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Study on the flavour characteristics of rattan tea liqueur based on sensory evaluation and electronic nose analysis

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Abstract: As a traditional Chinese alcoholic beverage with profound historical and cultural significance, the herbal liqueur is renowned for its nutritional diversity, varied styles, and health-promoting properties, demonstrating a broad market potential. This study innovatively explores the application of *Ampelopsis grossedentata* (rattan tea) in herbal liqueur production to enhance its utilisation value and develop novel products. Using rattan tea and strong-flavour Baijiu as raw materials, the effects of solid-to-liquid ratio (1 : 4–1 : 12 g·mL^{-1}), ethanol concentration (36–48% vol), extraction time (25–45 min), and temperature (45–65 °C) on flavonoid content and sensory quality were systematically investigated through single-factor and orthogonal experiments. Optimal extraction conditions were determined as follows: solid-to-liquid ratio of 1 : 8 g·mL^{-1}, ethanol concentration of 42% vol, extraction duration of 33 min, and temperature of 55 °C. Under these conditions, the resulting liqueur exhibited an ethanol content of 40.4% vol, total acid of 1.6 g·L^{-1}, total sugar of 12.6 g·L^{-1}, dry extract of 0.65 g·L^{-1}, and dihydromyricetin (DMY) content of 8 g·(100 g)$^{-1}$. The product achieved a sensory score of 90/100, characterised by a clarified pale-green appearance, rich aroma, and retention of the rattan tea distinctive flavour profile. These findings provide a theoretical foundation for optimising the production of functional herbal liqueurs and advancing the rattan tea-based product innovation.

Keywords: dihydromyricetin; herbal liqueur; flavonoid; extraction conditions

Rattan tea (*Ampelopsis grossedentata*), also known as 'rattan tea' or 'Gan Cha', is a medicinal and food plant, with a range of beneficial effects on human health. It belongs to the genus *Ampelopsis grossedentata* belongs to the genus *Ampelopsis* in the family *Vitaceae,* and its wild resources are mainly distributed in the southern part of China, such as the twin lakes, the two Guangxi, Jiangxi and other mountainous areas and areas with greater distribution of ethnic minorities (Diao et al. 2023). Rattan tea is sweet, light and cool in nature. It can clear heat and support detoxification, dispel wind-dampness (Senejou et al. 2012; Li et al. 2023), protect the liver, lower blood sugar, it has antioxidant, anti-inflammatory, anti-tumour (Zhang et al. 2021; Guo et al.

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2022) and other aspects of efficacy. Recent studies have also found that rattan tea is able to reduce the production of uric acid by inhibiting the activity of xanthine oxidase (XOD), which promotes the excretion of uric acid, and achieves the function of reducing the swelling and relieving the pain (Fan et al. 2024). Yi and Hu (2009) also reported that the extracts of rattan tea and its monomer constituent dihydromyricetin were found to show significant efficacy in non-infectious liver diseases. In addition, it was also found that rattan tea has a better free radical scavenging effect, stronger antioxidant capacity and that it significantly improves the survival of mice after the lethal dose of radiation. It reduces radiation-induced intestinal damage and plays a protective role against radiation (Li et al. 2025; Sun et al. 2025).

Herbal liqueurs, as a distinctive beverage category blending botanical essences with traditional spirits, are rapidly evolving from their traditional health-focused positioning toward modern, flavour-driven and wellness-oriented drinks (Niu et al. 2022). Current mainstream products primarily focus on three key directions: classic herbal blends, tea-infused spirits, and specialised tonic ingredients (Liu et al. 2024). This reflects both the category vitality and underlying concerns about homogenised competition. Against this backdrop, vine tea-based liqueurs, crafted with vine tea as the core ingredient, demonstrate distinct differentiation advantages: firstly, vine tea is rich in unique flavonoids like dihydromyricetin, endowing it with natural health attributes unmatched by other herbal liqueurs and establishing a clear functional positioning. On the other hand, through the process control, it achieves a harmonious integration of vine tea flavour, tea aroma, and liquor body, resulting in an elegant bouquet, mellow palate, and pleasant aftertaste. This effectively avoids the common issues of flavour separation or coarse texture found in typical plant-based liqueurs. Consequently, rattan tea liqueur not only adds a new stylistic option to the liqueur category but also it provides a viable pathway for the high-value utilisation of vine tea resources and product innovation.

At present, the main sales method for rattan tea is direct sales of primary agricultural products from their regions of origin. There are very few deep-processed products, and rattan tea liqueur is a brand-new processing attempt. With the improvement of living standards and health care awareness, people are more concerned about the health effects of rattan tea, and it has become an inevitable trend to increase the consumption of rattan tea in daily diet. Functional food and health care functional drinks represented by rattan tea are becoming the third largest beverage market after tea and coffee (Xu 1999). Investigations found that today's market rattan tea deep processing products are fewer, only made of rattan tea powder, rattan tea drinks, rattan tea hanging noodles and other products. In China, the industrial development of rattan tea products remains limited, with a relatively small production scale and a narrow range of refined products, although rattan tea has considerable potential for further development and value-added utilisation.

The main research content of this thesis is to explore the production conditions of rattan tea liqueur, to develop rattan tea liqueur, to improve the utilisation rate of rattan tea and to address the problem of a single product of rattan tea deep processing. The main objective of this thesis is to investigate the optimal conditions for the development of rattan tea liqueur by determining the flavonoid content and dihydromyricetin content during the development of rattan tea liqueur, based on sensory evaluation and correlation statistical analysis with colorimetric parameters.

MATERIAL AND METHODS

Material and instruments

Rattan tea: Enshi Rattan Tea (China); strong-aroma baijiu: Luzhou Pure Grain Old Winery (China); clear-flavoured white wine: Xinghuacun Jiu Ruquan Liquor (China); rice-flavoured white wine: Chu Nongfu Food Specialty Store (China)

Reagents: catechol, sodium hydroxide (all analytically pure): Chengdu Kelong Chemical Reagent Factory (China); guaiacol AR: Chongqing Chuandong Chemical Reagent Factory (China); sodium nitrite AR: Tianjin Fuchen Chemical Reagent Factory (China)

Instruments: PHSJ-3F pH metre: Shanghai Precision Scientific Instrument Co., Ltd (China); JYZ-5 wall breaker: Jiuyang Co. Ltd (China); DZKW electric thermostatic water bath: Beijing Yongmingming Medical Instrument Factory (China); A140 electronic balance: METTLER TOLEDO Instruments Co., Ltd. (China); I-nose: Shanghai Ruifen International Trading Co. (China)

Experimental methods

Basic flow of the test. The basic processing flow of rattan tea liqueur is shown in Figure 1.

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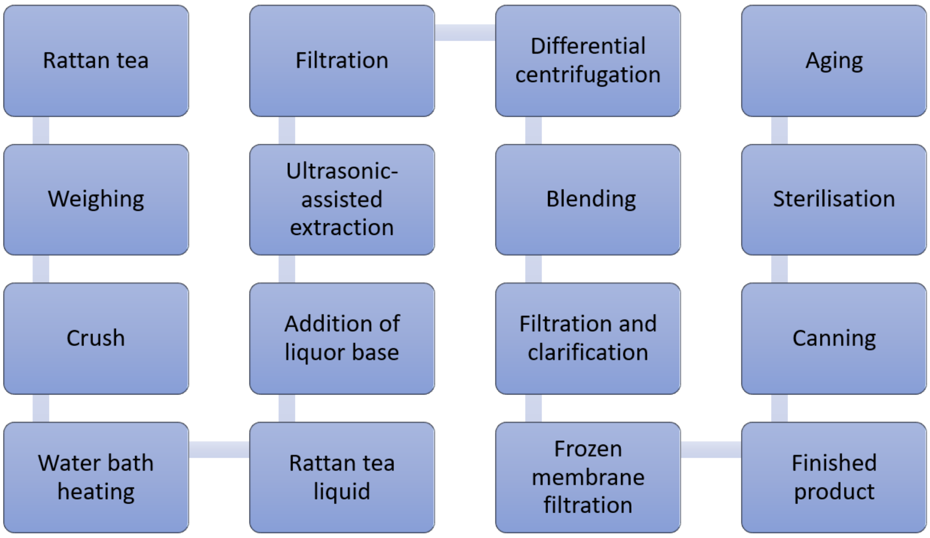

Figure 1. Basic processing flow of rattan tea liqueur

Operation points. Choose fresh rattan tea, rinse it with water to remove surface soil and dirt, then soak it in water to make it fully absorb water, and then drain it; the drained rattan tea is crushed with a wall-breaking machine until it is uniformly finely chopped. The base wine downgrading treatment adjusts the degree of wine according to the formula:

The amount of base wine required for the target degree of wine = (*the original target degree of wine* – 1 × *the quality of the original wine*) (1)

At the end of maceration, the material is sealed and stored in a refrigerator at 5 °C, protected from light. Parameters to be set for ultrasonic-assisted extraction: solid-to-liquid ratio (1 : 2, 1 : 5, 1 : 8, 1 : 11, 1 : 14, g·mL^{-1}), extraction degree (20, 28, 36, 42 and 50% vol), extraction temperature (40, 45, 50, 55 and 60 °C), extraction time (15, 25, 35, 45 and 55 min).

Extraction of rattan tea liquid. *i)* Rattan tea extract was prepared as follows: take 20 g of rattan tea raw material, grind it using a pulveriser, pass it through a 40-mesh sieve, and collect the powder for later use.

ii) Ultrasonic-assisted extraction: mix the rattan tea powder with a 60% (by volume) ethanol solution at a solid-to-liquid ratio of 1 : 10 (g·mL^{-1}). Add 0.3% (*w/w*) citric acid as an extraction aid to the mixture. Place the mixture in an ultrasonic extractor and extract at 50 °C and 100 W power for 30 min.

iii) Concentration: filter the mixture after extraction and collect the filtrate. Concentrate the filtrate to a final volume of 50 mL using a rotary evaporator (or equivalent equipment) to obtain the concentrate.

iv) Alcohol precipitation purification: mix the concentrate with 95% vol ethanol at a 1 : 1 (*v/v*) ratio and stir thoroughly. Allow to stand at 4 °C (or room temperature) for 24 h to precipitate impurities such as polysaccharides and proteins.

v) Centrifugation and storage: after ethanol precipitation, transfer the supernatant to a centrifuge tube. Pre-filter through a 40-mesh screen, then centrifuge at 3 600 rpm (approximately 600 × g) for 3 min. Collect the final supernatant as the rattan tea extract and store at 4 °C for future use.

Selection of base wine. *i)* Preliminary selection of base liquor types. Three representative baijiu varieties were selected for comparison: (*i*) Small-Qu clear-aroma type: fermented using a multi-grain substrate and small-qu saccharification process (Li & Shang 2022), it features a refined pure aroma and a mellow sweet palate. It is expected to harmoniously complement the inherent flavour of rattan tea. (*ii*) Rice-aroma type: a traditional low-alcohol spirit with a rich mellow mouthfeel and high nutritional content. Its elegant ethyl lactate aroma may enhance the wine smoothness (Chen et al. 2023). (*iii*) Strong-aroma type: characterised by ethyl acetate as its primary aroma compound (Yao et al. 2015), featuring an intense cellar fragrance and a velvety texture. This profile may create complex layers when paired with rattan tea flavours.

ii) Experimental parameter settings. Referring to the research by Lai et al. (2024), the rattan tea extract exhibits excellent solubility at 42.0% vol alcohol content (solubility rate ≥ 99.8%). Therefore, a 42% vol alcohol base was uniformly used throughout the experiment. Fixed extraction conditions were set as follows: solid-

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to-liquid ratio 1 : 20 (g·mL^{-1}), temperature 45 °C, extraction time 45 min.

iii) Screening and evaluation methods. The extracted alcohol samples underwent sensory evaluation (including colour, aroma, taste, and harmony) and key physicochemical parameter analysis. Through comprehensive assessment, the base spirit type with the highest sensory score was ultimately selected as the dedicated alcohol base for rattan tea liqueur.

Effect of extraction alcohol level on the extraction degree of rattan tea. A one-way experiment was set up to determine the feed-to-liquid ratio of 1 : 5, extraction temperature of 45 °C, extraction time of 35 min, and different extraction alcoholic strengths (20, 28, 36, 42 and 50% vol); ultrasonic extraction was carried out, and the extracts were placed in a refrigerator at 5 °C for 24 h to determine the content of flavonoids in the extracts, which was repeated for three times in each group of experiments. Finally, sensory evaluation was conducted to find out the highest-scoring single-factor conditions. The optimisation of process parameters was based on the sensory evaluation and the flavonoid extraction rate was expressed as the physicochemical index.

Effect of extraction time on the extraction degree of rattan tea. A one-factor experiment was set up to determine the feed-to-liquid ratio of 1 : 5 g·mL^{-1}, extraction temperature of 45 °C, extraction alcoholic strength of 42% vol, and different extraction times were set (15, 25, 35, 45 and 55 min); ultrasonic extraction was carried out, and the sample was placed in the refrigerator at 5 °C for 24 h to determine the content of flavonoids therein, while each group of experiments was repeated three times. Finally, sensory evaluation was conducted to find out the highest-scoring one-factor conditions. Finally, the process parameters were optimized based on the sensory evaluation and the flavonoid extraction rate was expressed as the physicochemical index.

Effect of extraction temperature on the extraction degree of rattan tea. A one-way experiment was set up to determine the feed-to-liquid ratio of 1 : 5, extraction time of 35 min, extraction alcoholic strength of 42% vol, different extraction temperatures (40, 45, 50, 55 and 60 °C); the sample was subjected to ultrasonic maceration and immersion under refrigeration at 5 °C for 24 h to determine the content of flavonoids while three parallel experiments were done. Finally, sensory evaluation was conducted to find out the highest-scoring one-factor conditions. Finally, the process parameters were optimized based on the sensory evaluation and the flavonoid extraction rate was expressed as the physicochemical index.

Effect of feed-to-liquid ratio on the extraction degree of rattan tea. A one-way experiment was set up to test the time of 35 min, extraction temperature of 45 °C, extraction alcoholic strength of 42% vol, different feed-to-liquid ratios (1 : 2, 1 : 5, 1 : 8, 1 : 11 and 1 : 14); the sample was subjected to ultrasonic extraction and soaking under refrigeration at 5 °C for 24 h to determine the content of flavonoids, while three parallel experiments were done. Finally, sensory evaluation was conducted to find out the highest-scoring one-factor conditions. Finally, the process parameters were optimised based on the sensory evaluation and the flavonoid extraction rate was expressed as the physicochemical index.

Orthogonal test to optimise the steeping conditions of rattan tea liqueur. A one-way test was conducted to verify that the flavour of rattan tea liqueur was mainly influenced by the extraction temperature (Factor 1: A), feed-to-liquor ratio (Factor 2: B), base liquor degree (Factor 3: C), and extraction time (Factor 4: D). The optimal single-factor conditions were identified through sensory evaluation: extraction temperature of 55 °C, extracted alcoholic strength of 42% vol, feed-to-liquid ratio of 1 : 8 g·mL^{-1}, and extraction time of 35 min.

A four-factor three-level orthogonal test was designed, and each group of experiments was repeated three times. The results of the test were based on the sensory evaluation, complemented by the physicochemical factors of flavonoid content.

Measurement of indicators for finished wines. The indexes of the finished wine were determined according to the GB/7588-2011 standard for liqueurs, measuring whether the contents of alcohol, total acid, total sugars, methanol and dry leachate were within the range of the national standard, as well as the flavonoid content and dihydromyricetin content were determined, along with the colouration of rattan tea liqueur.

Methods for determining physical and chemical indicators

Detection of total sugars. Determination of total sugars was carried out by direct titration and finally the total sugar content was calculated based on the amount of the sample liquid consumed (Fan et al. 2016).

Determination of total flavonoids. The aluminium nitrate colorimetric method was used with reference to the method of He et al. (2023), with some modifications. The standard curve was plotted with the concentration of rutin as the horizontal coordinate and the absorbance value as the vertical co-

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Table 1. Table of orthogonal factor levels

Level	A: Extraction temperature (°C)	B: Solid-liquid ratio ($g \cdot mL^{-1}$)	C: Base alcohol strength (% vol)	D: Extraction time (min)
1	53	1 : 6	40	33
2	55	1 : 8	42	35
3	57	1 : 10	44	37

ordinate, and the regression equation fitted to the standard curve was obtained as $y = 7.429\,6x–0.012\,7$ with the correlation coefficient of 0.998, which indicated that the results of this test had good regression and could be used as a standard curve. The table shows the values measured from the samples into the standard curve regression equation to obtain the flavonoid content in the fermentation broth.

Determination of total acid. Potentiometric titration was used, with reference to the method for the determination of total acid in wines in 'Winemaking Analysis and Testing' (Wang 2005).

Determination of dihydromyricetin (DMY).

Extraction method of DMY. The method of Jiang et al. (2020) was referred to and it was modified appropriately. An amount of 1.0 g of dried rattan tea leaves was accurately weighed, added hot water at 70 °C according to the feed-to-liquid ratio (1 : 100), and extracted by magnetic stirring for 40 min. After extraction, the filtrate was extracted and filtered according to the above method, and then the filtrate was combined and concentrated by rotary evaporation to about half its volume, and then filtered through a 0.22 μm filter head, and then it was stored (–20 °C) for measurement.

Preparation of test solution. An appropriate amount of rattan tea extract (equivalent to 5 to 20 mg of dihydromyricetin) was accurately weighed and subsequently placed in a 50 mL volumetric flask. A 30% ethanol solution was used, which was fully dissolved by sonication and accurately adjusted to the graduated line on the volumetric flask. Next, the solution was filtered using a 0.22-micron organic filter membrane to obtain the test solution to be tested.

Preparation of control stock solution. An aliquot of 16.54 mg of dihydromyricetin control was accurately weighed and placed in a 25 mL volumetric flask. Subsequently, the control stock solution was obtained by sonication using methanol to ensure that the control was completely dissolved and it was accurately adjusted to the graduated line on the volumetric flask. The concentration of dihydromyricetin in this stock solution was calculated to be 661.6 $mg \cdot L^{-1}$.

Determination of chromatographic conditions. Chromatographic column: Hypersil 8 column (4.6 mm × 250 μm); mobile phase: methanol-0.1% phosphoric acid (V:V) = 25 : 75; flow rate: 1.0 $mL \cdot min^{-1}$; detection wavelength: 290 nm; column temperature: 30 °C; injection volume: 10 μL. The control solution was taken, and the determination was carried out according to these chromatographic conditions.

Calculation of DMY by external standard method. The formula for calculating DMY content (W) in the sample by the external standard method is as follows:

$$w = A_1 \times C \times 25 \times \frac{100}{A_s \times 1000 \times m} \tag{2}$$

where: A_1 – the peak area of DMY in the sample solution; A_S – the peak area of DMY in the control solution; C – the mass concentration in the control solution ($mg \cdot mL^{-1}$); m – the mass of the sample (g).

Determination of dry extracts. In accordance with the GB/T 15038-2006 standard 'Wine, fruit wine general analytical methods' on the standard dry leachate measurement: the density bottle method was used to determine the density of the sample or of the sample after alcohol evaporation; its density value was used to obtain the total extract content from Appendix C of GB/T 15038-2006 (density-total extract content conversion table). Then the total sugar content was subtracted from it to obtain the dry leachate content.

Determination of alcohol content. The distillation method (Rebelein 1973) was applied to determine the alcohol content of rattan tea liqueur by measuring 100 mL of Garcinia tea liqueur samples and adding them to a 500 mL glass round-bottom flask, adding 100 mL of distilled water and four glass beads, heating to boiling, and collecting 100 mL of the distilled liquid to determine the alcohol content and temperature, which was then calculated according to the manual.

Colourimetric determination. The L^*, a^*, and b^* values of the samples were determined according to the CIELAB method OIV-MA-AS2-11 (OIV); the L^*, a^*, and b^* values of the samples were determined by a colourimeter, where L^* denotes the brightness value, a^* denotes the green-red value, and b^* denotes the blue-yellow value; and the colour change of the samples was

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Table 2. Rattan tea liqueur sensory tasting evaluation criteria

Assessed item	Standard	Score (points)
Colour (20 points)	turbid, with suspended matter, no lustre	0–5
	clarified, opaque, no inclusions, dull lustre	6–10
	clarified, transparent, dull lustre	11–15
	clarified, transparent, pleasantly harmonised, shiny	16–20
Aroma (30 points)	bad odour, making people disgusted	0–7
	tea and wine aroma is light, no bad odour	8–15
	stronger and more harmonious aroma of tea and wine	16–22
	strong and pure aroma of tea and wine, with harmonised aroma	23–30
Taste (30 points)	sour, bitter, bland, off-flavours	0–7
	moderate acidity, fuller body, natural sweetness, single aftertaste	8–15
	crisp, pleasant, smooth, good aftertaste	16–22
	full-bodied, mellow and harmonised, soft and light, with a long aftertaste	23–30
Style (20 points)	largely atypical	0–5
	slightly characteristic flavour of rattan tea, typicality is not obvious	6–10
	a distinctive flavour, typical of rattan tea liqueurs, with a good harmony of styles	11–15
	a unique flavour of rattan tea liqueur with perfect typicality and elegance	16–20
Total		100

described by the colour difference value (dE), which was calculated by the following formula:

$$dE = \left[\left(\Delta L^*\right)^2 + \left(\Delta a^*\right)^2 + \left(\Delta b^*\right)^2\right]^{1/2} \tag{3}$$

Measurement by an electronic nose. Odour analysis of the base wine was carried out using an iNose electronic nose (Shanghai Ruifen International Trading Co., Shanghai, China) with reference to Wei et al. (2014) and according to the instrument manual. Sensor-response data for each sample were recorded and saved. After all measurements were completed, the data were analysed collectively, and principal component analysis (PCA) was performed to evaluate differences among the base-wine samples.

Basis of evaluation criteria for rattan tea liqueur

The sensory scoring was formulated with reference to the GB/3405-2016 standard for the sensory scoring of rattan tea liqueur, focusing on the five main quality indicators of aroma, taste, flavour, organisation, and colour. The scoring team consisted of 10 persons who had received training in liqueur tasting and carried

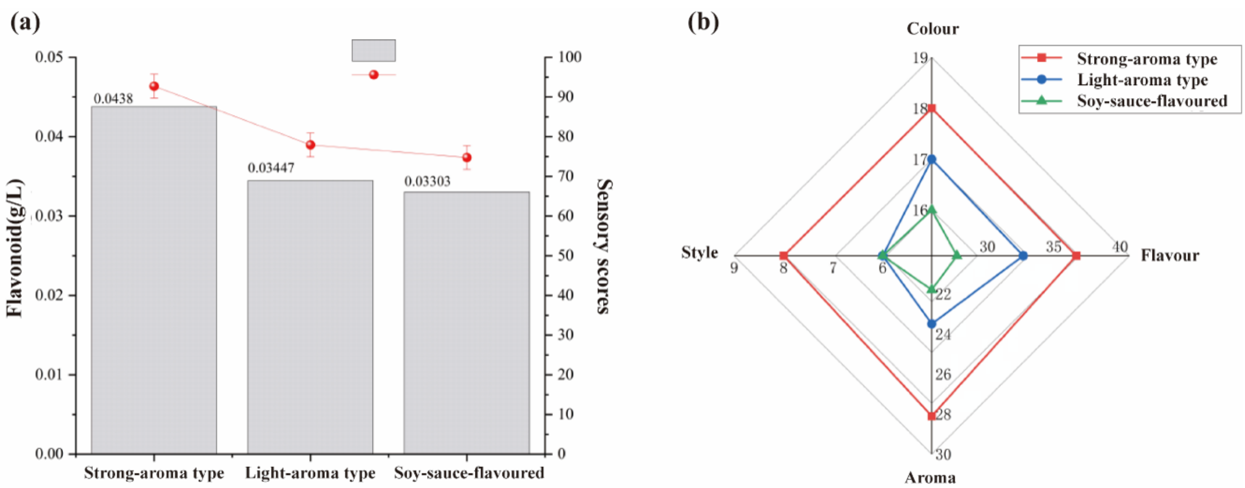

Figure 2. (A) Influence of base wines on rattan tea liqueurs; (B) sensory radar map

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out the evaluation of rattan tea liqueur in the translucent, ventilated and odourless tasting room; the scoring standard was referred to the sensory rating table of mulberry liqueur by Pan et al. (2013) with a slight modification, as shown in Table 2.

RESULTS AND DISCUSSION

Determination of the base wine. As can be seen from Figure 2A, different types of base wines were determined with different flavonoid contents. The highest flavonoid content of 0.043 8 g·L^{-1} was found when the base wine was strongly flavoured, while the lowest flavonoid content of 0.033 0 g·L^{-1} was found when the base wine was rice-flavoured.

Three different types of base wines were used for the test, and the results are shown in Figure 2B. The sensory scores of the three types of base wines were ranked in the following order: strong aroma > clear aroma > rice aroma. The body of Xiaoqu clear-flavoured white wine was delicate and coordinated, but the aroma was not rich enough, the aftertaste was obviously insufficient, and the overall body of the wine appeared thin. Rice wine has a light and elegant composite aroma with ethyl acetate and β-phenylethanol as the main body; it is mellow and sweet, and pleasant in the mouth, with a smooth body but a relatively single taste and lack of complexity. The strong-aroma Baijius have a strong, long-lasting aroma, a mellow, sweet and refreshing taste, and are very layered. Their sensory score of 90 points was also the highest among the three base wines. In conclusion, through sensory analysis and physical and chemical factors, combined with consumer preferences and geographical considerations (Yao and Tan 2018), the selection of 42% vol full-flavoured wine as the base wine was finally confirmed.

Influence of the feed-to-liquid ratio on the flavonoid content and sensory quality of rattan tea liqueur. The feed-to-liquid ratio has a significant effect on the flavour of rattan tea liqueur. This is mainly due to the fact that the amount of the rattan tea liquid added plays a decisive role in the flavour of rattan tea liqueur. As shown in Figure 3A, the flavonoid content in the extracted liquid generally showed an increasing trend with the increasing solvent amount in certain raw materials, similarly to the results of Zhang et al. (2015). The highest flavonoid content of 0.374 6 g·L^{-1} was found in the extract when the feed-to-liquid ratio was 1 : 2. The lowest flavonoid content of 0.075 0 g·L^{-1} was found in the extract when the feed-to-liquid ratio was 1 : 14.

As shown in Figure 3B, when the solid-to-liquid ratio of rattan tea and base wine is lower than 1 : 8, the style of rattan tea liqueur is basically atypical and the aroma is not obvious. When the solid-to-liquid ratio of rattan tea and base wine is higher than 1 : 8, the style and aroma of rattan tea liqueur is better, but the taste is not coordinated and the body is not plump. When the feed-to-liquid ratio is 1 : 8, the style, flavour and aroma are the most coordinated and typical.

Effect of maceration temperature on the flavonoid content and sensory quality of rattan tea liqueur. The maceration temperature also has a greater impact on the flavour of rattan tea. The appropriate maceration temperature is conducive to the dissolution of various substances in rattan tea, plus the fusion of rattan tea and liquor. As shown in Figure 4A, the flavonoid content increased gradually with the increase of the extraction temperature, but it showed a decreasing trend

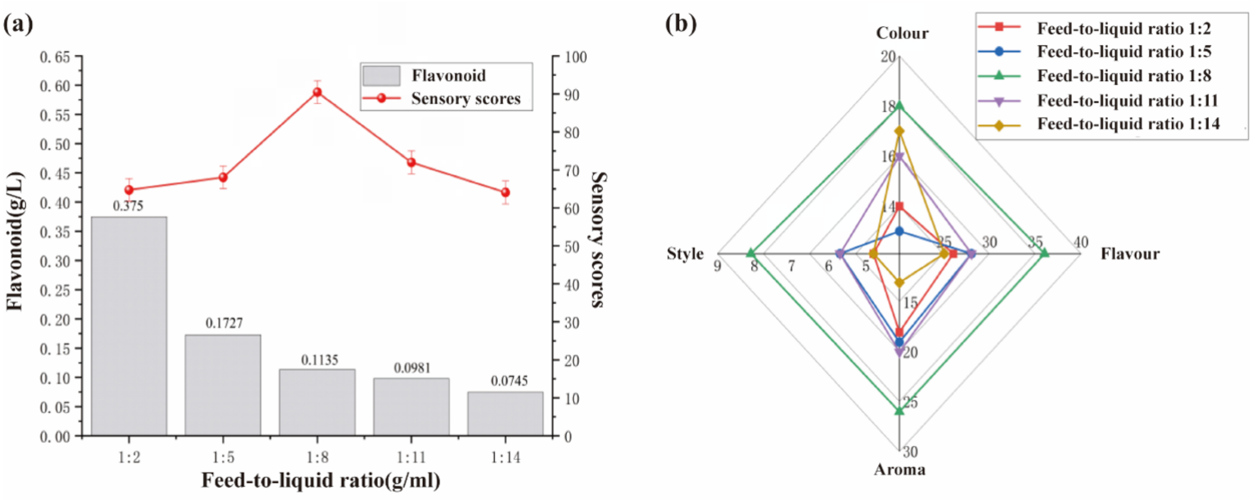

Figure 3. (A) Influence of feed-to-liquid ratio on rattan tea liqueur; (B) sensory radar map

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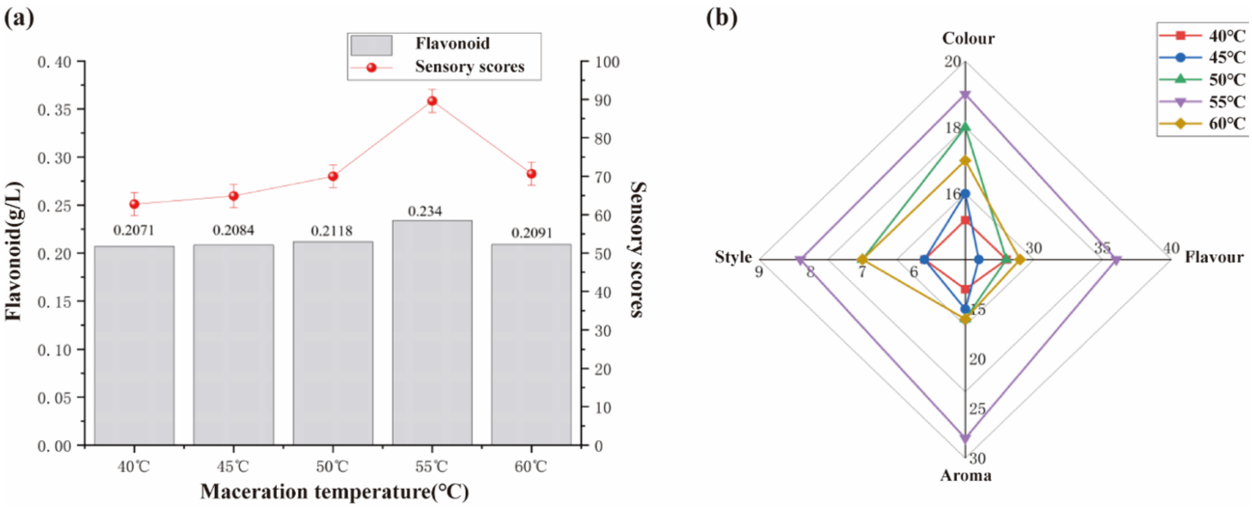

Figure 4. (A) Influence of maceration temperature on liqueur of rattan tea; (B) sensory radar map

after exceeding 55 °C. In particular, when the extraction temperature was set at 55 °C, the flavonoid content increased gradually. The flavonoid content reached 0.234 $g \cdot L^{-1}$, which was 7.32% higher than the initial value. This trend suggests that the increase in temperature favours the dissolution of flavonoids in rattan tea, thus accelerating the fusion of rattan tea and liquor. This finding is consistent with the findings of Zhang et al. (2015).

In terms of sensory scores, the sensory quality of rattan tea liqueur gradually improved with the increase of the extraction temperature. When the maceration temperature was 40 °C, the wine was clear and transparent with a light green colour, but the aroma was insufficient, and the sensory score was low, only 65 points. As the temperature increased, when it reached 55 °C, the wine remained clear and transparent with a light green colour, but the aroma was strong and the taste was harmonious; the sensory score reached a maximum of 90 points. However, when the maceration temperature was further increased to 60 °C, the wine clarity decreased, the astringency increased, and the sensory score dropped. This may be due to the fact that the excessively high temperature not only accelerated the dissolution of flavonoids, but also it promoted the leaching of tannins, acids and pectins, resulting in the deepening of the colour of wine, turbidity of wine, and sourness and astringency of the taste (Weng et al. 2025). In summary, to obtain the best sensory quality, we selected 55 °C as the leaching temperature for the subsequent orthogonal test.

Effect of alcohol content of the base wine on flavonoid content and sensory quality of rattan tea liqueur. The appropriate alcohol content of the base wine has a great influence on the flavour of rattan tea liqueur. If the alcohol content of the base wine is too

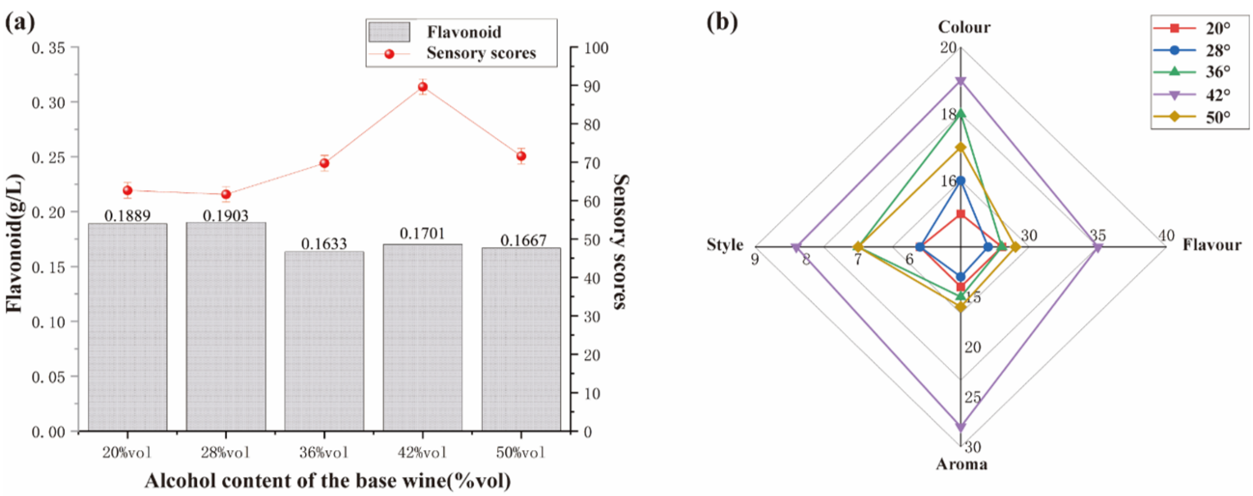

Figure 5. (A) Influence of alcohol content of the base wine on rattan tea liqueurs; (B) sensory radar map

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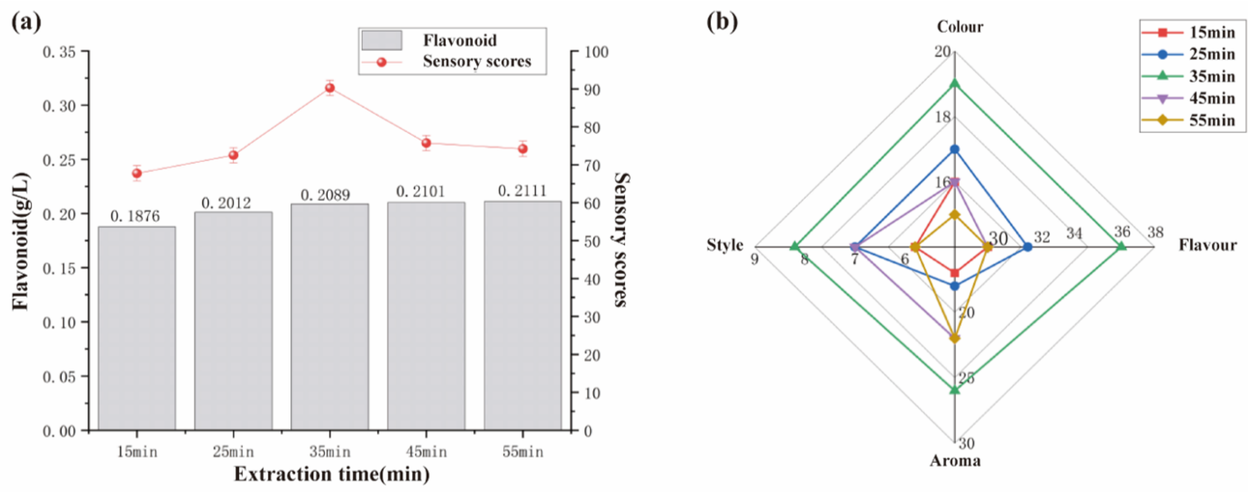

Figure 6. (A) Influence of steeping time on rattan tea liqueurs; (B) sensory radar map

low, it will not be favourable for the leaching of nutrients in rattan tea. However, if the alcohol content of the base wine is too high, it will lead to the loss of the original small amount of water in rattan tea, causing the surface of the rattan tea to become hard, which is even more unfavourable for the leaching of the active ingredients of rattan tea. As can be seen from Figure 5A, when the alcohol content of the base wine was in the range of 20% to 50%, the flavonoid content in the extract gradually showed an upward trend with the increase of the alcoholic strength, and reached the highest at 28% vol, with a significant drop from 28% vol to 36% vol, and then a gradual increase at 42% vol. The highest flavonoid content of 0.190 3 $g \cdot L^{-1}$ was found at 28% vol. The lowest flavonoid content of 0.163 3 $g \cdot L^{-1}$ was found at 36% vol.

As shown in Figure 5B, when the alcohol content of the base wine was 42% and more, the aroma of rattan tea liqueur was obviously insufficient and the colour was not too good. When the alcohol content of the base wine is lower than 42%, the style, aroma and colour of rattan tea liqueur are better, but the taste is not coordinated and the body is not full. When the alcohol content of the base wine is 42%, the flavour of rattan tea liqueur improves significantly. The style and aroma were the most harmonized and typical. In summary, the volume fraction of the base wine of rattan tea liqueur was chosen to be 42% vol for the next orthogonal optimisation experiment.

Determination of leaching time. The steeping time is related to the leaching of rattan tea nutrients, so it is said that the extraction time is also one of the factors influencing the flavour of rattan tea liqueur. As shown in Figure 6A, the range of extraction time was from 15 min to 55 min; the content of flavonoids gradually increased under the extraction conditions from 15 min to 35 min, the flavonoid content increased from 15 to 35 min and remained relatively stable between 35 and 45 min. The content of flavonoids was the highest at 55 min, which was 0.211 1 $g \cdot L^{-1}$ and the lowest at the extraction time of 15 min, which was 0.187 6 $g \cdot L^{-1}$. As seen from Figures 4–6B, the extraction time is also an influential factor on the flavour of *Garcinia cambogia* liqueur. As shown in Figure 6B, when the extraction time was less than 35 min, the aroma of rattan tea liqueur was obviously insufficient. When the maceration time was longer than 35 min, the style, aroma and colour of rattan tea liqueur were better, but the taste was not coordinated and the body was not full. At 35 min of steeping time, the flavour of rattan tea liqueur was significantly improved. The style and aroma were the most harmonised and typical. From the above analysis, the preliminary selection of rattan tea liquor extraction time of 35 min was used to carry out the next orthogonal optimisation experiment.

Orthogonal experiment results and analysis. Based on the comprehensive analysis of the one-way experiments, we observed that the base wine concentration, steeping time, maceration temperature, and solid-to-liquid ratio all had a significant effect on the flavour of rattan tea liqueur. To further optimise the steeping process of rattan tea liqueur, we designed an orthogonal experiment based on these four key factors. In this experiment, we used the sensory score as the core evaluation index to find the optimal steeping process parameters. Through the detailed data analysis, we derived the corresponding optimisation results, as shown in Table 3.

Experimental results indicate that factor B (solid-to-liquid ratio), factor A (extraction temperature), and

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Table 3. Rattan tea liqueur orthogonal test ($L4^3$) design and results

Test number	A: Extraction temperature (°C)	B: Solid-liquid ratio ($g \cdot mL^{-1}$)	C: Base liquor concentration (%)	D: Extraction time (min)	Sensory score
1	53	1 : 6	40	33	81
2	53	1 : 8	44	35	86
3	53	1 : 10	42	37	82
4	55	1 : 6	44	37	83
5	55	1 : 8	42	33	90
6	55	1 : 10	40	35	83
7	57	1 : 6	42	35	82
8	57	1 : 8	40	37	85
9	57	1 : 10	44	33	80
K1	249	246	249	251	
K2	256	261	254	251	
K3	247	245	249	250	
k1	83	82	83	83.666 7	
k2	85.333 3	87	84.666 7	83	
k3	82.333 3	81.666 7	83	83.333 37	
Range	3	5.333 37	1.666 7	0.333 3	

factor C (base liquor volume fraction) significantly influence the sensory quality of rattan tea liqueur ($P < 0.05$), while factor D (extraction time) shows no significant effect ($P = 0.862$). The strength of the influence for each factor was ranked as B > A > C > D. Factors B and A achieved F-values of 36.15 and 10.05, respectively, both indicating extremely significant levels. Orthogonal optimisation indicated the optimal extraction process as A2B2C2D1: material-to-liquid ratio 1 : 8, extraction temperature 55 °C, base liquor concentration 42% vol, extraction time 33 min. This combination achieved the highest sensory score (90 points) in experiments and can be directly applied to the standardised production of rattan tea liqueur.

Sensory evaluation. Sensory analyses were conducted to compare the differences in the aroma, flavour, style, and colour of rattan tea liqueur under different steeping conditions. The panellists' scores were summarised and plotted on a radar chart using Origin 2021 (OriginLab Corporation, Northampton, USA). The radar charts are shown in Figures 7A–B. The radar plots show the average scores of the compared items. The combined analysis shows that groups 2, 5, and 8 scored relatively close to each other, with significantly better aroma and style distributions than the other six groups. For further comparison, sample 5, in addition to higher style and aroma scores, was significantly higher than the other groups in terms of flavour richness and balance, with richer, more coordinated flavours and better crown acceptance compared to the other groups. This result is basically consistent with the results of the latter instrumental test, which further identified the optimal infusion of rattan tea liqueur.

As shown in Figure 7C, the highest sensory scores were obtained for group 5, followed by groups 2 and 8. The analysis shows that the feed-to-liquid ratio has the greatest influence on the flavour of rattan tea liqueur. This is mainly due to the fact that the amount of the rattan tea liquid added plays a decisive role in the flavour of rattan tea liqueur. When the amount of liquid rattan tea was insufficient, relatively few rattan tea components could be extracted, resulting in poor flavour; on the contrary, if too much rattan tea liquid was added, due to the limitation of the base wine volume, the effective extraction of rattan tea would be affected, so that the full potential of rattan tea flavour could not be fully developed. Therefore, after experimental validation and sensory evaluation, we finally determined the optimal solid-to-liquid ratio of 1 : 8 for rattan tea liqueur to ensure that the flavour of rattan tea could be optimised.

The maceration temperature also had a great influence on the flavour of rattan tea. The appropriate maceration temperature is conducive to the dissolution of various substances in the fruit, plus the integration of rattan tea and wine, which is similar to the results of the study by Zhang et al. (2015).

The volume fraction of base liquor also has a large influence on the flavour of rattan tea. The production

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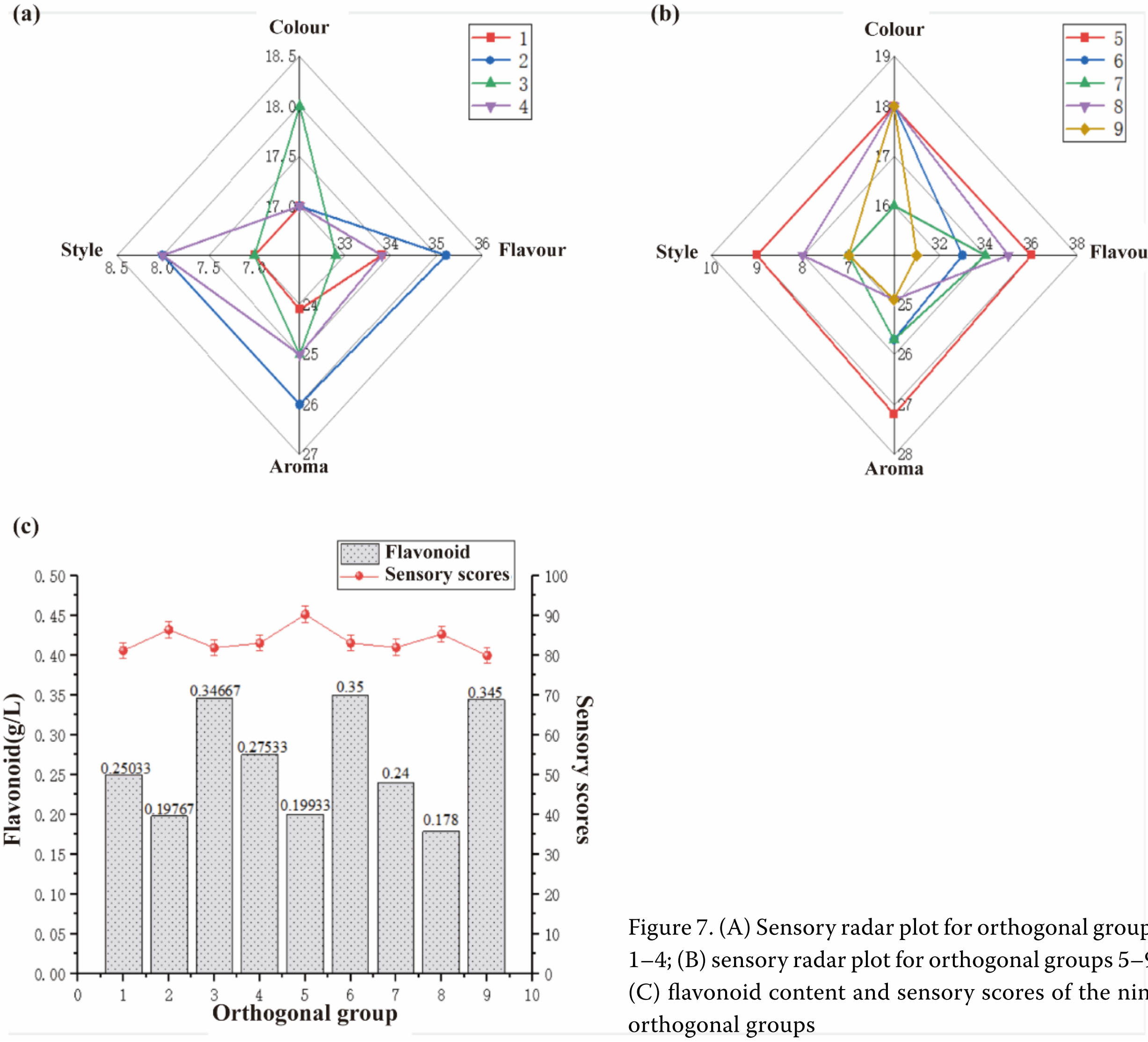

Figure 7. (A) Sensory radar plot for orthogonal groups 1–4; (B) sensory radar plot for orthogonal groups 5–9; (C) flavonoid content and sensory scores of the nine orthogonal groups

of medicinal wine mainly relies on alcohol, which is a semipolar organic solvent, and if the alcohol content of the base wine is too low, it is not conducive to the leaching of nutrients in rattan tea. However, if the al-

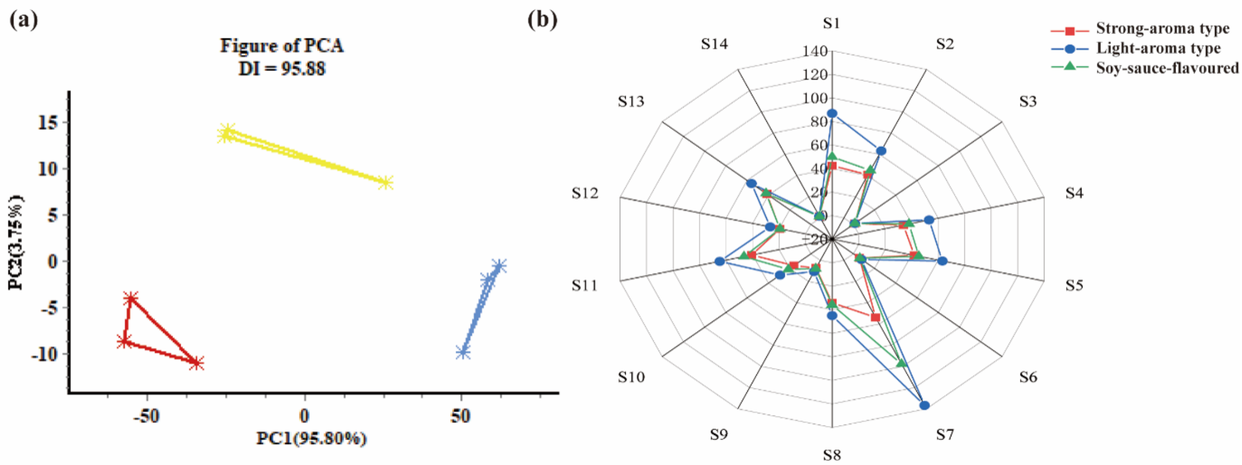

Figure 8. (A) Electronic nose analysis; (B) radar plot of electronic nose

DI – discrimination index

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Table 4. Analysis of variance

Source of variation	Sum of squares deviations from mean	Degrees of freedom	Mean square	F-value	P-value	Significance
A	44.667	2	22.333	10.050	0.001	**
B	160.667	2	80.333	36.150	< 0.001	**
C	16.667	2	8.333	3.750	0.044	*
D	0.667	2	0.333	0.150	0.862	
Error	40.000	18	2.222			

*and **significance at $^*P < 0.05$; $^{**}P < 0.01$ levels, respectively

cohol content of the base wine is too high, it will lead to the loss of the original small amount of water in the rattan tea, resulting in the surface of the rattan tea becoming hard, which is even more unfavourable to the leaching of rattan tea active ingredients. After experimental validation and sensory evaluation, we finally concluded that the optimal alcohol content of the base wine for rattan tea liqueur is 42% vol to ensure the best flavour of rattan tea.

The steeping time is also one of the influential factors of the flavour of rattan tea liqueur. From the orthogonal experiments, it can be concluded that the steeping time has the lowest influence on the leaching of rattan tea, mainly because the leaching of rattan tea is a very slow process. After experimental validation and sensory evaluation, we finally determined the optimal solid-to-liquid ratio of 1 : 8 for rattan tea liqueur to ensure the best flavour of rattan tea.

Electronic nose sensory analysis. The PCA results of different base wine samples evaluated using the electronic nose method are shown in Figure 8A. The contribution of PC1 was 95.8%, of PC2 it was 3.72%, and the cumulative contribution of the main components of PCA was 99.52%. The discrimination index (DI) and that the different base wine additions had a certain effect on the taste of rattan tea liqueur. The overall separation of the three base wines was large, with little intersection. This indicates that the three base wines are rather different, and the difference in style and odour is more significant. The analysis-of-variance results are presented in Table 4.

According to the comparison of volatile substances in each group and PCA results, in the three different types of base wines the addition of amines, hydrogen sulphide and aromatic compounds had a certain effect on the flavour substances of the wines, especially the most obvious difference was observed in the content of aromatic compounds. The content of aromatic compounds was significantly higher in concentrated white wines than in the other two types of base wines. The study showed that the aromatic compounds could increase the contents of ethyl acetate and phenethyl acetate, respectively, retaining better aroma and enabling the wine to express a stronger sense of hierarchy. Similarly to the results of the sensory analysis of the base wines, concentrated white wines had richer flavours than base wines. The amine compounds could also im-

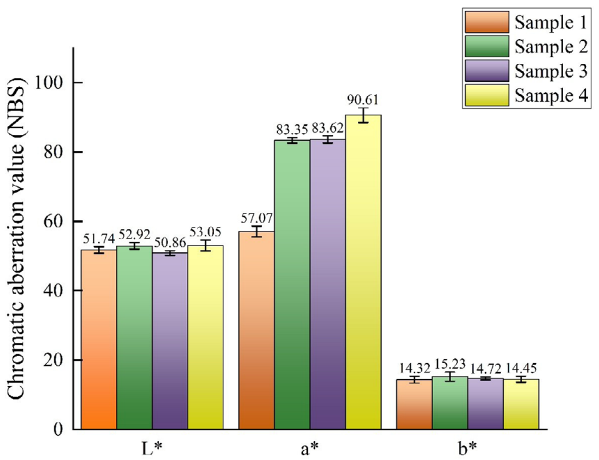

Figure 9. Measurement of colour difference of rattan tea liqueur

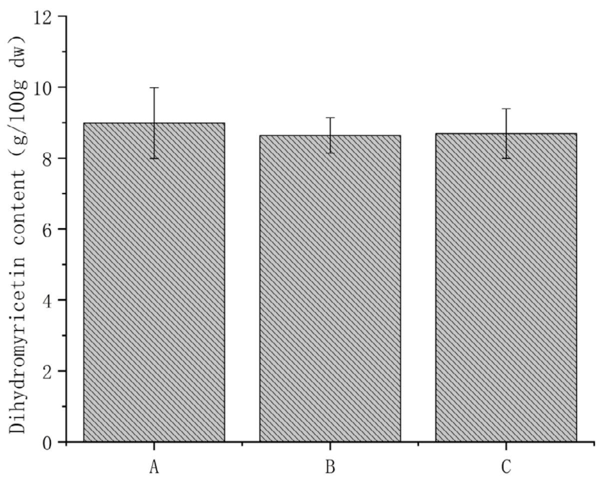

Figure 10. Dihydromyricetin content

dw – dry weight

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Table 5. Corresponding sensitive volatile gases

Sensor number	Corresponding to sensitive volatile gases
S1	ammonia, amines
S2	hydrogen sulphide, sulphur
S3	hydrogen
S4	alcohol, organic solvents
S5	volatile gases during food cooking
S6	methane, biogas, hydrocarbons
S7	flammable gas
S8	VOC
S9	oxy-hydroxide, gasoline, kerosene
S10	alkanes, flammable gas
S11	aromatic compound
S12	sulphide
S13	sterol, triterpenes
S14	lactone, pyrazine

VOC – volatile organic compounds

prove the flavour and mouthfeel of the herbal liqueur, while they could also have a significant diaphoretic effect on muscles and blood vessels. The corresponding sensitive volatile gases for sensors S1-S14 are listed in Table 5.

Colour of rattan tea liqueurs. The colour of the liqueur is an important indicator of the liqueur quality, affecting the sensory flavour and efficacy. As shown in Figure 9, the a^* value represents the red-green hue of rattan tea liqueur ($a^* > 0$ for red hue, $a^* < 0$ for green hue), and the b^* value represents the yellow-blue hue ($b^* > 0$ for yellow hue, $b^* < 0$ for blue hue). The average L^* luminance value of 52 indicates that rattan tea liqueur has a better clarification under the optimal maceration conditions.

Dihydromyricetin content in rattan tea liqueur. The DMY content is shown in Figure 10, with a low content of only 8 g·(100 g)$^{-1}$ of DMY in rattan tea liqueur. The DMY content in the dry matter of rattan tea was in the range of 21.2–36.2 g·(100 g)$^{-1}$. The reasons for these values were analysed: different origins and extraction methods may affect the extraction rate of DMY, which in turn affects the analytical results. Meanwhile, the factors such as extraction solvent, extraction temperature, extraction time, feed-to-liquid ratio and pH had different degrees of influence on the extraction rate of DMY (Xia et al. 2023). Similar results were shown in the study of Hu et al. (2023), who found that the DMY of *Garcinia cambogia* did not contain any flagellin, polyphenols

Table 6. Physicochemical indicators of rattan tea liqueur

Detection index	Standard requirement	Analysis result
Ethanol volume fraction (%)	4.0–60.0	40.4 ± 2.24
Total acid (g·L^{-1})	≥ 7.50	8.6 ± 0.20
Total sugar (g·L^{-1})	≤ 300.00	12.6 ± 1.12
Dry infusion (g·L^{-1})	≥ 0.30	0.65 ± 0.02
Flavone (g·L^{-1})	–	0.20 ± 0.02
Dihydromyricetin [g·(100 g)$^{-1}$]	–	23.2 ± 1.4

and DMY isomers. The main reason for the analysed differences may be that the samples of rattan tea in this study were not stored strictly enough during the test period, and the flavonoids in the early picking rattan tea samples may be oxidized and degraded, which ultimately led to insignificant differences between the samples of different picking times. The DMY content of rattan tea from different places of origin and different grades of rattan tea differed significantly, so it can be selected according to the requirements in practical applications.

Physical, chemical and hygienic indicator analysis. The analysis of the physical and chemical health indicators of rattan tea liqueur reveals that the total sugar content of rattan tea liqueur is 0.126%, which is less than 0.5%, so it is a sugar-free and healthier alcoholic drink (in China, beverages with a sugar content below 0.5% are classified as sugar-free). The methanol content of 0.11 g·L^{-1} is lower than the national standard GB 2757-2012 for distilled spirits and wines prepared from them, which is 0.6 g·L^{-1}. In addition, the alcoholic strength, contents of total acid, total sugar and dry leachate are in line with the requirements of GB/T 27588-2011 National Standard for herbal liqueur. The physicochemical indicators of the finished rattan tea liqueur are summarised in Table 6.

CONCLUSION

In this study, the effects of different extraction conditions on the quality of rattan tea liqueur were investigated using rattan tea and strong-aroma Baijiu as raw materials. The flavonoid contents under these conditions were analysed using one-way and orthogonal experimental methods. Through a systematic experimental design and analysis, the optimal extraction conditions for rattan tea liqueur were determined, and the main physical and chemical indices of the finished

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liquor were measured. The results showed that under the conditions of feed-to-liquid ratio of 1 : 8, ethanol volume fraction of 42% vol, maceration time of 33 min, and maceration temperature of 55 °C, the quality of rattan tea liqueur reached the best, and the content of flavonoids was also relatively high. The hygienic indexes of the finished wine conformed to the national standard. The experimental results of this thesis provide the data reference for enriching the varieties of liqueur and enhancing the deep processing and development of rattan tea related products.

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