HERBAL DRINK FORMULATION OPTIMIZATION OF TROLLIUS CHINENSIS BUNGE BY SENSORY FUZZY COMPREHENSIVE EVALUATION

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ABSTRACT

Background. Trollius chinensis Bunge is a common herbal plant used for pharmaceutical and food resources in China. The dry flowers of Trollius chinensis Bunge are also treated as a traditional Chinese tea for daily drinking, yet the Trollius chinensis Bunge tea will exhibit a bitter taste in a certain concentration range and is not always accepted among consumers. The aim of the study was to design a herbal drink with a good flavor and optimize the formulation.

Materials and methods. Trollius chinensis Bunge was purchased and ground. The sensory fuzzy comprehensive evaluation method and the orthogonal test were applied to optimize the formulation of the Trollius chinensis Bunge herbal drink.

Results. The results showed that the optimum formulation was as follows: an addition amount of Trollius chinensis Bunge extract solution of 30%; an addition amount of mint extract solution of 4%; an addition amount of liquorice extract solution of 7%; an addition amount of sugar of 3%; an addition amount of citric acid of 0.15%. The polysaccharide content decreased with an increase in storage time; the stability of the polysaccharides was not significantly affected by storage temperature (P > 0.05). The pH value of the samples was significantly affected by storage temperature (P < 0.01), which was basically unchanged at 4°C and 25°C, and relatively large at 37°C; the stability of color was significantly affected by temperature (0.01 < P < 0.05).

Conclusion. Sensory fuzzy comprehensive evaluation is an useful evaluation method in optimizing the formulation of a herbal drink. These results provide some theoretical basis for the food product development of Trollius chinensis Bunge.

Keywords: Trollius chinensis Bunge, sensory, fuzzy, formulation, optimization

INTRODUCTION

Trollius chinensis Bunge (T. chinensis Bunge) is a species of a genus in the Ranunculaceae family, most of which grow on grass slopes, loose forests and mountains with an altitude of about 1000–2200 m (Li and

Funding: This study was funded by the Scientific Research Foundation for Advanced Talents, Changshu Institute of Technology (Grant no. KYZ2018067Q).

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Liu, 2013). It has been reported that there are many active components in the dry flower of *T. chinensis* Bunge, including flavonoids, polysaccharides, organic acids, volatile oil and other components (An et al., 2015; Chen et al., 2017; Yan et al., 2019). Among them, flavonoids account for approximately 16% of the dried flowers and are considered to be one of the most important active ingredients amongst the dominant compounds it contains (Wang et al., 2008). The dry flowers of *T. chinensis* Bunge are used in traditional Chinese medicine to treat upper respiratory tract diseases, such as pharyngitis, bronchitis and tonsillitis etc. (Guo et al., 2017; Witkowska-Banaszczak, 2015). Many studies have also proved that the dry flower of *T. chinensis* Bunge exhibits significant antioxidant and antibacterial activities (Liu et al., 2013; Lu et al., 2014). In addition, the dry flowers of *T. chinensis* Bunge are also treated as a traditional Chinese tea for daily drinking due to the significant bioactivities in China (Lam et al., 2016). Yet the *T. chinensis* Bunge tea will exhibit a bitter taste in a certain concentration range and is not always accepted among consumers. Therefore, other Chinese herbal foods with a good flavor, such as mint and liquorice, could be added to improve the taste of *T. chinensis* Bunge tea (Zhang et al., 2016). However, from the literature available, there are few studies about making an herbal drink and optimizing the formulation of *T. chinensis* Bunge.

The sensory evaluation method has widely been applied to evaluate food quality in the development of herbal drinks and food engineering and processes for decades (Skelton, 1984) because it possesses the advantages of strong practicability, high sensitivity, simple operation, cost saving and so on. It has quickly been proved to be a significant technical analysis approach for modern food science and the food industry (Muir, 2007). Unfortunately, it is difficult to obtain objective and credible sensory evaluation results because it is often affected by external factors such as the experience and background of assessors, the evaluation environment and the methods, results analysis methods, etc. (Delahunty and Murray, 2001; Lieb et al., 2018). Fuzzy mathematics, which is widely used and solves many problems, is also a mathematical tool for studying such problems with unclear or ambiguous boundaries in the world. Fuzzy mathematics has been used to assist sensory evaluation in the evaluation of food quality due to the uncertainty and fuzziness of sensory descriptions of color, texture, taste and smell during sensory evaluation. It is proposed in the fuzzy evaluation model (Ioannou et al., 2002; Sakre et al., 2015). The characteristic of fuzzy mathematics is that simple linguistic formulations can be used to present complex system behaviors (Birle et al., 2013). Therefore, the sensory evaluation method combined with Fuzzy mathematics could be utilized to reduce the external factors to get relative objective and credible sensory evaluation results, especially in beverage formulation optimizations in the beverage industry. The aim of the study was to obtain a *T. chinensis* Bunge herbal drink with mint and liquorice and to optimize the formulation using a sensory fuzzy comprehensive evaluation. Furthermore, the product stability was investigated under different storage conditions. These results will provide a scientific basis for its application in functional drinks and the development and utilization of natural products in the food industry, amongst other things.

**MATERIALS AND METHODS**

**Materials and reagents**

The dry flower of *T. chinensis* Bunge was purchased from Yakeshi city, Inner Mongolia Autonomous Region, China in January 2019. The liquorice (*Glycyrrhiza uralensis* Fisch., artificial cultured in 2018), and mint (*Mentha haplocalyx* Briq., artificial cultured in 2018) leaves were purchased from Chengde city, Hebei province (located in North China, between 36°05′ – 42°40′N and 113°27′ – 119°50′E), China in January 2019. They were ground into a powder with a mill and then passed through a 40-mesh sieve and stored at room temperature. The reagents, including glucose (Tianjin Damao Chemical Reagent Factory, China, CAS: 50-99-7D), citric acid (Tianjin Damao Chemical Reagent Factory, China, 77-92-9), white sugar (Ganzhou Yunshen Agricultural Development Co., Ltd., China) etc., were all analytical grade.

**Extraction method of material**

All the material was extracted using the distilled water extraction method, taking the polysaccharide as the main component. According to the previous research (Liu et al., 2012), the extraction parameters of *T. chinensis* Bunge were as follows: material liquid ratio
1:60 (g:mL), temperature 80°C, extraction time 3 h, the extraction solution was stirred with a magnetic stirrer (Zhengzhou biochemical instrument Co., Ltd., China, SZCL-3B) and then filtered. From the literature available (You et al., 2014), the extraction parameters of liquorice were as follows: material liquid ratio 1:30 (g:mL), temperature 80°C, extraction time 3 h. The extraction solution was stirred with a stirrer and then filtered. The extraction parameters of mint were as follows (Li et al., 2014): material liquid ratio 1:25 (g:mL), temperature 100°C, extraction time 1 h. The extraction solution was stirred with a stirrer and then filtered. All the filtrate was reserved at 4°C for the experiment.

### Sensory evaluation of drink with different addition amounts of *T. chinensis* Bunge extraction solution

Sensory scoring was carried out on the drink with different addition amounts of *T. chinensis* Bunge extraction solution. Panelists (10 persons, 5 male, 5 female, 20–30 years of age) were selected among staff and students at the Changshu Institute of Technology and trained according to GB/T 16291.1 (2012). Sensory score and criterion are described in Table 1 and Table 2. The sensory criterion was divided into 4 grades of taste, color, aroma and state. The addition amount of the *T. chinensis* Bunge extraction solution was set

| Target          | Standard       | Score       |
|-----------------|----------------|-------------|
|                 | distinction    | good        | average    | poor        |
| Taste           | (76–100)       | (51–75)     | (26–50)    | (1–25)      |
| Coloration      | (76–100)       | (51–75)     | (26–50)    | (1–25)      |
| Status          | (76–100)       | (51–75)     | (26–50)    | (1–25)      |
| Aroma           | (76–100)       | (51–75)     | (26–50)    | (1–25)      |
| Suggestion      |                |             |            |             |
| Date            |                |             |            |             |
|                 |平均 score     |             |            |             |

Table 2. The criterion of sensory evaluation

| Distinction (76–100) | The color of the product is light yellow, pure and uniform. |
|----------------------|-------------------------------------------------------------|
| Good (51–75)         | The color is uniform and light yellow.                     |
| Medium (26–50)       | The color is uniform with a little impurity.               |
| Poor (1–25)          | The color is extremely nonuniform and dark.                |
| The taste is moderate, soft and refreshing, there is no bitterness. |
| The taste is slightly strong or light, soft and refreshing.         |
| The taste is strong or light, there is a little bitterness. The sour and sweet taste are not appropriate. |
| The taste is very strong or not obvious, the bitterness is heavy. The sour and sweet taste are not appropriate. |

| Distinction (76–100) | The aroma is fresh and pleasant, harmonious and uniform. |
|----------------------|-------------------------------------------------------------|
| Good (51–75)         | The aroma is slightly strong or light and harmonious.       |
| Medium (26–50)       | The aroma is light, with a slight odor, and it is not harmonious. |
| Poor (1–25)          | The aroma is light or strong and is not pleasant.           |
| It is clear, transparent without impurities, and good fluidity.  |
| It is clear and transparent, free of impurities and has good fluidity. |
| It is slightly clear and transparent, with impurities and fluidity. |
| It is not clear or transparent enough, with many impurities and poor fluidity. |
as 10%, 20%, 30%, 40% and 50%, the number of samples was 5, and the sample temperature was 20°C. The samples were encoded with random 3-digit numbers; each sample was submitted twice to each panelist; purified water was used to cleanse the mouth between samples (Chen et al., 2016). The sensory tests were conducted in a sensory analysis laboratory equipped with individual booths (room temperature 24°C, relative humidity 50% and combined artificial light with color temperature of 6500K), designed according to ISO 8589 (1988). The laboratory was located in room 309, Duxing Building, Changshu Institute of Technology. The session was conducted at most twice a day and took about 2 h each time. The addition amounts of other ingredients were as follows: liquorice 5%; mint extract 2.5%; cyclamate 0.05%; sugar 2.5%; citric acid 0.25%; liquorice 5%.

The sensory fuzzy comprehensive evaluation method

Establishment of evaluation domain. The number of samples was 29 and other sensory evaluation conditions were the same as above. Evaluation domain refers to a set of indicators that best reflect the quality of the food, usually expressed by $U = \{ u_1, u_2, u_3, ..., u_k \}$, with $u$ representing the evaluation indicators of the evaluated food. The evaluation indicators are taste, color, aroma and state; they are represented by $u_1$, $u_2$, $u_3$, and $u_4$, respectively. The evaluation domain of the herbal drink is set as $U = \{ u_1, u_2, u_3, u_4 \}$ (Debjani et al., 2013; Mukhopadhyay et al., 2013).

Establishment of comment domain. Comment domain refers to a complete collection of all evaluation results and feedback information after sensory evaluation of the food by all assessors. The process of establishing the evaluation domain is actually the process of determining the level of evaluation results. It is usually expressed as $V = \{ v_1, v_2, v_3, ..., v_n \}$. $V$ indicates the corresponding evaluation grade or score. In this experiment, $V$ represents the evaluation level. The evaluation results of herbal drink are divided into four grades of excellent, good, medium and poor, which are represented by $v_1$, $v_2$, $v_3$ and $v_4$, respectively. The comment domain of the herbal drink is set as $V = \{ v_1, v_2, v_3, v_4 \}$ (Hmar et al., 2017).

Setting the weight vector. Each evaluation indicator we measured has a different influence on the taste of the sample, so we can determine a weight vector according to the weight value of each indicator, which is $A = \{ a_1, a_2, a_3, ..., a_k \}$. $A$ corresponds to $U$, and $A$ is a fuzzy subset of $U$. The weight vectors were set as coloration, taste, aroma and status. Based on the experience, the assessors allocated 10 points to four evaluation indicators in the table and determined the weight vector after statistical analysis (Sakre, 2015).

Establishment of the fuzzy matrix. According to the evaluation results of the assessors, the fuzzy matrix was determined. The fuzzy matrix is expressed as $R = (r_{ij})$, where $r_{ij}$ represents the ratio of the number of people who chose this grade in the matrix to the total number of assessors (Sinija and Mishra, 2011).

Calculation of the comprehensive membership degree and comprehensive score. The calculation of the comprehensive membership degree of the samples is expressed as the calculation of the weight vector and fuzzy matrix by the matrix multiplication, $Y = A \cdot R = (b_1, b_2, b_3, ..., b_n)$. The calculation formula of the comprehensive score is $H = \Sigma b_j$. The comprehensive score is between 1–4; the 1, 2, 3 and 4 represent excellent, good, medium and poor, respectively. If the score is between 3 and 4, or the product score is close to 3, the product tends to be medium. If the score is between 1 and 2, or the product score is close to 1, the product tends to be excellent.

Orthogonal experimental design for herbal drink.

Taking the addition amount of the liquorice extract, mint extract, sugar and citric acid as factors, $L_9(3^4)$ orthogonal experiment was designed to optimize the

Table 3. Factor level of orthogonal experiment

|   | A  | B  | C  | D  |
|---|----|----|----|----|
| 1 | 3  | 5  | 2.5| 0.15|
| 2 | 3.5| 6  | 3  | 0.2 |
| 3 | 4  | 7  | 3.5| 0.25|

A – amount of mint, %, B – amount of liquorice, %, C – amount of sugar, %, D – amount of citric acid, %.
herbal drink formula and the sensory fuzzy comprehensive score was used as the standard of optimization. The single factor design is exhibited in Table 3. The general addition amount of raw and subsidiary materials was: *T. chinensis* Bunge extract 30%; licorice extract 5%; mint extract 2.5%; sugar 2.5%; citric acid 0.25%; cyclamate 0.05%.

**Determination of polysaccharide.** The phenol-sulfuric acid (PSA) method was used to determine the polysaccharide content of the herbal drink (Hu et al., 2018). Firstly, the glucose standard curve was analyzed. Glucose dried to a constant weight (105°C) of 50.00 mg was accurately weighed and diluted into a 100 mL volumetric flask to prepare the glucose standard solution. Solutions of 0.0 mL, 4.0 mL, 8.0 mL, 12.0 mL, 16.0 mL and 20.0 mL were aspirated and diluted into a 100 mL volumetric flask to obtain different concentrations of glucose diluent, respectively. The above diluent of 0.5 mL was aspirated into a 10.0 mL test tube, then 1.0 mL of 5% phenol was added, and concentrated sulfuric acid of 5.0 mL was immediately added. The solution was shaken well and left to react in a 40°C water bath for 30 minutes, and then put in a cold-water bath for 10 minutes. The absorbance was measured under the wavelength of 490 nm to determine the glucose content. Taking the glucose content as abscissa and the absorbance value as ordinate, the glucose standard curve was obtained. Secondly, the polysaccharides in the herbal drink was determined. A sample solution of 5.0 mL was added to a test tube of 30.0 mL, then 1.0 mL of 5% phenol was added and concentrated sulfuric acid of 5.0 mL was immediately added. The test tube was shaken well and left to react in a 40°C water bath for 30 min and then put in a cold-water bath for 10 min. The absorbance was measured at 490 nm. According to the measured absorbance value and the standard curve equation of glucose, the content of polysaccharides was calculated. The standard curve of glucose is shown in Figure 1. The linear regression equation was:

\[ y = 5.7729x + 0.0005; \quad R^2 = 0.9994 \]

It can be seen from the figure that the correlation coefficient of the linear regression equation is 0.9994, which proved the correlation was good in the content range of 0–0.12 mg/mL. The content of polysaccharides was calculated according to the linear regression equation.

**Processing technology of the herbal drink.** The prepared sample was filtered, clarified and homogenized (High pressure homogenizer, SRH 60-70, Shanghai shenlu homogenizer Co., Ltd., China), and then sterilized and sealed. The pasteurization method was used to sterilize the herbal drink, at 80°C with a sterilization time of 30 minutes. This method is easy to operate and does little damage to the nutrients in the beverage (Cifelli et al., 2010). Finally, the sample was sealed using a small beverage filling machine (Huili high cup sealing machine, WY-802D, Foshan Nanhai Bofei mechanical and Electrical Equipment Co., Ltd., China) in a sterile environment (Li et al., 2017).

**Stability evaluation of the herbal drink.** After sterilization and sealing, the samples were placed at 4°C, 25°C and 37°C for one month. The polysaccharide content was determined by PSA, the pH value was determined by acidometer (PH-100, Bangxi Instrument Technology Co., Ltd., China), and the color change was measured by the absorbance under a wavelength of 360 nm (Gül et al., 2017). In this experiment, according to the national standard (GB 4789.2-3-2016 of China), the total number of colonies and *Escherichia coli* were detected as microbial indicators.
RESULTS AND DISCUSSION

Determination of the addition amount of the *T. chinensis* Bunge extraction solution
The addition amount of the *T. chinensis* Bunge extraction solution was directly determined by sensory evaluation, because it was not designed as a single factor. From the results of the sensory evaluation observed in Table 4, the addition amount was set as 30%.

Table 4. Sensory evaluation results of addition amount with *T. chinensis* Bunge extraction solution

| Amount | 10% | 20% | 30% | 40% | 50% |
|--------|-----|-----|-----|-----|-----|
| Grade  | poor| good| excellent| medium| poor|

Evaluation of single factor using the sensory fuzzy comprehensive scoring method
Weight vector setting results of sensory evaluation. From the sensory evaluation, the results of the weight vector setting are shown in Table 5. The weight of the herbal drink was taste 43%, color 20%, aroma 18% and status 19%, the weight vector $A = (0.43, 0.2, 0.18, 0.19)$.

Table 5. The score of the weight vector setting survey

| Target  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Total | Weight % |
|---------|---|---|---|---|---|---|---|---|---|---|-------|-----------|
| Taste   | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 4 | 4 | 43    | 43        |
| Color   | 1 | 2 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 20    | 20        |
| Aroma   | 2 | 1 | 2 | 1 | 3 | 2 | 2 | 1 | 3 | 1 | 18    | 18        |
| Status  | 3 | 3 | 2 | 1 | 1 | 1 | 2 | 1 | 3 | 1 | 19    | 19        |

Calculation results of the sensory fuzzy comprehensive scoring method. The assessor’s choices of different grades for the single factor test of mint (101–105), liquorice (201–205), sugar (301–305) and citric acid (401–405) are shown in Table 6.

Table 6. Summary of evaluator choices of different grades for single factor test

| No. | Taste | Coloration | Status | Aroma |
|-----|-------|------------|--------|-------|
|     | A    | B | C | D | A | B | C | D | A | B | C | D |
| 101 | 1 | 2 | 7 | 0 | 8 | 2 | 0 | 0 | 5 | 4 | 1 | 0 | 4 | 5 | 1 | 0 |
| 102 | 1 | 7 | 2 | 0 | 9 | 1 | 0 | 0 | 7 | 3 | 0 | 0 | 5 | 4 | 1 | 0 |
| 103 | 0 | 5 | 5 | 0 | 7 | 3 | 0 | 0 | 6 | 1 | 3 | 0 | 4 | 4 | 2 | 0 |
| 104 | 3 | 3 | 4 | 0 | 9 | 1 | 0 | 0 | 7 | 3 | 0 | 0 | 5 | 2 | 3 | 0 |
| 105 | 0 | 7 | 3 | 0 | 8 | 2 | 0 | 0 | 8 | 2 | 0 | 0 | 7 | 3 | 0 | 0 |
| 201 | 4 | 6 | 0 | 0 | 9 | 1 | 0 | 0 | 9 | 1 | 0 | 0 | 7 | 3 | 0 | 0 |
| 202 | 4 | 6 | 0 | 0 | 8 | 2 | 0 | 0 | 8 | 2 | 0 | 0 | 8 | 2 | 0 | 0 |
| 203 | 4 | 6 | 0 | 0 | 7 | 2 | 1 | 0 | 6 | 4 | 0 | 0 | 6 | 4 | 0 | 0 |
| 204 | 3 | 7 | 0 | 0 | 7 | 3 | 0 | 0 | 7 | 3 | 0 | 0 | 7 | 3 | 0 | 0 |
| 205 | 3 | 6 | 1 | 0 | 7 | 3 | 0 | 0 | 6 | 3 | 1 | 0 | 8 | 2 | 0 | 0 |
| 301 | 2 | 4 | 3 | 1 | 6 | 4 | 0 | 0 | 6 | 2 | 2 | 0 | 4 | 5 | 1 | 0 |
| 302 | 1 | 6 | 2 | 0 | 5 | 2 | 3 | 0 | 4 | 2 | 4 | 0 | 3 | 6 | 1 | 0 |
| 303 | 2 | 5 | 3 | 0 | 6 | 4 | 0 | 0 | 5 | 2 | 3 | 0 | 3 | 7 | 0 | 0 |
| 304 | 3 | 6 | 1 | 0 | 6 | 4 | 0 | 0 | 6 | 3 | 1 | 0 | 4 | 5 | 1 | 0 |
| 305 | 5 | 3 | 2 | 0 | 7 | 3 | 0 | 0 | 7 | 2 | 1 | 0 | 4 | 5 | 1 | 0 |
| 401 | 7 | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 8 | 1 | 1 | 0 | 9 | 1 | 0 | 0 |
| 402 | 7 | 3 | 0 | 0 | 9 | 1 | 0 | 0 | 9 | 1 | 0 | 0 | 8 | 2 | 0 | 0 |
| 403 | 5 | 5 | 0 | 0 | 9 | 1 | 0 | 0 | 9 | 1 | 0 | 0 | 8 | 2 | 0 | 0 |
| 404 | 4 | 6 | 0 | 0 | 8 | 2 | 0 | 0 | 9 | 1 | 0 | 0 | 8 | 2 | 0 | 0 |
| 405 | 2 | 8 | 0 | 0 | 6 | 4 | 0 | 0 | 9 | 1 | 0 | 0 | 7 | 3 | 0 | 0 |

A – excellent, B – good, C – medium, D – poor.

No. 101 was taken as an example to calculate the sensory fuzzy comprehensive score. The specific calculation steps are as follows:

Fuzzy matrix:

$$R_{101} = (r_{ij}) = \begin{bmatrix} 1 & 2 & 7 \\ 10 & 10 & 10 \\ 8 & 2 & 0 \\ 10 & 10 & 4 \\ 5 & 1 & 0 \\ 10 & 10 & 10 \end{bmatrix}$$
Wight vector:

$$A = (0.43, 0.2, 0.18, 0.19)$$

Comprehensive membership degree:

$$Y = A \cdot R_{101} = (b_1, b_2, b_3, \ldots, b_n) = (0.43, 0.2, 0.18, 0.19)$$

$$Y = (0.37, 0.292, 0.338, 0)$$

Sensory fuzzy comprehensive score:

$$H = \sum b_j = 1 \times 0.37 + 2 \times 0.292 + 3 \times 0.338 + 4 \times 0 = 1.968$$

The calculation of the other samples is the same.

**The effect of single factors on the sensory fuzzy comprehensive score.** The effect of single factors on the sensory fuzzy comprehensive score are expressed in Figure 2. The lower the score, the better the sensory effect of the beverage. It can be seen from Figure 2A that the score showed a trend of increasing first and then decreasing, and the score is the lowest in the addition amount of 4% ($P < 0.05$). Therefore, the addition amount of the mint extract solution was determined as 4%. In addition, the effect of the addition amount with liquorice and sugar on the score exhibited a similar trend to that of mint from Figure 2B and Figure 2C. The addition amounts of liquorice extract solution and sugar were 6% ($P < 0.05$) and 3.5% ($P < 0.05$), respectively. In contrast, the score showed a trend of decreasing first and then increasing in Figure 2D, and the optimum addition amount of citric acid was 0.2% ($P < 0.05$).

**Analysis of orthogonal test results**

The result of the orthogonal test is displayed in Table 7. The closer the score is to 1, the better the product.

![Figure 2](image_url)

Fig. 2. Effect of single factors on the sensory fuzzy comprehensive score (different letters refers to $p < 0.05$)
Liu, Y., Ding, X., Zheng, L. X., Zhang, Y., Zhou, H. (2020). Herbal drink formulation optimization of *Trollius chinensis* Bunge by sensory fuzzy comprehensive evaluation. Acta Sci. Pol. Technol. Aliment., 19(2), 185–194. http://dx.doi.org/10.17306/J.AFS.2020.0776

Due to the R value, the influence order of several single factors on the results is $A > C > B > D$. After comparing the $k$ value, the optimum formulation was $A3B1C2D2$, and the addition amounts of mint extract solution, liquorice extract solution, sugar and citric acid were 4%, 5%, 3% and 0.2%, respectively. There is no experiment group in the orthogonal test. Meanwhile, the 9th group in the test has the lowest fuzzy score, and the addition amounts of mint extract solution, liquorice extract solution, sugar and citric acid were 4%, 7%, 3% and 0.15%, respectively. Therefore, a verified test needed to be carried out. After the verified test, the score of the $A3B1C2D2$ group was 1.225, which is greater than that of the 9th group (1.192). Finally, the 9th group was chosen as the optimum formulation. The optimum formulation was as follows: an addition amount of *T. chinensis* Bunge extract solution of 30%; an addition amount of mint extract solution of 4%; an addition amount of liquorice extract solution of 7%; an addition amount of sugar of 3%; an addition amount of citric acid of 0.15%.

### Table 7. Orthogonal test results

|   | A   | B   | C   | D   | Fuzzy score |
|---|-----|-----|-----|-----|-------------|
| 1 | 3   | 5   | 2.50| 0.15| 1.200       |
| 2 | 3   | 6   | 3   | 0.20| 1.224       |
| 3 | 3   | 7   | 3.50| 0.25| 1.428       |
| 4 | 3.50| 5   | 3   | 0.25| 1.412       |
| 5 | 3.50| 6   | 3.50| 0.15| 1.686       |
| 6 | 3.50| 7   | 2.50| 0.20| 1.381       |
| 7 | 4   | 5   | 3.50| 0.20| 1.211       |
| 8 | 4   | 6   | 2.50| 0.25| 1.254       |
| 9 | 4   | 7   | 3   | 0.15| 1.192       |
| $k_1$ | 1.284| 1.274| 1.279| 1.360 |
| $k_2$ | 1.493| 1.388| 1.276| 1.272 |
| $k_3$ | 1.219| 1.334| 1.442| 1.364 |
| R | 0.274| 0.114| 0.166| 0.092 |

A – amount of mint extract, %, B – amount of liquorice extract, %, C – amount of sugar extract, %, D – amount of lemon extract, %.

### Stability evaluation of the herbal drink

The stability of the polysaccharide content, pH value and color change were evaluated under the storage conditions of 4°C, 25°C and 37°C for one month, as is shown in Figure 3.

**Fig. 3.** Stability of herbal drink under different storage temperatures
The polysaccharide content decreased with an increase in storage time (Fig. 3A), and the stability of the polysaccharides was not significantly affected by storage temperature ($P > 0.05$). The pH value of the sample was significantly affected by storage temperature ($P < 0.01$), which was basically unchanged at 4°C and 25°C, and relatively large at 37°C (Fig. 3B). This phenomenon may demonstrate that the pH value is affected by a higher temperature. The stability of the color was significantly affected by temperature ($0.01 < P < 0.05$) (Fang et al., 2007), which was relatively more stable at 4°C and 25°C than at 37°C (Fig. 3C). These results suggest that the herbal drink was suitably stored under 4°C or at room temperature. The quality reduction of the herbal drink occurs at a high temperature.

Microbiological test results
The number of the Escherichia coli group was detected in the sample according to GB 4789.3 (2016). The total number of bacterial colonies of the sample was 60 CFU/mL according to GB 4789.2 (2016) of China. All the samples meet the requirements of GB 7101 (2015) of the China Standard for the microbial limit of beverages.

CONCLUSION
In this paper, the sensory fuzzy comprehensive evaluation method was applied to optimize the formulation of the *T. chinensis* Bunge herbal drink. The addition amounts of mint extract solution, liquorice extract solution, sugar and citric acid were designed as single factors, and the optimum formulation was optimized using the orthogonal test. The optimum formulation was as follows: an addition amount of *T. chinensis* Bunge extract solution of 30%; an addition amount of mint extract solution of 4%; an addition amount of liquorice extract solution of 7%; an addition amount of sugar of 3%; an addition amount of citric acid of 0.15%. The stability of the polysaccharides was not significantly affected by storage temperature ($P > 0.05$), meanwhile, the pH value ($P < 0.01$) and the stability of the color ($0.01 < P < 0.05$) were significantly affected by temperature. The formulation of a herbal drink with a good flavor was obtained and can be provided to consumers. These results provide some theoretical basis for the development of *T. chinensis* Bunge as a food product.

ACKNOWLEDGEMENTS
The authors express their gratitude to the Jilin Institute of Chemical Technology for data collection.

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