences acidity, whereas syrup exerts a comparatively minor effect. The rambutan-to-tea ratio emerges as a key determinant of overall quality, with the 3:7 ratio achieving the highest sensory acceptance. Under the tested conditions, the optimal formulation comprises extraction at 90°C for 10 minutes, combined with 40% syrup, 4% kumquat juice, and a 3:7 (w/w) ratio, yielding a well-balanced beverage with favorable antioxidant properties.

Keywords: rambutan tea, extraction conditions, formulation, canned beverage.

1. Introduction

Rambutan (Nephelium lappaceum L.) is a tropical fruit widely cultivated in Southeast Asia, including Vietnam, and is highly valued for its appealing appearance, sweet taste, and nutritional composition. The edible pulp is rich in sugars, organic acids, vitamins, and phenolic compounds, which contribute to its notable antioxidant activity (Yang et al., 2009). However, due to its high moisture content and metabolic activity, fresh rambutan is highly perishable, resulting in a limited shelf life and considerable postharvest losses (Manjunath et al., 2018). Consequently, the development of value-added rambutan-based products is necessary to enhance its utilization and economic value.

The incorporation of tea extract with rambutan pulp represents a promising approach for developing a novel functional beverage. Tea is a well-known source of bioactive compounds, particularly catechins and other polyphenols, which exhibit strong antioxidant properties (Cabrera et al., 2006). Meanwhile, rambutan pulp contributes natural sweetness, distinctive flavor, and additional nutrients, thereby enhancing both the sensory and nutritional quality of the product. Furthermore, canning technology offers advantages in terms of microbial stability, extended shelf life, and suitability for large-scale commercialization.

Extraction is a critical processing step that significantly influences the quality of tea-based beverages. Extraction parameters, particularly temperature and time, directly affect the release of soluble solids and phenolic compounds. Elevated temperatures may improve extraction efficiency; however, they can also accelerate the degradation of heat-sensitive compounds. In contrast, insufficient extraction conditions may result in low extraction yield and reduced functional quality (Vuong et al., 2010). Therefore, appropriate control of extraction conditions is necessary to achieve a balance between extraction efficiency and the preservation of bioactive compounds.

In addition to extraction conditions, formulation factors such as sugar concentration, acidity, and fruit-to-liquid ratio play a crucial role in determining the overall quality and consumer acceptability of the final product. These parameters influence physicochemical characteristics and sensory attributes, thereby affecting product stability and marketability. However, studies investigating the combined effects of extraction conditions and formulation parameters on the quality of canned rambutan tea remain limited. Therefore, this study aimed to evaluate the effects of extraction temperature and time on tea quality and to develop a suitable formulation for canned rambutan tea based on physicochemical properties and sensory evaluation.

2. Literature review

Previous studies have highlighted the important role of raw materials and processing conditions in determining the quality of fruit-based beverages. Rambutan (Nephelium lappaceum L.) is rich in bioactive compounds, particularly polyphenols, flavonoids, and vitamin C, contributing to its antioxidant potential (Tingting et al., 2022). Similarly, Hernández et al. (2017) reported that rambutan pulp contains significant levels of nutrients and phytochemicals, supporting its application in functional foods. However, most studies have focused on the extraction and characterization of bioactive compounds, especially from the peel and seeds, rather than on beverage development.

Tea (Camellia sinensis) has been widely studied as a functional ingredient due to its high catechin content and associated health benefits. Extraction parameters, particularly temperature and time, significantly affect the yield and stability of phenolic compounds (Vuong et al., 2010). While higher temperatures may enhance extraction efficiency, they can also accelerate the degradation of heat-sensitive compounds, thereby reducing antioxidant activity (Athirojthanakij & Rashidinejad, 2024). In addition, processing conditions influence key quality attributes such as color, astringency, and overall sensory acceptance (Kumar & Pandey, 2013).

Despite these advances, studies on canned rambutan–tea beverages remain limited. Moreover, the combined effects of extraction conditions and formulation on key quality attributes, such as physicochemical properties, sensory quality, and antioxidant activity, have not been comprehensively investigated. Therefore, a systematic evaluation of these factors is necessary to develop a high-quality canned rambutan tea product with desirable functional and sensory properties.

3. Materials and methods

3.1. Raw materials

Fresh rambutan (Nephelium lappaceum L.) fruits were obtained from a local market in Vinh Long, Vietnam. The fruits were selected based on uniform maturity and visual quality attributes, including size, color, and absence of defects, to ensure consistency and reproducibility. The pulp was manually separated from the peel and seeds prior to use.

Black tea leaves (Camellia sinensis, Cozy Barista brand) were purchased from a Co.opmart supermarket in Vietnam and stored in airtight containers under ambient conditions until use. Granulated sugar (food-grade sucrose) and kumquat juice were used as formulation ingredients. Distilled water was used throughout all experimental procedures.

3.2. Experimental design

The study consisted of two main experiments: (i) evaluation of tea extraction conditions and (ii) development of beverage formulation. The overall process included tea extraction, blending with rambutan pulp and other ingredients, and subsequent analyses.

3.2.1. Tea extraction

Tea extraction was performed using a solid-to-liquid ratio of 1:50 (g/mL), with 10 g of dried tea leaves added to 500 mL of distilled water for each treatment. The extraction was carried out in a temperature-controlled water bath at three temperatures (70, 80, and 90°C) and three extraction times (5, 10, and 15 min).

During extraction, the tea leaves were fully immersed and gently stirred to ensure uniform heat transfer and mass diffusion. The temperature was continuously monitored to maintain the desired conditions. At the end of the extraction period, the mixture was immediately filtered through filter paper to remove solid residues.

The obtained tea infusion was rapidly cooled to room temperature (approximately 30 °C) to minimize thermal degradation of bioactive compounds. The extracts were then stored in sealed containers and analyzed for physicochemical properties (pH, total dissolved solids, and total phenolic content).

3.2.2. Effect of syrup and kumquat juice concentration

A two-factor factorial experiment was designed to evaluate the combined effects of syrup and kumquat juice concentrations on the quality of rambutan tea. The first factor was syrup concentration at three levels (35%, 40%, and 45%), and the second factor was kumquat juice concentration at three levels (2%, 4%, and 6%).

Each treatment was prepared with a total sample weight of 200 g. Syrup and kumquat juice were added according to the specified percentages (w/w), and the remaining mass was adjusted with tea infusion to reach 200 g. The mixture was then homogenized and combined with rambutan pulp at a fixed fruit-to-liquid ratio of 3:7 (w/w). The prepared samples were evaluated for pH and titratable acidity.

3.2.3. Effect of rambutan-to-tea ratio

The second formulation experiment was conducted to evaluate the effect of the rambutan-to-tea ratio on beverage quality. Based on the optimal formulation obtained from Section 3.2.2., the composition of the liquid phase (tea infusion, syrup, and kumquat juice) was kept constant, while the proportion of rambutan pulp was varied.

For each treatment, the total sample weight was fixed at 200 g. Rambutan pulp and the prepared tea mixture were weighed according to the selected ratios and then combined. The ratios of rambutan pulp to tea mixture investigated in this study were 2:8, 3:7, and 4:6 (w/w).

The prepared samples were subsequently evaluated for physicochemical properties (pH, °Brix, titratable acidity) and sensory attributes to determine the most suitable formulation.

3.3. Analytical methods

3.3.1. pH and oBrix determination

The pH of the samples was measured using a calibrated digital pH meter (HANNA HI6221-02, Romania) at room temperature (30 ± 1°C). The instrument was standardized with buffer solutions at pH 4.0 and 7.0 prior to measurement.

The soluble solids content (°Brix) was determined using a digital refractometer (ATAGO Master-20M, Japan). The instrument was calibrated with distilled water before analysis. A small amount of sample was placed on the prism surface, and the °Brix value was recorded at room temperature (30 ± 1°C).

3.3.2. Titratable acidity (TA)

Titratable acidity was determined by titration with 0.1 N NaOH, using phenolphthalein as an indicator until a faint pink endpoint was reached. Results are expressed as grams of citric acid equivalents per 100 mL of sample (Tyl & Sadler, 2017).

3.3.3. Total phenolic content (TPC)

Total phenolic content was determined using the Folin–Ciocalteu assay with slight modifications. Briefly, 0.1 mL of sample was mixed with 2.0 mL of distilled water and 0.2 mL of Folin–Ciocalteu reagent. Subsequently, 1.0 mL of 15% sodium carbonate solution was added. The reaction mixture was incubated at room temperature for 120 min to allow color development.

After incubation, absorbance was measured at 765 nm using a spectrophotometer (Genesys 30, USA). TPC was calculated based on a gallic acid standard curve and expressed as mg gallic acid equivalents (GAE).

3.3.4. Total dissolved solids (TDS)

Total dissolved solids (TDS) were determined as the concentration of soluble substances in the beverage. The sample was filtered through Whatman No. 1 filter paper (11 μm) to remove suspended particles. The filtrate was then dried at 103-105°C until a constant weight was obtained. TDS was calculated based on the residue weight and expressed in g/L.

3.3.5. Sensory analysis

Sensory evaluation of rambutan tea was conducted using a 7-point hedonic scale with a panel of 30 trained assessors. Samples were randomly coded and presented in a randomized order under controlled conditions.

Panelists rated their degree of liking for color, aroma, taste, and overall acceptability on a scale from 1 (“dislike very much”) to 7 (“like very much”). Water was provided for palate cleansing between samples. The results were collected for statistical analysis.

3.3.6. Statistical analysis

Statistical analysis was conducted using SPSS software. All experiments were performed in triplicate, and the results are expressed as mean ± standard deviation. Analysis of variance (ANOVA) was used to evaluate significant differences among treatments. When significant effects were observed ($p < 0.05$), mean comparisons were performed using the least significant difference (LSD) test.

4. Results and discussion

4.1. Effect of extraction conditions on physicochemical properties and antioxidant activity of tea infusion

4.1.1. Effect on pH and TDS

The effects of extraction temperature and time on pH and TDS are presented in Tables 1 and 2. The pH varied slightly (7.403-7.564), whereas TDS showed a wider range (3.75-6.15 g/L).

Extraction time significantly affected both pH and TDS ($p < 0.001$). The pH decreased gradually with increasing time at all temperatures (e.g., from 7.555 to 7.421 at 70°C), as indicated by consistent lowercase groupings (a-c). This reduction is attributed to the release of weakly acidic compounds, such as organic acids and phenolics.

Table 2. Two-way ANOVA for the effects of extraction temperature and time on pH, TDS, and TPC

Source of variation	pH	TDS (g/L)	TPC (mg GAE/mL)
Temperature	ns	***	***
Time	***	***	***
Temperature + Time	ns	*	*

*ns: not significant ($p \geq 0.05$); * $p < 0.05$; *** $p < 0.001$*

In contrast, TDS increased significantly with extraction time, rising from 3.75 to 4.73 g/L at 70°C and from 4.65 to 6.15 g/L at 90°C. This reflects enhanced diffusion and mass transfer of soluble components into the solvent.

Temperature had no significant effect on pH ($p \geq 0.05$), indicating that it mainly influences the extraction rate rather than composition. However, it significantly affected TDS ($p < 0.001$), with higher temperatures yielding higher TDS (e.g., 4.13 to 5.47 g/L at 10 min), as indicated by distinct uppercase groupings (A-C). This is attributed to increased solubility and diffusion at elevated temperatures.

No significant interaction between temperature and time was observed for pH, whereas a significant interaction was found for TDS ($p < 0.05$), indicating a stronger effect of time at higher temperatures. An inverse relationship between pH and TDS was observed, suggesting that dissolved solids include weakly acidic compounds contributing to acidity. This is consistent with previous findings that prolonged extraction enhances the release of polyphenols and organic acids, increasing TDS while lowering pH (Cao et al., 2021).

Table 1. Effect of extraction temperature and time on pH and total dissolved solids

Temperature (°C)	Time (min)	pH	TDS (g/L)
70	5	7.555 ± 0.006^{aA}	3.75 ± 0.10^{cA}
70	10	7.469 ± 0.014^{bA}	4.13 ± 0.03^{bA}
70	15	7.421 ± 0.029^{cA}	4.73 ± 0.08^{aA}
80	5	7.548 ± 0.005^{aA}	4.10 ± 0.28^{cB}
80	10	7.453 ± 0.006^{bA}	4.80 ± 0.13^{bB}
80	15	7.403 ± 0.009^{cA}	5.28 ± 0.06^{aB}
90	5	7.564 ± 0.005^{aA}	4.65 ± 0.09^{cC}
90	10	7.477 ± 0.005^{bA}	5.47 ± 0.08^{bC}
90	15	7.405 ± 0.022^{cA}	6.15 ± 0.18^{aC}

Values are mean ± SD (n = 3). Different lowercase letters indicate significant differences among extraction times, while different uppercase letters indicate significant differences among temperatures ($p < 0.05$, LSD test).

4.1.2. Effect of extraction conditions on total polyphenol content (TPC)

The effects of extraction

temperature and time on total phenolic content (TPC) are presented in Figure 1. TPC increased significantly from 1.00 to 2.03 mg GAE/mL with increasing extraction intensity.

Extraction time had a significant effect on TPC ($p < 0.001$), with values increasing consistently from 5 to 15 min at all temperatures. This trend reflects enhanced diffusion of phenolic compounds due to prolonged solvent-solid contact.

Temperature also significantly influenced TPC ($p < 0.001$). At a fixed extraction time, higher temperatures resulted in higher TPC values, likely due to improved solubility and disruption of cell structures, facilitating the release of bound phenolics.

A significant interaction between temperature and time ($p < 0.05$) indicated a synergistic effect, with the increase in TPC over time being more pronounced at higher temperatures. The increase in TPC was consistent with the observed increase in TDS and decrease in pH, suggesting that phenolic compounds contribute to both dissolved solids and acidity.

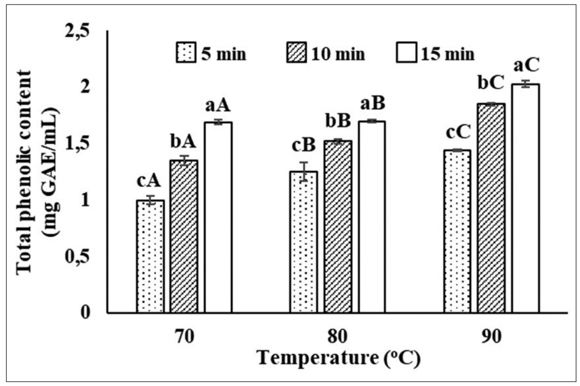
The obtained TPC values (1.00–2.03 mg GAE/mL) fall within the range reported for tea infusions and plant extracts. Previous studies have shown that TPC typically increases with extraction temperature and time due to enhanced diffusion and solubility of phenolic compounds (Cao et al., 2021; Vuong et al., 2010).

4.2. Effect of syrup and kumquat juice concentration on physicochemical and sensory properties of rambutan tea

Two-way ANOVA indicated that kumquat juice concentration significantly affected pH and titratable acidity ($p < 0.05$), whereas syrup concentration had a minor or non–significant effect. No significant interaction between the two factors was observed ($p > 0.05$). The effects of syrup and kumquat juice concentrations on pH and titratable acidity (TA) of rambutan tea are presented in Tables 3 and 4.

The pH decreased significantly ($p < 0.05$) with increasing kumquat juice, from approximately 4.28 (2%) to 3.51 (6%). This is attributed to the high content of organic acids, particularly citric acid, in kumquat, which increases the H^+ concentration in the

Figure 1. Effect of extraction temperature and time on total phenolic content (TPC)



Different lowercase letters indicate significant differences among extraction times, while different uppercase letters indicate significant differences among temperatures ($p < 0.05$, LSD test).

Table 3. Effect of syrup and kumquat juice concentration on pH of rambutan tea

Syrup (%)	Kumquat juice (%)		
	2%	4%	6%
35	4.28 ± 0.01^{aA}	4.03 ± 0.01^{bA}	3.56 ± 0.01^{cA}
40	4.23 ± 0.01^{aA}	3.88 ± 0.01^{bB}	3.54 ± 0.02^{cA}
45	4.19 ± 0.01^{aA}	3.84 ± 0.01^{bB}	3.51 ± 0.02^{cA}

Values are mean ± SD (n = 3). Different letters indicate significant differences among kumquat (lowercase) and syrup (uppercase) concentrations ($p < 0.05$, LSD test).

Table 4. Effect of syrup and kumquat juice concentration on titratable acidity (g/L)

Syrup (%)	Kumquat juice (%)		
	2%	4%	6%
35	1.45 ± 0.19^{cA}	2.05 ± 0.13^{bA}	3.11 ± 0.15^{aA}
40	1.45 ± 0.07^{cA}	2.18 ± 0.13^{bB}	3.03 ± 0.15^{aA}
45	1.45 ± 0.07^{cA}	2.05 ± 0.13^{bA}	3.07 ± 0.00^{aA}

Values are mean ± SD (n = 3). Different letters indicate significant differences among kumquat (lowercase) and syrup (uppercase) concentrations ($p < 0.05$, LSD test).

solution. Syrup showed only a slight effect on pH, likely due to dilution of acid concentration at higher sugar levels.

In contrast, TA increased significantly ($p < 0.05$) with increasing kumquat juice, from approximately 1.45 to 3.11 g/L, confirming that kumquat is the primary source of organic acids. Syrup concentration did not significantly affect TA ($p > 0.05$), indicating its negligible contribution to acidity.

The inverse relationship between pH and TA is consistent with acid-base principles and has been widely observed in fruit beverages. From a practical perspective, kumquat juice plays a key role in controlling acidity, thereby influencing flavor and product stability. A formulation with 4% kumquat juice provided balanced acidity suitable for product development.

4.3. Effect of rambutan-to-tea ratio on product quality

The effect of the rambutan-to-tea ratio on the physicochemical and sensory properties of the beverage is presented in Table 5 and Figure 2. The results showed that increasing the proportion of rambutan significantly affected pH, titratable acidity (TA), and sensory attributes ($p < 0.05$), while °Brix remained relatively constant.

Table 5. Effect of rambutan-to-tea ratio on Brix, pH and titratable acidity

Rambutan: Tea (w/v)	°Brix	pH	TA (g/L)
2:8	21.00 ± 0.00	3.71 ± 0.01^{c}	2.30 ± 0.13^{b}
3:7	21.00 ± 0.00	3.83 ± 0.01^{b}	2.13 ± 0.07^{a}
4:6	22.00 ± 0.00	3.87 ± 0.01^{a}	2.43 ± 0.13^{c}

Different letters within a column indicate significant differences ($p < 0.05$, LSD test).

The pH values increased significantly from 3.71 to 3.87 as the rambutan ratio increased from 2:8 to 4:6. This trend can be attributed to the dilution of acidic compounds from the tea infusion, which typically contributes more organic acids than the fruit pulp. As a result, increasing the fruit proportion reduced overall acidity, leading to higher pH values.

In contrast, titratable acidity exhibited a non-linear trend, with the lowest value observed at the 3:7 ratio (2.13 g/L), while higher values were recorded at both 2:8 and 4:6 ratios. This behavior may be explained by interactions between organic acids from tea and rambutan. While tea contributes phenolic acids, rambutan pulp contains various organic acids that can increase total acidity at higher concentrations.

Sensory evaluation using a 7-point preference scale (Figure 2) showed that the 3:7 ratio achieved the highest scores for color (5.73), taste (5.45), and overall acceptability (5.62), with significant differences compared to other formulations ($p < 0.05$). The higher acceptance at this ratio can be attributed to a balanced combination of sweetness, acidity, and mouthfeel. In contrast, the 2:8 ratio showed lower scores due to a diluted flavor and weaker body, while the 4:6 ratio, despite relatively high taste scores, resulted in lower overall acceptability

The relationship between physicochemical properties and sensory perception was evident. Samples with moderate acidity (lower TA and intermediate pH), particularly at the 3:7 ratio, were preferred by panelists. Excessive acidity at higher fruit ratios (4:6) or insufficient flavor intensity at lower ratios (2:8) negatively affected sensory quality.

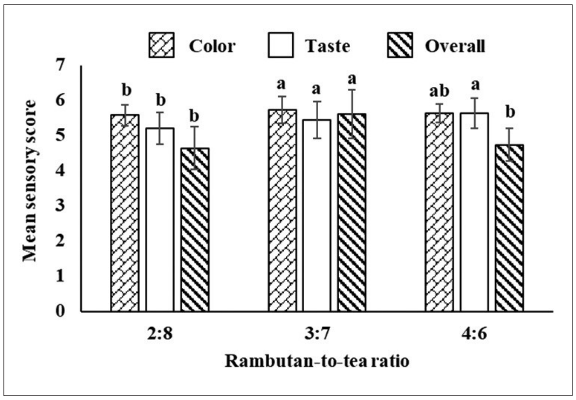
Overall, the 3:7 ratio provided the most balanced physicochemical and sensory characteristics, making it the optimal formulation for rambutan tea beverage development.

4.4. Selection of optimal formulation of rambutan tea

The optimal formulation of canned rambutan tea was selected based on a combined evaluation of extraction conditions, physicochemical properties, and sensory attributes.

For tea extraction, both temperature and time significantly increased TDS and TPC, reflecting improved extraction efficiency. However, excessive extraction may negatively affect flavor and stability. The condition of 90 °C for 10 min was selected, as it provided high phenolic content while maintaining moderate extraction intensity.

Figure 2. Effect of rambutan-to-tea ratio on sensory attributes



Different letters within a column indicate significant differences ($p < 0.05$, LSD test).

In terms of formulation, kumquat juice was the main factor influencing acidity. Increasing its concentration decreased pH and increased titratable acidity, while syrup had a minimal effect. A level of 4% kumquat juice provided balanced acidity, whereas 2% was insufficient and 6% was overly sour. A syrup concentration of 40% was selected to ensure adequate sweetness without masking the natural flavor.

The rambutan-to-tea ratio significantly affected both physicochemical and sensory properties. The 3:7 (w/w) ratio showed the most balanced pH and lowest titratable acidity, and achieved the highest scores for color, taste, and overall acceptability. Lower ratios resulted in weak flavor, while higher ratios negatively affected texture due to excess pulp.

Overall, the optimal formulation consisted of tea extracted at 90 °C for 10 min, with 40% syrup, 4% kumquat juice, and a 3:7 rambutan-to-tea ratio. This combination provided a balanced product with desirable quality and high sensory acceptance, making it suitable for canned beverage development.

5. Conclusion

Extraction conditions and formulation significantly affected the quality of canned rambutan tea. The optimal extraction condition was 90 °C for 10 min, providing high phenolic content and efficient extraction. A formulation with 40% syrup, 4% kumquat juice, and a 3:7 rambutan-to-tea ratio resulted in balanced physicochemical properties and the highest sensory acceptance ■

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ẢNH HƯỞNG CỦA ĐIỀU KIỆN TRÍCH LY VÀ CÔNG THỨC PHỐI CHẾ ĐẾN CHẤT LƯỢNG TRÀ CHÔM CHÔM ĐÓNG HỘP

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TÓM TẮT:

Nghiên cứu này đánh giá ảnh hưởng của điều kiện trích ly và công thức phối chế đến chất lượng trà chôm chôm đóng hộp. Trà được trích ly ở 70–90 °C trong 5–15 phút; các yếu tố phối chế gồm siro (35–45%), nước cốt tắc (2–6%) và tỷ lệ chôm chôm–trà (2:8–4:6). Việc tăng nhiệt độ và thời gian trích ly làm tăng tổng chất rắn hòa tan và hàm lượng hợp chất phenolic. Nước cốt tắc là yếu tố chính ảnh hưởng đến độ axit, trong khi siro có tác động không đáng kể. Tỷ lệ chôm chôm–trà ảnh hưởng rõ rệt đến chất lượng, trong đó tỷ lệ 3:7 cho mức chấp nhận cảm quan cao nhất. Công thức tối ưu gồm trích ly ở 90 °C trong 10 phút, với 40% siro, 4% nước cốt tắc và tỷ lệ 3:7 (w/w), tạo sản phẩm có tính chất cân bằng và tiềm năng chống oxy hóa tốt.

Từ khóa: Trà chôm chôm; Điều kiện trích ly; Công thức phối chế; Đồ uống đóng hộp.