Optimization of the Formulation and Processing Technology of Quinoa Bread by Response Surface Methodology

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Abstract: In order to ensure rich nutrition and diversified taste of bread, quinoa flour is added to provide consumers with a functional healthier bread. Through the single factor and response surface experiments, the production process of the bread was optimized. The optimal formula of quinoa bread was obtained as follows: Quinoa Powder 1%, Yeast Powder 1.00%, and Butter 5.48%. Under the formula, the sensory score of quinoa bread was 95.9.

1. Introduction
This project uses white quinoa from Qinghai as the research object. The secondary fermentation method is used to mix quinoa flour with high-gluten flour and other materials to process and prepare nutritious quinoa bread. For the experiment, response surface analysis was used to optimize the formula and process. The method is to optimize and determine the best process and formula to make quinoa bread, in order to provide a certain theoretical basis for future related products.

2. Materials and Methods

2.1. Materials and Reagents
White Quinoa was made from Xining, Qinghai, High-gluten wheat flour purchased from, Golden Bakery 1 # Bread Flour (COFCO Group Co., Ltd.,) Dry Yeast supplied by Angel Yeast Co., Ltd., Edible Salt from Zhongyan Tianjin Changlu Salt Industry Co., Ltd., Butter: Anjia; For sale and Eggs purchased from local market.

2.2. Instruments
GN-20 Crusher, Guangzhou Xulang Machinery Equipment Co., Ltd.; SM-25 Mixer, Xinmai Machinery China Co., Ltd.; SM-40SP Proofing Box, Xinmai Machinery China Co., Ltd.; SJ-493 Oven, Xinmai Machinery China Limited Company; ES-A precision electronic balance, Tianjin Deant Sensor Technology Co., Ltd.

2.3. Preparation of Quinoa Flour
Use white quinoa from Xining, Qinghai which is carefully selected to remove any impurities. Quinoa must be pulverized after being crushed by a high-speed pulverizer. Once pulverized, it is sieved and must be refrigerated for later use.
2.4. Production process of quinoa bread
Weighing of raw and auxiliary materials → preparation of dough → first proofing → splitting, rounding, exhausting air bubbles → relaxation → shaping → second proofing → baking → cooling → packaging.

2.5. Single factor test for making quinoa bread
According to the manufacturing process of quinoa bread, based on the total mass of 100g of gluten flour and quinoa flour, the sensory score was adopted by changing the amount of quinoa flour, yeast and butter added. The relationship between each factor and the quality of quinoa bread was determined. Quinoa flour is added at 8%, 10%, 12%, 14%, and 16%; yeast powder is added at 0.50%, 0.75%, 1.00%, 1.25%, and 1.50%; butter is added at 4.50%, 5.00%, 5.50%, 6.00%, 6.50%. The other auxiliary materials were added with 42% water, 1.5% salt, and 17% eggs.

2.6. Response surface test for making quinoa bread
On the basis of the single factor test, three factors including the amount of quinoa flour (%), the amount of yeast (%), and the amount of butter (%) were selected as independent variables, and the sensory score was used as the response value. According to the Box-Behnken center Group and design, the principles were used for response surface analysis. Three factors and three levels of response surface analysis tests were performed on the production of quinoa bread to optimize the best process formula of quinoa bread. The analysis factors and levels are shown in Table 1.

| Level | A  | B  | C  |
|-------|----|----|----|
| -1    | 10 | 0.75 | 4.5 |
| 0     | 12 | 1.00 | 5.0 |
| 1     | 14 | 1.25 | 5.5 |

3. Results and Analysis

3.1. Effect of quinoa flour addition on bread quality

It can be seen from Figure 1 that when the added amount of quinoa flour is 12%, the sensory quality score of bread is the highest. With the increase of the amount of quinoa flour, the sensory quality score value increased till it reached the optimal state then decrease as more was added. This is due to the richer trace elements in quinoa flour, which is beneficial to the fermentation of the bread. If too much quinoa flour is added, the crust of the quinoa bread appears to be wrinkled and collapsed, affecting the overall quality. Comprehensive analysis shows, the appropriate amount of quinoa flour to add is 12%.
3.2. Effect of yeast powder addition on bread quality

It can be seen from Figure 2 that the amount of yeast added has a great impact on the appearance and quality of bread. Too little addition will cause insufficient dough development and affect bread volume. Too large an addition will cause excessive fermentation inside the bread and cause the dough to go flat. It makes the appearance of bread collapsed and affects the quality of bread. By comprehensive analysis, the amount of yeast powder should be at 1%.

3.3. Effect of butter addition on bread quality

It can be seen from Figure 3 that as the amount of butter increases, the sensory quality score of the bread first increases and then decreases. If the amount of butter added is too small to completely wrap the gluten protein, it will cause the carbon dioxide gas after fermentation to easily overflow. As a result, the volume of the bread reduces increasing hardness and reducing the sensory score. If excessive amount of butter is added, it will play a role of dehydration by affecting the formation of gluten network and limit the volume expansion of yeast dough. Comprehensive analysis shows the amount of butter should be 5%.

3.4. Response surface analysis test results

The test results are shown in Table 3. Using Design Expert 10.0.3 to perform a binary regression fit on the test results, the regression equation is

\[ Y = 95.06 + 0.34A + 0.40B + 0.89C - 0.23AB - 0.30AC - 0.23BC - 6.06A^2 - 3.48B^2 - 0.45C^2 \]

The analysis of variance can be seen in Table 4. Analyzing the data in Table 4, p <0.0001 surface regression model is highly significant; the misfit phase p = 0.6872 > 0.05, which indicates that the reliability of the regression model is relatively high; the coefficient of determination \( R^2 = 0.9983 \), which indicates that the model has a good fit; The signal-to-noise ratio is 58.783 > 4, indicates that the test accuracy is very high. Therefore, the regression model can accurately simulate the effect of the three factors of quinoa flour addition, yeast addition and butter addition on the sensory score of quinoa bread.
One-time terms A, B, C and two sub-items $A^2$, $B^2$, and $C^2$ are extremely significant, and the second term AC bets, but AB and BC are not significant. The magnitude of each factor affecting the sensory score of bread is $C$ (Addition of butter) $>$ $B$ (Addition of yeast powder) $>$ $A$ (Addition of quinoa flour). Through the analysis of the regression equation and Table 4, Figures 4, 5, and 6, the optimal process conditions are as follows: the amount of quinoa flour added, the amount of yeast powder added, and the amount of butter added. Under the best process conditions, the predicted value of bread sensory score is 95.5 points.

### Table 2. Response surface test results

| Test number | A Addition of quinoa flour /% | B Addition of yeast powder /% | C Addition of butter /% | Sensory score |
|-------------|--------------------------------|-------------------------------|------------------------|---------------|
| 1           | -1                             | 0                             | -1                     | 87.1          |
| 2           | -1                             | -1                            | 0                      | 84.4          |
| 3           | 0                              | 0                             | 0                      | 95.3          |
| 4           | 0                              | 0                             | 0                      | 95.1          |
| 5           | 0                              | 0                             | 0                      | 94.7          |
| 6           | 1                              | 1                             | 0                      | 86.2          |
| 7           | -1                             | 1                             | 0                      | 85.8          |
| 8           | 1                              | 0                             | 1                      | 89.4          |
| 9           | 1                              | 0                             | -1                     | 88.2          |
| 10          | 0                              | -1                            | 1                      | 91.9          |
| 11          | -1                             | 0                             | 1                      | 89.5          |
| 12          | 0                              | 1                             | -1                     | 90.8          |
| 13          | 0                              | 0                             | 0                      | 95.3          |
| 14          | 0                              | 1                             | 1                      | 92.1          |
| 15          | 0                              | 0                             | 0                      | 94.9          |
| 16          | 1                              | -1                            | 0                      | 85.7          |
| 17          | 0                              | -1                            | -1                     | 89.7          |

### Table 3. Analysis of variance results

| Source of variance | Sum of squares | Degrees of freedom | Standard deviation | F value | P value | Saliency |
|--------------------|----------------|--------------------|--------------------|---------|---------|----------|
| Regression model   | 228.66         | 9                  | 25.41              | 468.64  | <0.0001 | ++       |
| A                  | 0.91           | 1                  | 0.91               | 16.81   | 0.0046  | ++       |
| B                  | 1.28           | 1                  | 1.28               | 23.61   | 0.0018  | ++       |
| C                  | 6.30           | 1                  | 6.30               | 116.23  | <0.0001 | ++       |
| AB                 | 0.20           | 1                  | 0.20               | 3.74    | 0.0946  | -        |
| AC                 | 0.36           | 1                  | 0.36               | 6.64    | 0.0366  | +        |
| BC                 | 0.20           | 1                  | 0.20               | 3.74    | 0.0946  | -        |
| $A^2$              | 154.37         | 1                  | 154.37             | 2847.42 | <0.0001 | ++       |
| $B^2$              | 50.99          | 1                  | 50.99              | 940.55  | <0.0001 | ++       |
| $C^2$              | 0.87           | 1                  | 0.87               | 16.08   | 0.0051  | ++       |
| Residual           | 0.38           | 7                  | 0.054              |         |         |          |
| Lack of fit        | 0.11           | 3                  | 0.036              | 0.53    | 0.6872  | -        |
| Pure error         | 0.27           | 4                  | 0.068              |         |         |          |
| Cor error          | 229.04         | 16                 |                    |         |         |          |

Note: “+” means the difference is significant ($p < 0.05$), “++” means the difference is extremely significant ($p < 0.01$), “-“ means the difference is not significant ($p > 0.05$)
3.5. **Response surface analysis verification test**

After the correction, the optimal process conditions are quinoa flour addition amount is 12%, yeast powder addition amount is 1.00%, and butter addition amount is 5.48%. Based on this optimal process condition, three sets of parallel verification tests were performed. The facial sensory quality scores were 96.1, 95.7, and 96.0, with an average of 95.9 points. Compared with the predicted value, the relative error was only 0.42%. It shows that it is reliable to optimize the processing conditions of quinoa bread by response surface method.
4. Conclusion
Quinoa is processed into flour and added to the production process of bread. Using single-factor tests and response surface tests, the optimal formula of quinoa bread is determined by adding quinoa flour at 12%, yeast powder at 1.00%, and butter at 5.48%. The average sensory score of the product was 95.9 points, which accorded with the predicted value. The industrial production of quinoa bread has promoted through research. By adding quinoa flour to bread it has enriched bread, added new varieties for the development of quinoa food.

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