Optimization of Process Technique of Rice Milk Drinks via Response Surface Methodology (RSM)

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Abstract: In this manuscript, the production process of rice drink was optimized by response surface analysis. The results showed the best process conditions for rice milk drinks as follow: ratio of material to liquid was 1:18, the amount of maltose added was 5.4% and the amount of non-dairy cream was 1.3%. The product was an ivory emulsion, which not only had a strong rice flavor and frankincense, but also had a delicate and smooth taste without condensation and stratification which provided new ideas and methods for the intensive processing of glutinous rice.

1. Introduction

China was the world's largest rice producing country. Rice riches in starch, protein, fat, vitamins and 11 kinds of minerals [1], its starch content vary from 67.72% to 73.48% [2], which is good for human health. Among them, carbohydrates account for 75% [3], protein accounts for 7% to 8% and fat accounts for 1.3% to 1.8%. The order of protein content in rice is glutenin, oryzenin and globulin. The biological value of rice protein (nitrogen retention / nitrogen uptake) is as high as 77, exceeding most plant proteins such as soybeans, peanuts and potatoes [4]. The digestibility of rice is 93% and its net protein utilization rate (biomass×digestibility) is 71.61%, while rice starch is almost completely absorbed [5].

In China, rice has amazing production, but deep processing technology lags behind many developed countries and the added value of products is lower than others. Huang Liang [6], Yu Wenwen [7] studied the material-liquid ratio, fermentation time, fermentation temperature and auxiliary factors of the factors affecting rice milk fermentation and optimized the process. This paper not only used rice and glutinous rice as raw materials, through a series of producing processes such as baking, enzymatic hydrolysis and blending, but also used the response surface method to effectively reduced costs and optimize processing conditions and develop a kind of drinks with color, fragrance and taste suitable for the public.

2. Materials and Methods

2.1 Materials and reagents

Rice, JinZhu panjin japonica rice; Glutinous rice, for sale; Creamer, jiangxi hengding food limited company; Malt syrup, clear garden syrup.
2.2 Instruments and equipment
PJ23C-SC1 microwave oven: midea company; DJ13R-P3 broken wall soybean milk machine: Joyoung limited company; FM300 homogenizer: Shanghai fluck fluid machinery manufacturing limited company; TDL-5-A low-speed desktop large-capacity centrifuge: Shanghai anting scientific instrument factory; LDZF-50KB Vertical pressure steam sterilizer: Shanghai shenan medical instrument factory; SL-250A high-speed multifunctional grinder: songqing hardware factory, yongkang city, zhejiang province; DHG-9055A electric blast drying box: Shanghai yiheng scientific instrument limited company; XMTD-4000 thermostatic water bath pot: Beijing yongguangming medical instrument limited company.

2.3 Rice milk preparation process
Raw materials→crushing→weighing (ratio of material to water: 1:15)→gelatinization for 15 min→gelatinization by alpha-amylase→5 min by water bath at 85 °C→centrifugation at 4000 r/min→filtration of superant solution→mixing (soybean seed coat polysaccharide 0.5%, carrageenan 0.05%, CMC 0.06%, plant lipase 1.3%, malt syrup 5.4%)→homogenization→filling→pasteurization→cooling→products.

2.4 Sensory evaluation
According to the technological process of rice milk beverage, the supernatant of raw material rice is obtained after enzymatic hydrolysis reaction and some additives are needed to adjust the color, taste and flavor of the beverage. Malt syrup is used as sweetener to make the beverage sweet and thick. Implanting fat powder is added to improve the color of the beverage. A certain proportion of glutinous rice is used to improve the viscosity and stability of the beverage. The evaluation group consists of 5 groups and 3 persons from each group to conduct sensory evaluation of the products. The evaluation content includes the color, smell, taste and texture of the products. The scoring standards are shown in table 1. After evaluation, the average value was taken as the final recorded value of the experiment.

Table 1 Rice milk sensory evaluation standard.

| Level | Color (20) | Smell (20) | Taste (30) | Quality (30) |
|-------|------------|------------|------------|--------------|
| One   | Cream or beige, shiny (16-20) | The rice fragrance is rich, the flavor is various, no bad smell (16-20) | Soft flavor, sweet and sour, with a rice aftertaste, no bad smell, good taste (24-30) | Flow in liquid form, no suspended solids, no stratification, uniform texture (24-30) |
| Two   | Yellow, slightly shiny (12-16) | The rice fragrance is light, the flavor is various, no bad smell (12-16) | More appropriate sweet and sour, aftertaste, no bad smell, taste appropriate (18-24) | Flow liquid, a little precipitation, no suspended matter, uniform texture (18-24) |
| Three | Tawny, dark, dull (0-12) | No rice fragrance, the flavor has bad smell (0-12) | Deterioration, bad smell, poor taste (0-18) | Poor fluidity, precipitation and suspended matter, poor texture (0-18) |

2.5 Response surface analysis test design
Response surface Design was carried out by using the Design Expert software. According to the combined Design principle of Box-Behnken, response surface analysis tests of 17 test sites with three factors and three levels were designed by taking the ratio of feed to liquid, the addition amount of plant fat powder and malt syrup as independent variables and the sensory score as the response value. The selection of factor level is shown in table 2.

Table 2 Factors and levels for surface and analysis.

| Level | A ratio of Material:liquid | B Non-dairy creamer added% | C Malt syrup added% |
|-------|---------------------------|--------------------------|-------------------|
| -1    | 1:10                      | 0.8                      | 3                 |
Data were analyzed by Design Expert software. Three parallel experiments were conducted on the optimal addition amount and sensory evaluation was conducted by 15 sensory evaluators to obtain the actual value of sensory score.

3. Results and Discussion

3.1 The effect of the ratio of rice and glutinous rice on the sensory quality of the product
The amount of glutinous rice added affects the viscosity of the rice milk drink. If the ratio is not suitable, the stability of the obtained rice milk is lowered and stratification occurred precipitation. According sensory evaluation, when the ratio of rice to glutinous rice was 1:1, rice milk tissue viscosity was moderate, structure is stable and sensory effect is well.

3.2 Effect of material-liquid ratio on sensory quality of products.
If the ratio is not suitable, the viscosity of the gelatinized liquid is increased and the enzyme to substrate are contacted badly during enzymatic hydrolysis or the product structure is thinner, no precipitation, fragrance is lighter and sensory evaluation value decreased. According sensory evaluation, when the ratio of material to liquid was 1:18, the product better than before.

3.3 The effect of the amount of non-dairy cream on the sensory evaluation of the product.
When non-dairy cream added exceed 1.3%, the odor of the non-dairy creamer masks the odor of the glutinous rice, causing lose its original characteristics and sensory rating decreases. According sensory evaluation, when the amount of the non-dairy cream was 1.3%, the rice milk beverage has the highest sensory evaluation value.

3.4 Effect of the addition amount of maltose syrup on sensory evaluation of products.
The sweetener in the maltose syrup and the organic acid in the components effected the taste, formed a suitable ratio of sweet to sour by the synergistic, so that the taste of the beverage is fine and mellow [8]. According sensory evaluation, when the amount of maltose syrup added was 5%, the sensory evaluation value of the rice milk beverage taste best.

3.5 Response Surface Methodology to Optimize Preparation Process of Rice Milk Beverage

3.5.1 Establishment of regression model
The formula of the rice milk beverage is determined initially according to the results of the single factor test. The sensory score is an important indicator of the quality of the product. Therefore, the ratio of rice to water (A), the amount of the non-dairy cream (B) and the amount of the maltose syrup (C) are set. For the three independent variables, the sensory score is the response value for the response surface test to determine the optimal process conditions. The sensory score is evaluated by 10 sensory assessors.

| Source of variation | Sum of square | Freedom degree | Mean square | F value | P value |
|---------------------|--------------|----------------|-------------|---------|---------|
| Model               | 267.84       | 9              | 29.76       | 297.39  | <0.0001** |
| A                   | 7.22         | 1              | 7.22        | 72.15   | <0.0001** |
| B                   | 4.96         | 1              | 4.96        | 49.58   | 0.0002** |
| C                   | 8.20         | 1              | 8.20        | 81.95   | <0.0001** |
| AB                  | 5.684×10^{-14} | 1          | 5.684×10^{-14} | 5.68×10^{-13} | 1.0000 |
| AC                  | 0.040        | 1              | 0.040       | 0.40    | 0.5473  |
After analysis, the binary multi-regression simulation equation is:

\[ Y = 86.38 + 0.95A + 0.79B + 1.01C + 0.0004AB - 0.10AC + 0.13BC - 6.23A^2 - 3.00B^2 - 2.45C^2 \]

A, B, and C are the ratio of material to liquid, the amount of non-dairy cream and the amount of maltose. The absolute value of each coefficient in the equation reflected the influence of each factor on the response value directly and the positive and negative coefficients reflected the direction of influence [9]. It can be seen from table 3 that the relationship between the influencing factors of the overall model and the regression equation reaches a very significant level \((P<0.01)\) [10]. The larger the value of the model \(R^2\), the better the correlation coefficient is \(R^2=0.85\), indicating that the model conformity reached 85%. This result showed that the model could be used for the prediction and evaluation of actual values and the test method was true and reliable. The amount of maltose added was most significant for rice milk beverages, followed by the amount of creamer added and the ratio of material to liquid. The influence of \(A^2\), \(B^2\) and \(C^2\) in the quadratic term is extremely significant. The interactions \(AB\), \(AC\), and \(BC\) were not significant.

### 3.5.2 Response surface analysis of sensory scores

As shown in Fig A, under the condition of a ratio of material to liquid of 1:18, the sensory score of the rice milk beverage first increased and then decreased with the increase of the amount of the creamer. However, under the condition of 1.3% addition of the non-dairy creamer, the sensory score of the rice milk beverage increased first and then decreased with the increase of the ratio of the liquid. As shown in Fig B, under the condition of 1:18 ratio of material to liquid, the sensory score of the rice milk beverage increased first and then decreased with the increase of the amount of maltose added. However, under the condition of 5.4% addition of maltose syrup, the sensory score of the rice milk beverage also increased first and then decreased with the decrease of the ratio of the liquid solution. As shown in Fig C, with the addition of 1.3% of the non-dairy creamer, the sensory score of the rice milk beverage increased first and then decreased with the increase of the amount of maltose added. However, under the condition of adding 5.4% of maltose syrup, with the increase of the amount of non-dairy cream, the sensory score of the rice milk beverage increased first and then decreased under the condition of different honey addition.
3.5.3 Verification test of response surface method
Through the response surface test and analysis of the three optimal influence factors, a set of optimal addition ratios was obtained: ratio of material to liquid 1:18, the amount of fat added was 1.3% and the amount of maltose added was 5.4%. Under this condition, the sensory score of the rice milk drink was 85.036. The above-mentioned optimal ingredient addition amount is used to prepare rice milk beverage. After three parallel experiments, the actual sensory score was 86.7. It is close to the predicted sensory score of 85.036, which indicates that the optimized process parameters obtained by the successful response surface methodology of the response surface optimization test. The result were accurate and have practical application value. Compared the figures, the amount of maltose added had the greatest influence on rice milk drinks.

4. Conclusions
Through three-factor three-level response surface method test, a mathematical model between the response value and each factor was established. According to this quadratic regression model, the optimal process parameters of the rice milk beverage were determined: the feed liquid 1:18, the maltose syrup addition amount 5.4% and the non-dairy cream addition amount 1.3%.

Acknowledgements
This work was financed by the National Natural Science Foundation of China (31701618), Natural Science Foundation of Liaoning province (20180551103) in China, and Liaoning Revitalization Talents Program in China. We thank Dr. He Liu (Bohai University, CN) for his critical review of this manuscript.

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