Optimization of The Fermentation Process of Kimchi

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Abstract. This paper focuses on the effects of salt, sugar and temperature on the sensory evaluation of the product. The fermentation process is optimized by single factor experiment and orthogonal experiment. The results showed that salt, sugar and temperature had significant effects on the sensory score of naturally fermented kimchi. The optimum process parameters were: 3% of salt, 2% sugar, 30 °C fermentation temperature and 4 days fermentation time. The kimchi produced by this formula and process has the highest sensory score of 89.0 points. Under the best formula, kimchi has a strong aroma, moderate sweet and sour taste, and has the unique aroma of pickled kimchi. It has a rich aftertaste, good chewability and no roughness.

1. Introduction
With the gradual improvement of people's living conditions, the improvement of production and manufacturing capabilities, the stability of the market supply and demand structure, people's table and food diet are also developing in many aspects. The demand for pickled fermented vegetable products with the aim of being close to the people, convenient and fast is increasing, expanding the market demand of the kimchi industry, increasing the consumption of kimchi, and providing strong market conditions for the kimchi processing plant projects.

2. Flow chart

![Figure 1. Process of kimchi production](image-url)
3. Indicator detection
(a). Determination of acidity
Take 5 ml of cabbage fermentation broth in a triangular flask, add phenolphthalein, titrate with 0.1 mol/mL NaOH solution, and continue to gently shake the flask until the liquid reddish does not fade in half a minute.

$$\text{Total acidity (\%)} = \frac{C \times (V_1 - V_2) \times k \times V_0 \times 100}{m \times V_3},$$  

where $k = 0.09$ (converted to the coefficient of the appropriate acid).

C: concentration of standard NaOH solution mol/L 
$V_1$: volume of standard lye consumed by titration 
$V_2$: volume of standard lye consumed by blanks ml 
$V_0$: sample dilution total volume ml 
$V_3$: the volume of the sampling solution for titration 
M: sample mass or volume (g or ml)

(b). pH: pH meter determination.

(c). Preparation of nitrite standard curve: Take nine 50 ml colorimetric tubes, add 0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.5, 2.0, 2.5 ml of 5g/ml sodium nitrite standard solution, then add p-amino 2 ml of benzenesulfonic acid solution and 1 ml of a solution of naphthylamine hydrochloride, deionized water was added to 50 ml to volume, shaken, and 0 tube blank was compared, and a standard curve was drawn at a wavelength of 538 nm.

Sample determination: 5 ml of juice was weighed into a 50 ml beaker and 10 ml of deionized water was added. Measure 12.5 ml of saturated borax solution in a beaker, mix well, rinse the sample with about 150 ml of deionized water, rinse into a 250 ml volumetric flask, and remove it in a water bath at 80 °C for 20 min. 5 ml of potassium ferrocyanide solution was added, shaken, and 5 ml of zinc acetate solution was added to precipitate the protein. Add deionized water to a volume of 250 ml, shake well, filter after 30 min, discard the primary filtered liquid, and then use the filtrate as a sample for use.

| Table 1. Determination of solution ratio of nitrite in sample |
|-------------------------------------------------------------|
| **Number(50ml)**    | 0  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | sample |
| Sodium nitrite (ml) | 0.0 | 0.2 | 0.4 | 0.6 | 0.8 | 1.0 | 1.5 | 2.0 | 2.5 |         |
| Sample filtrate (ml) | 0  | 39.2 | 39.6 | 39.4 | 39.2 | 39 | 38.5 | 38 | 37.5 | 40     |
| P-aminobenzenesulfonic acid solution (ml) | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Naphthylamine hydrochloride (ml) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Add deionized water to 50ml | Mix | Stand still | 3–5 | minute | | | | | |

At a wavelength of 538 nm, the curve and concentration of nitrite are obtained.

4. Experimental results and analysis
The standard curve for making nitrite is shown in Figure 2:
Figure 2. Nitrite absorbance at 538nm

The trend line is: $y = 1.0299x - 0.008$, $R^2 = 0.9955$, where the concentration is too large when the concentration is 0.15, and it is rounded off. Under the basic formula, the amount of salt added was 2%, 3%, 4%, the amount of sugar added was 3%, and the fermentation was carried out at 30°C for 4 days. After the fermentation was completed, the pH, total acidity and nitrite concentration of the kimchi juice were measured. The sensory evaluation showed an optimum salt concentration of 3%.

Table 2. Determination of each index under the change of salt concentration

| NaCl concentration variable | 538nm | Nitrite concentration | pH | Total acidity % |
|-----------------------------|-------|-----------------------|----|-----------------|
| 2.00%                       | 0.019 | 0.026                 | 3.7| 0.504           |
| 3.00%                       | 0.018 | 0.025                 | 3.36| 0.396          |
| 4.00%                       | 0.019 | 0.026                 | 3.67| 0.324          |

Under the premise of screening the optimum salt content of 3% and other fermentation conditions, the sugar addition amount was 2%, 3%, 4%, and the fermentation was completed to determine the pH value and nitrite content and acidity of kimchi juice. After the evaluation, the sugar concentration was optimally 2%.

Table 3. Determination of each index under the change of sugar concentration

| Sugar concentration variable | 538nm | Nitrite concentration | pH | Total acidity % |
|------------------------------|-------|-----------------------|----|-----------------|
| 2%                           | 0.015 | 0.022                 | 3.75| 0.324           |
| 3%                           | 0.013 | 0.020                 | 3.3 | 0.81            |
| 4%                           | 0.008 | 0.016                 | 3.7 | 0.396           |

Under the premise of the same amount of 3% salt added, 2% sugar addition and other fermentation conditions, the fermentation temperature was 25 °C, 30 °C, 35 °C, and the pH and nitrite content of kimchi juice were measured. After sensory evaluation. The optimum temperature is 35 °C.

Table 4. Determination of each index under temperature change

| Temperature variable | 538nm | Nitrous acid concentration | pH  | Total acidity % |
|----------------------|-------|---------------------------|-----|-----------------|
| 25 °C                | 0.019 | 0.026                     | 3.17| 1.8             |
| 30 °C                | 0.02  | 0.027                     | 3.41| 1.08            |
| 35 °C                | 0.019 | 0.026                     | 3.26| 1.53            |
Sensory evaluation of the color, aroma, taste and brittleness of kimchi was carried out by fuzzy mathematics comprehensive evaluation method, as shown in Table 5:

### Table 5. Three-factor three-level score sheet

| Test number | Salt concentration (%) | Sugar concentration (%) | Temperature (°C) | Total score |
|-------------|------------------------|-------------------------|------------------|-------------|
| 1           | 2                      | 2                       | 25               | 82          |
| 2           | 2                      | 3                       | 30               | 76          |
| 3           | 2                      | 4                       | 35               | 81          |
| 4           | 3                      | 3                       | 30               | 83          |
| 5           | 3                      | 4                       | 35               | 89          |
| 6           | 3                      | 2                       | 25               | 90          |
| 7           | 4                      | 4                       | 35               | 83          |
| 8           | 4                      | 2                       | 25               | 81          |
| 9           | 4                      | 3                       | 30               | 78          |

### Table 6. Three factors and three levels of kimchi

| Factor      | Salt concentration | Sugar concentration | Temperature |
|-------------|--------------------|---------------------|-------------|
| Mean 1      | 79.667             | 82.667              | 83.000      |
| Mean 2      | 87.333             | 82.000              | 83.111      |
| Mean 3      | 80.667             | 83.000              | 81.667      |
| Extreme difference | 7.666             | 1.000               | 1.333       |

It can be seen from the above table that the range $R_A>R_C>R_B$, so the order of factors is A (salt concentration), C (temperature), B (sugar concentration). The level corresponding to the maximum value of $k_1$, $k_2$, and $k_3$ of each factor is selected. Salt concentration: $k_2>k_3>k_1$, sugar concentration: $k_1>k_3>k_2$, temperature: $k_2>k_1>k_3$, so the most suitable scheme is $A_2B_1C_2$, i.e: 3% salt addition, 2% sugar addition, temperature control 30°C.

The evaluation results showed that: 3% salt concentration, 2% sugar concentration, and the acceptance of kimchi fermented at a temperature of 30°C was greater than the other variables, and the kimchi produced according to the formula was more in line with the taste of the public.

### 5. Basic principles of factory design

(a). It conforms to the local planning and conforms to the production process of the factory, which facilitates the cooperation between workers and the transportation of raw materials, and has a compact layout and reasonable land use.

(b). The layout of the plant and the layout of the water and electricity are combined to improve work efficiency. Food factory hygiene and process pipeline requirements must be met to avoid cross-contamination of raw materials, semi-finished products, and people.

(c). The factory building meets the requirements of lighting and ventilation, and some special facilities need to be protected from light.

(d). The main building layout of the plant meets the planning requirements, the traffic flow and the flow of people are separated, and the natural conditions are rationally utilized.

(e). Appropriately increase the green area, provide a comfortable working environment for workers' work, and increase work efficiency.

(f). Reserve a certain amount of blank green space to set aside the necessary production areas for future expansion.

(g). The water supply and drainage system should be larger than the production needs to prevent the use of the amount within the necessary time period.
(h). The factory layout is simple and generous, and it is complicated and simplified.

6. Conclusion
Through research, the best formula for making kimchi was obtained. The main results are as follows:
(a) Single factor experiment showed that when the salt concentration was 3%, the sugar concentration was 2%, and the temperature was 30 °C, the effect on the sensory evaluation of the product was significant, indicating the salt concentration. Factors such as sugar concentration and temperature conditions have different sensory effects on the production of kimchi. (b) Using the horizontal factor to analyze the taste of kimchi, under the basic formula, the salt concentration is 3%, the sugar concentration is 2%, and the temperature is 30 °C. At this time, the sensory evaluation of the product is the highest, 90, and the taste is the best. (c) Sensory evaluation of the appearance, histology, color and flavor of natural fermented kimchi by fuzzy mathematics comprehensive evaluation method, and the evaluation result was “favorite”. (d) This product is fermented by lactic acid bacteria. Compared with traditional salting, the product has a white and sturdy color, full of fragrance, elasticity, good slicing, delicate taste, moderate spicy taste and no odor.

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