An Exploratory Study on the Development of a Sensory Wheel Affiliated with the Emotional Lexicon for Chrysanthemum Infusion

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Abstract

Chrysanthemum infusion has gained popularity ~~bey~~o~~nd~~utside of the East Asian market in recent years. However, ~~D~~despite the growing international demand, standardized methods to evaluate the sensory attributes of chrysanthemum tea, which are essential for guiding consumers and ensuring quality control, remain underdeveloped. In this study, a trained panel conducted a quantitative descriptive analysis (QDA) of eight chrysanthemum samples, successfully distinguishing between them. Additionally, consumer emotional responses to chrysanthemum infusion were assessed using the Check-All-That-Apply (CATA) method. By mapping the descriptive sensory data with emotional response data through Partial Least Squares Regression (PLSR), we identified sensory drivers that elicit specific emotional responses. For this analysis, the emotion lexicon from EsSense25 was clustered into six dimensions: pleasant, tame, warm, active, negative, and bored. Our findings indicate that attributes such as smoothness and chrysanthemum-cucumber flavour induce calm and reassuring emotions (e.g., secure, understanding, calm, and tame). Conversely, sweetness and floral flavour are associated with positive emotions such as happiness, joy, and general well-being, suggesting that floral sweet beverages can mitigate negative emotions. However, sensory attributes such as bitterness, astringency, and vegetal aroma were linked to negative emotions and were sometimes associated with feelings of activity. The development of a sensory wheel, integrated with the emotional lexicon for chrysanthemum infusion, provides a tool for identifying sensory drivers behind emotional experiences. This tool offers valuable insights for market applications and product development, enhancing consumer satisfaction by aligning product attributes with desired emotional outcomes.

KEYWORDS: Sensory wheel, Emotional lexicon, Chrysanthemum infusion

Highlights

- QDA of eight chrysanthemum samples linked sensory attributes to emotional responses.
- Smoothness and chrysanthemum-cucumber flavor induce calmness.
- Sweetness and floral flavor evoke happiness.
- Sensory wheel links attributes to emotions, aiding market and product development.

1. Introduction

Chrysanthemum infusion, a traditional herbal tea deeply rooted in Chinese culture, is celebrated for its vibrant color, unique aroma, and subtly bitter taste/flavour. This beverage, derived primarily from the buds of *Chrysanthemum morifolium* and *Coreopsis tinctoria*, undergoes a simple yet delicate process of selection, drying, and packaging. Its popularity now extends far beyond East Asia, finding a global audience due to its versatility in beverages, pharmaceuticals, as well as commemorative products (Van Huylenbroeck, J., 2018). Recent studies have highlighted its health benefits, including its anti-hyperlipidemia, anti-anxiety, anti-inflammatory, and antioxidant effects (Li, Yang, & Luo, 2019; Hussaini, Tula, Onyeje, et al., 2018; Xue, Jiang, Zhao, et al., 2019), further fueling demand amongst health-conscious consumers. Despite its growing popularity, there remains a significant gap in consumer understanding of the sensory differences among chrysanthemum infusion varieties. This lack of awareness hinders the growth of the market for this beverage, as consumers are often unable to make informed choices based on their own sensory preferences. Consequently, there is an urgent need to develop standardized methods or tools for evaluating the sensory properties of chrysanthemum infusion to guide consumers and ensure quality control (Schmelzle, 2009; Su et al., 2021).

The primary factors influencing the quality of chrysanthemum infusion include its appearance, taste, and aroma, with the latter two being crucial for consumer acceptance (Su et al., 2021). The sensory characteristics of chrysanthemum infusions vary based on the origin, production system, and picking period (Han, Nam, Kim, et al., 2019; Xia, Song, Lee, et al., 2020). For example, Boju infusion is known for its medicinal undertones, while Hangju infusion is sought for its mild taste and aroma. The overall character of the infusion is also influenced by external factors such as the mineral content (and type) of the brewing water and its temperature, etc. (Jakubczyk, Ligenza, Gutowska, & Janda-Milczarek, 2022).

To quantify these sensory properties, methods such as traditional cupping, quantitative descriptive analysis (QDA), and rapid sensory profiling techniques, e.g. check-all-that-apply (CATA) have been used (Torrico, Mehta, & Borssato, 2023; Di Donfrancesco, Gutierrez Guzman, & Chambers, 2014; Tong, Zhu, Li, et al., 2022). However, the development of a comprehensive sensory lexicon, vital for these methodologies, has yet to be developed. Sensory lexicons, with their rich descriptive terms, are essential for capturing the nuanced experiences associated with a product (Koch, Muller, Joubert, Van der Rijst, & Næs, 2012; de Godoy, Chambers IV, & Yang, 2020). To make these lexicons more accessible to a broader audience, including consumers, marketing researchers, and customer support, it is important to integrate consumer input in their development (Silvello, Bortoletto, & Alcarde, 2020). A sensory wheel can serve as a dynamic visual tool that encapsulates these lexicons, offering an insightful overview of the sensory attributes of chrysanthemum infusions (Asih, Ramadhanty, Ramandias, Azkarama, & Sunarharum, 2021; Suwonsichon, 2019). The development of such a sensory wheel would likely help to enhance understanding and communication of the product's sensory nuances among various stakeholders.

In the development of sensory wheels for various products, two primary methods have been used: trained panels and focus group discussions (FGD) with Mean Drop (M) value calculations. Trained panels, consisting of individuals skilled in sensory analysis, offer precise and reliable evaluations using standardized descriptors, albeit at a higher cost and with a potential disconnect from general consumer preferences (Lawless & Heymann, 2010; Stone & Sidel, 2004). On the other hand, FGDs, though subjective and less precise, provide direct insights into consumer perceptions and broader perspectives, that are likely crucial for market research (Greenbaum, 1998; Moskowitz, Beckley, & Resurreccion, 2006). The emphasis on a consumer-sourced lexicon in FGDs is particularly significant, as it aligns more closely with actual consumer needs and preferences, making it a valuable tool in predicting and meeting market demands. This approach underscores the importance of integrating consumer feedback into the sensory evaluation process, balancing technical precision with real-world applicability. In the current study, the sensory descriptors were initially developed through FGD and further validated by the trained panel to form the sensory wheel.

Sensory experience is crucial in influencing consumers' product choices. However, research has shown that measuring sensory appeal alone fails to capture the full extent of consumer preferences (Gutjar et al., 2015; Stasi et al., 2018; Kaneko et al., 2018). In the past decade, food-evoked emotions have gained attention for their ability to enhance product value beyond sensory experience, satisfaction, and consumer evaluation, ultimately impacting consumption choices (Hu & Lee, 2019). To address this, a variety of methods, both implicit and explicit, have been developed to measure emotional responses (Kaneko et al., 2018). One notable tool in food research is the EsSense Profile®

questionnaire, which emphasizes predominantly positive emotions across various products (Nestrud et al., 2016). Integrating a product-specific lexicon, as seen in studies on coffee, beer, and other products (Hu & Lee, 2019; Eaton et al., 2018), provides a more nuanced understanding of the emotional responses elicited by specific products, although generalization has not been fully validated. The current study adopted the EsSense Profile 25 to evaluate chrysanthemum infusion, focusing on the emotional responses related to corresponding sensory sensations. The primary aim is to conduct a comprehensive analysis of various chrysanthemum infusions, identifying key sensory attributes that influence consumer preferences.

The~~is~~ aim of the study was ~~aimed~~ to develop a sensory lexicon and wheel that accurately capture the diverse sensory experiences of chrysanthemum infusions. Initially, a comprehensive sensory lexicon was established by collecting consumer experiences through focus group discussions, resulting in a lexicon of 42 attributes that formed a preliminary sensory wheel. To validate its accuracy and practicality, trained expert panelists conducted quantitative descriptive analysis (QDA) on eight typical chrysanthemum samples, confirming that the sensory lexicon effectively differentiated among the samples and produced distinct sensory profiles. In the third phase, consumer emotional experiences were gathered using Check-All-That-Apply (CATA) analysis, incorporating relevant emotional terms from the EsSense Profile 25. The emotional data were then correlated with the sensory attributes, revealing the relationship between emotions and sensory experiences. This correlation led to the integration of the emotional lexicon into the outer layer of the sensory wheel, resulting in a comprehensive sensory-emotional wheel for chrysanthemum infusion. This approach not only deepens the understanding of the sensory-emotional interplay in consumer preferences for chrysanthemum infusions but also contributes to the broader field of sensory science and consumer behavior, offering valuable insights into how emotional responses, alongside sensory attributes, influence consumer choices and product evaluations.

2. Materials and methods

2.1. Samples

In this study, thirty distinct varieties of dried chrysanthemums, purchased from local cultivators, were examined (as detailed in Supplementary Table 1). The principal cultivars included Anhui Boju, Jinsi Huangju, Chuju, and several others, encompassing both organic and conventional types from various regions. These chrysanthemum samples varied not only in cultivar but also in harvesting times, categorized as embryo chrysanthemum and flower chrysanthemum within the same cultivar. This sampling strategy ensured a comprehensive assessment of the sensory nuances and variations in the chrysanthemum infusions under study. The thirty dried chrysanthemum samples were used in focus group discussions. This deliberate diversification was designed to enable the identification of a broad spectrum of sensory descriptors by consumers. According to the sensory characteristics of the initial batch of chrysanthemum infusion samples, eight representative samples were selected for quantitative descriptive analysis and consumer test. This rigorous approach verified the accuracy of the sensory wheel developed for chrysanthemum infusions and facilitated the creation of an associated emotional wheel.

To ensure the reliability and repeatability of sensory evaluation, we employed a meticulous sample preparation approach. A range of ratios, spanning 1:100, 1:150, 1:200, and 1:250, underwent rigorous testing. Integrating insights from marketing data and the preferences of 300 consumers (200 females and 100 males, 67% aged 18-25 years and 33% aged over 25 years), we determined the optimal brewing mode for chrysanthemum infusion to be a chrysanthemum-to-water ratio of 1:150 by weight. Consistent with the methodology used by Song et al. (2021), the sample preparation entailed fully immersing dried chrysanthemums in boiling water (at 100℃). It is noteworthy that the infusion comprised solely dried chrysanthemum and water, with no additional ingredients introduced into the tea. The water used for brewing was sourced from an Amway eSpring purifier (Amway (China) Co., Ltd, Guangzhou, China). Samples were brewed using a glass teapot equipped with a stainless steel tea strainer. After each pre-set brewing time of 5 minutes, the tea strainer was promptly removed from the teapot. This was done to ensure consistency and to eliminate any potential variations caused by differences in the number or shape of chrysanthemum flowers in the dried samples. Importantly, the participants were only presented with chrysanthemum infusion during the taste test, devoid of any actual chrysanthemum flowers. Despite keeping the teapots containing the samples warm on an electronic heating mat, servings were dispensed within 5 minutes of filtering to mitigate potential alterations resulting from polyphenol oxidation.

All experimental samples, totaling 30 mL each, were carefully dispensed into approximately 50 mL odorless plastic cups (manufactured by Yuandian Paper Cups Co., Shanghai, China). To prevent bias, each cup was labeled with a unique 3-digit random number. For all samples, a temperature range of 50–55°C was meticulously maintained during serving.

2.2. Experiment design

In total, three experiments were discussed in this paper. The first experiment involved focus group discussion (FGD) to collect sensory attributes and corresponding intensities for 30 chrysanthemum infusion samples. Geometric mean values (M-values) were used to filter these attributes, resulting in a sensory lexicon specific to chrysanthemum infusion, and the development of sensory wheels for chrysanthemum infusion's color, taste, and aroma.

The second experiment employed quantitative descriptive analysis (QDA). Nine trained panelists evaluated eight representative chrysanthemum samples. The objective was to establish a more standardized evaluation system, validate the accuracy and practicality of the chrysanthemum sensory wheel, and create detailed sensory profiles for the eight chrysanthemum samples.

The third experiment was a consumer test based on EsSense Profile 25, using Check-All-That-Apply (CATA) method to explore the emotions evoked by the 8 representative chrysanthemum samples. The sensory wheel was then supplemented based on the correlation between emotional terms and sensory attributes.

2.3. Method

2.3.1. Generation of sensory lexicons through Focus Group Discussion （FGD）

For this study, we recruited 24 habitual consumers of chrysanthemum infusion with consumption frequency of once per week, comprising a diverse group of 16 females and 8 males aged 18 to 55 years. The participants were strategically divided into three focus groups, each consisting of 8 individuals. Efforts were made to ensure that the groups were as balanced as possible in terms of age, gender, and consumption frequency. Before conducting FGD, we restructured the 30 samples into three differentiated groups based on consumer insights, chrysanthemum breeding information and sensory team tasting results to balance the samples in different groups. ~~Th~~Ne~~n~~xt, each group of chrysanthemum samples was tasted by different groups of participants and the samples were prepared and tasted one by one. All of the samples were refilled if the participant needed more.

Before the FGDs, structured scripts focusing on the sensory qualities of chrysanthemum infusion were prepared. These scripts included a compilation of existing sensory vocabulary relevant to chrysanthemum infusion and a set of structured guiding terms to streamline discussion. Each FGD began with a brief introduction by the moderator, emphasizing the identification of vocabulary that aptly described the sensory characteristics of chrysanthemum infusion across various dimensions such as appearance, aroma, taste, and mouthfeel. The FGDs were conducted in a well-facilitated conference room, with participants seated around a circular table to encourage interactive dialogue. Each participant was provided with an A4 sheet to note down sensory vocabulary and its corresponding intensity (rated on a scale of 1-weak, 2-moderate, 3-strong) observed during the tasting sessions. The moderator played a pivotal role in engaging each participant actively in the discussion. Each FGD session was conducted over a span of approximately two hours. Notably, after conducting three FGD sessions, it was observed that additional data collection ceased to contribute any new sensory vocabulary, indicating a saturation point in data richness. This process was critical in identifying unique sensory attributes inherent to different chrysanthemum products. The discussions were methodically structured, starting with the evaluation of appearance, progressing to aroma and taste, and concluding with mouthfeel assessments.

2.3.2. Selection of descriptors and construction of the sensory lexicon and wheel

The sensory descriptors generated from the FGDs were meticulously analyzed. The first step involved removing hedonistic terms (e.g., pleasant, beautiful), quantitative terms (e.g., too strong, too weak), as well as synonyms, antonyms, and irrelevant descriptors, particularly those not pertaining to the aroma of chrysanthemum infusion. Subsequently, the selection of descriptors was refined based on the intensity scores obtained from the FGDs, using the geometric mean M value calculation, defined as "$M = \sqrt{(F \times I)}$". Here, 'F' represents the frequency of a descriptor's mention as a percentage of the total possible references, and 'I' denotes the average intensity given to a descriptor by the focus groups, expressed as a percentage of the maximum possible intensity. Descriptors with lower M values, indicating minimal contribution to the sensory profile of chrysanthemum infusion, were excluded.

The finalized terms, having undergone rigorous screening, were then compiled into the sensory lexicon for chrysanthemum infusion. Drawing inspiration from existing sensory wheels of Hunan fuzhuan brick tea infusion, honeybush tea, and beer (Li et al., 2019; Silvello, Bortoletto, & Alcarde, 2020; Theron, Muller, Van der Rijst, Cronje, Le Roux, & Joubert, 2014), the selected terms were meticulously categorized and organized. This classification process involved a thoughtful arrangement of terms based on their sensory relevance and interrelationships. The culmination of this methodical process led to the visualization of the sensory wheel, a comprehensive and intuitive representation capturing the intricate sensory characteristics of chrysanthemum infusion. This sensory wheel serves not only as a reflection of the unique flavour profile of chrysanthemum infusion but also as a valuable tool for understanding and communicating its complex sensory attributes (Su et al., 2021; Yu et al., 2022).

2.3.3 Descriptive Analysis

The lexicon from the sensory wheel was u~~tiliz~~sed in quantitative descriptive analysis (QDA) to establish a sensory evaluation system. This rigorous system was aimed to verify the accuracy of the sensory wheel developed for chrysanthemum infusions and facilitated the creation of an associated emotional wheel.

This study adhered to the ISO 8586-2023 standard for sensory evaluation. Participants were selected based on specific criteria: non-smoking university students with no history of allergies and ample availability. The sensory ability test administered to these participants included a comprehensive range of assessments such as color vision testing (for color blindness and weakness), basic taste and olfactory recognition, triangle tests, ranking tests, and quantitative estimation tasks. Following the sensory ability test, the participants underwent an interview process to evaluate their descriptive and expressive skills. A sensory panel consisting of nine judges (three males and six females aged 20 to 23 years) was established.

This panel underwent an initial training stage, totaling 10 hours, to verify the lexicon derived from FGDs, define these attributes, and establish the relevant reference samples. Further, a total of 30 hours were taken for the panel to familiarize themselves with the lexicon and rating calibration. This was aimed to ensure the panel's proficiency in differentiation, consistency, and repeatability of assessments, which were further examined. The evaluation of the samples used a quantitative descriptive analysis approach, using a 15-cm line scale for quantitative estimation. During the training sessions, all thirty cultivars were evaluated and through the initial evaluation, the eight representative chrysanthemum samples in the following analysis were identified according to their differences during this stage (as outlined in Table 1).

The samples were placed in clear, lidded plastic cups, each labeled with a unique three-digit code.

Considering the impacts of tea oxidation, the evaluations were conducted within 10 minutes after brewing. To ensure consistency, the temperature of all samples was maintained at between 50-55°C. Each sample underwent two rounds of assessment in separate sessions for a comprehensive analysis. All evaluations took place in the standard sensory laboratory at Jiangnan University.

2.3.4 Selection of emotional lexicon embedded in the sensory wheel

To develop corresponding emotional wheel along with the established sensory attributes, the Check-All-That-Apply (CATA) methodology was used, namely the short version of the EsSense Profile®, the EsSense25 scale. The study involved 159 consumers, aged 18 to 40 years, with 61% of the participants being female. All participants reported consuming the product at least once every fortnight or more frequently. In the test, the participants were provided with the same eight chrysanthemum tea samples as used in the descriptive analysis. The sample presentation followed a Williams Latin square design to mitigate order effects, with a randomized sequence of emotional vocabulary for each participant through an electronic questionnaire. All of the sensory evaluations were conducted in a professional sensory testing room in Jiangnan University. The sample preparation mirrored that of the descriptive analysis, with soda crackers and water provided to consumers between samples.

This methodological approach aimed to validate the efficacy of a previously established flavour wheel, using consumer insights to differentiate the sensory characteristics of eight representative samples. The objective was to demonstrate the comprehensiveness and specificity of the flavour wheel. Furthermore, the study sought to enrich the sensory flavour wheel for chrysanthemum tea by selecting the most appropriate emotional vocabulary from the EsSense profile, based on these representative tea samples.

Ethical approval for involving human subjects in this study was granted by the Jiangnan University Medical Ethics Committee (Reference Number: JNU20221201IRB03). Participants in the experiment were given gifts as a token of appreciation for their involvement.

2.4. Statistical analysis

Data analysis was rigorously executed using a suite of specialized software to ensure comprehensive statistical evaluation and visualization. Assessors' performance was evaluated using PanelCheck 1.4.2 software (Tomic et al., 2010), which facilitated the assessment of panelist consistency and accuracy. This software provided metrics such as the inter-rater reliability and the panel's overall performance, ensuring that the data quality was high. Statistical differences between samples were determined using Analysis of Variance (ANOVA) in conjunction with Tukey's Honest Significant Difference (HSD) test for post-hoc comparisons, performed with IBM SPSS Statistics 26. ANOVA allowed for the examination of differences in means across multiple groups, while Tukey's HSD test identified specific pairs of groups with significant differences. The significance level was set at $p \leq 0.05$.

Principal Component Analysis (PCA) was us~~tiliz~~ed to explore the relationships between color, taste, mouthfeel, and aroma attributes of eight chrysanthemum infusions. This analysis, conducted using XLSTAT 2019, reduced the dimensionality of the data, enabling the identification of key attributes that differentiate the infusions. A bi-plot was created to visually represent the contributions of each attribute to the principal components, facilitating the interpretation of the data patterns. The construction of the sensory wheel was performed with XLSTAT 2019 to graphically represent the key sensory attributes. This wheel provided a visual summary of the sensory profile of the chrysanthemum infusions, highlighting the relative intensities of different attributes. Additional visualizations, including charts and figures, were generated using Microsoft Excel 2019 and Origin 2022. These tools were employed to create high-quality, informative figures that illustrated the results clearly.

To examine the relationship between sensory attributes and emotional responses to the drinking experience, Partial Least Squares Regression (PLSR) was conducted using XLSTAT 2019. In this analysis, sensory attributes were treated as predictor (X) variables, while emotional responses were treated as response (Y) variables. PLSR enabled the identification of the latent variables that best explain the variation in emotional responses, providing insights into how sensory attributes influence the overall drinking experience.

3. Results and discussion

3.1. Development of sensory wheel for chrysanthemum infusion

3.1.1 Selection of sensory descriptors

A total of 321 terms were generated to characterize the 30 chrysanthemum tea samples by the 24 consumers during the three focus groups. To refine these descriptors, the semantic filtering method described by De Pelsmaeker et al. (2019) was applied. This method involved several key steps: Merging fuzzy and repetitive descriptors (e.g., combining 'medicinal taste' and 'herbal taste' into 'herbal taste'), resolving semantic opposites (e.g., retaining 'brightness' over 'darkness'), and those eliminating descriptors that conveyed subjective emotions (e.g., 'disgusted' and 'good').

Following this rigorous filtering process, a consolidated set of 68 sensory descriptors specific to chrysanthemum tea were identified, including 9 related to appearance, 6 to taste, 7 to mouthfeel, and 46 to aroma, as detailed in Table 2. Based on the M-value, 9 appearance attributes (M > 0.200), 4 taste attributes (M > 0.300), 2 mouthfeel attributes (M > 0.500), and 26 aroma attributes (M > 0.100) were selected from the list of descriptive terms. This process resulted in a total of 41 sensory descriptors forming the sensory lexicon for chrysanthemum infusion.

The descriptors were then organized into a coherent category system, according to the discussion of the focus group and the professional study of the sensory wheel (Asih et al., 2021). The 41 descriptors were visualized as a three-tiered sensory wheel, as shown in Figure 1. The outermost tier contained specific attributes, grouped into secondary descriptors in the second tier. The innermost tier consisted of four sensory dimensions: appearance, taste, texture, and aroma of chrysanthemum infusion.

3.1.2 Validation of sensory wheel

3.1.2.1 *Development of sensory lexicon*

The analysis of eight chrysanthemum infusion samples by a trained panel identified 35 attributes for characterization, rather than utilizing the 41 attributes listed in the existing sensory wheel. These attributes, along with their definitions and reference samples, are detailed in Table 3. According to He and Chung (2019) and Koch et al. (2012), the precise definition of descriptors and the selection of appropriate reference samples are crucial in quantitative descriptive analysis (QDA).

In terms of appearance, the sensory wheel's descriptors highlighted differences in colour and shape across chrysanthemum varieties. The primary color descriptors—red, yellow, and green—were chosen from the second tier, with corresponding Pantone color cards serving as reference samples. Since all chrysanthemum infusion samples were brewed with purified water and the infusions appeared clear and bright, the colour descriptors from the third tier were deemed unnecessary. Thus, three colour descriptors were selected from the nine appearance attributes of the sensory wheel for subsequent evaluation.

Regarding taste, the panel determined that the intensity of bitterness varied at different stages of consumption, leading to the categorization of bitterness into three distinct phases: initial bitterness, mid-tasting bitterness, and bitter aftertaste (Tian et al., 2022). It is important to note that while most aromas were detected through both orthonasal and retronasal olfaction during consumption, certain flavours, such as milk, could only be perceived retronasally and were not detectable orthonasally. Furthermore, not all 26 taste attributes were identifiable in each sample; unique aromas such as those found in roasted coffee or wolfberry, characteristic of XueJu infusions, were not universally present.

Overall, the selection of specific attributes and reference samples enhanced the accuracy and reliability of QDA for chrysanthemum infusions. The detailed descriptors and their precise definitions, along with the choice of relevant reference samples, ensure a robust and comprehensive sensory evaluation.

3.1.2.2 Panel Performance

In our commitment to methodological precision and neutrality, as advocated by McEwan et al. (2003), a comprehensive review was conducted of the performance data from nine expertly-trained panelists in terms of their discriminability, repeatability, and panel consistency.

The F-value plot (Figure 1) visually demonstrates the exceptional ability of these panelists to discern subtle differences. Notably, more than 80.4% of the sensory attributes assessed were found to have F-values that exceeded the significance threshold, indicated by a horizontal line at the 5% level. This superior discriminative performance is depicted on the plot where black markers represent a p-value of less than 0.05, and red markers denote a more stringent p-value of less than 0.01. Such a consistent pattern across all attributes not only highlights the acute sensory differentiation skills of the panelists but also confirms the robustness of their assessments in identifying distinct differences among the sample infusions.

The Mean Squared Error (MSE) values (see Figure 2), were examined, revealing that the panelists maintained impressively consistent evaluations with very low MSE values (MSE ≤ 1). For the majority of attributes, it was observed that the MSE values were below 0.6, underscoring a high degree of accuracy in their assessments. This level of precision was particularly notable in the identification of aroma attributes specific to different chrysanthemum varieties. By integrating these MSE results with the F-value data, it becomes evident that the panelists developed a deep comprehension of the sensory descriptors being evaluated. Their competence is manifested not only in the consistency of their repeated evaluations but also in their skillful discrimination between the subtle sensory nuances of various chrysanthemum samples. Therefore, the collective analysis of F-values and MSE metrics portrays the panelists not merely as consistent but as experts capable of precisely and reliably distinguishing the unique sensory properties of the infusions under scrutiny.

Further insights were provided by the analysis of the Tucker-1 correlation diagrams (see Figure 3), which explored the panelists' evaluative consistency for diverse sensory attributes. With the exception of a few aroma descriptors—specifically sophora flower, mint, soy milk, and pine nuts—significant uniformity was noted among the panelists in assessing the majority of sensory characteristics related to appearance, taste, and mouthfeel. This suggests robust group concordance in the detection and appraisal of these attributes. Although the consistency of aroma attributes in panelist ratings was slightly less compared to other sensory categories, the repeatability for certain aroma descriptors was still more pronounced than for some appearance and taste attributes. This might be attributed to the unique nature of these aromas, which are inherent to specific chrysanthemum varieties and more readily identifiable by the panelists. Additionally, variations in aroma attribute consistency could be linked to potential olfactory fatigue, which may occur as the panelists engage in the complex task of distinguishing multiple olfactory notes during evaluations. The Tucker-1 diagrams not only elucidate these subtleties in panelist performance but also provide a comprehensive overview of their collective expertise and the specific challenges encountered in the sensory evaluation of chrysanthemum infusions.

3.1.2.3 Sensory Profiles of the Eight Different Varieties of Chrysanthemum Infusion

Principal Component Analysis (PCA) was conducted on the correlation matrix using the color, taste and mouthfeel and aroma attributes to visualize the relationships of the attributes to the chrysanthemum samples (Borgognone et al., 2001). This comprehensive sensory profiling demonstrates the sensory wheel's proficiency in discriminating among the eight distinct varieties, encompassing both orthonasal and retronasal aromatic perceptions.

For the color attributes, F1 explain 80.15% of the variance, whereas F2 explain 12.07% of the variance, for a total of 92.22% of the variation of the data represented in the biplot. The PCA biplot for color attributes (see Figure 5a) illustrates that Sample S8 (XueJu) is uniquely characterized by a vibrant red hue, diverging significantly from the cluster of other samples, which are primarily associated with yellow and green attributes. Samples S3 (HuangJu), S5 (Lanxi HangBaiJu), and S7 (Shanxi HangBaiJu) grouped together, indicating a deeper yellow-green hue, suggestive of a more concentrated colour expression. Conversely, Samples S2 (ChuJu), S4 (JiaJu), and S6 (QiBaiJu) possessed a lighter infusion colour, indicative of a more delicate visual presentation.

F1 and F2 explain for a total of 92.22% of the variation of taste and mouthfeel scores. The PCA biplot for taste and mouthfeel attributes (see Figure 5b) establishes a pronounced bitter profile for Samples S1 (BoJu) and S8 (XueJu), with a supplementary palate of sourness and astringency, articulating a multifaceted and robust flavour composition. By contrast, Samples S4 (JiaJu), S2 (ChuJu), and S5 (Lanxi HangBaiJu) aligned closely with sweet and smooth sensory notes, reflecting a harmonious and pleasing tasting experience, with a notable sweet aftertaste and smooth mouthfeel during consumption. The remaining taste attributes, while present, did not show an exclusive association with particular samples, thereby underscoring a more evenly distributed sensory profile across the samples.

The first and second Fs for the aroma attributes describe 43.34% and 25.52% of the variance, explaining 68.86% in total. The F1 (X-axis) mainly represents floral and vegetal attributes. The left side of F1 is the light aromas and the intense terms are on the right side. The PCA biplot for aroma attributes (Figure 5c) highlights that Sample S8 (XueJu) possesses a highly distinctive aroma profile. Its bouquet, characterized by notes of fermentation, wood, and a roasted essence, is potentially influenced by its high-altitude cultivation, revealing the complexity of aromas that emerge in the second tier of the sensory wheel. This unique aromatic signature set XueJu apart from its counterparts, implying a rich, layered sensory experience. In contrast, Samples S5 (Lanxi HangBaiJu), S7 (Shanxi HangBaiJu), and S2 (ChuJu) were denoted by a potent sweet fragrance and traditional chrysanthemum scent, indicating a robust and classic floral aroma profile that aligned with consumer expectations for chrysanthemum infusions. Samples S1 (BoJu), S3 (HuangJu), and S6 (QiBaiJu) expressed a diverse vegetal aroma palette, with pronounced herbal and earthy undertones. This vegetal complexity suggests an intricate relationship with the infusion's terroir and processing, which could be further explored for sensory optimization.

By adding aroma attributes to the existing color and taste profiles, the PCA biplots have rendered a multidimensional sensory wheel capable of distinguishing the intricate characteristics of each chrysanthemum infusion sample. The sensory wheel not only differentiates the samples based on traditional attributes but also captures the essence of unique and subtle notes that may arise from specific cultivation conditions or processing methods.

The sensory wheel's validation through PCA analysis underscores its effectiveness as a descriptive tool that encapsulates the diversity and specificity of chrysanthemum infusion sensory attributes (Aparicio & Morales, 1995). This validation supports the sensory wheel's role in guiding consumers toward an informed selection of chrysanthemum infusions based on their flavour and aroma preferences, thereby enriching the consumer experience.

3.2 Selection of the emotional lexicon attached to the sensory wheel for chrysanthemum infusion

3.2.1 Analysis based on the current emotional lexicon

Dartora et al. (2023) used Check-All-That-Apply (CATA) to assess the sensory characterization of Kombuchas made from black tea, green tea, and yerba-mate, revealing distinct physiochemical features, perceived sensory attributes, and emotions evoked by different tea leaves. Similarly, Souza et al. (2022) indicated that the consumer acceptance of coffee varied according to the expected emotional pattern when evaluating different samples, suggesting that appropriately triggered emotions at specific intensities directly impacted acceptance and could guide consumer choices. Building on these insights, our study explored the relationship between the sensory attributes of chrysanthemum infusion and the emotional changes experienced during consumption. The emotional lexicon was embedded into the flavour wheel to further elucidate consumer preferences for chrysanthemum infusion.

We divided sensory attributes into two dimensions—appearance and taste-aroma attributes—to study the emotional responses when consumers observed and drank chrysanthemum infusion. A Partial Least Squares (PLS) regression model was constructed to investigate the relationships between sensory attributes and **emotions (Bhumiratana et al., 2014),** using the emotional reactions during/after drinking as the Y variable, and the color and taste-aroma attributes as the X variables, respectively. The results indicated strong predictive capability and explained variance for both models. For taste-aroma attributes, according to the first four factors ($p < 0.05$, $Q^2 = 0.412$), the X variable ($R^2X = 0.870$) explained the Y variable ($R^2Y = 0.897$). For color attributes, the X variables ($R^2X = 0.809$) explained the variation in the Y variables ($R^2Y = 1.000$) according to the first two factors ($p < 0.05$, $Q^2 = 0.283$). The lower predictability of Q2 may be attributed to the large and complex variable set, and the sensory attributes used in the X matrix had already been selected, suggesting that the PLSR model should primarily focus on reducing emotional response variability.

The PLS regression model for color attributes demonstrated that Sample S8 (XueJu) evoked feelings of nostalgia and enthusiasm, associated with its vibrant red hue. Samples like S3 (HuangJu) and S7 (Shanxi HangBaiJu), which indicate a yellow-green hue, elicited feelings of calmness and pleasantness, aligning with consumer expectations for chrysanthemum infusion. The PLS regression model for taste and aroma attributes highlighted that Sample S8 (XueJu), with a robust bitter profile and complex aroma including notes of roasted coffee and oolong tea, evoked emotions such as nostalgia and adventurousness. In contrast, Samples S5 (Lanxi HangBaiJu), S7 (Shanxi HangBaiJu), and S2 (ChuJu) with sweet and smooth sensory notes elicited feelings of happiness, satisfaction, and security. Biplots illustrated the differences between samples, with closer proximity between attributes and sentiments indicating higher correlations. The small ellipse represents 50% interpreted variance, and the large ellipse represents 100% interpreted variance (Yin et al., 2021).

3.2.2 Clustered Emotion Lexicon and Enhanced Sensory Wheel

To further understand the distribution of emotions corresponding to different attributes, we reduced and clustered the emotion lexicon. Cardello et al. (2012) compared consumers' emotional responses after tasting different common foods and clustered the 39 food-related emotions from EsSense. We referred to Cardello's classification method to divide the emotion lexicon from EsSense 25 into six factors (Table 4). The clustered emotion lexicon helped us understand why bitterness could trigger different dimensions of emotions. Attributes such as bitterness could bring strong sensations of stimulation, leading to greater mood swings. Consumers tended to choose emotional terms such as active, adventurous, wild, and aggressive at the same time as feeling disgusted and worried. Infusions with a smooth mouthfeel and chrysanthemum aroma made people feel bored due to the milder stimulation and fewer emotional fluctuations.

PLSR analysis was then used to investigate the relationships between sensory attributes (X variables) and the clustered emotion lexicon (Y variables) **(Bhumiratana et al., 2014).** For the taste-aroma model, the cumulative Q2 increased from 0.412 to 0.599, and the cumulative Q2 of the color model also increased from 0.283 to 0.520. It seemed that the simplified model could better predict emotional reactions to sensory attributes. To determine the correlation between consumers' emotions and the sensory attributes of the samples, we calculated the recognition coefficient VIDs for each attribute variable (Appendix A). VID values for each type of emotion and different sensory attributes ranged between -1 and +1 (Kebede et al., 2018). Attributes with a VID coefficient greater than 0.400 were considered highly correlated with the emotion and likely to elicit specific emotional responses. Attributes such as smoothness, chrysanthemum, and cucumber flavour seemed to soothe consumers and make people feel calm, though they also induced boredom due to their blandness. Sweetness, sophora flower, rice soup, and soy milk not only brought comfort but also enhanced happiness and satisfaction, thus improving the drinking experience and bringing pleasure.

Conversely, consumers disliked attributes such as bitterness, astringency, sourness, and wormwood. Tasting samples with these characteristics often led to emotions such as being active, aggressive, and finding the samples disgusting. Bhumiratana et al. (2019) found that bitterness in coffee could enhance consumer energy, classifying "active" as positive-high energy feelings, while bitterness in chrysanthemum elicited negative-high energy feelings, further illustrating the need to regroup the emotion lexicon in different food contexts. Additionally, some attributes had a weak correlation with emotional changes (yellow, barley, raw bean, pea, Platostoma palustre, vegetable core, sour bamboo shoots, Houttuynia cordata), with VID coefficients below 0.4. The polarizing preferences for attributes like sour bamboo shoots and Houttuynia cordata led to inconsistent emotional responses among consumers, resulting in weak correlations with sensory attributes.

By integrating emotional lexicons with sensory attributes, the enhanced sensory wheel offers a multidimensional tool to understand the intricate relationship between sensory experiences and emotional responses. This approach aids in differentiating chrysanthemum infusion samples and provides valuable insights for tailoring products to match consumer preferences and enhance overall satisfaction.

3.3 Development of the emo-sensory wheel for chrysanthemum infusion

The emo-sensory wheel of chrysanthemum infusion was developed based on the sensory wheel obtained in Section 3.1.1. Using the descriptive terms generated by the panel, the sensory wheel was modified and supplemented, with some color attributes removed and some taste attributes added. The final wheel consists of 35 sensory attributes and 6 emotional dimensions, forming a new four-tiered sensory wheel that clearly displays the sensory and emotional profile of the samples. The inner tier of the wheel contains the three major sensory modalities: appearance, taste, and aroma. The second tier represents the categories of specific attributes, while the third tier details the specific sensory attributes. The outer tier displays the emotions elicited by these sensory attributes, based on the results of the PLSR analysis and the simplified emotion lexicon.

The new chrysanthemum emo-sensory wheel indicates significant differences in the relationship between various sensory attributes of chrysanthemum infusion and the emotional responses they elicit. This tool allows researchers and product developers to segment sensory attributes with similar emotional characteristics. For instance, the flavour of cucumber and chrysanthemum does not lead to increased physiological arousal, evoking only emotions in the categories of "tame" and "bored." In addition to having a strong correlation with these emotions, the sweet taste and floral aroma can bring more “pleasant” and “warm” emotions to consumers while soothing the heart and calming the mind. This indicates that sweet floral beverages can alleviate negative emotions. Conversely, consumers' negative emotions are influenced by characteristics such as bitterness, astringency, and vegetal aroma. Unlike vegetal aroma, bitterness and astringency are also associated with emotions that have a larger arousal change, such as "active."

The sensory lexicon and emo-sensory wheel of chrysanthemum are based on only 8 varieties of chrysanthemum samples, which is a relatively small sample size. Further research is needed to determine if the generated attribute and emotion lexicon are widely applicable to all varieties of chrysanthemum. By analyzing more varieties of chrysanthemum samples, we aim to expand and validate the chrysanthemum sensory wheel. The original emotion lexicon used in this study was EsSense 25, developed by Nestrud et al. (2016), which is applicable to the evaluation of common foods. Hu and Lee (2019) developed a specific emotion lexicon for coffee drinking, considering cultural and contextual influences and conducting a consumer-led translation of emotion terms from coffee drinking experience into Chinese and Korean. We will also attempt to translate a version of the emotion lexicon that is more suitable for chrysanthemum consumers in various countries based on different cultural backgrounds. Further research on the chrysanthemum emotion lexicon may be valuable for understanding the emotional responses of chrysanthemum consumers with different preferences.

4. Conclusions

By establishing an emo-sensory wheel, the key sensory attributes influencing consumer preferences were identified. The results of Quantitative Descriptive Analysis (QDA) validated the chrysanthemum sensory lexicon, confirming that the sensory terms could effectively distinguish between different chrysanthemum samples. The consumer-led Check-All-That-Apply (CATA) analysis further revealed the variations in emotions elicited by different varieties of chrysanthemum infusion. To better understand the relationship between sensory attributes and emotional reactions, we developed a reduced chrysanthemum emotion lexicon, clustering the EsSense25 terms into six aspects: pleasant, tame, warm, active, negative, and bored. The Partial Least Squares Regression (PLSR) results demonstrated that sensory descriptive data could be used to identify which attributes influence emotional responses in consumers, thereby describing the emotion profiles elicited by chrysanthemum infusion. Unlike the traditional hedonic scale method, the use of an emotion lexicon allowed for the subdivision of samples with similar degrees of preference, identifying sensory drivers for the emotions experienced by each cluster. This approach is valuable for both market segmentation and product development, offering insights that can enhance consumer satisfaction and guide the creation of products that align more closely with consumer emotional responses.

CRediT authorship contribution statement

Yixun Xia: Conceptualization, Data curation, Formal analysis, Methodology, Writing - original draft. Jiaoliang Hou: Methodology, Supervision. Jiayi Qian: Conceptualization, Methodology, Data curation. Feifei Zhao: Conceptualization, Methodology. Gangqiang Dong: Conceptualization, Methodology, Supervision. Charles Spence: Methodology, Writing - review & editing. Fang Zhong: Conceptualization, Methodology, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Table 1. Code, variety and origin of the chrysanthemum infusion under study.

Code	Variety	Origin
S1	BoJu	Bozhou, Anhui Province
S2	ChuJu	Chuzhou, Anhui Province
S3	HuangJu	Wuyuan, Jiangxi Province
S4	JiaJu	Jiaxiang, Shandong Province
S5	HangBaiJu	Lanxi, Zhejiang Province
S6	QiBaiJu	Anguo, Hebei Province
S7	HangBaiJu	Yuncheng, Shanxi Province
S8	XueJu	Hetian, Xinjiang Province

Table 2. M-value of sensory descriptors of Chrysanthemum infusion.

Descriptor	*F-value* [a]	*I-value* [b]	*M-value* [c]	Descriptor	*F-value* [a]	*I-value* [b]	*M-value* [c]
Red	0.958	1.000	0.979	Honey	0.083	0.333	0.167
Orangey-red	0.833	1.000	0.913	Lime	0.010	0.333	0.057
Golden	0.284	1.000	0.533	Rice soup	0.867	0.667	0.760
Bright yellow	0.308	1.000	0.555	Milk	0.042	0.333	0.118
Yellow-green	0.643	1.000	0.802	Pine nut	0.050	0.333	0.129
Grass-green	0.149	1.000	0.386	Peanut	0.022	0.667	0.122
Bright	0.694	0.667	0.680	Roasted	0.021	0.333	0.083
Light	0.867	0.667	0.760	Barley	0.031	0.333	0.101
Clear	0.900	1.000	0.949	Wolfberry	0.067	1.000	0.258
Bitter	0.967	1.000	0.983	Fermented bamboo shoots	0.035	0.333	0.108
Sweet	0.639	0.333	0.461	Houttuynia cordata	0.036	0.333	0.110
Sweet after taste	0.367	0.333	0.350	Cabbage	0.900	0.333	0.548
Sour	0.333	0.333	0.333	Chrysanthemum	0.933	1.000	0.966
Umami	0.011	0.333	0.061	Sophora flower	0.400	0.333	0.365
Salty	0.003	0.333	0.030	Jasmine	0.004	0.333	0.037
Transient	0.200	0.667	0.365	White plum blossoms	0.008	0.333	0.053

Clean	0.067	0.333	0.149	Platostoma palustre	0.767	0.333	0.506
Lingering	0.200	0.333	0.258	Lotus leaf	0.013	0.333	0.065
Smooth	0.667	1.000	0.816	Soy milk	0.533	0.667	0.596
Astringent	0.800	0.667	0.730	Raw bean	0.367	0.667	0.494
Rough	0.017	0.333	0.075	Pea	0.433	0.333	0.380
Thin	0.489	0.333	0.404	Mung bean porridge	0.003	0.333	0.030
Oolong tea	0.067	1.000	0.258	Cucumber	0.733	0.667	0.699
Raw vegetable	0.011	0.333	0.061	Mint	0.600	1.000	0.775
Earth	0.600	1.000	0.775	Watermelon rind	0.026	0.333	0.094
Dust	0.011	0.667	0.086	Sugarcane	0.028	0.333	0.096
Pine needles	0.100	0.333	0.183	Pear	0.021	0.333	0.083
Camphor wood	0.028	0.333	0.096	Wormwood	0.933	1.000	0.966
Pine rosin	0.067	0.333	0.149	Licorice	0.026	0.333	0.094
Wet bark	0.025	0.333	0.091	Raw potatoes	0.010	0.333	0.057
Herbal	0.667	1.000	0.816	Pod	0.014	0.333	0.068
Sweet rice wine	0.200	0.667	0.365	Fennel	0.004	0.333	0.037
Cinnamon	0.006	0.333	0.043	Roasted coffee	0.096	0.333	0.179
Jujube	0.018	0.333	0.078	Brown	0.007	0.333	0.048

sugar

[a] F represents the frequency of a descriptor's mention as a percentage of the total possible references.
[b] I denotes the average intensity given to a descriptor by the focus groups, expressed as a percentage of the maximum possible intensity. [c] M is geometric mean, M = $\sqrt{M \times I}$.

Table 3. Definition and reference of *Chrysanthemum* infusion descriptive attributes.

Description	Definition	References
Yellow(a) [a]	Shade of yellow	Pantone 393=3 394=8 396=12
Green(a) [a]	Shade of green	Pantone 379=3 380=8 382=12
Red(a) [a]	Shade of red	Pantone 1485=3 1505=8；021=12
Initial bitterness(t) [b]	The maximum intensity of bitterness felt at the beginning of drinking (1-2s)	
Mid-tasting bitterness(t) [b]	The maximum intensity of bitterness felt during a stay in the mouth for 5 seconds	0.03% lotus plumule solution =3 0.05% lotus plumule solution =6 0.08% lotus plumule solution =10
Aftertaste bitterness(t) [b]	The maximum intensity of bitterness felt after swallowing (including aftertaste)	
Initial sweetness(t) [b]	The maximum intensity of sweetness felt when starting to drink (1-2s)	
Mid-tasting sweetness(t) [b]	The maximum intensity of sweetness felt with drink in the mouth for 5 seconds	0.3% sucrose solution =2 0.5% sucrose solution =5
Aftertaste sweetness(t) [b]	The maximum intensity of sweetness felt after swallowing (including aftertaste)	0.008% aspartame solution =3 0.009% aspartame solution =7
Sourness(t) [b]	The maximum intensity of sourness felt while drinking	0.005% citric acid solution monohydrate =2 0.01% citric acid solution monohydrate =6
Astringency(m) [c]	A feeling of a puckering or a tingling sensation on the surface and/or edge of the tongue and mouth	0.012% alum solution =3 0.024% alum solution =6
Smoothness(m) [c]	The degree of full-bodied and smooth	5.0% skim milk =5

	mouthfeel during drinking	
Chrysanthemum (o/r) [de]	Aromatics associated with traditional chrysanthemum tea	0.2% Hangbaiju solution =3 0.5% Hangbaiju solution =6 1.0% Hangbaiju solution =10
Chinese herbal medicine (o/r) [de]	Aromatics associated with Chinese herbal medicine	0.05% Yejuhua solution =2 0.20% Yejuhua solution =5
Sophora flower(o/r) [de]	Aroma of sophora flower	0.05% sophora flower solution =2 0.50% sophora flower solution =7
Earth(o/r) [de]	Aromatics associated with wet earth	0.05% liquorice solution =4 0.20% liquorice solution =8
Platostoma palustre(o/r) [de]	Typical flavour of Platostoma palustre in herbal tea	10.0% Wanglaoji herbal tea =3 50.0% Wanglaoji herbal tea =6
Wormwood(o/r) [de]	Aroma of wormwood	0.5% Hangbaiju solution =3 1.0% Hangbaiju solution =5 5.0% Hangbaiju solution=10
Raw bean(o/r) [de]	Aroma of raw bean	1.0% raw soybean powder solution =4 10.0% raw soybean powder solution =8
Soy milk(o/r) [de]	Sweet flavour of soy milk	0.5% low-sugar vita soy milk =4 1.0% low-sugar vita soy milk =10
Rice soup(o/r) [de]	Flavour of water vapour when steaming rice	0.1% rice soup =2 0.25% rice soup =6
Mint(o/r) [de]	Typical flavour of mint leaves	0.05% mint solution =3 0.25% mint solution =6
Vegetable core (o/r) [de]	Flavour of water vapour when steaming rice	0.5% cabbage inner core boiling filtrate =4 1.0% cabbage inner core boiling filtrate =9
Sweet ferment rice(o/r) [de]	Flavour of sweet ferment rice	50.0% Xinghualou sweet ferment rice =6

Cucumber(o/r) [de]	Fresh flavour of cucumber	1.0 Dutch cucumber slices =6
Wolfberry(o/r) [de]	Flavour of wolfberry solution	0.5% wolfberry solution =4 1.0% wolfberry solution =8
Oolong tea(o/r) [de]	Flavour of oolong tea	50.0% Suntory oolong tea =6
Roasted coffee(o/r) [de]	Flavour of roasted coffee	0.5g Nescafe espresso powder =8
Pine nuts(o) [d]	Flavour of unshelled pine nuts	1.0 g pine nuts =5
Pea(o) [d]	Aroma of greenery which is typical of peas	1.0 g frozen peas =6
Pine needles(o) [d]	Aroma of dried pine needles	1.0 g pine needles =5
Pine rosin(o) [d]	Aroma of galbanum	1.0 g galbanum =6
Houttuynia cordata(o) [d]	Aroma of houttuynia cordata	1.0 g houttuynia cordata =8
Sour bamboo shoots(o) [d]	Typical flavour of sour bamboo shoots	0.1% sour bamboo shoot solution =8
Barley(o) [d]	Aroma of boiled barley tea	0.5% barley tea =8

[a] *a* represents appearance attributes. [b] *t* represents taste attributes. [c] *m* represents mouthfeel attributes. [d] o represents orthonasal olfactory attributes for sniffing. [e] r represents retronasal olfactory attributes during tasting.

Table 4. Six factors of emotional terms from EsSense 25.

Factor	Emotion terms
Pleasant	Happy, joyful, good, interested, pleasant, good natured, satisfied, loving, free
Tame	Secure, understanding, calm, tame
Active	Enthusiastic, adventurous, aggressive, wild, active
Warm	Warm
Negative	Nostalgic, disgusted, guilty, worried
Bored	Mild, bored

Fig. 1. Chrysanthemum infusion sensory wheel

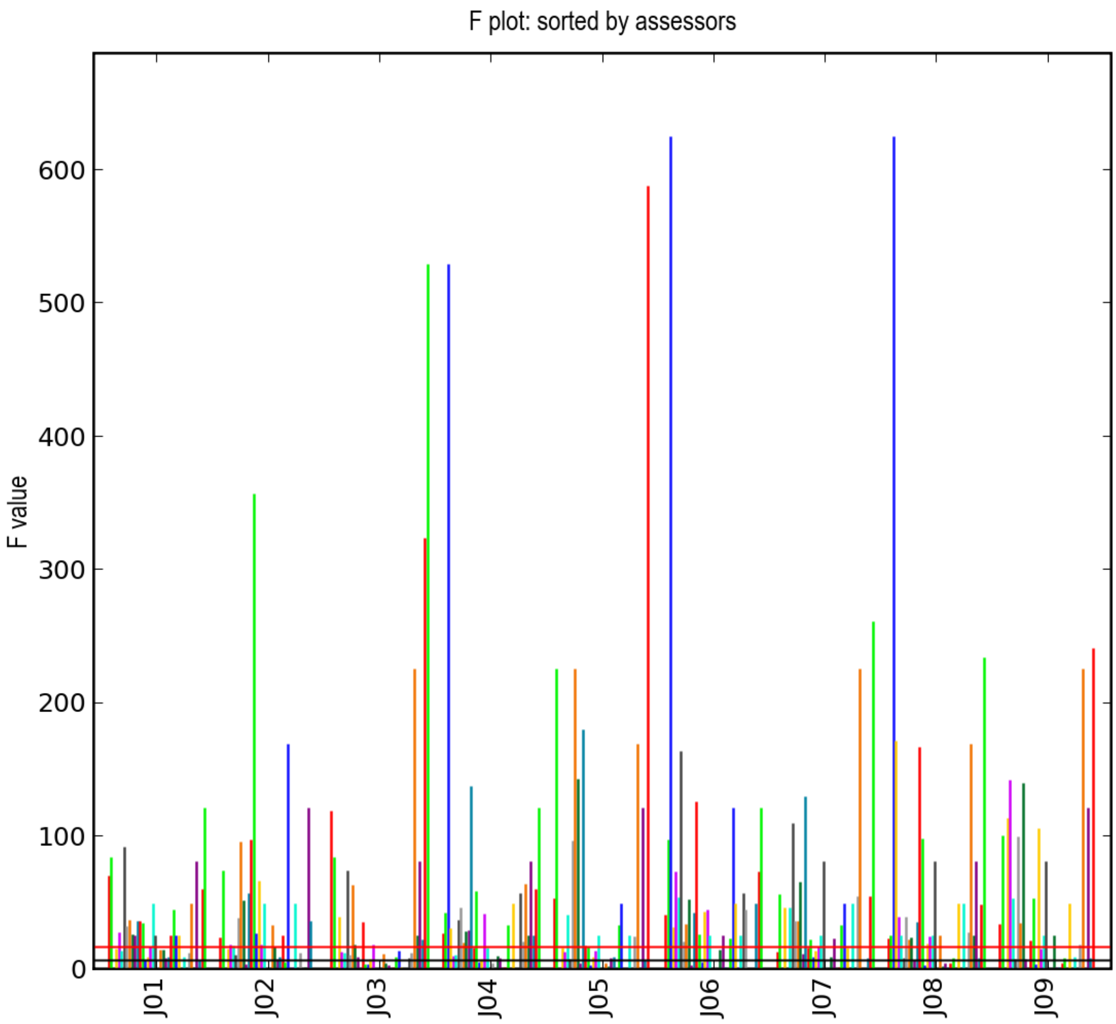


Fig. 2. F plots visualising the panelists’ ability to discriminate between the tested samples for each attribute. J01, J02, J03, etc. represent different panelists.

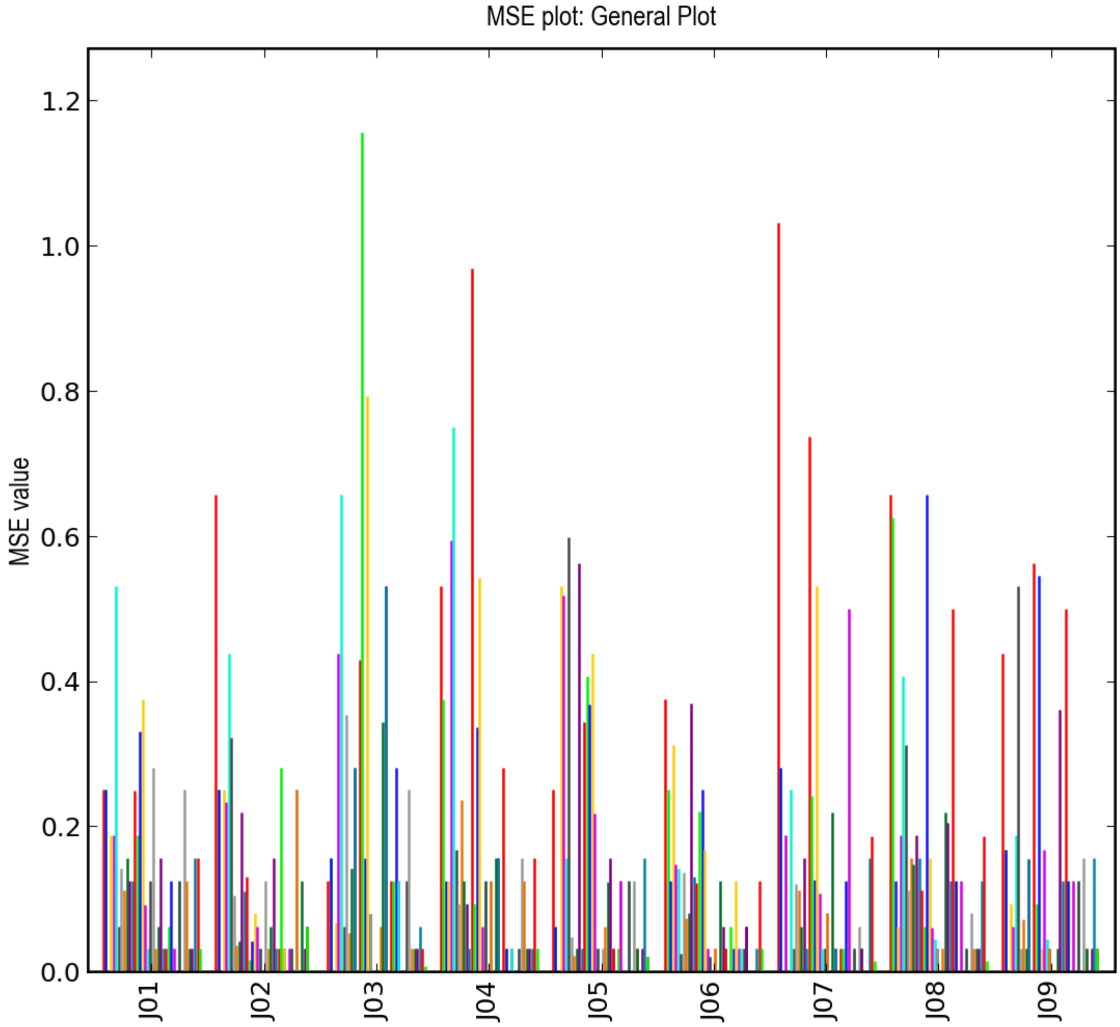


Fig. 3. MSE plot visualizing the repeatability of each panelist. J01, J02, J03, etc. represent different panelists.

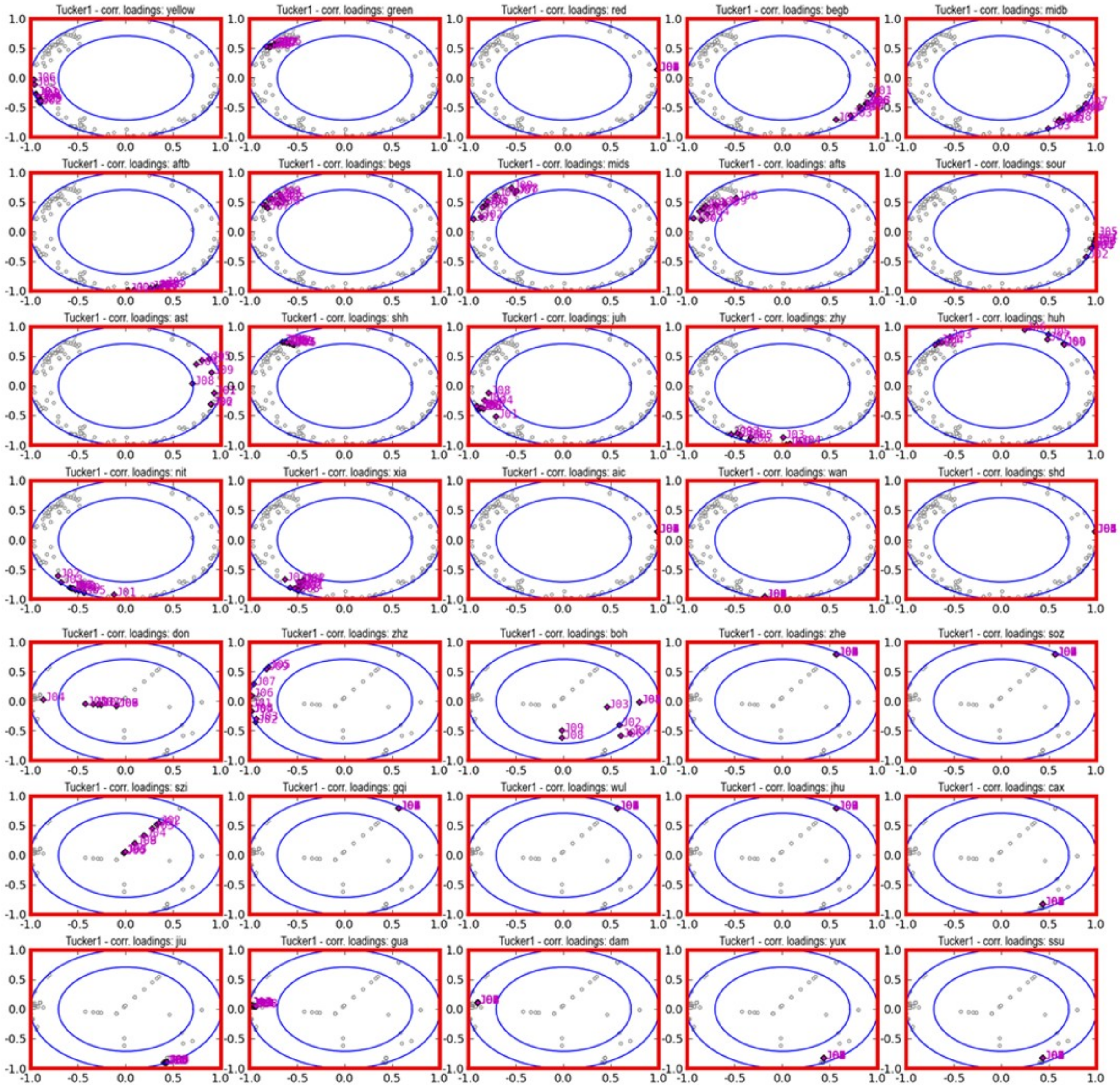
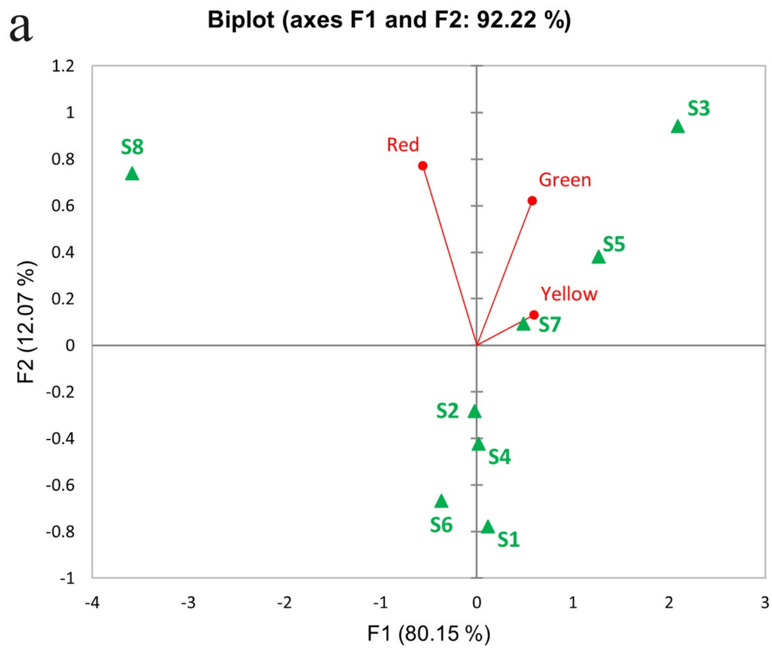
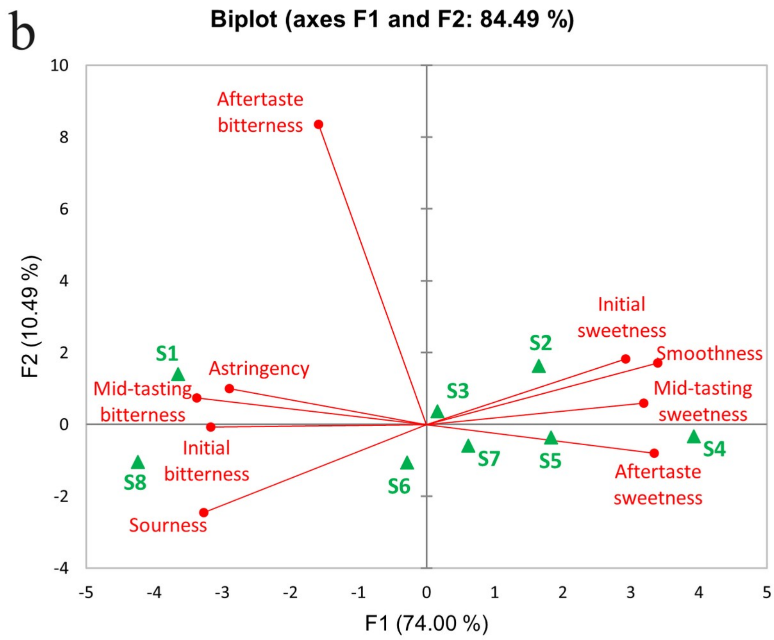


Fig. 4. 35 identical Tucker-1 plots with each plot highlighting one of the 35 attributes used in the profiling. The plots are based on raw data of panelists J01-J09.


a
Biplot (axes F1 and F2: 92.22 %)
F2 (12.07 %)
F1 (80.15 %)
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-4
-3
-2
-1
0
1
2
3
S8
S3
Red
Green
S5
Yellow
S7
S2
S4
S6
S1


b
Biplot (axes F1 and F2: 84.49 %)
F2 (10.49 %)
F1 (74.00 %)
10
8
6
4
2
0
-2
-4
-5
-4
-3
-2
-1
0
1
2
3
4
5
Aftertaste bitterness
Initial sweetness
S2
Smoothness
S1
Astringency
S3
Mid-tasting sweetness
Mid-tasting bitterness
Initial bitterness
S4
S7
S5
S8
S6
Aftertaste sweetness
Sourness

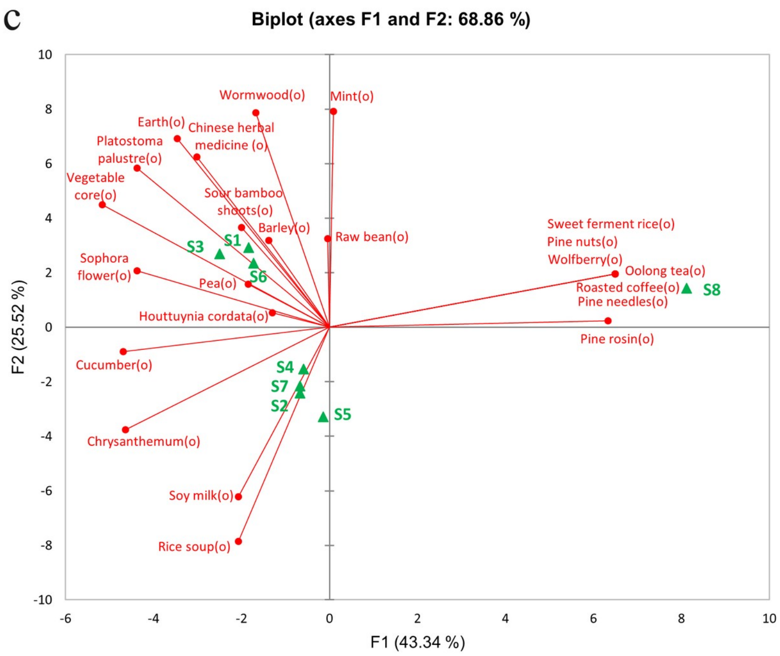
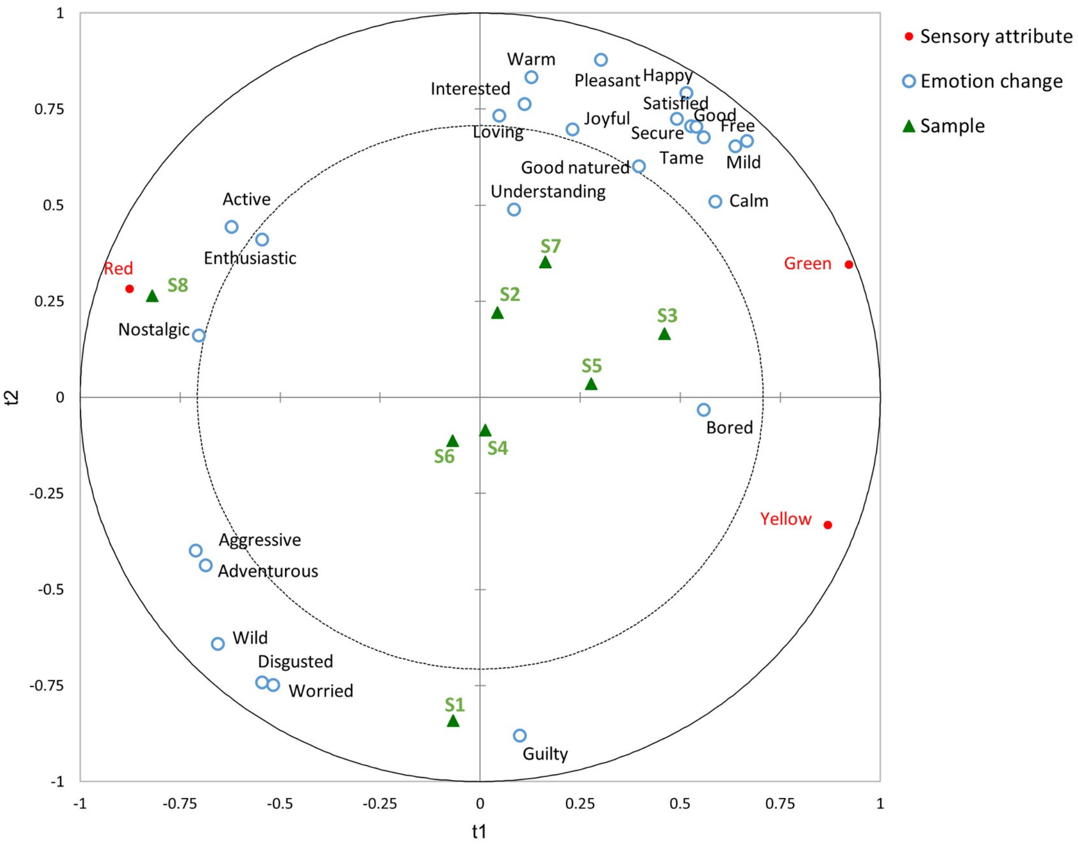


Fig. 5. PCA analysis of significant attributes for the eight chrysanthemum samples (S1 - S8) on (a) color, (b) taste and mouthfeel, (c) aroma. S1 represents "BoJu", S2 represents "ChuJu", S3 represents "HuangJu", S4 represents "JiaJu", S5 represents "Lanxi HangBaiJu", S6 represents "QiBaiJu", S7 represents "Yuncheng HangBaiJu", and S8 represents "XueJu".

a


Sensory attribute
Emotion change
Sample
Warm
Pleasant
Happy
Interested
Satisfied
Joyful
Good
Loving
Secure
Free
Tame
Mild
Good natured
Understanding
Calm
Active
Enthusiastic
S7
Green
Red
S8
S2
S3
Nostalgic
S5
Bored
S6
S4
Yellow
Aggressive
Adventurous
Wild
Disgusted
Worried
S1
Guilty
t1
t2
1
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
-1
-1
-0.75
-0.5
-0.25
0
0.25
0.5
0.75
1

b

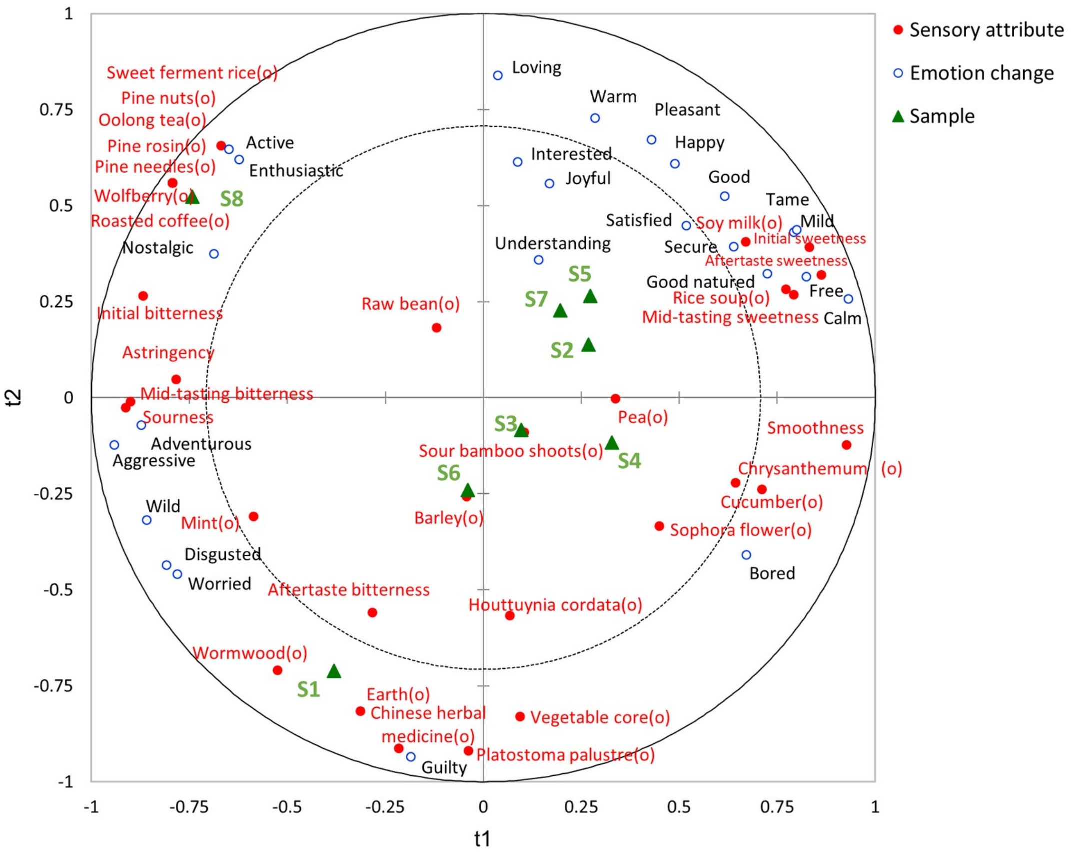


Fig. 6. Correlation load diagram of PLSR model for emotion changes and (a) colour, (b) taste and aroma attributes. (a) Q^2=0.283, R^2Y=1.000, R^2X=0.809. (b) Q^2=0.412, R^2Y=0.897, R^2X=0.870. S1, S2, S3, etc. represent different varieties of chrysanthemum samples. S1 represents “BoJu”, S2 represents “ChuJu”, S3 represents “HuangJu”, S4 represents “JiaJu”, S5 represents “Lanxi HangBaiJu”, S6 represents “QiBaiJu”, S7 represents “Yuncheng HangBaiJu”, S8 represents “XueJu”.

Fig. 7. Chrysanthemum infusion sensory wheel affiliated with emotions.