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Research Article

Optimization of Brewing Process Vine Tea and Flavor Analysis of Different Brewing Processes

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As a traditional Chinese medicine with the dual use of medicine and food, vine tea has been utilized for centuries as a daily health beverage due to its various health benefits. The primary component responsible for its biological activity is its total flavonoid content. While numerous studies have been conducted on the extracts of vine tea, research has primarily centered on its ingredients and effects, with limited focus on its sensory characteristics. As it has the problems of the undesirable flavor of bitterness and astringency, the development of the vine tea industry is limited. Furthermore, there is currently no standardized brewing process for vine tea. Therefore, it is essential to find a brewing method that is universally applicable and balances a high level of active ingredients with a rich sensory experience. In this study, we conducted a comprehensive investigation into the impact of various water qualities, tea-water ratios, brewing temperatures, steeping times, and frequencies on the total flavonoid content. To investigate the differences between samples from different brewing methods, one-factor experiments ($n = 20$) and orthogonal experiments were conducted. The total flavonoid content was measured using UV spectrophotometry. To thoroughly examine the flavor compounds, we employed mathematical relationship analysis, radar-gram analysis, principal component analysis (PCA), and odor fingerprinting. By integrating these methods with the electronic tongue and electronic nose, we were able to compare the flavor variances between samples and offer a concise analysis of the flavor compounds. The brewing process is influenced by several factors, with the tea-to-water ratio having the most significant impact, followed by brewing temperature and then brewing time. Electronic tongues and electronic noses can distinguish vine tea samples with different brewing processes to a certain extent. The optimal brewing conditions determined in this study were pure water, a 1 : 50 tea-to-water ratio, an 85°C brewing temperature, an 8-minute brewing time, and a single brew cycle. These conditions produced the highest total flavonoid content in the vine tea, at 326.8 mg/g, and the best flavor quality. This study offers novel approaches to standardize the brewing process of vine tea, along with valuable perspectives for enhancing the sensory attributes of the tea. It can serve as a benchmark for the industry's future growth in the canning of vine tea, facilitating the creation of diverse vine tea drinks.

1. Introduction

Vine tea (*Ampelopsis Grossedentata*), also known as *Meicha* in Chinese, is a wild vine plant of the Ampelopsis genus in the Vitis vinifera family. It is commonly referred to as *Tujia Shencha*, *Shenxiancao*, and other names. This wild vine plants are primarily found in areas south of the Yangtze River, such as Guangxi, Hunan, and Guizhou. They are often used as a health drink by the Tujia ethnic group [1]. Vine tea is primarily recommended for treating jaundice, wind-heat colds, sore throats, and other conditions [2]. Many people believe that the longer a product is made and stored, the better its effect [3].

The economic value of tea lies primarily in its flavor compounds, which are combined in specific forms and proportions to create various styles and grades. Vine tea, however, has a distinctive flavor profile. It begins with a bitter and astringent taste, but after a brief period, the bitterness quickly gives way to sweetness, leaving a refreshing sensation in the mouth. This distinctive taste profile is the reason why most people cannot tolerate it, limiting its widespread acceptance [4]. Therefore, vine tea has only achieved a certain level of recognition in its growing regions. Furthermore, the current beverage industry is closely linked to economic development trends, and vine tea as a standalone beverage falls short of meeting market demands for product diversity.

As a natural health tea, the traditional manufacturing process of vine tea closely resembles that of green tea [5], with people typically preparing it by steeping the leaves in boiling water as a health beverage in China. The taste of tea is a comprehensive sensory experience derived from water-soluble substances present in the tea infusion [6]. The primary flavor components include polyphenols, alkaloids, amino acids, carbohydrates, and others [6]. The taste of tea, which is primarily determined by its chemical composition and content, is a crucial aspect in assessing tea quality. It also significantly impacts consumer acceptance. The fragrance of tea is also a significant factor that influences the quality of tea [7]. The Chinese Standardization Administration has published the "GB/T 23776-2018 Methodology for Sensory Evaluation of Tea," which has become the most widely utilized and fundamental evaluation approach for green tea, which is associated with limitations including time consumption, labor intensiveness, and subjectivity [8–10]. To address these issues, it is essential to develop a sensory evaluation system that combines traditional sensory assessment with the analysis of physical and chemical sensory indicators using advanced intelligent sensory technologies. By leveraging the benefits of modern instrumentation, such as increased sensitivity, accuracy, and speed, this system can provide more consistent and reliable assessments while reducing the influence of personal subjective factors. The integration of an electronic nose and an electronic tongue has been shown to enhance the accuracy of results [11], enabling a more precise assessment of the odor and taste information of the sample under investigation.

Modern research has shown that vine tea mainly contains compounds such as flavonoids, phenols, steroids, terpenoids, volatile components, and various nutritional components such as amino acids, mineral elements, and vitamins [1]. It exhibits biological activities such as anti-inflammatory and analgesic, antibacterial, antioxidant, antitumor, liver protection, blood lipid-lowering, blood sugar-lowering, and immune enhancement [5, 7, 12–27]. In addition, it is safe and nontoxic. Flavonoids, an essential component in a variety of nutraceutical, pharmaceutical, and cosmetic applications, are identified as the major metabolites and bioactive ingredients in vine tea. Flavonoids make up the most significant portion of vine tea, comprising up to 45% of its composition, and are also the primary contributors to its health benefits [28–30]. As a result, vine tea is also often referred to as the "king of flavonoids" [31].

There is a wealth of scientific evidence demonstrating the numerous health benefits of tea associated with the quality and quantity of its phytochemicals [5]. In terms of *Ampelopsis grossedentata* leaves, they are notable for their exceptionally high total flavonoid content. This exceptional property renders this plant an optimal choice for large-scale production/extraction of total flavonoids [32, 33]. While there have been some preliminary studies exploring the extraction of total flavonoids from plants, most of these studies require complex or highly specialized protocols/equipment [34, 35]. This contradicts the use of vine tea as a daily health beverage. In general, the mass of the raw material remains constant, while composition and overall volume of the prepared sample are influenced by numerous parameters. For example, higher concentrations can be obtained by increasing the extraction temperature or time. Nevertheless, once the extraction temperature or duration stabilizes, there may be a decrease in the content. Moreover, with an increase in the number of extractions and the liquid-to-feedstock ratio, there is a decrease in the sample content and an increase in the total volume of the prepared sample. Various solvents also differ in terms of their yield. As such, these five factors exert a notable influence on extraction [23, 36].

This study employs ultraviolet spectrophotometry to measure the flavonoid content and utilizes a single-factor control method to examine various factors including water quality, tea-water ratio, brewing temperature, brewing time, and number of tea brewing. In addition, orthogonal tests are conducted to identify the brewing process that yields the highest total flavonoid content. The combination of traditional sensory assessment with advanced intelligent sensory technologies to analyze the variations in flavor of vine tea samples resulting from different brewing processes. This approach aims to provide a more intuitive analysis of the influence of various factors on the flavor of vine tea. The aim of this study was to determine the most effective experimental conditions for extracting total flavonoids from Chinese vine tea leaves without requiring extensive or highly specialized procedures or equipment. Furthermore, we sought to address the main limitation impeding widespread use and application: a poor sensory experience. Therefore, research aimed at preserving the nutrients of vine tea while balancing its bitter and sweet flavors holds significant potential for application. Notably, the exceptional health benefits of vine tea render it highly valuable for both food and medical research. The standardized brewing process for vine tea can serve as a benchmark for the future development of canned vine tea beverages. The growing market demand for vine tea will spur efforts to protect and develop wild Garcinia cambogia germplasm resources, which is beneficial for promoting economic development in mountainous regions.

2. Materials and Methods

2.1. Materials and Instruments. Vine tea for brewing comes from Jiangxi (Pingxiang), China. Boiling water for brewing vine tea was boiled from the tap in the laboratory; the mineral water used is the Wahaha brand sourced from China (Zheijiang); pure water is produced by a laboratory water purification system from China (Shanghai). The rutin standard in the experiment was produced in China (Beijing, Solabao). The electronic tongue is made of INSENT from Japan. The reason for this choice is that the company's most important technical feature in the design and production of the sensors is that the taste indicators detected should match the human sensory indicators and have a better correlation. Ultra-fast gas phase electronic nose (French): sensory attributes can be described and compounds can be identified based on the sensory data collected. It helps to more intuitively understand the odor characteristics of different samples of vine tea.

2.2. Experimental Methods

2.2.1. Single-Factor Experiments. Tea ranks among the most widely consumed beverages [37]. Beverages are regularly consumed on a daily basis to derive health benefits. Polyphenols play a significant role in determining the flavor, aroma characteristics, and color of tea [38]. They exhibit pH sensitivity, and their properties remain stable under low pH conditions [39]. Various water qualities encountered in everyday life can lead to variations in pH levels.

Numerous studies have demonstrated the significant impact of brewing time and temperature on the extraction of bioactive compounds in tea [40–42]. The preparation of green tea typically involves steeping dry green tea leaves in hot water at temperatures ranging from 80 to 90°C for a duration of 3-4 minutes. In contrast, white tea is advised to be steeped at a lower temperature of 60°C for 5 minutes. Consequently, the brewing time and temperature differ for various types of tea. Shannon and colleagues [43] determined that the extraction efficiency of compounds is significantly influenced by water temperature and tea steeping time. At home, the brewing temperatures generally ranged from 65 to 95°C. It was also discovered that prolonged brewing times (>10 minutes) led to an increase in astringency and bitterness, which had an impact on the sensory characteristics of the beverage. Furthermore, Zhang et al. [44] examined the impact of various brewing parameters on the flavor of white tea. Their findings indicated that a tea-water ratio of 1 : 50 and an initial brewing step produced the most favorable sensory score in terms of color, aroma, and taste.

Based on the aforementioned preliminary investigation, the study examined various factors including the tea-water ratio (1 : 20, 1 : 30, 1 : 40, 1 : 50, 1 : 60, g : ml), brewing temperature (70, 75, 80, 85, 90, °C), brewing time (2, 3, 4, 5, 6, 7, 8, 9, minutes), water quality (pure water, boiled water, and mineral water), brewing frequency (1, 2, 3, brewing), etc., and their impact on the extraction rate of total flavonoids. The study also analyzed the observed trends.

Take 20.0 mg of rutin standard and accurately weigh it. Place the standard in a 10 mL volumetric flask, add the appropriate amount of pure water, and dissolve it using ultrasonic treatment at 60°C. Adjust the volume with pure water, shake it thoroughly, and obtain a 2 mg/mL standard solution sample.

To prepare a series of standard solution samples of rutin, precise measurements of 0.00 ml, 0.10 ml, 0.20 ml, 0.30 ml, 0.40 ml, 0.50 ml, 0.60 ml, 0.70 ml, 0.80 ml, 0.90 ml, and 1.00 ml are required. These measurements will result in a standard solution of rutin to prepare standard solution series samples of 0.00 mg/ml, 0.02 mg/ml, 0.04 mg/ml, 0.06 mg/ml, 0.08 mg/ml, 0.10 mg/ml, 0.12 mg/ml, 0.14 mg/ml, 0.16 mg/ml, 0.18 mg/ml, and 0.20 mg/l for experimental use.

The total flavonoid content was quantified following the method outlined in reference [45]. A volume of 25 μL of the reference solution and 25 μL of the test sample solution are to be precisely pipetted into a 96-well plate. Subsequently, 110 μL of a 5% sodium nitrite test solution is added, and the mixture is shaken well and left to stand for 5 minutes. Following this, 15 μL of 10% aluminum chloride solution is added, and the solution is shaken well and allowed to react for 6 minutes. Next, 100 μL of a 1% sodium hydroxide test solution is added. The solution is then shaken and left to stand for 10 minutes. Subsequently, the solution is scanned at full wavelength in the range of 200–700 nm, and the maximum absorption wavelength is determined to be 510 nm, which is deemed the most suitable wavelength for the determination. 25 μL of the standard was dispensed into a 96-well plate, followed by the addition of 110 μL of a 5% sodium nitrite solution. After a 5-minute incubation period, 15 μL of a 10% aluminum chloride solution was added and thoroughly mixed. The reaction was allowed to proceed for 6 minutes before the addition of 100 μL of a 1% sodium hydroxide solution. Following a 10-minute incubation, a blank control was prepared using pure water. The absorbance at a wavelength of 510 nm was measured. The absorbance data obtained from the series of standard solution samples was used to derive the univariate linear regression equation describing the relationship between absorbance and concentration.

Determine the absorbance using the aforementioned method, compute the total flavonoid concentration of vine tea based on the regression equation, and calculate the total flavonoid extract using the formula provided [46]:

The yield of the total flavonoid extract (mg/g) can be calculated using the following formula:

$$Y = \frac{C \times n \times V}{m} \tag{1}$$

In the formula, Y stands for total flavonoid content (mg/g); C represents the solution concentration in milligrams per milliliter (mg/ml); n denotes the number of dilution cycles; V stands for the volume of the extract in milliliters (ml); and m represents the mass of vine tea in grams (g).

2.2.2. Orthogonal Experiments. According to the findings of the single-factor experiments, the three variables of tea-water ratio, brewing temperature, and brewing time were each set at three levels. An L_9 (3^3) orthogonal table was utilized to design the experiment in order to optimize the various brewing processes of vine tea. The total flavonoid extraction rate served as the criterion for identifying the optimal brewing process.

2.2.3. Sensory Evaluation

(1) Traditional Sensory Evaluation. A group of ten tea drinkers, evenly divided between the sexes and ranging in age from 20 to 30 years, were recruited for a sensory evaluation study. The samples were prepared under the specified conditions as outlined in Table 1. The tea samples were evaluated according to the Chinese National Tea Evaluation Standards (GB/T23776-2018). Each tea sample was assessed for appearance (25%), color (10%), aroma (25%), flavor (30%), and infused leaves (10%). In this experiment, our goal was to detect the flavor of vine tea; therefore, we did not analyze its appearance or leaves. After assigning percentages to the other three criteria, the breakdown was as follows: color (15.5%), aroma (38.5%), and flavor (46%). The specific sensory evaluation criteria are detailed in Table 2. Additionally, they provided comments and assigned scores to each sample. Finally, the total sensory quality score for each tea sample was determined based on its specific gravity value.

(2) Modern Sensory Evaluation Techniques. The electronic tongue is used to simulate a mammalian gustatory system for the purpose of assessing the taste substances in liquid samples, facilitating the identification of sample "taste" [47]. The technology of the electronic tongue can be employed for the qualitative and quantitative analysis of the taste quality of tea. The electronic tongue plays a significant role in qualitative analysis by identifying the grade, variety, and origin of tea [48, 49]. Electronic tongues are predominantly utilized in quantitative analysis for the detection of substances in tea. The electronic tongue is distinguished by its rapid and straightforward operation, its capacity to detect multiple samples, and its high reliability and repeatability [7].

To prepare and filter the tea solution according to the specified numbers and brewing conditions outlined in Table 1, the solution was subjected to centrifugation at a speed of 8000 rpm for 10 minutes to obtain the supernatant. The electronic tongue system is equipped with sensitive sensors that can detect and differentiate between various tastes. The six chemical sensors include sourness (CA0), bitterness and aftertaste bitterness (C00), astringency and aftertaste astringency (AE1), saltiness (CT0), sweetness (GL1), and freshness and richness (AAE). Prior to the analyses, the sensors were immersed in a reference solution consisting of a 30 mmol/L KCl solution with 0.3 mmol/L tartaric acid, and pretreatment was conducted. The various tea samples should be placed in a specialized electronic tongue detection cup for analysis using electronic tongue detection. The perception of sweetness was observed as distinct from other taste sensations. The potential of the flavor sensor membrane is determined by the phase transition of the reference electrode. Before conducting measurements, the electronic tongue goes through self-testing, activation, calibration, and diagnostic procedures to guarantee the reliability and stability of the gathered data [50]. Conditions for electronic tongue detection require that the temperature of each sample solution and reagent solution be maintained at room temperature. The taste sensor and ceramic reference electrode underwent a combined cleaning process lasting 330 seconds, followed by a 30-second equilibration period, and then the sample was tested for 30 seconds before undergoing an additional 6-second cleaning process. Each tea sample was replicated four times in parallel, and the initial tea sample was discarded to ensure precision. The performance of the electronic tongue sensor is presented in Table 3.

An electronic nose system is designed to replicate the human olfactory system for odor recognition [11]. The electronic nose detection method is distinguished by its simple sample preprocessing, rapid detection, high sensitivity, and nondestructive sampling [51]. Moreover, it provides the benefits of objectivity and stability, in contrast to artificial sensory assessment. It is also capable of detecting toxic and harmful gases [44], thereby aiding in the prevention of direct exposure to testing personnel. Hence, electronic olfaction devices are extensively utilized in the realms of food, environmental surveillance, and healthcare [52].

The tea brewing process can be accurately described as a complex interaction of dissolution and flavor formation, aligning with the principles of a ternary phase diagram. Within the tea-water system, there exists a phase equilibrium among three primary components: water, tea leaves (both soluble and insoluble tea solids), and the headspace above the liquid. This equilibrium is dynamically maintained during the infusion process, as volatile organic compounds (VOCs) are released from the tea leaves into the tea infusion and VOCs are emitted into the headspace through thermophysical and chemical reactions. It is important to note that the nature and percentage of compounds in the tea leaves, particularly soluble substances, as well as the brewing conditions, play a significant role in determining the outcome of this phase equilibrium [53].

According to the quantities and brewing parameters outlined in Table 1, the procedure involves brewing, filtering, centrifuging at 8000 revolutions per minute for 10 minutes, and subsequently collecting the supernatant. The electronic nose is comprised of various metal oxide sensors, a gas flow control system, and analysis and control software. Metal oxide semiconductors exhibit sensitivity to specific odors. Transfer 2 ml of each sample into a headspace bottle. Electronic nose detection conditions: The electronic nose utilizes a headspace automatic sampling program, operating at an incubation temperature of 70°C and a retention time of 110 s. Each sample is replicated three times.

2.3. Data Processing. All experiments were performed three times to ensure the reliability of the results. Statistical analysis of orthogonal experimental data was performed using IBM SPSS 21.0 (SPSS Inc., Chicago, IL, USA). The analysis software is utilized to evaluate the statistical significance of the data. To explore the correlation between sensory characteristics and brewing methods, the study employed Origin 2021 (Origin Lab, Northampton, MA, USA) and SIMCA 14.1 (Sartorius AG, Göttingen, Germany) software for data visualization and graph generation,

Table 1: Design of brewing conditions.

Constituencies	Tea to water ratio (g : ml)	Brewing temperature (°C)	Brewing time (minutes)	Water quality	Number of brewing
1	1 : 20	85	8	Pure water	1
2	1 : 30	85	8	Pure water	1
3	1 : 40	85	8	Pure water	1
4	1 : 50	85	8	Pure water	1
5	1 : 50	85	8	Pure water	2
6	1 : 50	85	8	Pure water	3
7	1 : 60	85	8	Pure water	1
8	1 : 50	70	8	Pure water	1
9	1 : 50	75	8	Pure water	1
10	1 : 50	80	8	Pure water	1
11	1 : 50	90	8	Pure water	1
12	1 : 50	85	2	Pure water	1
13	1 : 50	85	3	Pure water	1
14	1 : 50	85	4	Pure water	1
15	1 : 50	85	5	Pure water	1
16	1 : 50	85	6	Pure water	1
17	1 : 50	85	7	Pure water	1
18	1 : 50	85	9	Pure water	1
19	1 : 50	85	8	Boiled water	1
20	1 : 50	85	8	Mineral water	1

Table 2: Sensory evaluation criteria.

Quality	Characteristics	Grade
Color (15.5%)	Bright young green or bright green	Excellent (≥85)
	Fairly bright green or bright yellow-green	Good (80–85)
	Dark yellow or yellowish green, not bright	Medium (75–80)
	Dark yellow or yellow-green, not bright or cloudy	Poor (≤75)
Aroma (38.5%)	Pure aroma, high freshness, unadulterated odor	Excellent (≥85)
	Aroma is still pure, no impurity odor	Good (80–85)
	Fairly pure aroma, with smoke, slightly coarse, etc	Medium (75–80)
	Fairly pure aroma, heavy smoke, coarse, etc	Poor (≤75)
Taste (46%)	Fresh and sweet and mellow	Excellent (≥85)
	Fresh and mellow	Good (80–85)
	Approach fresh and mellow	Medium (75–80)
	Less fresh and brisk	Poor (≤75)

Table 3: Electronic tongue sensor performance description.

Serial number	Sensor name	Performance description
1	CA0	Sensitive to sourness, can measure sourness
2	C00	Sensitive to bitterness, can measure bitterness and aftertaste of bitterness
3	AE1	Sensitive to astringency, can measure astringency and aftertaste of astringency
4	AAE	Sensitive to umami, can measure umami and the degree of taste caused by umami
5	CT0	Sensitive to saltiness, can measure saltiness
6	GL1	Sensitive to sweetness, can measure sweetness

including odor fingerprint, thermal map, radar chromatogram, and principal component analysis (PCA). To investigate the correlation between sensory characteristics and chemical compounds in vine tea, the gas phase electronic nose was employed to identify compounds based on sensory descriptions. Excel was utilized to filter the identification of potential compounds with a retention index (RI) greater than 90.

3. Result

3.1. Single-Factor Experiment. The regression equation was fitted using the mass concentration C (mg/ml) as the independent variable and absorbance as the dependent variable. The regression equation for pure water is represented as $y = 0.4045x + 0.0013$, $R^2 = 0.9979$, $F = 4372.602$, $p < 0.001$, indicating a significant fit of the equation.

The standard curve for boiled water and mineral water was prepared using the aforementioned method. The standard curve for boiled water is represented by the equation $y = 0.3658x - 0.0029$, $R^2 = 0.996$, $F = 2261.042$, $p < 0.001$. The standard curve for mineral water is represented by the equation $y = 0.4301x - 0.0041$, $R^2 = 0.9955$, $F = 1973.386$, $p < 0.001$. These results indicate the significance of the standard curve.

3.1.1. The Impact of the Tea-to-Water Ratio on the Total Flavonoid Content of Vine Tea Samples. To investigate the impact of varying tea-water ratios on the total flavonoid content, 1 g of rattan tea was precisely weighed and brewed under specific conditions, including the use of pure water, a single brewing cycle at 85°C, and a brewing duration of 5 minutes. The findings are presented in Figure 1. The figure illustrates that as the ratio of tea to water decreases (indicating an increase in the amount of extraction solvent), there is a gradual increase in the total flavonoid content. When the ratio of tea to water is 1 : 40, the concentration is at its peak. If the ratio of tea to water continues to diminish, the overall content will also decrease. As the quantity of extraction solvent is augmented, the solubility of total flavonoids in the solvent also rises, leading to an increase in the overall flavonoid content. Excessive extraction solvent volume can result in dilution of the water sample's concentration and potential dissolution of other substances, such as polysaccharides, which may lead to a reduction in the overall flavonoid content [54]. Consequently, orthogonal experiments were carried out using tea-to-water ratios of 1 : 30, 1 : 40, and 1 : 50.

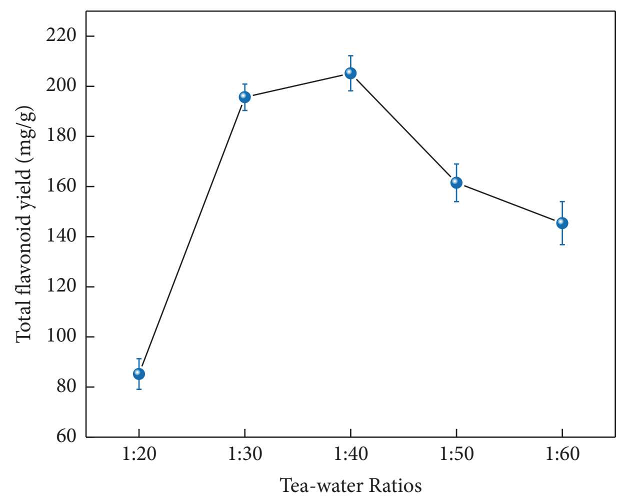

Figure 1: The impact of tea-water ratio on vine Tea's total flavonoid content.

3.1.2. The Impact of Brewing Temperature on the Flavonoid Content of Vine Tea-Water Samples. To accurately measure 1 g of vine tea and brew it in pure water under specific conditions (brewing once, 1 : 50 ratio, 5 minutes) to study the impact of various brewing temperatures on total flavonoid content. The results are depicted in Figure 2. When the brewing temperature rises, the total flavonoid content also increases. Under elevated temperature conditions, it is likely that tea leaves become more easily accessible, leading to an increased surface area for interaction with water, thereby facilitating greater overall flavonoid extraction [55]. The highest content is achieved when the brewing temperature reaches 80°C. As the temperature of the brewing process rises, there is a corresponding decrease in the overall flavonoid content. This phenomenon may be attributed to the potential degradation of specific flavonoid compounds at high temperatures. Consequently, orthogonal experiments were carried out at temperatures of 75°C, 80°C, and 85°C.

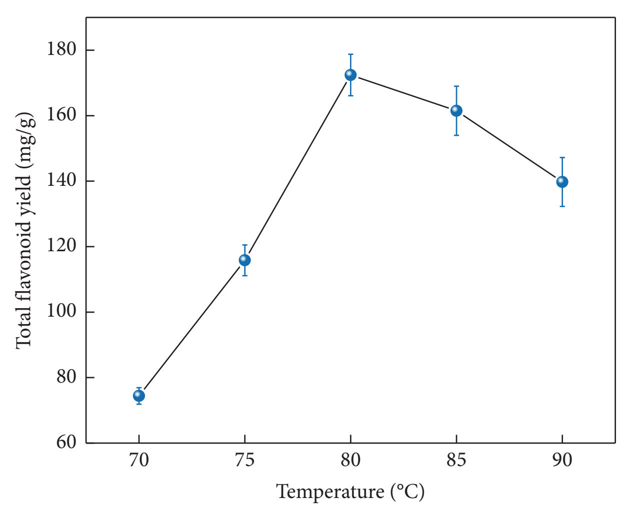

Figure 2: The impact of brewing temperature on the total flavonoid content of vine tea.

3.1.3. The Impact of Brewing Time on the Flavonoid Content of Vine Tea Samples. To accurately measure 1 g of vine tea and brew it under specific conditions (i.e., pure water, single brewing, 1 : 50 ratio, 85°C), an investigation was conducted to examine the impact of varying brewing durations on the overall flavonoid content. The findings are depicted in Figure 3. It is evident that an increase in brewing time leads to a corresponding increase in the total flavonoid content, with the highest content observed at 8 minutes. This phenomenon occurs because an extended duration facilitates the dissolution of a greater quantity of total flavonoids. Nevertheless, prolonged brewing time results in a reduction in the overall flavonoid content. This phenomenon may be attributed to the complete dissolution of total flavonoids and prolonged exposure to high temperatures, leading to the oxidation and destruction of some total flavonoids at a rate that exceeds their slow dissolution rate. Consequently, orthogonal experiments were carried out at time intervals of 7, 8, and 9 minutes.

3.1.4. The Impact of the Number of Brews on the Overall Flavonoid Content of Vine Tea Samples. To accurately measure 1 g of vine tea and prepare it under specific conditions (pure water, 1 : 50 ratio, 85°C, 5 minutes) in order to

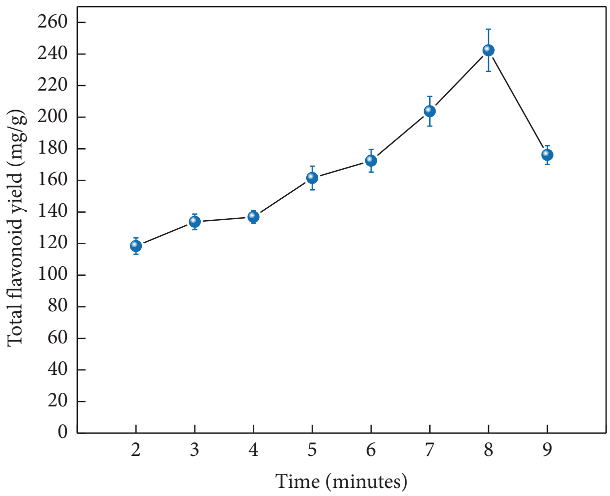

Figure 3: The impact of brewing time on the flavonoid content of vine tea samples.

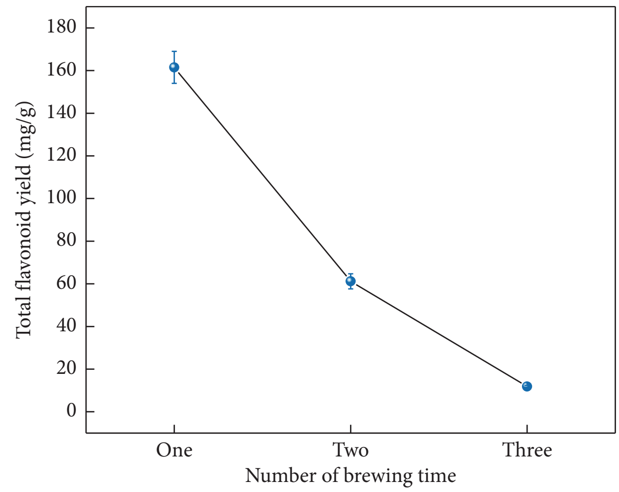

Figure 4: The impact of the number of brews on the overall flavonoid content of vine tea samples.

examine the impact of varying brewing frequencies on the total flavonoid content. The findings are depicted in Figure 4. As the brewing frequency increased, there was a significant decrease in the total flavonoid content. Upon the second brewing, the content is reduced to less than half of the original amount, and the overall flavonoid content in the tea decreased to a lower level as a result of the high tenderness of the *Ampelopsis Grossedentata* leaves, leading to a faster leaching rate of chemical components. Consequently, following two brewing cycles, the chemical constituents in the tea infusion were effectively extracted, resulting in the maximum dissolution of total flavonoids. However, taking all factors into consideration, the initial brewing is the most favored.

3.1.5. The Effect of Water Quality on the Total Flavonoid Content of Vine Tea-Water Samples. To accurately measure 1 g of vine tea and steep it under the specified conditions (1 : 40 ratio, 80°C, 8 minutes, single brewing) in order to examine the impact of varying water quality on the overall flavonoid content. The findings are depicted in Figure 5. The variation in total flavonoid content is evident when the brewing water quality differs. The highest content is achieved when the beverage is brewed with pure water, and the total flavonoid content in plain water is equivalent to that in mineral water. The leaching of active material may be influenced by factors such as water pH and the presence of minerals such as calcium and magnesium. Minerals have the potential to engage in complexation reactions with active compounds, leading to a reduction in the concentration of these compounds in the tea sample, specifically a decrease in the total flavonoid content. The superiority of brewing *Ampelopsis Grossedentata* with pure water is evident.

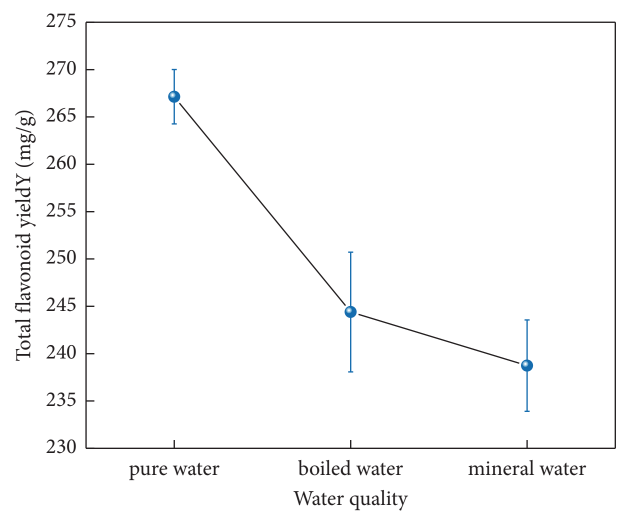

Figure 5: Effect of water quality on the total flavonoid content of vine tea.

3.2. Orthogonal Experiments. Based on the outcomes of the individual factor experiments, the brewing technique of *Ampelopsis Grossedentata* was meticulously optimized using orthogonal experiments. The levels of each factor are summarized in Table 4. The L_9 (3^3) three-factor, three-level orthogonal experiment was conducted, incorporating the aforementioned factors. The results and corresponding analysis are presented in Table 5. Excluding the interaction effects, the order of factors influencing the brewing technique stands as follows: tea-water ratio, brewing temperature, and finally brewing time. Table 6 clearly demonstrates that the tea-water ratio holds the most significant impact on total flavonoid yield. While the brewing temperature exhibits a slightly less significant effect than the tea-water ratio, the brewing time exerts the least influence and is considered insignificant. Therefore, the optimal process conditions for extracting total flavonoids from *Ampelopsis Grossedentata* are as follows: a tea-to-water ratio of 1 : 50, brewing temperature of 85°C, and a brewing time of 8 minutes. Boiling water should be used for a single brewing cycle, which is expected to yield 32.68% of total flavonoids.

Table 4: Electronic tongue sensor performance description.

Level	Factor		
	A: Tea to water ratio (g : ml)	B: Brewing temperature (°C)	C: Brewing time (minutes)
1	1 : 30	75	7
2	1 : 40	80	8
3	1 : 50	85	9

Table 5: Orthogonal experimental results.

Serial number	A: Tea to water ratio (g : ml)	B: Brewing temperature (°C)	C: Brewing time (minutes)	Total flavonoid yield (%)
1	1	1	1	26.28
2	1	2	2	28.68
3	1	3	3	28.10
4	2	1	2	28.32
5	2	2	3	29.46
6	2	3	1	30.94
7	3	1	3	28.78
8	3	2	1	30.28
9	3	3	2	31.45
$k1$	83.06	83.38	87.50	
$k2$	88.72	88.42	88.45	
$k3$	90.51	90.49	86.34	
R	2.48	2.37	0.70	
Optimal level		$A_3B_3C_2$		
Order of priority		$A > B > C$		

Annotated drawing: *1.2.3 for categories A, B and C correspond to those in Table 4, respectively.

Table 6: Analysis of variance for orthogonal experiments.

Source of variation	SS	degree of freedom	MS	F	P
A: Tea to water ratio	10.08	2	5.04	19.75	<0.05 (0.048)
B: Brewing temperature	8.92	2	4.46	17.47	>0.05 (0.054)
C: Brewing time	0.74	2	0.37	1.46	>0.05 (0.407)

*SS stands for sum of squares of deviation from mean; MS stands for mean square; F is the ratio of the sum of squared deviations between and within groups to the degrees of freedom.

3.3. Sensory Evaluation

3.3.1. Traditional Sensory Evaluation. The sensory qualities of the vine teas were investigated. The sensory evaluation findings (Supplementary Table S1) showed that all tea samples displayed a yellow-green color, except for samples No. 5 (1 : 50-2) and No. 6 (1 : 50-3). When the tea-water ratio was 1 : 20 or 1 : 30 and the brewing time was less than or equal to 4 minutes, the aroma and taste were found to be unpleasant and rough. This finding suggests that a brief brewing time and low tea-water ratios have a negative impact on the sensory quality of the tea samples. In terms of the total score, the optimal brewing process for achieving an overall sensory score above 80 is achieved when the tea-water ratio is ≥1 : 50, the temperature is ≥80°C, and the time is ≥7 minutes. These parameters should serve as the foundation for the optimal brewing process.

3.3.2. Modern Sensory Evaluation Techniques. The taste analysis of vine tea-water samples from different brewing processes was conducted using an electronic tongue. Figure 6 presents the clustering thermal map analysis of the electronic tongue's taste analysis of 20 vine tea samples from different brewing processes. According to the figure, the 20 samples can be categorized into 5 groups, with samples 1 : 50-2 and 1 : 50-3 grouped into one category. These two tea samples exhibit strong acidity, bitterness, and sweetness, but have low levels of aftertaste-A, freshness, saltiness, and richness. The six tea samples of 5 minutes, 6 minutes, T70, T75, T80, and 1 : 40 can be grouped into one group, and their expression of sour taste is similar. Overall, the expression of various flavors was relatively flat. Sample 4 minutes, 3 minutes, and 2 minutes can be clustered into one group, and the expression of aftertaste-B in these three tea samples was relatively low, with similar acidity, bitterness, and astringency. Samples 1 : 60, 1 : 50-1 can be clustered into one

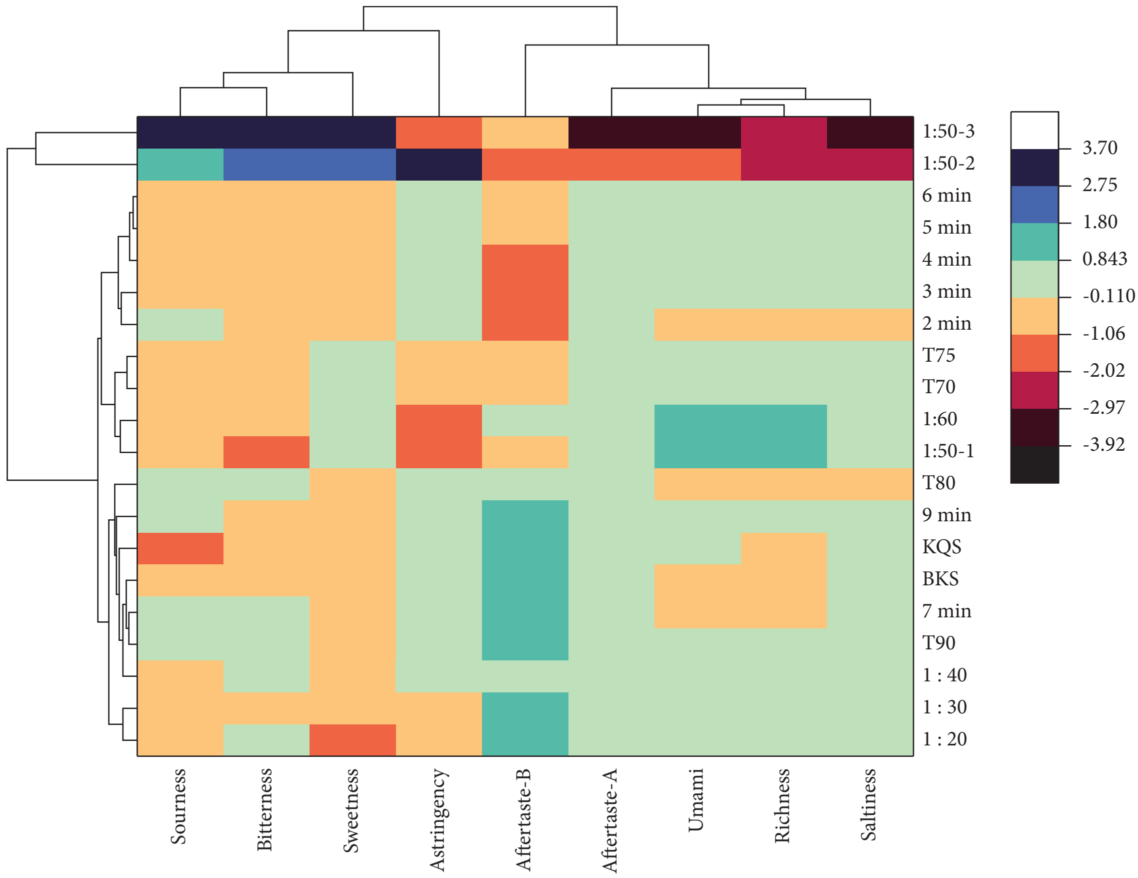

Figure 6: Thermal map of electronic tongue taste clustering of vine tea with different brewing processes.

category, and these two tea samples had a higher freshness and richness, while the astringency was lower. Samples 9 minutes, KQS, BKS, 7 minutes, T90, 1 : 20, 1 : 30 can be grouped into one category, and these seven samples have a stronger expression of aftertaste-B and less sweetness. The same results as the clustering thermal map can also be seen in the radar map in Figure 7. These clustering results are consistent with the findings in Figure 7's radar map.

(1) Vine Tea Samples with Different Tea-Water Ratios. It is evident from Figure 8 that each dot on the PCA plot represents a sample, and the distance between the dots signifies the magnitude of the disparities among the samples. The 1 : 50 to 1 and 1 : 60 vine tea samples are situated in the fourth quadrant, with overlapping regions of similarity and minimal differences. Conversely, the 1 : 20, 1 : 30, and 1 : 40 teas are clearly distinguished in the first, second, and third quadrants, exhibiting substantial differences in distance, thus indicating notable disparities in taste.

According to numerous studies, the flavor of green tea is intricately linked to the concentration of water extract, amino acids, and tea polyphenols within the tea leaves. As the concentration of water extract increases, so does the taste threshold of the tea. The tea polyphenols, primarily responsible for the astringency of tea, and the rise in amino acid content enhances the freshness of the tea. It has been established that the more amino acids that are dissolved in the tea samples, the better the taste, and vice versa. Notably, the tea-to-water ratio significantly impacts the flavor profile of vine tea. As seen in Figure 9, the sweetness, bitterness, astringency, and richness of vine tea vary significantly across different tea-water ratios. In contrast, the sourness and aftertaste remain relatively consistent, indicating that the tea-water ratio has a greater impact on these attributes rather than sourness or aftertaste. For vine tea, umami and sweetness are considered the primary tastes [56], and flavors such as sourness, astringency, and bitterness are undesirable in tea. From the radar chart, as the ratio of tea to water decreases, the expression of sweetness, richness, and freshness increase, while intensity of bitterness and astringency diminishes. At a ratio of 1 : 50-1, the tea exhibits the most prominent sweetness, richness, and freshness, with the least amount of bitterness and astringency. Therefore, a tea-to-water ratio of 1 : 50 is optimal for achieving the best flavor profile in vine tea.

Using the ultra-fast gas chromatography electronic nose, six samples of vine tea with different tea-to-water ratios were analyzed. After subtracting the blank, the signals collected by the MXT-5 column were imported into the Origin 2021 software. This process enabled us to generate the odor fingerprint of vine tea, as presented in Figure 10. It is evident that vine tea has two main aroma peaks at different brewing temperatures, and the peak time at which these peaks occur remains consistent. However, the magnitude of these peaks

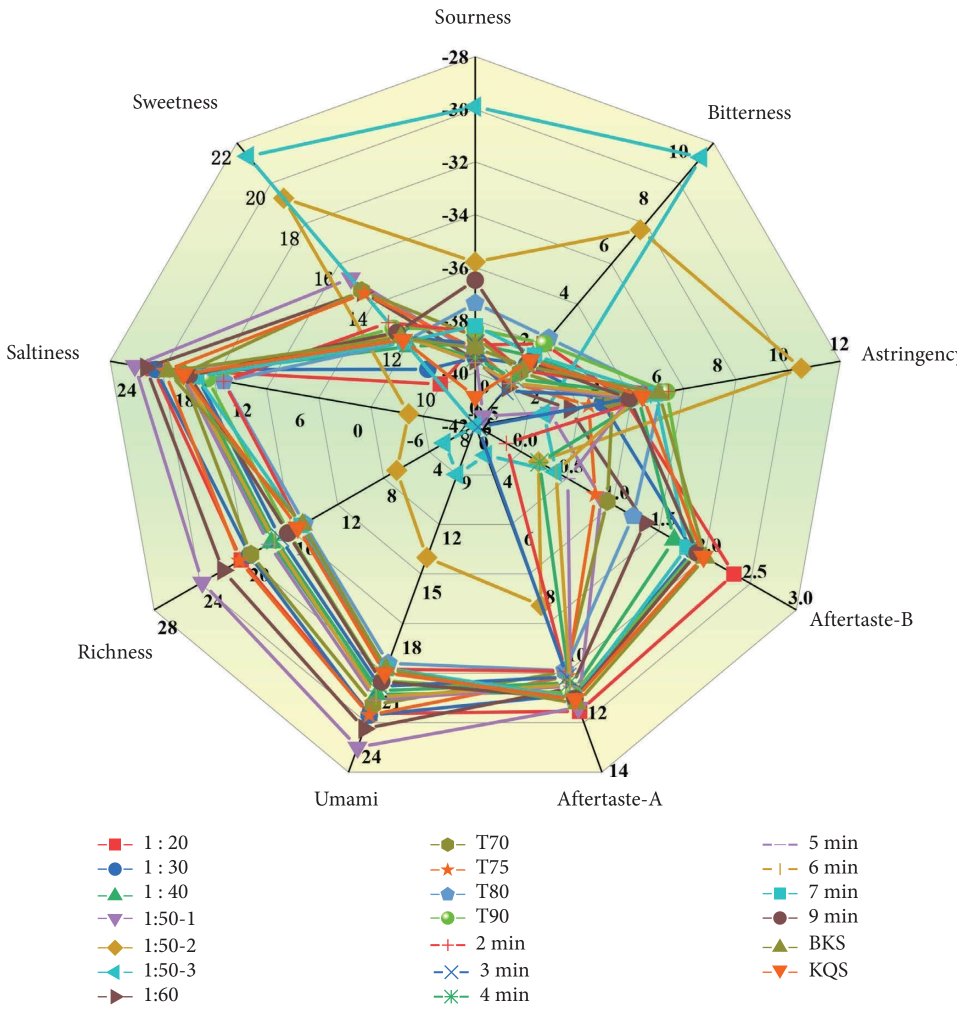

Figure 7: Electronic tongue taste radar of vine tea with different brewing processes.

varies, indicating that the tea-water ratios have a significant impact on the aroma of vine tea. Specifically, when the tea-water ratios are 1 : 40, 1 : 50, and 1 : 60, the difference in peak odor intensity is minimal, indicating that the volatile compounds present in the tea are similar across these ratios. The common tea flavor substances are mainly acetoin, cyclopentane, 1-ethyl-3-methyl-, and 1-chloropentane. Characteristic odors expressed are: aromatic, sweet, herbaceous, fruity, etc. In the tea-to-water ratio of 1 : 30, the maximum intensity of aroma is achieved, while it is the lowest at the ratio of 1 : 50-1, indicating that the concentration of volatile substances is highest when the tea ratio is 1 : 30. As the tea-water ratio decreases, the intensity of the aroma decreases. In addition, the peak intensity of the aroma at the 10th percentile is significantly higher than at the 60th percentile. Figure 11 shows that the PCA analysis of vine tea samples with various tea-water ratios indicates a cumulative contribution rate of 87.70% for the two components. The vine tea samples with a tea-water ratio of 1 : 20 (located in the fourth quadrant of PCA) and 1 : 30 (located in the third quadrant of PCA) are significantly distant from each other and can be clearly distinguished. In addition, the samples with tea-water ratios of 1 : 40, 1 : 50-1, and 1 : 60 are situated in the third quadrant of the PCA chart, indicating that the flavor substances share certain commonalities. Even though the distance is shorter, they are still distinguishable. The analysis of the odor fingerprint in Figure 10 is consistent.

(2) Vine Tea Samples at Different Brewing Temperatures. The distance between the points in the PCA diagram represents the magnitude of the feature difference between the samples. As can be observed in Figure 12, the tea samples of T70 and T75 are situated in the fourth quadrant of the PCA diagram. The distance between these two samples is relatively similar, indicating that their flavors profiles are closely aligned. However, when compared to the tea soups T85 (located in the first quadrant), T90 (located in the second quadrant), and T80 (located in the third quadrant), the distance is greater, indicating significant differences that can be easily distinguished.

As Figure 13 clearly demonstrates, there is a notable divergence in the levels of saltiness, richness, and freshness when various brewing temperatures are applied. Conversely, the acidity and aftertaste-B remain relatively consistent across different brewing temperatures, signifying that temperature variations have a more significant impact on

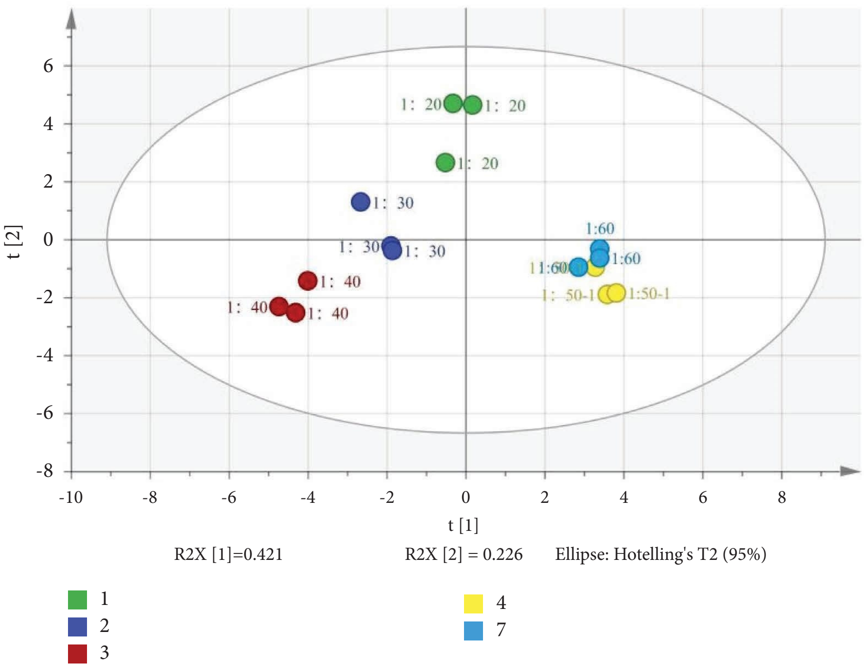

Figure 8: PCA graph of electronic tongue with different tea-water ratios of vine tea.

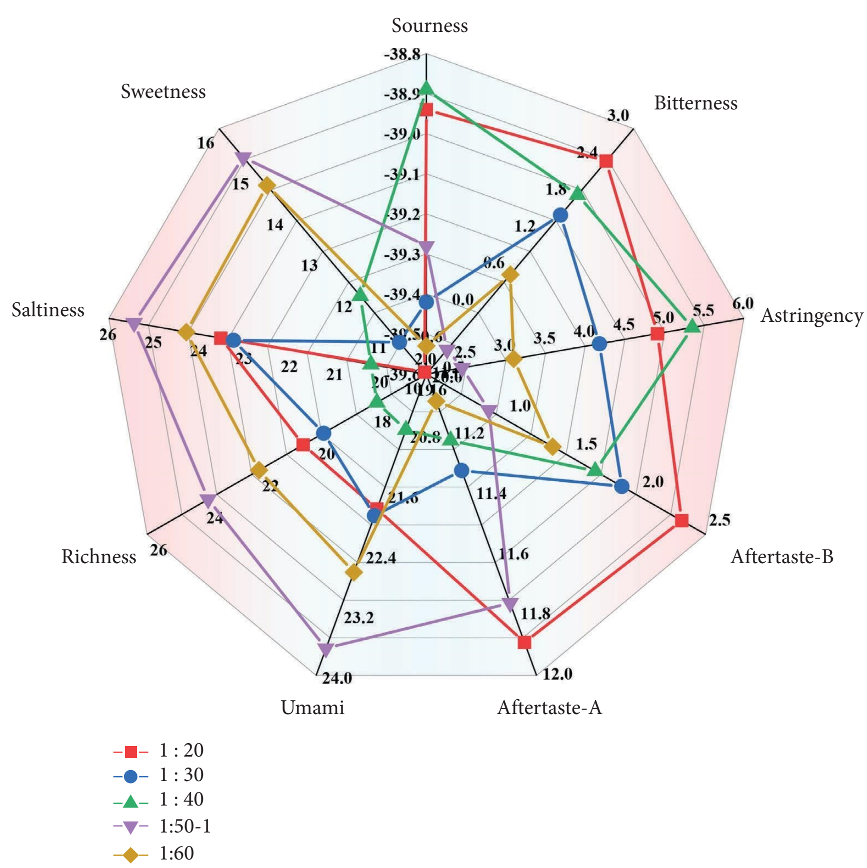

Figure 9: Radar chart of different tea-to-water ratios of vine tea.

saltiness, richness, and freshness, while exerting minimal influence on acidity and aftertaste-B. Notably, as brewing temperature rises, the perception of bitterness and astringency intensifies. This was caused by the high temperatures at which tea leaves breakdown, releasing a significant amount of tannic acid and aromatic compounds

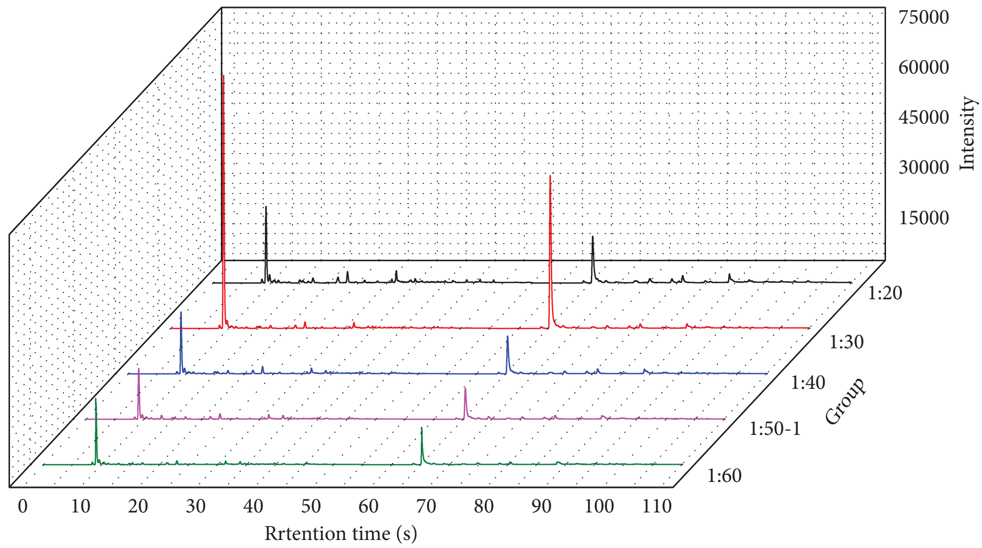

Figure 10: Odor fingerprints of vine tea with different tea-water ratios.

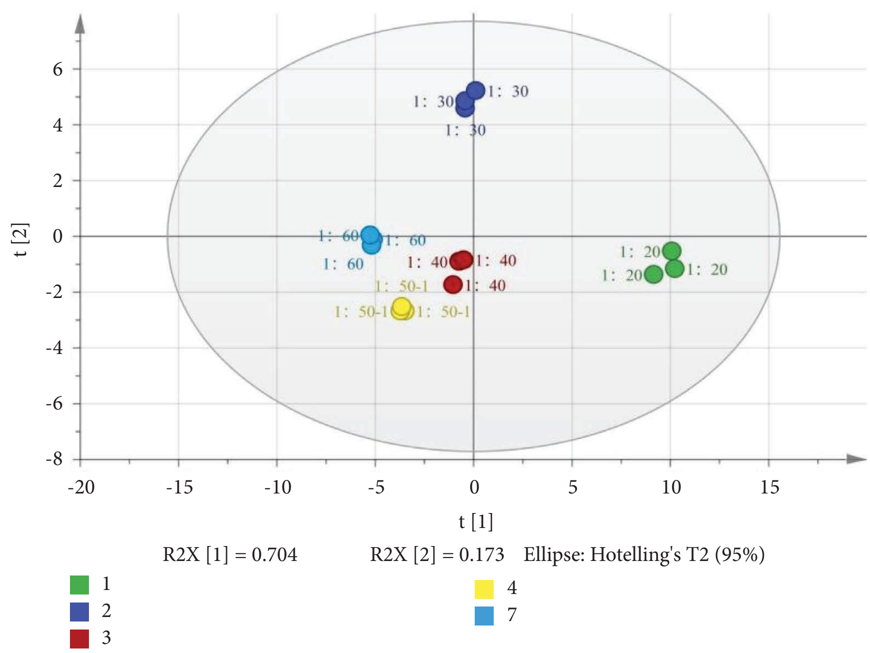

Figure 11: PCA graph of electronic nose with different tea-to-water ratios of vine tea.

that combine with caffeine, tea polyphenols, and other ingredients to make the tea bitterer overall and significantly lower its nutritional value. The strongest flavors are sweetness, richness, freshness, and aftertaste-A at brewing temperature of 85°C (1 : 50-1), while the weakest flavors are bitterness and astringency. As a result, the optimal flavor of vine tea is achieved at a brewing temperature of 85°C, making this the most ideal temperature.

As Figure 14 illustrates, the odor fingerprint of vine tea exhibits distinct patterns when brewed at various temperatures. Notably, as the temperature increases from T70 to T75, the intensity of the odor peak response becomes more prominent. This suggests that elevating the temperature aids in the temperature increases; it is conducive to the dissolution of volatile compounds within vine tea. However, upon further temperature increments, the intensity of the odor peak response diminishes, reaching its lowest point at T90. This decline may be attributed to the thermal degradation of volatile substances contained in the tea, leading to a reduction in their concentration and a correspondingly weaker odor peak response. For example, the volatile components with an orange flavor, namely, L-Limonene, gamma-Terpinene, and Limonene, disappear at temperatures exceeding 85°C. Interestingly, while the position and number of odor peaks remain consistent across different brewing temperatures, their response intensity varies, leading to

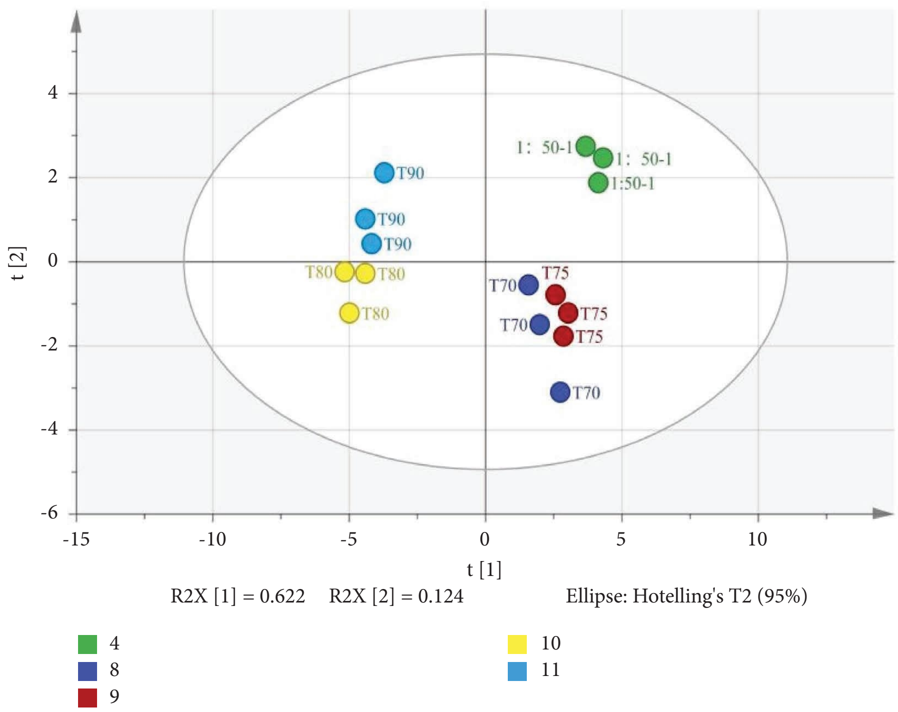

Figure 12: PCA graph of electronic tongue with different brewing temperatures of vine tea.

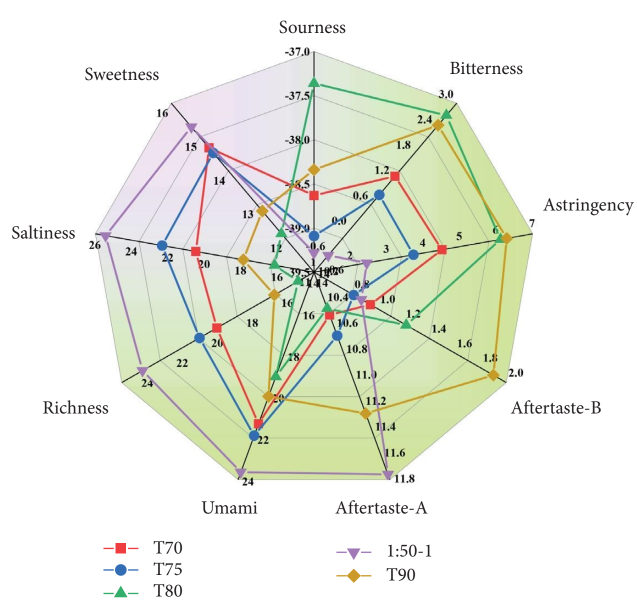

Figure 13: Radar chart of vine tea with different brewing temperatures.

distinct peak areas. This is evident in the PCA diagram presented in Figure 15, which compares vine tea samples brewed at various temperatures. Notably, 75°C (T75), 85°C (1 : 50-1) and 90°C (T90) are situated in distinct quadrants of the PCA graph, indicating that the flavor profiles are well-separated. However, T70 and T80 were close together, indicating that the odor substances contained are similar and cannot be well distinguished.

(3) Vine Tea Samples at Different Brewing Times. As Figure 16 reveals, it is evident that at various brewing durations, the flavor profile varies significantly. Notably, the 2-minute and 8-minute (1 : 50-1) intervals—found in the first and second quadrants, respectively—exhibit a noticeable divergence in flavor that can be distinguished well. However, the remaining brewing durations, particularly those in the third and fourth quadrants, display a high degree of similarity and are challenging to differentiate. For instance, the 5-minute and 6-minute intervals occupy the third quadrant, while the 7-minute and 9-minute intervals occupy the fourth quadrant. Although these pairs have distinguishable flavors, their closeness on the PCA plot undermines their distinguishability.

From the radar plot in Figure 17, it becomes evident that the flavor variations across different brewing durations are minimal. Notably, the radar plot's response shape remains consistent from 3 minutes to 6 minutes, indicating a similar flavor profile within this duration range. This observation aligns with the PCA plot's analysis, highlighting the similarity in flavor among these brewing durations.

On the other hand, significant differences in radar plot response shape emerge after 2 minutes, 7 minutes, 8 minutes (1 : 50-1), and 9 minutes of brewing. In particular, the 2-minute brew exhibits the most prominent astringency and the feeblest aftertaste and richness, signifying that insufficient brewing time can lead to incomplete tea leaf saturation and restricted release of tea's constituent flavors.

When the brewing period reaches 7 minutes, the bitterness of the tea attains maximum expression, while the sweetness, richness, and freshness are at their lowest. When brewed for 9 minutes, the umami and richness of the tea are

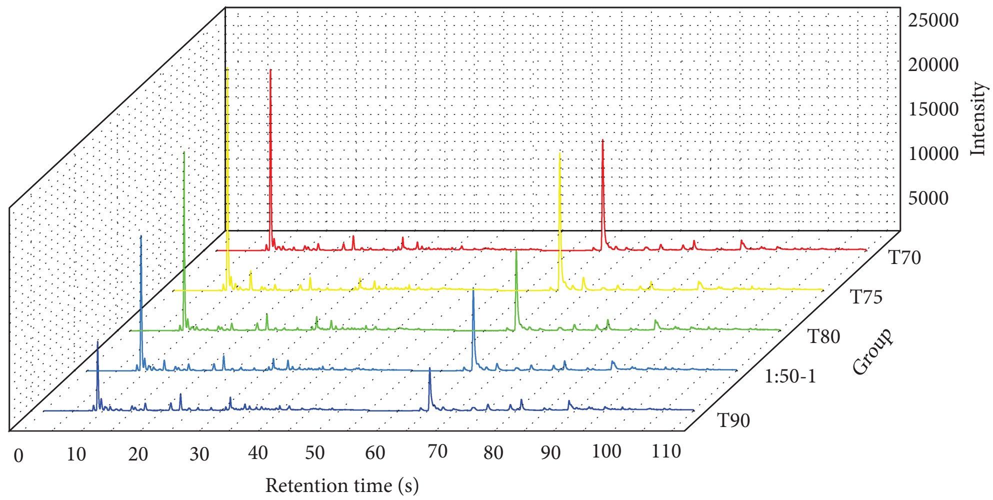

Figure 14: Odor fingerprint of vine tea samples with different brewing temperatures.

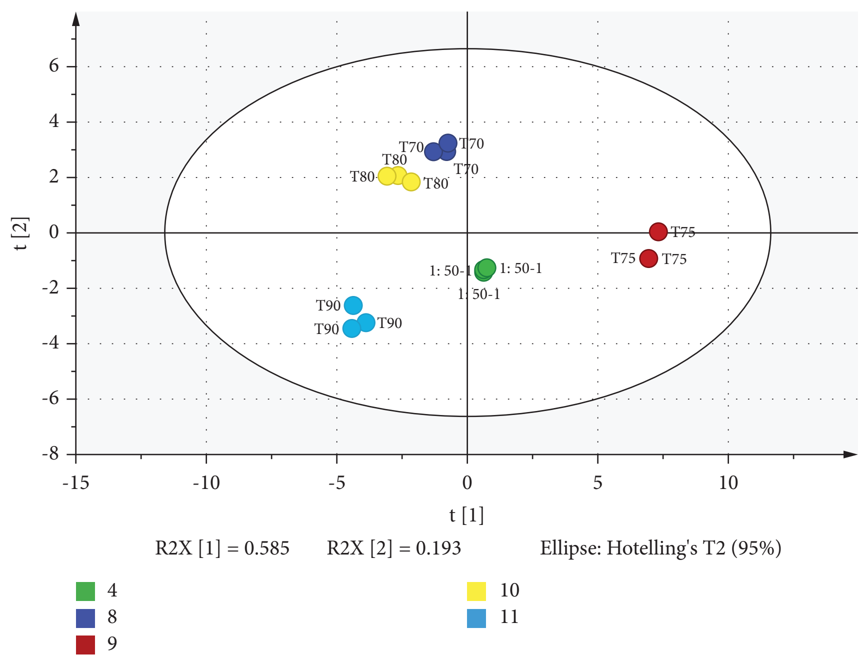

Figure 15: PCA graph of electronic nose with different brewing temperatures of vine tea.

at their minimum, with the acidity and bitterness being at their peak. This suggests that beyond a brewing time of 9 minutes, the original flavor of the tea begins to diminish, leading to the emergence of adverse flavors. At an intermediate brewing time of 8 minutes, the expression of sweetness, richness, umami and aftertaste-A is at its maximum, with sourness, bitterness, and astringency being at their lowest. This indicates that when brewed for 8 minutes, the tea attains the most optimal flavor profile. Therefore, 8 minutes is the optimal brewing time for obtaining the best flavor from vine tea.

In the study by Long [57], tea soluble is divided into three classes: effectively instantaneous soluble, rapid soluble, and slower soluble. As depicted in Figure 18, the aroma profile of vine tea alters with varying brewing times, suggesting that the taste of vine tea also changes accordingly. The rate-limiting step of diffusion is primarily determined by the solubility of compounds. As the brewing time increases, the peak odor response initially weakens and subsequently strengthens. The volatile organic compounds (VOCs) initially rise and then decrease [58]. The odor profile of the volatile components starts out as predominantly grassy, fruity, and sweet notes, which gradually transition to alcoholic, pungent, and fermented. Notably, when the brewing time is 8 minutes (1 : 50-1), the flavor peak response is the most intense, while at 7 minutes, it is the weakest. Therefore, it can be inferred that when the brewing time is 8 minutes, the flavor of vine tea is optimal. The PCA diagram for vine tea samples with various brewing times (Figure 19) supports these findings. As evident in the figure, brewing times of

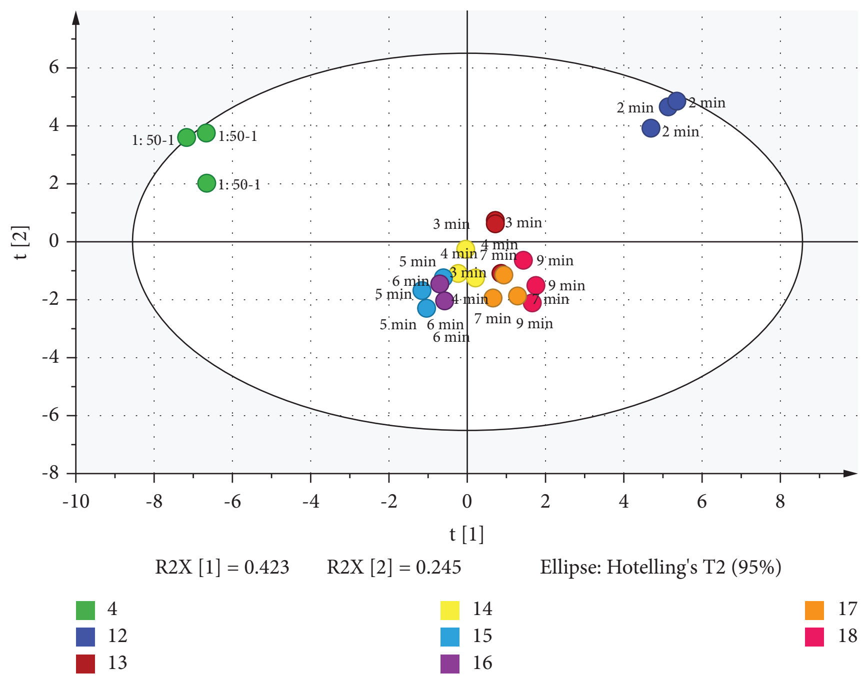

Figure 16: PCA graph of electronic tongue with different brewing times of vine tea.

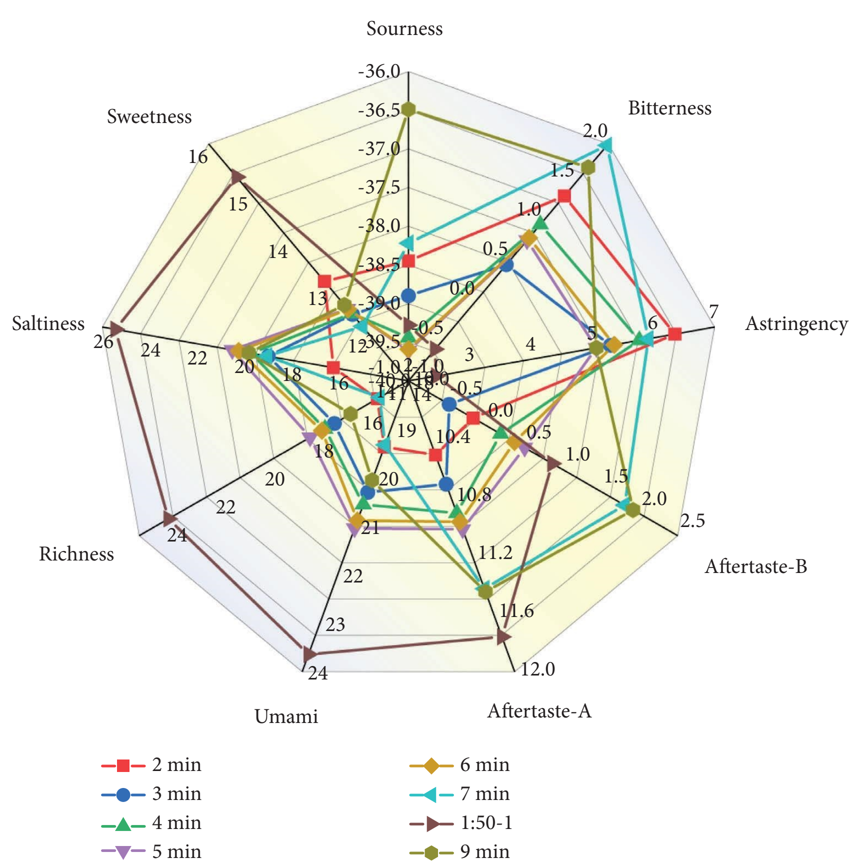

Figure 17: Radar graph of vine tea with different number of brewing times.

2 minutes (located in the first quadrant of the PCA diagram), 8 minutes (1 : 50-1) (located in the fourth quadrant), and 7 minutes (located in the third quadrant) are distinctly separate from each other, indicating that their flavor substances have quite significant differences in their flavor profiles and can be easily distinguished. Conversely, the

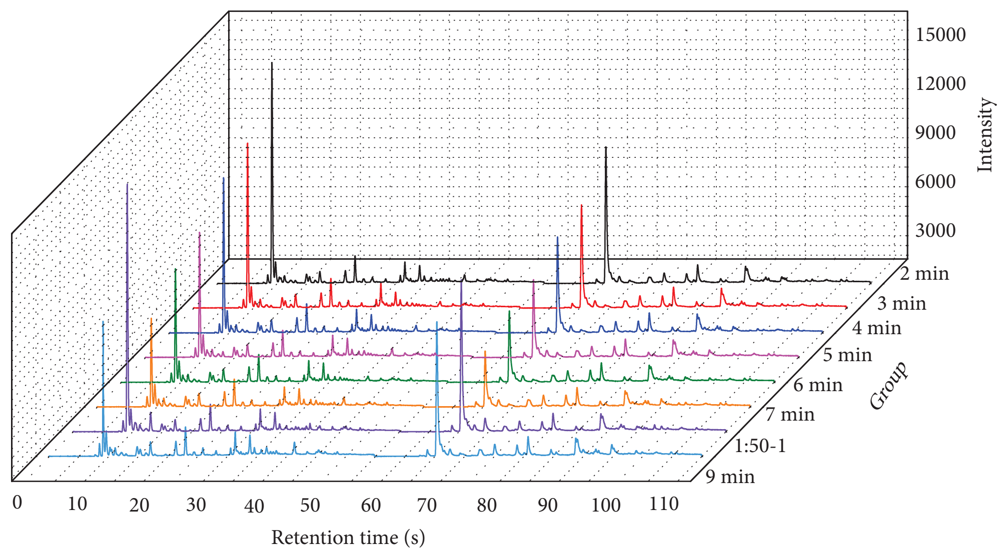

Figure 18: Odor fingerprint of vine tea samples with different brewing times.

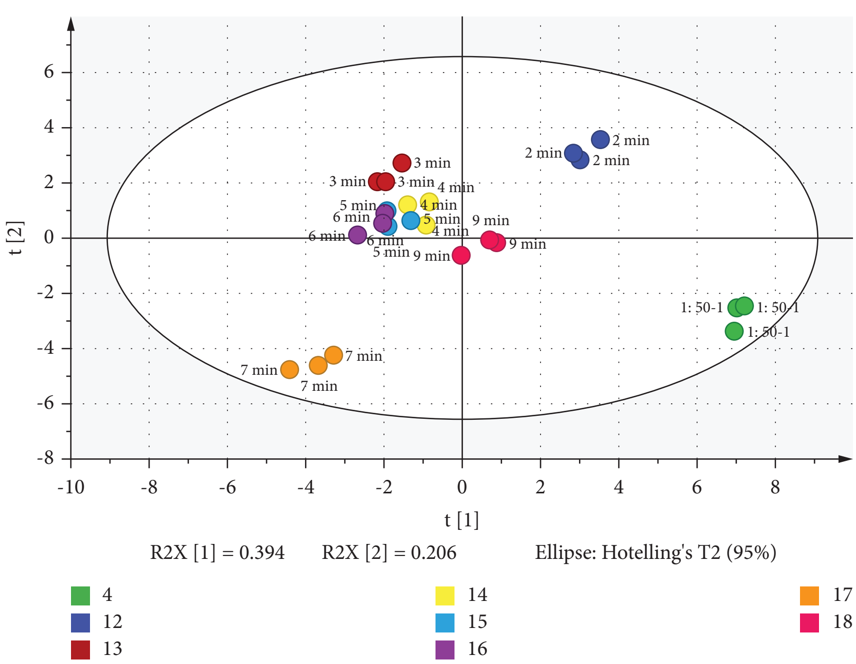

Figure 19: PCA graph of electronic nose with different brewing times of vine tea.

remaining brewing times are clustered together in the second quadrant of the PCA diagram and are relatively indistinguishable from each other.

(4) Vine Tea Samples at Different Number of Brewing Times. It is evident from Figure 20 that the taste of vine tea is significantly influenced by the duration of brewing. The tea samples occupy distinct quadrants on the PCA plot, distinct flavor profiles. The first brewing (1 : 50-1) falls in the third quadrant, the second brewing (1 : 50-2) occupies the first quadrant, and the third brewing (1 : 50-3) lies in the fourth quadrant. The considerable difference between the groups highlights a significant in taste. As inferred from the radar chart in Figure 21, the taste response varies with the frequency of brewing. The first brewing (1 : 50-1), exhibits the most prominent sourness, aftertaste, umami, richness, and umami expression, while exhibiting the least bitterness. The second brewing (1 : 50-2) enhances astringency and bitterness, with the strongest astringency and the weakest aftertaste-B. Other flavor expressions are also relatively weaker. In the third brewing (1 : 50-3), bitterness and sweetness are most prominent, while other flavors are relatively subdued. This suggests that as the number of brews increases, the dissolved substances in the tea decrease, leading to a blander flavor profile. Although sourness is strong in the first brewing (1 : 50-1), bitterness and

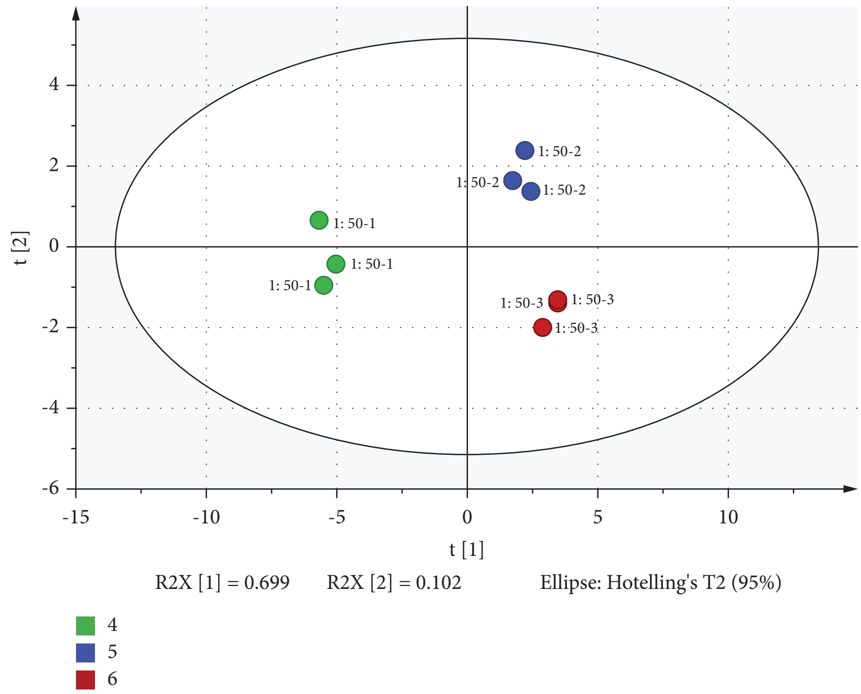

FIGURE 20: PCA graph of electronic tongue with different number of brewing times of vine tea.

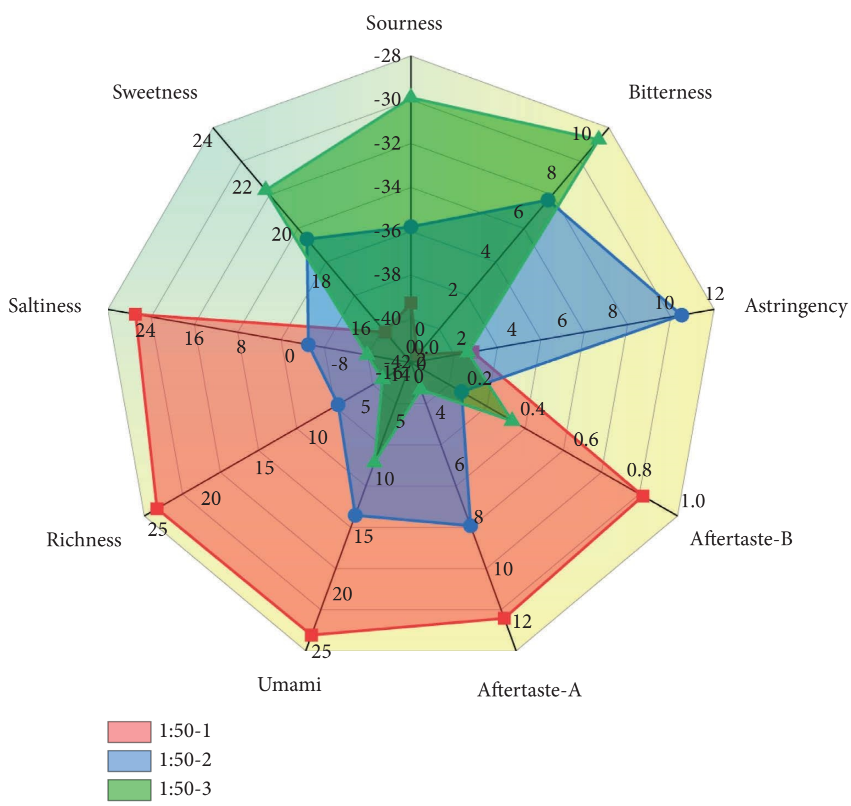

FIGURE 21: Radar graph of vine tea with different number of brewing times.

astringency are undesirable flavors. Considering all factors, the flavor of vine tea is optimal when brewed once. Therefore, it is advisable to brew vine tea once.

As Figure 22 demonstrates, the odor fingerprint of vine tea brewed for varying lengths of time is presented. The figure clearly illustrates that the flavor of vine tea is

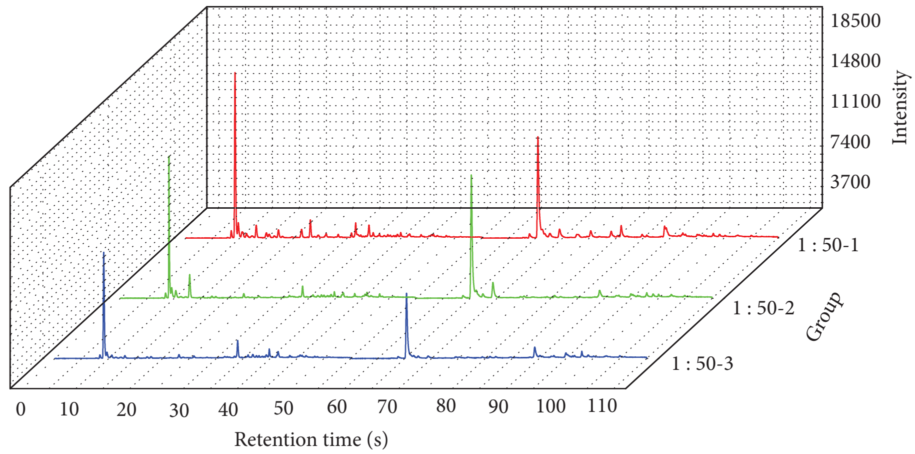

FIGURE 22: Odor fingerprint of vine tea samples with different number of brewing times.

influenced by the duration of brewing. As the brewing time increases, the intensity of the odor peak response weakens. It is noteworthy that the first brewing (1 : 50-1) exhibits the most intense odor peak response, while the third brewing (1 : 50-3) demonstrates the weakest, indicating a decrease in newly generated volatile components as the number of brewing sessions increases. This trend can be attributed to a gradual reduction in flavor precursor substances with each subsequent brewing. Therefore, it is advisable to brew vine tea only once to achieve optimal flavor. Figure 23 presents the principal component analysis (PCA) plot for vine tea brewed at different times. The figure reveals that the two components together account for a total contribution rate of 90.70%, which effectively captures the essence of the original data. Notably, the first brewing (1 : 50-1) is located in the fourth quadrant of the PCA plot, the second brewing (1 : 50-2) is situated in the second quadrant, and the third brewing (1 : 50-3) is found in the third quadrant. The significant distance between these points indicates significant flavor variations across different brewing sessions of the tea sample, making them easily distinguished.

(5) Vine Tea-Water Samples at Different Water Quality. As Figure 24 demonstrates, the flavors of vine tea brewed with various water qualities vary. Notably, mineral water (KQS) is situated in the first quadrant of the PCA figure, while boiled water (BKS) is located in the fourth quadrant. However, the distance between these two is relatively close, indicating that the flavor substances of BKS and KQS are similar and challenging to distinguish. In contrast, it is easily distinguished from pure water (1 : 50-1). The radar chart in Figure 25 further highlights the distinct responses of vine tea flavor substances brewed with different water qualities due to the varying levels of active substance leaching. The impact of water quality on tea quality is primarily associated with the physicochemical properties of the water, including acidity, hardness, ion content, electrical conductivity, and more.

According to research, when the plasma in water contains high levels of Ca^{2+} and Mg^{2+}, it can easily react with tea polyphenols, carbon dioxide, and other substances. This leads to the formation of complexes and organic acid salt precipitates, such as calcium carbonate. These reactions can reduce the solubility of the active ingredients in tea, which can impact the taste and clarity of tea beverages. When brewed with pure water (1 : 50-1), the expression of sweetness, saltiness, umami, richness, and aftertaste-A is the strongest, and the expression of undesirable flavors such as sourness, astringency, and bitterness is the weakest [59]. When brewing vine tea with boiled water (BKS), the bitterness and astringency are particularly prominent, while the richness and umami are relatively weak. This is due to the high chloride ion content in tap water, which interacts with tea polyphenols to produce a “rusty oil” on the surface of the tea, leading to a bitter and astringent tea broth. When making tea with mineral water (KQS), the resulting brew exhibits strong bitterness and astringency. It also has a pronounced sour taste, and the umami and richness are notably subdued. These characteristics suggest that when brewed with KQS and BKS, it may lead to unfavorable flavor profiles. The ion content of water can significantly impact tea flavor, as ions such as Ca^{2+}, Mg^{2+}, and Cl^-can interact with tea’s polyphenols, amino acids, organic acids, caffeine, and other taste-producing compounds [10]. These interactions can influence the amount of volatile aroma components released during brewing, leading to variations in taste attributes like umami, astringency, bitterness, and the type, purity, and intensity of tea’s aroma [29].

As we can see in Figure 26, the quality of water used for brewing vine tea significantly impacts its flavor. It is evident that when brewed with pure water (1 : 50-1), the odor peak response is the strongest, indicating a higher concentration of flavor substances. Boiled water (BKS) and mineral water (KQS) produce a similar response intensity, but both exhibit greasy odors caused by components such as 2-hexanol, (Z)-3-hexenal, hexanal, and others. Therefore, to achieve the best flavor in vine tea, pure water should be used during brewing.

Figure 27 presents the PCA diagram for vine tea brewed with different water qualities. The analysis reveals that the two main components contribute to an 85.30% cumulative contribution rate. Vine tea brewed with different water qualities occupies distinct quadrants in the PCA diagram,

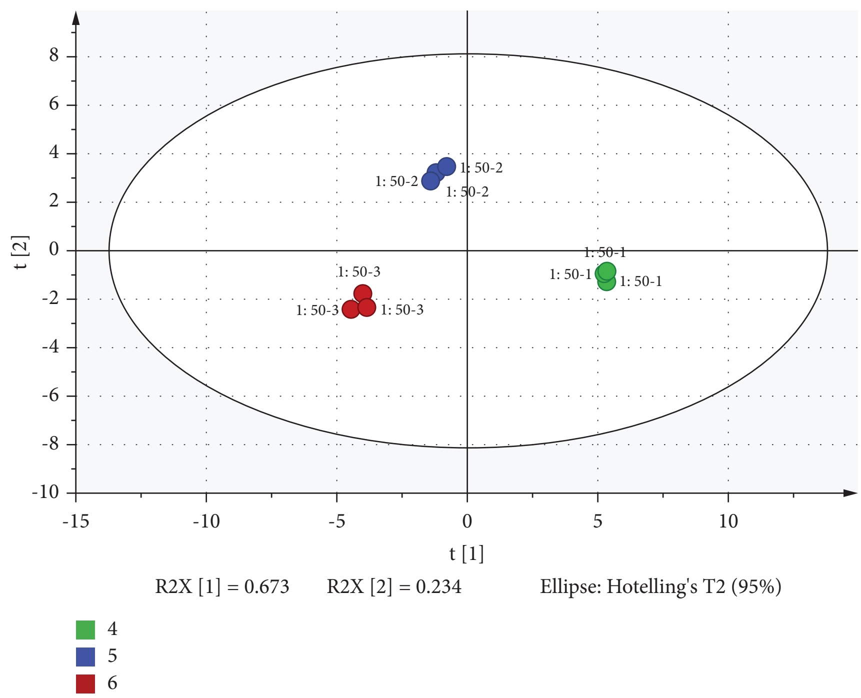

FIGURE 23: PCA graph of electronic nose with different number of brewing times of vine tea.

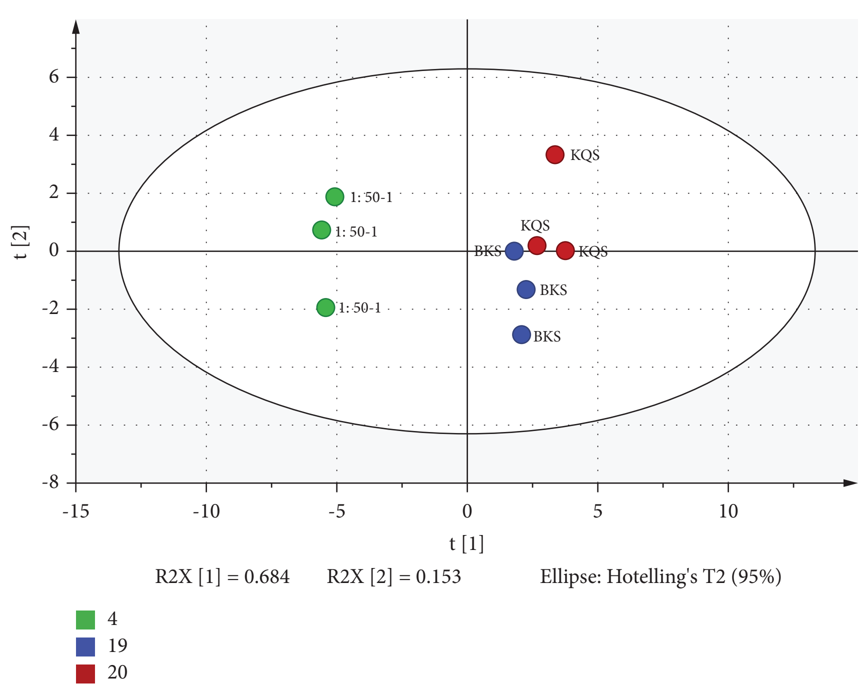

FIGURE 24: PCA graph of electronic tongue with different water quality of vine tea.

indicating variations in flavor substances. Notably, boiled water (BKS) falls within the second quadrant, while mineral water (KQS) is situated in the third quadrant. Despite having somewhat comparable placements, which suggests that their flavor components are similar, they can be distinguished from pure water (1:50-1), which is in the first quadrant in line with an electronic tongue examination.

3.4. Qualitative Analysis of Vine Tea Odor. To identify the key odor components of vine tea, the retention time of its odor fingerprint was converted into a retention index. All potential compounds under various brewing conditions were then listed and those with a retention index greater than 90 were selected, as detailed in Table 7. It has been observed that vine tea may contains 45 different odorants, with 7 main

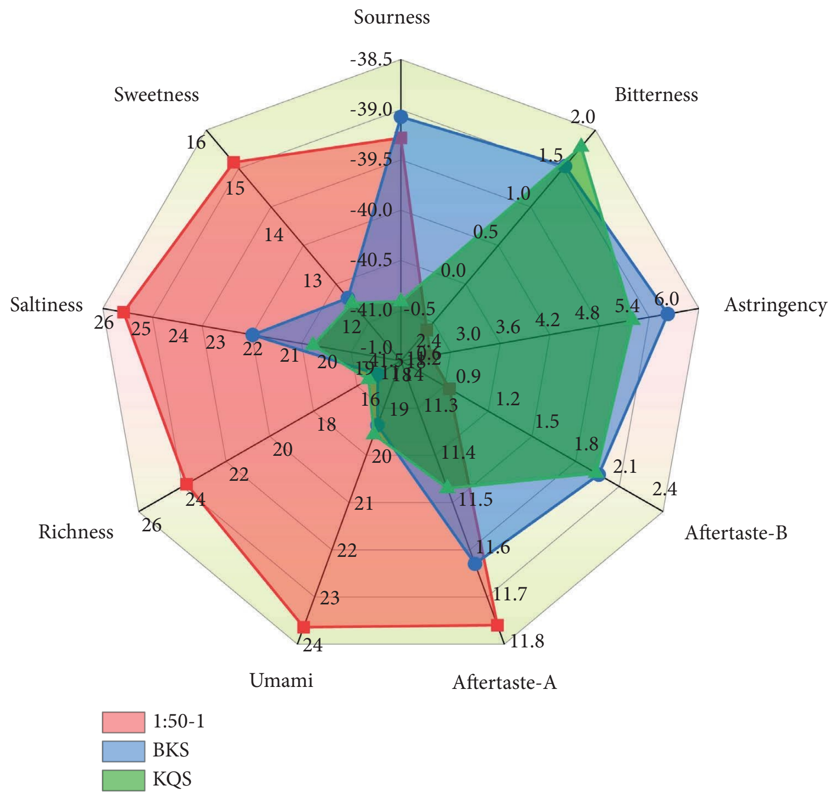

Figure 25: PCA graph of vine tea with different water quality.

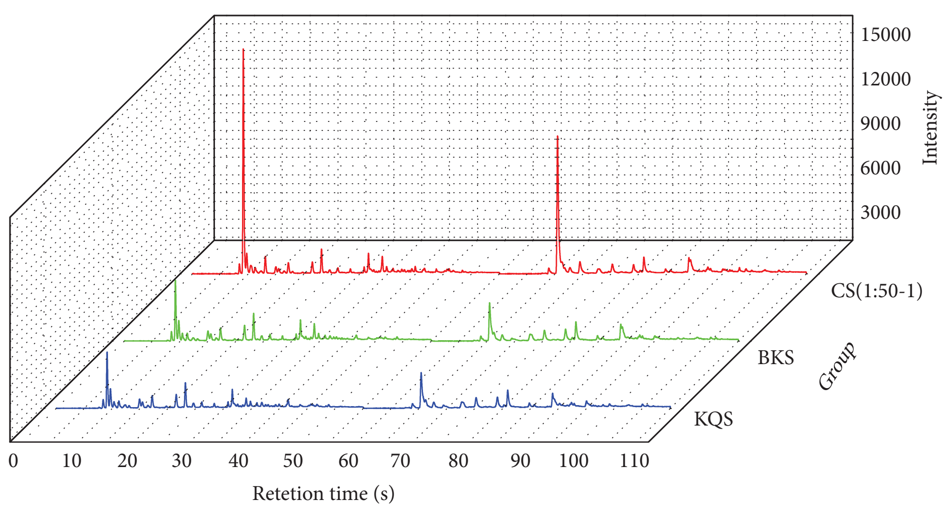

Figure 26: Odor fingerprint of vine tea samples with different water quality.

compounds including terpenes, olefins, alkanes, alcohols, aldehydes, esters, ethers, and ketones [60, 61]. From the organoleptic description, 23 compounds were identified as "sweet," indicating that the primary flavor of vine tea is sweet. There are 4 compounds with a "fermented" aroma, 20 compounds with a "grassy" aroma, and 3 compounds with a "woody" aroma. This is consistent with the production process of vine tea, which is made through the fermentation of herbs. In addition, the alcohol content contributes to the tea's floral and fruit flavor, including pentanol, 3-methylbut-2-1-ol, linalool, 2-nonanol, 2-phenylethanol, and 2-undecanol. Most of the aldehydes in tea have been reported to contribute to the infusion of citrus and green flavors, for instance, valeraldehyde, phenylacetaldehyde, 2-octenal, (E)-2-nonenal, (E, E)-2,4-nonadienal, n-nonal, Neral, and (Z)-citral. In addition, some of these substances are similar to bitter almonds, such as glutaraldehyde, acetophenone, and 2-formyl-5-methylthiophene. There are also

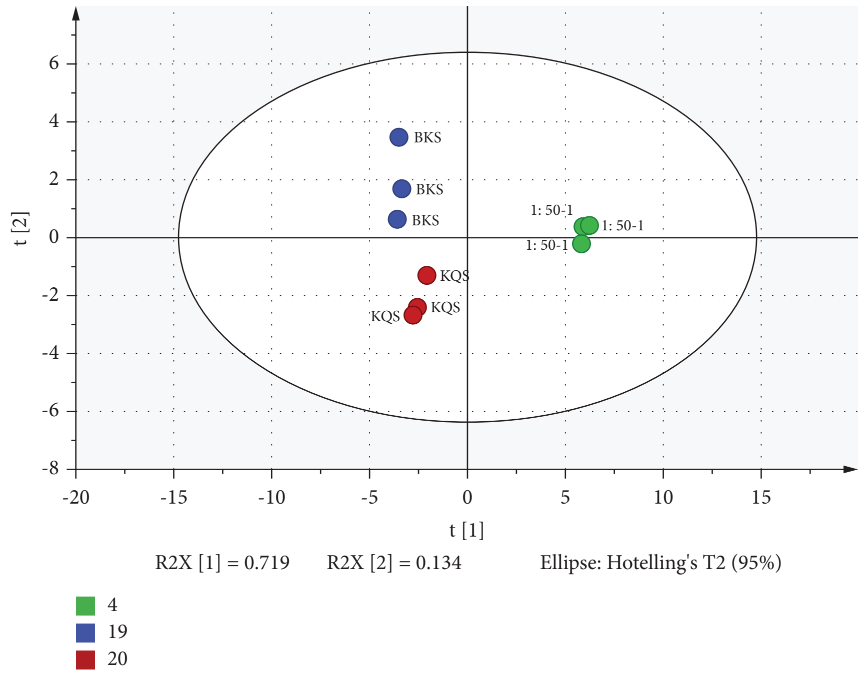

Figure 27: PCA graph of electronic nose with different water quality of vine tea.

volatile compounds that contribute to a honey flavor, such as phenylacetaldehyde and 2-phenylethanol and even fatty odor notes. Ketones constitute the second largest group of odorants that have been reported in tea to date, contributing to flowery, fruity, and woody aroma notes [3, 62], for example, 3-hexanone, acetophenone, and methyl nonane dione.

According to the sensory description results, the largest number of compounds are considered to be "sweet." This indicates that the taste of vine tea is "sweet." When the brewing conditions were pure water, 1 : 50, 85°C, 8 min, and 1 brewing cycle, 16 compounds were detected using an ultra-fast vapor phase electronic nose with a correlation index higher than 90. Among these compounds, 9 were identified as "sweet," representing the highest proportion of "sweet" compounds in all brewing conditions. This suggests that vine tea has the most favorable flavor, as indicated by electronic tongue radar analysis.

4. Discussion

According to literature, the main factors contributing to tea flavor are enzymatic reactions, which occur during the growth of the tea plant before harvesting and postharvest processing, as well as thermophysical and chemical reactions that occur during partial postharvest processing, storage, and consumption [63]. Tea brewing can be viewed as a process encompassing substance dissolution and the development of flavor within tea infusions, aligning with the tenets of ternary phase diagram theory. The phase equilibrium of the tea-water system consists of three primary components: water, tea leaves (including soluble and insoluble tea solids), and headspace. In essence, the system tends to achieve equilibrium during the brewing process, involving the release of volatile organic compounds (VOCs) from tea leaves into the tea infusion, as well as the subsequent diffusion of these VOCs from the tea infusion into the headspace through a series of thermophysical and chemical reactions [61]. Furthermore, the properties and the percentage of the compounds in tea leaves, especially soluble substances, as well as the brewing conditions, played crucial roles in this step. This phenomenon also explains why the volatile matter content is highest when the tea-water ratio is 1 : 30. When the tea-water ratio is too large, the water system becomes smaller, limiting the solubility of soluble components. In order to maintain equilibrium in the tea-water system, the content of volatile organic compounds in the headspace portion increases accordingly.

To date, it has been established that polyphenols, amino acids, and caffeine are the main factors contributing to the taste. The bitterness and astringency of tea infusions are primarily caused by the presence of tea polyphenols and caffeine. Catechins, which account for 70–80% of total tea polyphenols, are typically responsible for these flavors [64]. Amino acids are a significant factor in determining the umami of green tea and may help reduce the astringency and bitterness caused by polyphenols and caffeine [65, 66]. It is commonly believed that the stronger the bitter and astringent flavor, the higher the total flavonoid content. However, the vine tea discussed in this paper demonstrates a combination of high flavonoid content and robust sensory qualities. Why is this the case? The key lies in the distinctive flavor of vine tea, which delivers a sequence of flavor variations in the mouth. It begins with a primarily bitter taste, which gradually transitions to the sweetness that overpowers the bitterness, and finishes with a lingering sweet aftertaste.

Table 7: Information on possible compounds in vine tea and sensory descriptions.

MXT-5	MXT-1701	CAS	Molecular formula	compound	RI	Sensory description
551	635	1975-5-8	C_2H_3N	Acetonitrile	96.05	Aromatic, aromatic flavor; sweet
551	635	75-15-0	CS_2	Carbon disulfide	95.65	Aromatic, Aromatic Flavor; Burnt; Fruit; Sulfurous; Sweet
612	679	156-59-2	$C_2H_2Cl_2$	Ethene, 1,2-dichloro, (Z)-	98.8	Sweet
612	679	141-78-6	$C_4H_8O_2$	Ethyl Acetate	98.41	Acidic; Butter; Caramel; Atmospheric; Fruit; Fresh Cut Grass; Orange; Pineapple; Pungent; Solvent; Sweet
612	679	96-33-3	$C_4H_6O_2$	Methyl 2-propenoate	98.34	Pungent
612	679	107-03-9	C_3H_8S	1-propanethiol	98.02	Onion flavored; cabbage, cabbages; onion; sweet
652	680	71-55-6	$C_2H_3Cl_3$	Trichloroethane	96.75	Chloroform; Atmospheric; Mild; Sweet
652	680	110-82-7	C_6H_{12}	Cyclohexane	96.6	Chloroform
698	788	110-62-3	$C_5H_{10}O$	Pentanal	96.45	Pungent; Almond; Berry; Fermented, Brewed; Fruit; Fresh-cut Grass; Herbal; Malt; Nutty; Pungent; Rubber
698	788	6032-29-7	$C_5H_{12}O$	pentan-2-ol	95.59	Alcohol; Atmosphere; Fermented, Brewed; Fruit; Hashish; Fresh cut grass; Fresh cut grass (not strong); Mild; Nutty; Oil; Plastic; Spicy; Raspberry; Sweet
773	859	556-82-1	$C_5H_{10}O$	3-Methylbut-2-en-1-ol	97.95	Fruity; Fresh cut grassy; Herbal; Lavender
773	859	79-00-5	C_2H3Cl_3	Ethane, 1,1,2-trichloro-	97.55	Pleasant; Sweet
773	859	1629-60-3	$C_6H_{10}O$	1-Hexen-3-one	97.38	Lush; Flaxseed oil; Metal; Vegetables; Vegetables (cooked)
773	859	868-57-5	$C_6H_{12}O_2$	Methyl 2-methylbutanoate	96.42	Apple; Chewing gum; Greasy; Fruit; Fresh cut grass; Lily; Powder flavor; Solvent; Alcohol flavor
773	859	589-38-8	$C_6H_{12}O$	3-hexanone	96.13	Atmospheric; Fresh; Fruit; Fruity (sweet); Grape; Rum; Sweet; Candle-flavored
773	1084	3726-47-4	C_8H_{16}	Cyclopentane, 1-ethyl-3-methyl-	95.57	Pungent; unflavored synthetic acids
859	978	122-78-1	C_8H_8O	Phenylacetaldehyde	99.11	Cocoa; Flowering, vegetative; Grass; Fresh cut grass; Hawthorn; Honey; Hyacinth; Rose; Sweet
859	978	2548-87-0	$C_8H_{14}O$	2-Octenal, (E)-	97.88	Burdock; Burnt; Greasy; Fruit; Fresh cut grass; Mushroom; Nutty; Sour; Sweet; Butter; Candle flavored
859	978	98-86-2	C_8H_8O	Acetophenone	97.34	Almond; Cheese; Chemical; Floral, Vegetable; Glue; Hawthorn; Jasmine; Musty; Orange; Orange Blossom; Spicy; Sweet
859	978	34590-94-8	$C_7H_{16}O_3$	Dipropylene Glycol Methyl Ether	96.84	Atmosphere
904	882	111-84-2	C_9H_{20}	Nonane	95.76	Alkanes; Heteroalcohols; Gasoline
904	998	543-49-7	$C_7H_{16}O$	heptan-2-ol	95.46	Pungent; Polar berry; Cheese; Cheese (feta); Greasy; Flowering, vegetative; Fresh; Fruit; Freshly cut grass; Herbaceous; Lemon; Lemon (fresh);Melon; Moldy; Mushroom; Greasy; Pungent; Sweet
990	1191	142-62-1	$C_6H_{12}O_2$	Hexanoic acid	98.72	Cheese; Greasy; Goat; Pungent; Rancid; Sour; Sweet
990	1191	108-95-2	C_6H_6O	Phenol	96.9	Pungent; Aromatic; Aromatic flavor; Medicinal; Phenol; Plastic; Rubber; Sweet
990	1191	4630-82-4	$C_8H_{14}O_2$	Methyl cyclohexanecarboxylate	96.38	Berry; Ester; Fruit; Pineapple
1072	1287	110-44-1	$C_6H_8O_2$	2,4-Hexadienoic acid	95.33	Odorless
1108	1207	124-19-6	$C_9H_{18}O$	n-nonanal	98.42	Aldehyde; Chlorine; Orange; Oily; Floral, Vegetable; Fresh; Fruit; Gaseous; Gravy; Fresh-cut Grass; Lavender; Melon; Orange; Orange Peel; Hatchet; Leathery; Pungent; Rose; Soap; Sweet; Butter; Candle-Scented
1108	1207	78-70-6	$C_{10}H_{18}O$	Linalool	98.31	Aniseed; Bergamot; Orange; Floral, Vegetal; Aromatic; Fresh; Fruity; Fresh-cut Grass; Lavender; Lemon; Lily; Musk, Muscat Grape; Oil; Parsley; Rose; Spicy; Sweet; Terpene; Woody
1108	1207	628-99-9	$C_9H_{20}O$	2-nonanol	98.03	Cheese; Tangerine; Creamy; Cucumber; Fruit; Fresh Cut Grass; Orange; Solvent; Candle Flavor
1108	1207	13327-56-5	$C_6H_{12}O_2S$	Ethyl 3-methylthiopropionate	97.88	Fruity; Metallic; Pineapple; Sulfurous; Tomato

Table 7: Continued.

MXT-5	MXT-1701	CAS	Molecular formula	compound	RI	Sensory description
1108	1207	624-51-1	$C_9H_{20}O$	3-Nonanol	97.81	Herbal; Oily
1108	1299	78-40-0	$C_6H_{15}O_4P$	Triethyl phosphate	96.91	Mild; Pleasant
1108	1299	576-26-1	$C_8H_{10}O$	Phenol, 2,6-dimethyl-	96.65	Coffee; Medicinal; Phenol; Root flavored; Sweet
1108	1299	1960/12/8	$C_8H_{10}O$	2-Phenylethanol	96.31	Floral; Vegetable; Flower; Honey; Lilac; Perfume; Rose; Spicy
1108	1299	13679-70-4	C_6H_6OS	2-formyl-5-methylthiophene	95.43	Almond; Cherry; Fruit; Moldy; Sulfurous; Sweet; Woody
1246	1402	113486-29-6	$C_{10}H_{18}O_2$	3-Methylnonane-2,4-dione	98.8	Burnt; Fruit; Straw
1246	1402	5392-40-5	$C_{10}H_{16}O$	Neral	98.08	Orange; Fresh cut grass; Lemon; Leathery; Sharp; Strong; Sweet
1246	1402	106-26-3	$C_{10}H_{16}O$	(Z)- Citral	98.08	Orange; greasy; fruit; lemon; musty; oily; leathery; sharp; strong; sweet
1246	1402	4940/11/8	$C_7H_8O_3$	ethyl maltol	97.9	Candy; Caramel; Marshmallow; Jam; Strawberry; Sweet
1309	1402	1653-30-1	$C_{11}H_{24}O$	2-Undecanol	97.82	Fresh; Fruit; Candle flavored
1309	1402	112-44-7	$C_{11}H_{22}O$	Undecanal	97.76	Aldehyde; Orange; Greasy; Floral, Vegetable; Fresh; Fruit; Fresh-cut Grass; Oily; Spicy; Soap; Sweet; Candle Scented
1309	1402	110-42-9	$C_{11}H_{22}O_2$	Methyl decanoate	96.81	Floral; Vegetable; Fruit; Greasy; Wine
1309	1402	4180-23-8	$C_{10}H_{12}O$	Anethole	96.72	Fennel; Herbal; Licorice; Oil; Spicy; Sweet
1398	1402	41446-63-3	$C_{14}H_{28}$	E-Tetradec-7-ene	95.26	Freshly cut grass
1398	1402	629-59-4	$C_{14}H_{30}$	Tetradecane	95.26	Alkanes; Heteroalcohols; Herbaceous (mild); Sweet

Nevertheless, the mechanism behind the sweetness of vine tea has not been elucidated, and it remains to be explored where the sweetness originates after the bitterness.

Flavonoids, a type of polyphenols, can be categorized into flavones, flavonols, flavanols, isoflavones, flavanones, and anthocyanins. Up to now, 28 flavonoid compounds have been isolated and identified in vine tea, including flavonols, dihydroflavonols, isoflavones, dihydroflavonoids, isoflavanes, flavonoids, and other types [21]. The flavonol glycosides are prone to glycosidized at the C-3 position and therefore often exist in the plant in the form of glycosides. The presence of both flavonoid glycosides and flavonol glycosides may be the main cause of astringency in vine tea. Moreover, the superimposed stimulation of flavonol glycosides in a short period of time further intensifies the perception of astringency in the oral cavity. In red wine and tea, flavonol glycosides are the main source of bitterness and astringency, and it was found that the astringency intensity markedly escalates with each consumption of red wine, reaching its zenith within 6 to 8 seconds postswallowing. Thereafter, it progressively wanes until the next sip, at which point it ascends rapidly once more. This identical pattern is exhibited by both tea and red wine, with the peak intensity for each sip and the nadir of astringency value between sips incrementing alongside the number of sips [67]. Consequently, it may be postulated that consuming vine tea follows a similar trajectory, wherein the astringency values also increase progressively.

Natural flavonoids, which can undergo deglycosylation through the natural hydrolytic activity of glycosidases, generate corresponding glycosidic ligands or partially deglycosylated flavonoids [68]. For instance, β-glucosidase has the ability to cleave nonreducing β-glucosidic bonds while liberating β-glucose and the associated ligands. Nonsweet glycosides hydrolyze to produce the sweet-tasting glucose, but since the hydrolysis reaction takes some time, the sweetness effect is delayed. From this perspective, it is highly likely that flavonoid glycosides and flavonol glycosides present in vine tea may bring a sweet taste to the oral cavity through a similar mechanism.

In addition, terpenes in grapes exist in both free and bound glycoside forms. The free terpenes are volatile compounds that directly contribute to the aroma and flavor of grapes. Nonetheless, glycosides can be hydrolyzed to generate volatile compounds, thereby enhancing the aromatic properties of grapes [69]. Consequently, a similar phenomenon might occur in vine tea terpenes. In addition to the bitter and sweet taste shock, glycosides primarily composed of monoterpene enol and aromatic alcohol ligands are enzymatically cleaved or hydrolyzed under physically stressful conditions, releasing glycosides with floral and fruity fresh aromas. Consequently, flavonols and their glycosides, such as rutin, quercetin, kaempferol, and kaempferol-3-O-glucoside in vine tea, might not directly enhance taste stimulation but rather contribute to a fruity flavor in the tea liquid. Floral, fruity, and green flavors are considered excellent aroma characteristics of tea.

This inference has not been experimentally validated and awaits future confirmation through the design of aroma reconstitution and deletion experiments for vine tea.

5. Conclusion

In this study, we conducted a thorough examination of different brewing methods for vine tea. We conducted an analysis of the total flavonoid content and sensory evaluation at two distinct levels. To assess the impact of brewing conditions on the overall flavonoid yield in tea, we utilized one-factor experiments and orthogonal tests. The experimental results revealed that the optimal brewing conditions for vine tea were achieved when the tea-water ratio was 1 : 50, using pure water at 85°C for 8 minutes. This resulted in a peak total flavonoid content of 32.68%. Among the various factors that influenced the brewing process, the tea-water ratio had the greatest impact, followed by brewing temperature and time.

In our sensory analysis, we utilized a combined approach of conventional human sensory evaluation and advanced assessment techniques to conduct a comprehensive analysis of the flavor and aroma characteristics of vine tea. This evaluation allowed us to gain insights into the quality and uniqueness of the tea when subjected to different brewing processes. Drawing from traditional human sensory evaluation, we determined that an overall sensory score of 80 or higher could be achieved when the tea-water ratio was ≥1 : 50, the temperature was ≥80°C, and the brewing time was ≥7 minutes. Therefore, the optimal brewing process should be based on these parameters.

Using precise instruments such as an electronic tongue and an ultra-fast gas-phase electronic nose, a meticulous analysis was conducted on the impact of different brewing processes on Garcinia Cambogia tea. The findings indicate that the flavor characteristics of rattan tea are significantly influenced by brewing temperature, brewing time, number of infusions, and water quality. To visualize flavor variations, advanced techniques including principal component analysis plots, radar plots, and odor fingerprints were employed. By employing sensory descriptions, we have deciphered the overriding "sweet" attribute of vine tea, as well as various other flavor nuances.

In addition, a comprehensive qualitative analysis of odorants identified 45 potential compounds across seven categories, including terpene hydrocarbons, alkanes, alcohols, aldehydes, esters, ethers, and ketones. Notably, aldehydes and alcohols were particularly prevalent. Moreover, we have comprehensively examined the taste and compositional aspects of vine tea, discerning notable disparities in volatility. This finding further validates the impact of different treatments on volatile components.

In order to obtain as much extract as possible, most studies on tea brewing technology have shown that the brewing and extraction times are relatively long [7]. The literature [44] suggests that for longer brewing times (>10 min), astringency and bitterness increased over time. This study optimized the brewing time to 8 minutes, which not only saved experimental time, ensured high sensory quality, but basically complied with people's daily tea-drinking habits.

However, flavored tea beverages with added sugar, fruits, or milk have become phenomenally popular [70]. The market share of various bottled ready-to-drink tea products has surpassed that of traditional tea beverages; these modern products are attractive to younger individuals [71]. By contrast, the group of people who prefer hot-infused tea is gradually aging. Therefore, in order to further cater to the public's tastes, the transformation of vine tea is essential.

The purpose of this article is to provide a brewing process for the general public to drink vine tea without the hassle and effort, with the high content of vine tea health components and the high quality sensory. This study offers novel approaches to standardizing the brewing process of vine tea, along with valuable perspectives for enhancing the sensory attributes of the tea. It can serve as a benchmark for the industry's future growth in the canning of vine tea, facilitating the creation of diverse vine tea drinks. However, other potentially influential factors, such as the cultivar of vine tea, the geographic origin of the tea leaves, storage time, and variations in processing techniques, were not systematically explored. The research technique of the aforementioned characteristics can be utilized in the subsequent study to investigate additional potential factors, analyze flavor variances, and investigate the best brewing method for rattan tea with varying origins and storage durations to aid in consolidating and growing the rattan tea industry.

Data Availability

The data relevant to the study are available from the first author upon reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Authors' Contributions

H.Z. and Z.L. conceptualized this study. Y.X. was responsible for the methodology. L.W. was responsible for the software. M.X. and Y.L. validated the study. H.Y. performed formal analysis. S. L., Q. Z., and J. L. investigated the study. Y.X. and Z.L. collected the resources. L.W. and J.W. curated the data. L.W. was responsible for writing the original draft. L.W. and H. Z. wrote, reviewed, and edited the study. L.W. performed visualization. H.Z. and Y. X. supervised the study. Y.X. administered the project. Y.X. funded the acquisition. All authors have read and agreed to the published version of the manuscript.

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Supplementary Materials

Supplementary Table S1: Green tea samples sensory quality. (*Supplementary Materials*)

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