Oil Tea Soup Formula Optimization Based on Orthogonal Test and Fuzzy Mathematics Sensory Evaluation

Liao Fen^{1,2}, Wen Ren-De², Yang Liu^{2,3}, Yang Ren-Gui³, He Quan-Guang³ and Zhang Er-Zhen³

1. Sugarcane Research Institute, Guangxi Academy of Agricultural Science, Sugarcane Research Center, Chinese Academy of Agricultural Sciences-Guangxi Academy of Agricultural Sciences, Key Laboratory of Sugarcane Biotechnology and Genetic Improvement (Guangxi), China Ministry of Agriculture, Nanning 530007, China

2. Guangxi Crop Genetic Improvement Laboratory, Nanning 530007, China

3. Agro-food Science and Technology Research Institute, Guangxi Academy of Agricultural Sciences, Nanning 530007, China

Abstract: The aim of this study is to optimize the formula of oil soup, which was one of traditional food of Guangxi province, south China. Tea leaves, bone soup, beans and other minor ingredients in the formula of oil tea soup are selected as the research objects. The sensory evaluation factors such as flavor, taste, color, aroma were selected to optimize the formula of oil tea soup based on orthogonal test and fuzzy mathematics comprehensive evaluation. The results showed the most important factor that affected the quality of the oil tea soup was tea leaves content, followed by the proportion of bone soup, minor ingredient and beans content. The study indicated that the optimal recipe of oil tea soup was as follow: 0.6% tea, 0.4% beans, and 0.5% other ingredients. The ratio of material to solution of bone soup was 1:5.

Key words: Oil tea soup, traditional food, orthogonal design, fuzzy mathematical, sensory evaluation.

1. Introduction

Oil tea soup was a characteristic diet in northern Guangxi area, which was initiated in the Tang Dynasty, and dating back to more than a thousand years in history [1]. All the minorities in Guangxi such as the Miao, Yao, Zhuang, Dong minorities and even the Han nationality people had the habit of having oil tea soup as diet. In Guangxi province, the preparation process of oil tea soup is known as “Dayoucha” (oil tea soup cook process), which is an innovative diet style developed by Guangxi people in the adaption to the outside environment [2]. Chinese traditional food has a very long history, with rich connotation and cultural heritage, and a lot of traditional food also has very important health care

functions. However, with the development of modern food science and technology, many traditional food processing methods and market demand have also been severely challenged [3]. Different stages of food industry development will also put forward different requirements for the processing technology. New industrial production technology used in traditional food not only can meet the requirements of the product standardization and economics, but also provide better guarantee in respect of nutrition, quality and health. It will also be the development trend of traditional food in the future [4]. There was not much literature research on the processing technology, processes, standards and so on of the traditional Guangxi oil tea soup in depth and systematic. The lack of basic research of tea oil soup has been restricted its industry and large-scale production. For this purpose, this study aims to optimize the formula

Corresponding author: Wen Ren-De. Research fellow, his research interests include grapes cultivation and traditional food process.

of Guangxi oil tea soup based on orthogonal test and fuzzy mathematics sensory evaluation method. The study results could provide reliable references for industrialized production process, standard and quality control of Guangxi oil tea soup in the future.

The current researches on Guangxi oil tea soup are mostly based on the aspect of cultural propaganda, [5] studied the cultural development of Gongcheng oil tea soup. As the most famous oil tea soup cradle, Gongcheng county people have excellent skill to cook oil tea soup which was listed in the second batch of intangible cultural heritage of Guangxi province in 2008. “Gongcheng oil tea soup” obtained the trademark of geographical indication and is authorized by the Trademark Department of the National industry and Commerce Bureau in 2011. [1] introduced the raw materials and cook methods of oil tea soup. The main ingredient of oil tea soup is tea, supplemented by other ingredients such as ginger, garlic clove, peanuts, fried rice crackers, etc., and made by soaking, stir-frying, simmering and boiling, filtering and other cooking methods. With the improvement of people’s living standards, a lot more minor ingredients are added to make new flavors oil tea soup. Cooking oil tea soup and drinking oil tea soup has gradually become an important way for people to enhance friendships and build interpersonal relationships [2]

1.2 Preparation Process of Oil Tea Soup

Beans: The proportion of the green beans, black beans, small red beans and peanuts added is 1:1:1:1, and the proportion of peanut oil, ginger, mushroom and scallion with fibrous root is 3:5:30:30 in this experiment.

1.3 Brief Description of Process

Pretreatment of tea leaves and beans: First soak the tea leaves in warm water with the temperature of

studied the development and cultural traditions of the oil tea industry. But there are few researches on the formula optimization, process improvement of oil tea soup or the industrialized formula upgrading of oil tea soup. In this study, the proportion of various raw materials in oil tea soup proportion is determined, and the degree of impact of each raw material on the quality of the oil tea soup is analyzed so as to propose the optimization scheme for the formula of oil tea soup.

1. Materials and Methods

1.1 Materials and Main Equipments

Tea: Longjing green tea.

Beans: Green beans, black beans, small red beans, peanuts.

Minor ingredients: Peanut oil, ginger, mushroom, scallion with fibrous root.

Bone soup: Pork marrowbone, water.

All raw materials and minor ingredients are commercially available.

Main equipment: Induction Cooker ST2106 (Guangdong Midea Electric Appliance Manufacturing Co., Ltd.), Electronic Balance ALC-210.4 (Germany Sartorius), Ultrafine Grinder ZKY-303AS (Beijing Zhongke Haoyu Technology Development Co., Ltd.).

40-50 °C until they are fully expanded. And then remove and drip-dry the tea leaves for being used. Pre-soak the beans in 25 °C ± 1 °C water until the skin bulges and peels off. Then drip-dry and steam for being used. Clean the ginger, mushroom and scallion with fibrous root and cut into small segments of 1-2 cm.

Baking treatment for aroma: Heat the pot over 40-50 °C. Then stir-fry the tea leaves and beans until

the water content was about 15%-25% respectively. Heating the pot over 50-70 °C, added peanut oil, stir-fry the ginger, mushroom and scallion with fibrous root until aroma comes out and then add the baked tea leaves, beans and minor ingredients.

Ultrafine grinding treatment: Put the baked tea leaves, beans and minor ingredients in the ultrafine grinder to crush to fineness of 100-200 mesh.

Bone soup treatment: Add pork bone and water by a certain percentage of weight, boil at 100 °C above, and then simmer over low heat at 40-50 °C for 60 minutes to obtain the soup base.

Preparation of oil tea soup: Add the ultrafine tea leaves, beans, ginger, mushrooms and scallion with fibrous root to the boiled bone soup proportionally while stirring, until all the powder is evenly dissolved in the soup. Boil for 5 minutes, then the oil tea soup is obtained.

1.4 Orthogonal Experimental Design

According to the results of the basic formula in the preliminary test and single factor experiment, $L_9(3^4)$ orthogonal experimental design scheme is applied for optimizing the formula of oil tea soup [6]. The factors and levels refer to Table 1.

1.5 Sensory Evaluation Index, Data Matrix and Calculate Formula

A total of 20 experienced experts were selected as sensory evaluation panelists. They will score different oil tea soup samples according to the evaluation standards which were shown in Table 2. Data matrix and calculate formula were as follow:

Elements set $\{U\}$ included “flavor, taste, soup color, aroma” which was the four evaluation index of oil tea

soup and set as (1). Comment set $\{V\}$ included “Excellent, good, medium, poor” that defined comment level of samples and showed as (2). The comment set V of different index of ample was according to the formula (3). In this experiment, forced decision method [7, 8] was adopted to determine the weight coefficient of the four factors in the sensory evaluation of the oil tea soup. According to early single factor experiment, weight coefficient four evaluation characteristic “favor, taste, soup color, aroma” of oil tea soup was set as A_{fixed} (4). Weight coefficient $\{A\}$ set was mark as $\{A_v\}$ when was used to calculate comment set $\{V\}$ weight coefficient. It was set as $\{A_u\}$ when it was used to calculate elements set $\{U\}$ weight coefficient. Score of “excellent, good, medium, poor” comment level was set as $\{95, 85, 75, 50\}$ respectively, and marked as data matrix $Y_{\text{comment}} = \{95, 85, 75, 50\}$, Score (Y) of every sample was calculated according to (5).

(1) Evaluation elements set $U = \{U_{11}, \dots, U_{ni}\}$; n means the n -th sample, $I = \{\text{Flavor, taste, soup color, aroma}\}$;

(2) Comment set $V = \{V_{n1}, \dots, V_{nj}\}$; n means the n -th sample, $j = \{\text{Excellent, good, medium, poor}\}$;

(3) V_{nj} = People number of evaluation panelists who chose j level / Total people number of evaluation panelists;

(4) Fixed weight coefficient set $A_{\text{fixed}} = \{0.35, 0.25, 0.15, 0.25\}$;

Weight coefficient set A of V is shown as $A_v = \{A_{v11}, \dots, A_{vni}\}$;

Weight coefficient set A of U is shown as $A_u = \{A_{u11}, \dots, A_{uni}\} = A_{\text{fixed}} \times A_v$;

(5) $Y = Y_{\text{comment}} \times A_u$.

Table 1 Factors and levels of orthogonal test.

Levels	Factors			
	A (Tea leaves content %)	B (Beans content %)	C (Bone soup proportion)	D (Minor ingredients content %)
1	0.3	0.2	1:3	0.5
2	0.6	0.4	1:4	1.0
3	0.9	0.8	1:5	1.5

2. Results and Analysis

2.1 The Standard of Evaluation Characteristics, Comment and Grade Score of Oil Tea Soup

Table 2 showed the standard of sensory evaluation of oil tea soup. Flavor, taste, soup color and aroma were four main evaluation indexes of oil tea soup. The comment of each evaluation characteristics was classified as excellent, good, medium and poor four levels. The grade score range of excellent was 85-95, of good was 75-84, of medium was 61-74 and of poor

was 50-60 respectively. Evaluation panelists will give score and comment to every sample according the standard listed in Table 2.

2.2 Calculated Result of Fuzzy Matrix

Table 3 shows the number of evaluation panelists who rate excellent, good, medium and poor for flavor, taste, soup color and aroma of each sample. For sample 1, the data of flavor is 0 evaluation panelist rates excellent, 6 rates good, 6 rates medium and 8 rates poor. That means for Sample No. 1, 0 person

Table 2 Standard of sensory evaluation.

Indicator	Evaluation standard	Comment	Grade score
Flavor	Mellow flavor, soft, with the aftertaste of tea	Excellent	85-95
	Slightly mellow flavor, soft, no odd flavor	Good	75-84
	Slightly light flavor, with a little aftertaste, no odd flavor	Medium	61-74
	Light flavor or no flavor or heavily bitter flavor	Poor	50-60
Taste	Smooth and delicate taste	Excellent	85-100
	Slightly smooth taste, not grainy	Good	75-84
	Slightly smooth taste, slightly grainy	Medium	61-74
	Poor taste, obviously grainy, too thin or too thick	Poor	50-60
Soup color	Yellow-green shiny tea soup color, appropriate thickness	Excellent	85-100
	Yellow-green tea soup color, slightly thin	Good	75-84
	Slight yellow-green tea soup color, not shiny, too thin or too thick	Medium	61-74
	Tea soup color is not green, with light color or yellow-brown or dark-brown color	Poor	50-60
Aroma	With the typical fresh and elegant green tea aroma, strongly fragrant and pleasant aroma in minor ingredients	Excellent	85-100
	With tea aroma, fragrant and pleasant aroma in minor ingredients	Good	75-84
	With slight green tea aroma, slightly light aroma in minor ingredients	Medium	61-74
	With very light or no green tea aroma, very light or no aroma in minor ingredients	Poor	50-60

Table 3 Sensory evaluation results of oil tea soup.

Samples	Flavor				Taste				Soup color				Aroma			
	Excellent	Good	Medium	Poor	Excellent	Good	Medium	Poor	Excellent	Good	Medium	Poor	Excellent	Good	Medium	Poor
1	0	6	6	8	2	3	10	5	6	6	7	1	0	2	10	8
2	2	6	7	5	0	2	10	8	5	6	7	2	2	6	7	5
3	1	8	6	5	1	4	9	6	6	6	7	1	3	4	8	5
4	3	4	7	6	9	8	3	0	7	8	5	0	12	7	1	0
5	15	4	1	0	14	3	3	0	5	7	7	1	14	3	2	1
6	7	9	4	0	4	5	7	4	5	7	7	1	15	4	1	0
7	2	8	5	5	4	5	7	4	6	6	7	1	1	4	9	6
8	2	8	5	5	4	5	7	4	6	6	7	1	1	4	9	6
9	0	6	7	13	4	5	7	4	2	2	9	7	0	1	7	12
Weight coefficient	0.35				0.25				0.15				0.25			

thinks it is excellent, 6 think it is good, 6 think it is medium, 8 think it is poor, and thus according to formula (4), $Av_{\text{flavor}} = [0, 0.3, 0.3, 0.4]$ is obtained. For the taste index, 2 people think it is excellent, 3 think it is good, 10 think it is medium, 5 think it is poor, and thus $Av_{\text{taste}} = [0.1, 0.15, 0.5, 0.25]$ is obtained. Similarly, $A_{\text{soup color}} = [0.3, 0.35, 0.35, 0.05]$ and $A_{\text{aroma}} = [0, 0.1, 0.5, 0.4]$ is obtained.

Finally, the evaluation matrix of sample No. 1 is obtained as

$$U_1 = \begin{bmatrix} 0 & 0.3 & 0.3 & 0.4 \\ 0.1 & 0.15 & 0.5 & 0.25 \\ 0.3 & 0.35 & 0.35 & 0.05 \\ 0 & 0.1 & 0.5 & 0.4 \end{bmatrix}$$

Similarly, the evaluation matrix of other samples can be obtained as follow:

$$U_2 = \begin{bmatrix} 0.1 & 0.3 & 0.35 & 0.25 \\ 0 & 0.1 & 0.5 & 0.4 \\ 0.25 & 0.3 & 0.35 & 0.1 \\ 0.1 & 0.3 & 0.35 & 0.25 \end{bmatrix}$$

$$U_3 = \begin{bmatrix} 0.05 & 0.4 & 0.3 & 0.25 \\ 0.05 & 0.2 & 0.45 & 0.3 \\ 0.3 & 0.3 & 0.35 & 0.05 \\ 0.15 & 0.2 & 0.4 & 0.25 \end{bmatrix}$$

$$U_4 = \begin{bmatrix} 0.15 & 0.2 & 0.35 & 0.3 \\ 0.45 & 0.4 & 0.15 & 0 \\ 0.35 & 0.4 & 0.25 & 0 \\ 0.6 & 0.35 & 0.05 & 0 \end{bmatrix}$$

$$U_5 = \begin{bmatrix} 0.75 & 0.2 & 0.05 & 0 \\ 0.7 & 0.15 & 0.15 & 0 \\ 0.8 & 0.15 & 0.05 & 0 \\ 0.7 & 0.15 & 0.1 & 0.05 \end{bmatrix}$$

$$U_6 = \begin{bmatrix} 0.35 & 0.45 & 0.2 & 0 \\ 0.2 & 0.25 & 0.35 & 0.2 \\ 0.95 & 0.05 & 0 & 0 \\ 0.7 & 0.15 & 0.1 & 0.05 \end{bmatrix}$$

$$U_7 = \begin{bmatrix} 0.1 & 0.4 & 0.25 & 0.25 \\ 0.2 & 0.25 & 0.35 & 0.2 \\ 0.3 & 0.3 & 0.35 & 0.05 \\ 0.75 & 0.2 & 0.05 & 0 \end{bmatrix}$$

$$U_8 = \begin{bmatrix} 0.1 & 0.4 & 0.25 & 0.25 \\ 0.2 & 0.25 & 0.35 & 0.2 \\ 0.3 & 0.3 & 0.35 & 0.05 \\ 0.05 & 0.2 & 0.45 & 0.3 \end{bmatrix}$$

$$U_9 = \begin{bmatrix} 0 & 0.3 & 0.35 & 0.65 \\ 0.2 & 0.25 & 0.35 & 0.2 \\ 0.1 & 0.1 & 0.45 & 0.35 \\ 0.05 & 0.2 & 0.45 & 0.3 \end{bmatrix}$$

According to formula (4), weight coefficient matrix of each sample was obtained as following:

$$Au_1 = A_{\text{fixed}} U_1 = \{0.35, 0.25, 0.15, 0.25\} \times$$

$$\begin{bmatrix} 0 & 0.3 & 0.3 & 0.4 \\ 0.1 & 0.15 & 0.5 & 0.25 \\ 0.3 & 0.35 & 0.35 & 0.05 \\ 0 & 0.1 & 0.5 & 0.4 \end{bmatrix}$$

$$= \{0.220, 0.210, 0.245, 0.200\}$$

$$Au_2 = \{0.220, 0.210, 0.245, 0.200\}$$

$$Au_3 = \{0.225, 0.200, 0.240, 0.225\}$$

$$Au_4 = \{0.230, 0.280, 0.260, 0.305\}$$

$$Au_5 = \{0.320, 0.305, 0.325, 0.310\}$$

$$Au_6 = \{0.265, 0.235, 0.345, 0.310\}$$

$$Au_7 = \{0.235, 0.235, 0.245, 0.320\}$$

$$Au_8 = \{0.235, 0.235, 0.245, 0.210\}$$

$$Au_9 = \{0.290, 0.235, 0.215, 0.210\}$$

The score of every sample was calculated according to formula (5) and the final fuzzy evaluation score of each sample was obtained as following:

$$Y_1 = Y_{\text{comment}} \times Au = \{90, 80, 70, 50\} \times \{0.220, 0.210, 0.245, 0.200\} = 65.75$$

$$Y_2 = 66.55$$

$$Y_3 = 67.70$$

$$Y_4 = 79.60$$

$$Y_5 = 94.55$$

$$Y_6 = 85.40$$

Table 4 Results of orthogonal evaluation.

Experiment No.	A	B	C	D	Comprehensive sensory evaluation score
1	1	1	1	1	65.75
2	1	2	2	2	66.55
3	1	3	3	3	67.70
4	2	1	2	3	79.60
5	2	2	3	1	94.55
6	2	3	1	2	85.40
7	3	1	3	2	76.30
8	3	2	1	3	69.70
9	3	3	2	1	72.55
K ₁	200	221.65	220.85	232.85	
K ₂	259.55	230.8	218.7	228.25	
K ₃	218.55	225.65	238.55	217	
R	19.85	3.05	6.62	5.28	

$$Y_7 = 76.30$$

$$Y_8 = 69.70$$

$$Y_9 = 72.55$$

2.3 Results of Orthogonal Test

Table 4 showed the results of 9 samples of oil tea soup based on orthogonal test. K means the score sum of different factor's orthogonal test level. K of each factor is calculated by the formula (6). In this experiment, K of sample No. 1 of level 1 on factor A is $(K_{1A}) = 65.75 + 66.55 + 67.7 = 200$. The same K_i of factor B, factor C, factor D were obtained and can be seen at Table 4.

$$K_{in} = \sum_{i=1}^3 Y_i \quad (6)$$

where i means the level of each factor of orthogonal test, n means the factor of orthogonal test.

R means range, $R_{in} = (K_{in_{max}}/m) - (K_{in_{min}}/m)$, i means the level of each factor of orthogonal test, n means the factor of orthogonal test; m means level amount of each factor. In this experiment, R of sample No. 1 of level 1 on factor A $(R_{1A}) = (259.55/3) - (200/3) = 59.55$. The same R_i of factor B, factor C, factor D were obtained and can be seen at Table 4.

From Table 4, sample No. 5 has the highest score 94.55 which suggests the oil tea soup cooked by its formula has the best quality. According to the range analysis method, factor with high R value hints that it

would be the main factor affecting the quality of oil tea soup. In this experiment, R of factor A was 19.85, which suggested factor A (tea leaves content) was the most influential factor on oil tea soup quality. The second key factor was factor C (bone soup proportion) with R value 6.62. The third key factor was factor D (minor ingredients). The factor that affects the least was factor B (beans content).

According the results of orthogonal test, the optimum combination of oil tea soup is A2B2C3D1. That means, the optimum formula of oil tea soup was as follow: 0.6% tea leaves, 0.4% beans, (1:5) of bone soup, 0.5% minor ingredients.

3. Discussion

Orthogonal experimental design is one design method used to study the multi factors and multi levels test. It is a very effective experimental design method in the scientific research of food with advantage of high efficiency, rapid calculation [7, 9]. Orthogonal experimental test can reduce the test combinations and quickly obtain the experimental optimization results. Fuzzy comprehensive evaluation is a method used to convert the qualitative evaluation into quantitative evaluation [8, 10, 11]. Based on the membership degree theory of fuzzy mathematics, it is mainly applied in the overall evaluation of things or objects which are restricted by multiple factors.

Attributing to the strong systematic and clear evaluation structure, it is very suitable for the interpretation of problems that are fuzzy, difficult to quantify and non-deterministic. Sensory evaluation method is a statistical analysis method based on sensation, which can distinguish the difference of food very well and determine the size of difference, and is very suitable for judging the difference of two or more target food [9, 12]. Fuzzy mathematics comprehensive evaluation theory is considered to be a mathematical method especially in the sensory evaluation of food quality, and very suitable to deal with the fuzzy concepts and things. It can eliminate the negative influence of subjective scoring arbitrariness and one-sidedness thereby obtaining relatively objective test results [10, 13, 14].

In this test, the aforementioned three methods were all used to optimize the oil tea soup formula. The results showed that tea leaves content has the greatest influence on the quality of oil tea soup with the R value of 19.83 (Table 4), which is far greater than the proportion of bone soup, beans and other minor ingredients. Beans have the smallest impact on the quality of oil tea soup. The bone soup and the minor ingredients have similar influence. The result of orthogonal experimental test, fuzzy mathematics and sensory evaluation method showed that the optimum formula of the oil tea soup as follows: 0.6% tea leaves, 0.4% beans, (1:5) of bone soup, 0.5% minor ingredients. The sensory evaluation score of oil tea soup cooked as the optimum formula is 91.15 points, which has further verified the accuracy and feasibility of the orthogonal experimental results.

4. Conclusion

In this experiment, orthogonal experiment design and fuzzy mathematics evaluation method are combined to obtain the optimum combination of oil tea soup formula as A2B2C3D1, namely: 0.6% tea leaves, 0.4% beans, (1:5) of bone soup, 0.5% minor ingredients. The results can provide the data basis for

the industrial production of oil tea soup. This study has only optimized the oil tea soup formula, in the future, further research needs to do deeply and widely on process, such as the stir-frying temperature of each raw material, grinding particle size, simmering temperature, time and other process parameters shall be tested, as well as the research on the lab batch, pilot batch and other parameters.

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