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# Optimization of One-step Processing Technology of Soy Sauced Beef Based on Fuzzy Sensory Evaluation and Box-behnken Method

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***Abstract:***

Taking beef as raw material, the processing technology of soy sauced beef was optimized by Box-behnken method, in combination with fuzzy mathematics sensory evaluation method. The effects of meat-sauce ratio, cooking temperature, cooking time and other factors on the quality of soy sauced beef were studied. On this basis, the Box-behnken method was used for optimization, and a one-step marinating technology was put forward. The results showed that the best one-step technology of soy sauced beef was as follows: meat-sauce ratio of 11%, marinating temperature of 111℃ and marinating time of 62 min. The sensory quality and texture of soy sauced beef prepared under this technology were similar to those of traditional marinating technology, and obviously superior to those of sterilization technology. Moreover, the one-step technology simplified the sterilization technology and effectively shortened the production cycle of the product.

***Keywords**: One-step processing technology, Fuzzy mathematical sensory evaluation, Box-behnken, Texture, Flavor.*

## I. INTRODUCTION

Sauced meat with sauce is one of the traditional characteristic foods in China, and its annual output accounts for more than 50% of the meat products in China [1]. During the processing of soy sauced beef, there are chemical processes including fatty acid oxidation [2], Strecker degradation [3], Maillard reaction [4] and thiamine reaction [5], which forms unique flavor and nutritional characteristics. Thus, soy sauced beef is deeply loved by consumers [6, 7].

The processing of soy sauced beef includes thawing, pickling, marinating, cooling, packaging, sterilization and other unit operations [8]. The traditional production technology of soy sauced beef is pickling and then marinating; the industrialized production technology is first marinating and then sterilizing, that is, sterilization technology. Compared with the traditional technology, the sterilization link

[9] is added, which improves the safety and storability of the product. However, sterilization will affect the quality of products. Especially, the tissue structure of meat is destroyed and the nutritional components are lost during high temperature and high-pressure treatment [10, 11]. Zhang Zhiqing et al. [12] pointed out that under the condition of autoclaving, the shelf life of food can be extended to more than 90 days, but high-intensity heat treatment will reduce the sensory quality of products. Zhou Xin's [13] research also confirmed that the flavor, texture and nutrition of food products were affected under the condition of high-pressure sterilization. Studies by Wang Haijun et al. [14] show that the texture characteristics of products such as hardness, adhesive viscosity and chewiness are greatly affected by high temperature. In recent years, with the improvement of people's consumption level, high-temperature meat products have become synonymous with low-grade meat products, which do not conform to consumers' pursuit of food nutrition and delicacy [15]. How to improve the quality of traditional sauced meat products has become a research hotspot.

In this experiment, the two steps, marinating and sterilizing, were combined. In addition, combined with the quantitative marinating technology [16], the one-step processing technology was innovatively designed. That is, the beef is firstly marinated quantitatively, and then sterilized and cooked directly after vacuum packaging, so that the marinating, cooking and sterilization are carried out simultaneously. Fuzzy mathematical sensory evaluation and Box-behnken method were used to optimize the one-step processing technology of soy sauced beef. The quality of the processed products was compared with that of the traditional marinating and sterilization process. Based on the study, certain technical reference can be provided for the storage and innovation of soy sauced beef.

## II. MATERIALS AND METHODS

### 2.1 Instruments and Materials

#### 2.1.1 Materials and reagents

Raw material: beef chuck roll (Bengbu Hongye Meat United Processing Co., Ltd., Bengbu). Accessories: spiced old marinade (commercially available).

#### 2.1.2 Instruments and equipment

Multifunctional vacuum packaging machine, DZ-280/2SE, Zhengzhou Yuxiang Machinery Equipment Co., Ltd.; Texture analyzer, TA XTC-18, Shanghai Baosheng Industrial Development Co., Ltd.; Homogenizer, Shanghai Baosheng Industrial Development Co., Ltd.; Electronic nose CNose, CT-500, SuhnerAG, Switzerland; Electrothermal incubator, DNP-90521A, Shanghai Sanfa Scientific Instrument

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Co., Ltd.; Vortex mixer, Vortex-M, Shanghai Huxi Industrial Co., Ltd.

2.2 Experimental Methods

2.2.1 Processing technology

Preparation of marinade: adding 120g spiced marinade into 1200mL of water, keeping boiling for 10min, and then naturally cooling to room temperature to obtain the marinade.

Raw meat processing and cutting: removing the connective tissue and fat from the surface of beef, cleaning it, and cutting it into 10cm* 15cm* 5cm cubes (about 150 g).

Pickling: mixing the processed meat pieces with the marinade about 30% of the meat's weight, and kneading the meat in a tumbler at 4℃ for 90 min in vacuum.

Marinating: perform vacuum packaging of the marinated meat pieces with a certain proportion of marinade, marinating at 115℃ for 60 min, taking out and cooling to obtain the finished product.

2.2.2. Single factor experiment

Meat-sauce ratio was set at 5%, 10%, 15%, 20% and 25% respectively, and the marinating temperature was set to 100℃, 105℃, 110℃, 115℃ and 120℃ respectively. The marinating time was 30 min, 40 min, 50 min, 60 min and 70 min respectively. The effects of meat-sauce ratio, marinating temperature and marinating time on sensory score of products were studied, respectively.

2.2.3 Experimental design of Box-behnken

On the basis of single factor experiment, taking meat-sauce ratio (A), marinating temperature (B) and marinating time (C) as variables and fuzzy mathematical sensory evaluation as response value (Y), the technological parameters were optimized by Box-Behnken Design (BBD) in Design Expert 8.06 software. The experimental factors and levels of Box-behnken are shown in Table 1.

**Table 1. Factors and levels of Box-behnken design**

| **Level** | **A: Meat-sauce ratio (%)** | **B: Marinating temperature (℃)** | **C: Marinating time (min)** |
|---|---|---|---|
| -1 | 5 | 105 | 50 |

| | | | |
|---|---|---|---|
| 0 | 10 | 110 | 60 |
| 1 | 15 | 115 | 70 |

2.2.4 Sensory evaluation

Ten trained food professionals were selected as evaluators to evaluate soy sauced beef from five aspects: color, texture, flavor, taste and chewiness. Each indicator was divided into seven grades: excellent, good, good, fair, poor, poor and extremely poor. The evaluation criteria are shown in Table 2.

**Table 2. Sensory evaluation standards for soy sauced beef**

| Subitem | Standard |
|---|---|
| COLOR | The appearance is dark red, and shiny. After cutting, the inside is sauce red, without obvious red or gray spots |
| TEXTURE | The meat surface is smooth, firm and glossy |
| FLAVOR | There is special flavor of soy sauced beef, and no fishy smell or other peculiar smell |
| TASTE | Moderate degree of saltiness, and strong sauce flavor |
| CHEWINESS | Fleshy elastic teeth, moderate hardness, no obvious roughness |
| GRADING STANDARDS | 30-extremly poor, 40-poor, 50-relatively poor, 60-general, 70-fair, 80-good, 90-excellent. |

2.2.4 Establishment of Fuzzy Mathematical Model

Factor U has five indicators, color, texture, flavor, taste and chewiness. Comment V has seven grades: excellent（$V_7$）, good（$V_6$）, relatively good（$V_5$）, fair（$V_4$）, relatively poor（$V_3$）, poor（$V_2$） and extremely poor（$V_1$）. The four indicators of each product are scored and rated by sensory method. W=A*R represents the comprehensive evaluation result of fuzzy relation. A represents the weight set, and R represents the evaluation matrix.

Factor set $U=\{u_{color}, u_{texture}, u_{flavor}, u_{taste}, u_{chewiness}\}$, comment set $V=\{v_{excellent}, v_{good}, v_{relatively\ good}, v_{fair}, v_{relatively\ poor}, v_{poor}, v_{extremely\ poor}\}$, weight set $A=\{a_{color}, a_{texture}, a_{flavor}, a_{taste}, a_{chewiness}\}=\{0.2,0.15,0.2,0.25,0.2\}$.

2.2.5 Texture analysis and determination

Referring to the method of Chen [17], a slight change was made: cooling the sample to room

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temperature, cutting it into 1 cm×1 cm×1 cm cubes in the direction parallel to the muscle fibers, placing them on a texture analyzer, and using the P/50 probe for the "full texture" experiment. The downward speed of the probe is 1.0 mm/s. The deformation is 30%, and the return speed of the probe is 1.0mm/s. The indicators are hardness, elasticity, cohesion, adhesion, chewiness and resilience [18].

2.2.6 Determination of volatile flavor substances

Referring to the method of Wang Shuting [19], a slight change was made: cutting the sample into pieces, weighing 4.0 g of the sample and putting it in a 50 mL empty bottle. After sealing, letting it stand at room temperature for 2 h, and then using electronic nose for detection. Electronic measurement parameters are as follows: sample size of 500 μL, headspace heating temperature of 65℃, headspace heating time of 180s, delay acquisition time of 600 s, data acquisition time of 60 s, flow rate of 1L/min, and cleaning time of 120 s. Each sample was measured in parallel for 5 times, and the data were collected and processed by Win Muster software, as is shown in Table 3.

**Table 3. Performance description of the electronic nose sensor**

| Sensor No. | Performance description |
|---|---|
| S1 | Short-chain alkane, nitrogen oxide, carbide |
| S2 | Sensitive to aldehydes and ketones, alcohol irritants, nitrogen oxides and carbides |
| S3 | Mainly selective to ammonia and sensitive to sulfide and benzene flavortic components |
| S4 | Sensitive to organic sulfides and short-chain alkanes |
| S5 | Sensitive to ammonia-like flavortic components |
| S6 | Selective to benzene flavortic components and sensitive to aldehydes, ketones and alcohols |
| S7 | Sensitive to volatile gas, benzene series flavortic components |
| S8 | Selective to short-chain paraffin, sulfide and phenolic flavortic components |
| S9 | Mainly selective to ammonia and benzene flavortic components and sulfides |
| S10 | Sensitive to short-chain hydrocarbon compounds and flammable gases |
| S11 | Sensitive to short-chain alkanes, flavortic hydrocarbons, aldehydes and ketones |
| S12 | Selective to flavortic compounds and ester compounds |
| S13 | Sensitive to nitrogen, carbide, sulfide and other substances |
| S14 | Sensitive to short-chain paraffins, aldehydes and ketones flavortic components |

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2.2.7 Determination of total number of colonies

Performing detection according to the method in GB4789.2-2016 Detection of Total Number of colonies.

2.2.8 Data analysis

Each group of experiment performed determination three times in parallel, and the results were expressed as "average ± standard deviation". The data were statistically analyzed by SPSS (IBM SPSS Statistics 25), with significant difference $P < 0.05$.

## III. RESULTS AND ANALYSIS

3.1 Fuzzy Mathematics Comprehensive Evaluation Results of Soy Sauced Beef Using One-step Technology

According to BBD experimental design, there were 17 groups of experiments (Table 4). See Table 5 for the summary of evaluation results of 17 groups of soy sauced beef by the evaluation team. According to the scores of different sensory evaluation indicators of each group of soy sauced beef, a fuzzy matrix was established. For example, in the color evaluation of the first group of soy sauced beef in Table 3, 0 people felt extremely poor, 2 people felt poor, 2 people felt fair, 2 people felt relatively good, 0 people felt good, and 0 people felt excellent. So, the V color = {0, 0.2, 0.4, 0.2, 0.2, 0.0}. The evaluation of tissue, flavor, taste and chewiness is the same. The matrix R was established:

$$R_1 = \begin{bmatrix} 0 & 0.2 & 0.4 & 0.2 & 0.2 & 0 & 0 \\ 0 & 0.2 & 0.4 & 0.2 & 0.2 & 0 & 0 \\ 0 & 0.1 & 0.2 & 0.5 & 0.2 & 0 & 0 \\ 0 & 0.2 & 0.5 & 0.2 & 0.1 & 0 & 0 \\ 0 & 0.2 & 0.4 & 0.3 & 0.1 & 0 & 0 \end{bmatrix}$$

Similarly, R2-R17 can be obtained. The weight sets A and R were fuzzy transformed, that is, W=A*R. The approval ratio of sensory evaluation can be obtained, such as W1:

$$W_1 = A * R_1 = [0.2 \quad 0.15 \quad 0.2 \quad 0.25 \quad 0.2] * \begin{bmatrix} 0 & 0.2 & 0.4 & 0.2 & 0.2 & 0 & 0 \\ 0 & 0.2 & 0.4 & 0.2 & 0.2 & 0 & 0 \\ 0 & 0.1 & 0.2 & 0.5 & 0.2 & 0 & 0 \\ 0 & 0.2 & 0.5 & 0.2 & 0.1 & 0 & 0 \\ 0 & 0.2 & 0.4 & 0.3 & 0.1 & 0 & 0 \end{bmatrix}$$

$$= [0 \quad 0.14 \quad 0.35 \quad 0.30 \quad 0.19 \quad 0.02 \quad 0.00]$$

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According to the distribution of evaluation indicator levels of the comment set, the comments were set: extremely poor =30 points, poor =40 points, relatively poor =50 points, fair=60 points, relatively good =70 points, good =80 points, excellent =90 points, that is, the comment set M= {30, 40, 50, 60, 70, 80}. The fuzzy comprehensive score of soy sauced beef is Y=M*W. For example, the score of the first group of soy sauced beef is Y1=0×30+0.14×40+0.35×50+0.30×60+0.19×70+0.02×80+0×90=56.10. In the same way, the scoring results of 17 groups of soy sauced beef are shown in Table 4.

3.2 Establishment of Box-behnken Model

3.2.1 Box-behnken test results

Taking the fuzzy mathematics sensory evaluation score (Y) as the response value, BBD design was adopted to optimize the one-step technology parameters. See Table 4 for the experimental design and results.

**Table 4. Design and results of BBD**

| Experiment No. | A | B | C | Y |
|---|---|---|---|---|
| | Meat-sauce ratio/% | Marinating temperature/℃ | Marinating time /min | Sensory score/point |
| 1 | -1 | -1 | 0 | 56.10 |
| 2 | 1 | -1 | 0 | 60.95 |
| 3 | -1 | 1 | 0 | 59.10 |
| 4 | 1 | 1 | 0 | 64.65 |
| 5 | -1 | 0 | -1 | 57.45 |
| 6 | 1 | 0 | -1 | 63.00 |
| 7 | -1 | 0 | 1 | 52.60 |
| 8 | 1 | 0 | 1 | 53.40 |
| 9 | 0 | -1 | -1 | 58.00 |
| 10 | 0 | 1 | -1 | 66.10 |
| 11 | 0 | -1 | 1 | 52.90 |
| 12 | 0 | 1 | 1 | 48.75 |
| 13 | 0 | 0 | 0 | 77.00 |
| 14 | 0 | 0 | 0 | 75.80 |
| 15 | 0 | 0 | 0 | 75.35 |

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| | | | | |
|---|---|---|---|---|
| 16 | 0 | 0 | 0 | 76.15 |
| 17 | 0 | 0 | 0 | 74.70 |

**Table 5. Summary of sensory evaluation of beef in one-step sauce**

| Sample | Color | | | | | | | Tissue | | | | | | | Flavor | | | | | | | Taste | | | | | | | Chewiness | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | V1 | V2 | V3 | V4 | V5 | V6 | V7 | V1 | V2 | V3 | V4 | V5 | V6 | V7 | V1 | V2 | V3 | V4 | V5 | V6 | V7 | V1 | V2 | V3 | V4 | V5 | V6 | V7 | V1 | V2 | V3 | V4 | V5 | V6 | V7 |
| 1 | 0 | 2 | 4 | 2 | 2 | 0 | 0 | 0 | 2 | 4 | 2 | 2 | 0 | 0 | 0 | 1 | 2 | 5 | 2 | 0 | 0 | 0 | 2 | 5 | 2 | 1 | 0 | 0 | 0 | 0 | 2 | 4 | 3 | 1 | 0 |
| 2 | 0 | 1 | 3 | 4 | 2 | 0 | 0 | 0 | 1 | 3 | 3 | 2 | 1 | 0 | 0 | 0 | 1 | 5 | 3 | 1 | 0 | 0 | 1 | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 1 | 3 | 4 | 2 | 0 |
| 3 | 0 | 0 | 2 | 3 | 4 | 1 | 0 | 0 | 1 | 4 | 3 | 2 | 0 | 0 | 0 | 0 | 2 | 4 | 3 | 1 | 0 | 0 | 1 | 3 | 3 | 3 | 0 | 0 | 0 | 2 | 3 | 4 | 1 | 0 | 0 |
| 4 | 0 | 0 | 1 | 3 | 4 | 2 | 0 | 0 | 1 | 2 | 3 | 3 | 1 | 0 | 0 | 0 | 1 | 3 | 4 | 2 | 0 | 0 | 0 | 2 | 2 | 4 | 2 | 0 | 0 | 1 | 2 | 3 | 3 | 1 | 0 |
| 5 | 0 | 1 | 2 | 4 | 3 | 0 | 0 | 0 | 1 | 2 | 5 | 2 | 0 | 0 | 0 | 2 | 3 | 4 | 1 | 0 | 0 | 0 | 2 | 3 | 3 | 2 | 0 | 0 | 0 | 1 | 1 | 4 | 3 | 1 | 0 |
| 6 | 0 | 0 | 2 | 4 | 3 | 1 | 0 | 0 | 0 | 2 | 5 | 2 | 1 | 0 | 0 | 0 | 2 | 5 | 1 | 2 | 0 | 0 | 1 | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 3 | 4 | 3 | 0 |
| 7 | 0 | 1 | 2 | 4 | 3 | 0 | 0 | 1 | 4 | 4 | 1 | 0 | 0 | 0 | 0 | 2 | 4 | 3 | 1 | 0 | 0 | 0 | 2 | 4 | 3 | 1 | 0 | 0 | 0 | 3 | 4 | 2 | 1 | 0 | 0 |
| 8 | 0 | 1 | 2 | 3 | 3 | 1 | 0 | 1 | 3 | 4 | 1 | 0 | 0 | 0 | 0 | 1 | 4 | 4 | 1 | 0 | 0 | 0 | 2 | 4 | 3 | 1 | 0 | 0 | 0 | 2 | 3 | 4 | 1 | 0 | 0 |
| 9 | 0 | 1 | 2 | 4 | 1 | 1 | 0 | 0 | 2 | 2 | 4 | 2 | 0 | 0 | 0 | 1 | 3 | 4 | 2 | 0 | 0 | 0 | 0 | 2 | 6 | 2 | 0 | 0 | 0 | 0 | 2 | 4 | 3 | 1 | 0 |
| 10 | 0 | 0 | 1 | 3 | 4 | 2 | 0 | 0 | 0 | 1 | 3 | 4 | 2 | 0 | 0 | 0 | 1 | 3 | 4 | 2 | 0 | 0 | 0 | 2 | 3 | 3 | 2 | 0 | 0 | 0 | 2 | 3 | 3 | 2 | 0 |
| 11 | 0 | 1 | 3 | 4 | 2 | 0 | 0 | 1 | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 2 | 4 | 3 | 1 | 0 | 0 | 0 | 2 | 4 | 2 | 2 | 0 | 0 | 0 | 3 | 4 | 2 | 1 | 0 | 0 |
| 12 | 0 | 1 | 4 | 4 | 1 | 0 | 0 | 2 | 4 | 3 | 1 | 0 | 0 | 0 | 0 | 2 | 4 | 3 | 1 | 0 | 0 | 0 | 3 | 3 | 2 | 1 | 0 | 0 | 1 | 3 | 5 | 1 | 0 | 0 | 0 |
| 13 | 0 | 0 | 0 | 1 | 3 | 4 | 2 | 0 | 0 | 0 | 1 | 3 | 4 | 2 | 0 | 0 | 0 | 1 | 3 | 4 | 2 | 0 | 0 | 0 | 2 | 1 | 5 | 2 | 0 | 0 | 0 | 1 | 3 | 4 | 2 |
| 14 | 0 | 0 | 0 | 2 | 2 | 4 | 2 | 0 | 0 | 0 | 1 | 4 | 4 | 1 | 0 | 0 | 0 | 2 | 3 | 3 | 2 | 0 | 0 | 0 | 2 | 3 | 3 | 2 | 0 | 0 | 0 | 1 | 2 | 5 | 2 |
| 15 | 0 | 0 | 0 | 2 | 3 | 3 | 2 | 0 | 0 | 0 | 0 | 4 | 3 | 2 | 0 | 0 | 0 | 1 | 4 | 3 | 2 | 0 | 0 | 0 | 1 | 3 | 4 | 2 | 0 | 0 | 0 | 1 | 3 | 4 | 2 |
| 16 | 0 | 0 | 0 | 2 | 3 | 3 | 2 | 0 | 0 | 0 | 1 | 3 | 4 | 2 | 0 | 0 | 0 | 2 | 2 | 4 | 2 | 0 | 0 | 0 | 1 | 4 | 3 | 2 | 0 | 0 | 0 | 1 | 3 | 4 | 2 |
| 17 | 0 | 0 | 0 | 2 | 3 | 4 | 1 | 0 | 0 | 0 | 1 | 4 | 3 | 2 | 0 | 0 | 0 | 2 | 4 | 2 | 2 | 0 | 0 | 0 | 2 | 4 | 2 | 2 | 0 | 0 | 0 | 1 | 4 | 3 | 2 |

3.2.2 Establishment of regression model and significance analysis

Through regression fitting analysis of the experimental data, the quadratic multiple regression simulation equation of sensory score (Y), meat-sauce ratio (A), marinating temperature (B) and marinating time (C) is: Y=75.80+2.09*A+1.33*B-4.61*C+0.1750*AB-1.19*AC-3.06*BC-7.71*A2-7.89*B2-11.48*C2. The variance analysis of the model is shown in Table 5.

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**Table 6. Results of ANOVA for the secondary regression model**

| Variance source | Sum of squares | Freedom | Mean square | F value | P value | Significance |
|---|---|---|---|---|---|---|
| MODEL | 1448.70 | 9 | 160.97 | 80.65 | ＜0.0001 | ** |
| A | 35.07 | 1 | 35.07 | 17.57 | 0.0041 | ** |
| B | 14.18 | 1 | 14.18 | 7.10 | 0.0322 | ** |
| C | 170.20 | 1 | 170.20 | 85.28 | ＜0.0001 | ** |
| AB | 0.1225 | 1 | 0.1225 | 0.0614 | 0.8114 | |
| AC | 5.64 | 1 | 5.64 | 2.83 | 0.1366 | |
| BC | 37.52 | 1 | 37.52 | 18.80 | 0.0034 | ** |
| A2 | 250.45 | 1 | 250.45 | 125.49 | ＜0.0001 | ** |
| B2 | 261.95 | 1 | 261.95 | 131.25 | ＜0.0001 | ** |
| C2 | 554.42 | 1 | 554.42 | 277.79 | ＜0.0001 | ** |
| RESIDUAL | 13.97 | 7 | 2.00 | | | |
| LACK DF FIT | 11.00 | 3 | 3.67 | 4.93 | 0.0787 | |
| PURE ERROR | 2.98 | 4 | 0.7438 | | | |
| TOTAL DEVIATION | 1462.67 | 16 | | | | |
| DETERMINATION COEFFICIENT R2 | 0.9904 | | | | | |
| PREDICT R2 | 0.8765 | | | | | |
| ADJUST R2 | 0.9782 | | | | | |
| C.V% | 2.24 | | | | | |

Note: * * means extremely significant ($P < 0.01$), and * means significant ($P < 0.05$).

It can be seen from Table 6 that $P < 0.01$ for the model, indicating that this regression model is extremely significant; $P > 0.05$ for missing term, indicating that the regression equation is not false; R2 =0.9904, indicating that the fitting degree and reliability of the equation are high; the value of C.V is inversely proportional to the accuracy of the experiment. The low value of C.V in this experiment indicates that the experiment is feasible and can be used for the research of this technology.

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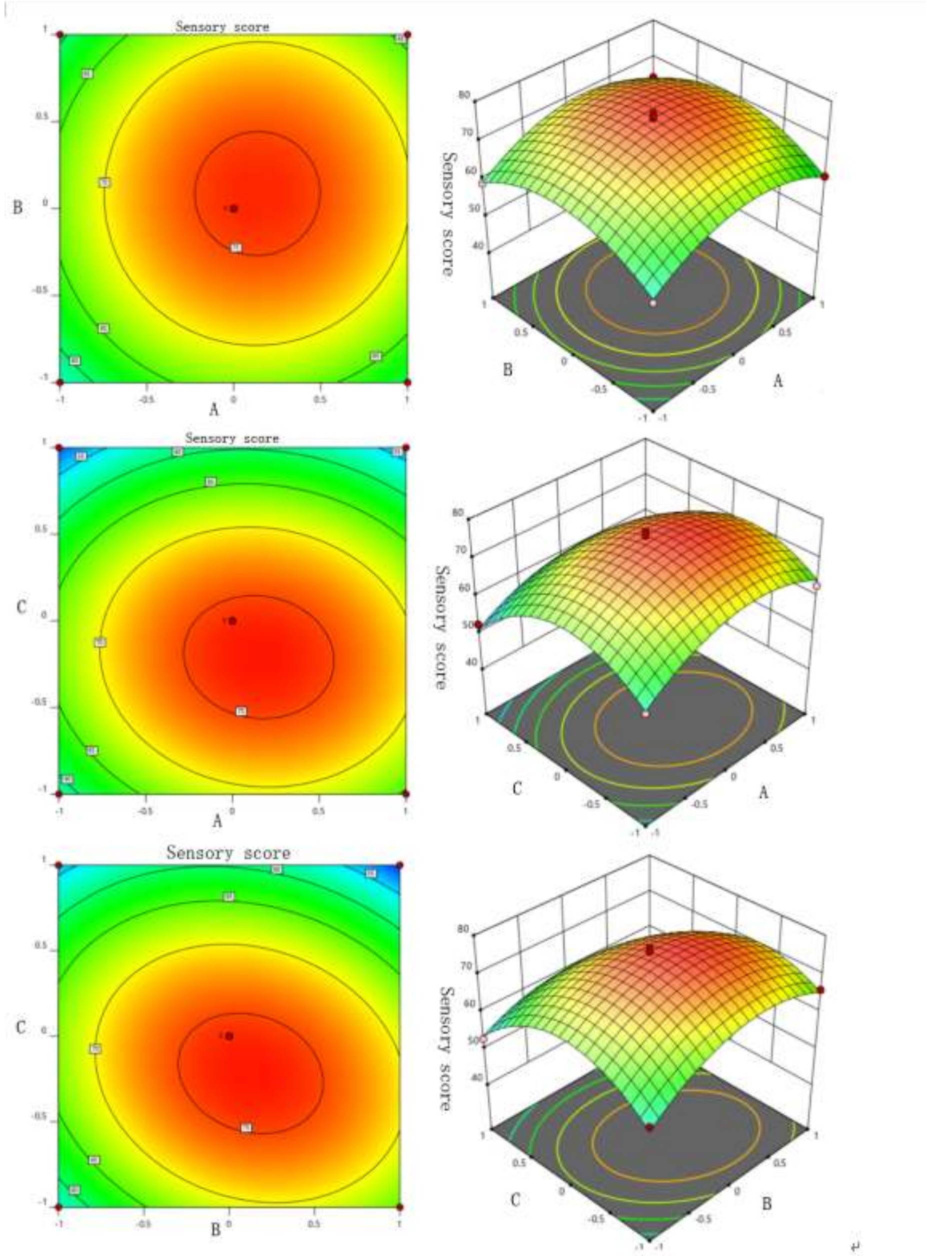


Figure 1: Contour and response plots of the effects of factor interactions on sensory scores

The interaction among various factors and the contours are shown in Figure 1. Among them, the interaction between BC (marinating temperature and marinating time) is significant; seen from the contour, the intensity of axial change is B > C > A, and it can be concluded that the order of fuzzy mathematical sensory scores of various factors in the experimental range is: marinating temperature (B) > marinating time (C) > meat-sauce ratio (A). The steepness of the curved surface in Box-behnken map can indicate the degree of influence of variables on sensory score. The steeper slope indicates the greater influence, whereas the opposite is less [20]. As can be seen from the figure, the slope of BC is greater than AB and

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AC, which indicates that marinating temperature (B) and marinating time (C) have more significant effects on fuzzy mathematics sensory score, and the result is consistent with variance analysis.

3.2.3 Optimization and verification of technological parameters

Through Box-behnken analysis, the best soy sauced beef using one-step technology technology is as follows: meat-sauce ratio of 10.775%, marinating temperature of 111.3℃, marinating time of 62.26 min, and theoretical predicted value of sensory score of 76.57 points. Considering the operability of actual production, the technological parameters were adjusted as follows: meat-sauce ratio of 11%, marinating temperature of 111℃ and marinating time of 62 min. Five validation tests were carried out by using these technological parameters. The final average score of fuzzy mathematics sensory scores of soy sauced beef was 75.48±1.02, lose to the predicted value. It showed that the regression model could reflect the influence of various factors on fuzzy mathematics sensory score of soy sauced beef, and the reliability of the model results was verified.

3.3 Comparison of quality of soy sauced beef using three technologies

3.3.1 Sensory quality of three kinds of soy sauced beef.

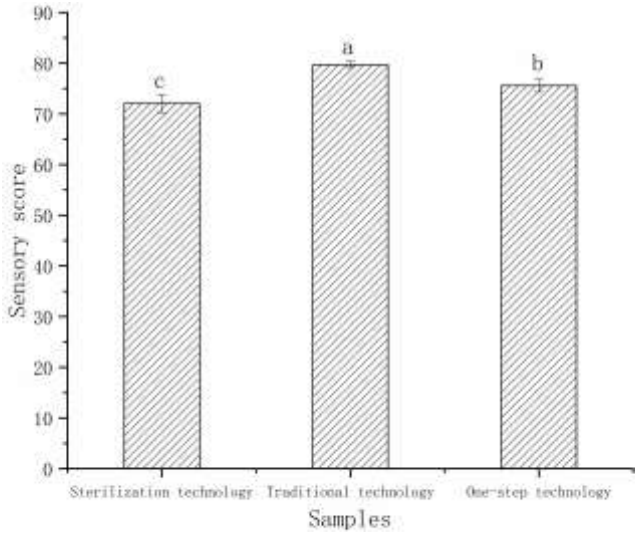


Figure 2: Sensory scores of soy sauced beef using different technologies

Comparing the soy sauced beef using one-step technology with the traditional high-temperature sterilized products and sterilized products, it is found that the sensory scores of the products obtained by different technologies are significantly different. The soy sauced beef using the traditional technology has the highest score of 79.71; the sensory score of soy sauced beef using one-step technology is 75.57, which

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is between those of traditional technology and sterilization technology, as is shown in Figure 2.

3.3.2 Texture of soy sauced beef using three technologies

**Table 7. Texture of soy sauced beef using different processes**

| Sample | Traditional handicrafts | Sterilization process | One step process |
|---|---|---|---|
| HARDNESS/gf | 5334.55±163.56a | 1264.93±72.30a | 1997.32±132.04b |
| FLEXIBILITY | 0.64±0.03a | 0.66±0.02a | 0.57±0.01b |
| CHEWINESS/gf | 1609.25±68.46a | 194.13±6.22c | 520.20±22.76b |
| ADHESION /gf | 2445.20±128.43a | 290.85±21.31c | 849.74±44.63b |
| COHESION | 0.47±0.03a | 0.23±0.02b | 0.38±0.11a |
| RESLILENCE | 0.16±0.00b | 0.76±0.02a | 0.15±0.01b |
| SHEAR FORCE/gf | 3864.29±86.50b | 5875.18±90.52a | 1842.29±53.36c |

Heat treatment denatures the collagen of meat products, resulting in changes in the structure and mechanical properties of intramuscular connective tissue, thus affecting the meat quality [21]. The texture indicators of soy sauced beef using three processes are shown in Table 7. It can be seen from the table that there are significant differences in texture of products using different technological conditions ($P < 0.05$). The traditional soy sauced beef is not sterilized, and its heat treatment strength is low. Its hardness, chewiness, adhesiveness and cohesion are high, but its elasticity and resilience are poor. After the same treatment, the hardness and chewiness of the soy sauced beef after sterilization decreases significantly, which may be caused by the increase of heat treatment intensity, protein denaturation in soy sauced beef and the loss of fat and water [22]; and the elasticity and resilience obviously increases, which is due to the fact that after the soy sauced beef is sterilized for a short time, the muscle protein is heated to form elastic gel, which increases its elasticity and resilience [23]. The hardness, chewiness and adhesiveness of soy sauced beef using one-step technology are significantly lower than those of traditional technology and sterilization process ($P < 0.05$). Long-term heating treatment makes muscle protein soft, leading to decrease of chewiness and hardness, and reducing the sustained resistance of beef to chewing [24]. The elasticity, cohesion and resilience of soy sauced beef using one-step technology are between those using traditional technology and sterilization technology. Combined with sensory score, the quality of soy sauced beef using one-step technology is better than that of soy sauced beef using sterilization process.

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3.3.3 Volatile substances in soy sauced beef using three technologies

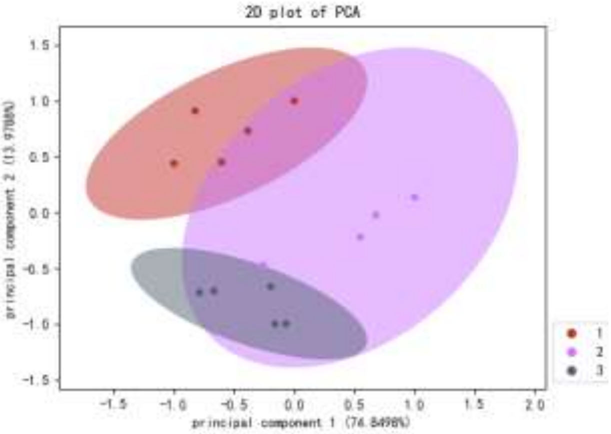


Figure 3: LDA Analysis Drawing of Three soy sauced beef.
(1: Traditional technology; 2: sterilization technology; 3: One-step technology)

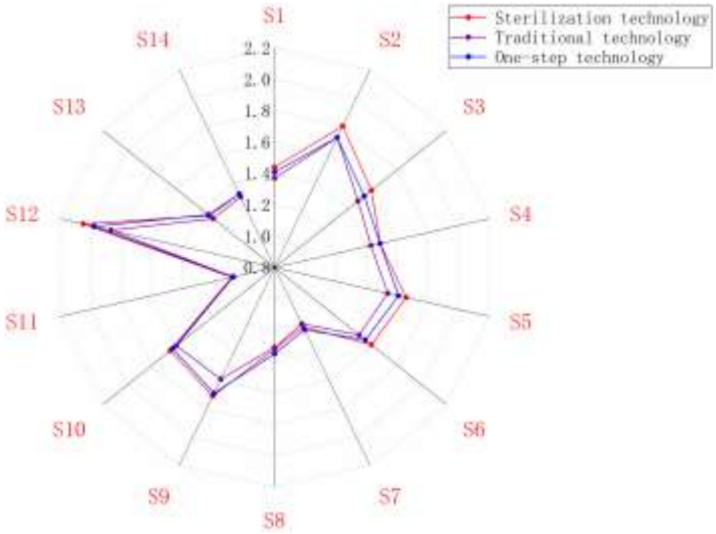


Figure 4: Analysis of the contribution rate of different sensors of the three soy sauced beef

The volatile substances of soy sauced beef using three technologies are shown in Figure 3. It can be seen from Figure 3 that: the differentiated contribution rate of the first principal component is 74.8498%. The differentiated contribution rate of the second principal component is 13.9788%. The cumulative contribution rate is 88.83%, indicating that principal component 1 and principal component 2 already contain a large amount of information and can reflect the overall information of the sample. On the whole, the soy sauced beef using one-step technology is closer to that using the traditional technology, which

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indicates that the flavor of the soy sauced beef using the improved technology is similar to that of the soy sauced beef using sterilization technology, and the difference is small; in terms of first principal component, the soy sauced beef using sterilization technology is closer to that using one-step technology, which indicates that the flavor of the soy sauced beef using the improved technology is similar to that of the soy sauced beef using sterilization technology, and the difference is small; the difference between the soy sauced beef using sterilization technology and the soy sauced beef using one-step technology is mainly in the second principal component, and the flavor has changed obviously. In addition, it can be seen from Figure 4 that the flavor differences of three soy sauced beef are small on sensors S2, S7, S8, S10, S11, S13 and S14, but are large on sensors S1, S3, S4, S5, S6, S9 and S12.

3.3.4 Germicide effect of soy sauced beef using three technologies

**Table 8. Gericide effect of the three products**

| Sample | Traditional technology | Sterilization technology | One-step technology |
|---|---|---|---|
| TOTAL NUMBER COLONIES/(CFU/g) | 198.67±4.55 | <10.00 | <10.00 |

The total number of colonies of soy sauced beef using different processing techniques is shown in Table 8. The detected total number of colonies of traditional soy sauced beef is 198.67 CFU/g, which is a high content. The detected total number of colonies of soy sauced beef using sterilization process and improved technology is far lower than the limit (1.0× 104CFU/g) in national standard [22].

## IV. CONCLUSION

Fuzzy mathematics sensory evaluation and Box-behnken method were used to optimize the one-step processing technology of soy sauced beef. The results showed that the fuzzy mathematics sensory score was the highest with meat-sauce ratio of 11%, cooking temperature of 111℃ and cooking time of 62min. Under these conditions, the marinated soy sauced beef had strong flavor, moderate hardness and rich taste. The production cycle was greatly shortened, and the total number of colonies of the product was far below the national food safety standard. On the whole, the soy sauced beef using the optimized technology parameters in this study could give consideration to both quality requirements and sterilization effect. On the premise of ensuring the quality, it improved the thermal sterilization effect and simplified the processing technology, providing important practical reference for industrial production.

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