Response Surface Methodology for Optimization of L-Arabinose/Glycine Maillard Reaction through Microwave Heating

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1. Introduction

The Maillard reaction is a series of complex reactions that occur between the free amino groups of amino acids, peptides or proteins, and carbonyl groups of sugar, especially reducing sugars, to produce the Maillard reaction products (MRPs) [1]. Under different reaction conditions, the reaction pathway and the mechanism will be greatly different, and most of the formed products have a specific flavor and color. MRPs contain volatile substances including low-molecular-weight hydrocarbons, alcohols, aldehydes, ketones, esters, ethers, and heterocyclic compounds, and some large-molecular-weight materials containing polyphenols, peptide polymers, melanoidins, and so on. Melanoidins (melanoidin) or melanoidins (melanoprotein) are brown part of the Maillard reaction in the ultimate stage polymer and copolymer containing nitrogen and are part of the brown macromolecular substances.
in this area is likely to be valuable. Z.-c. Tu et al. [6] described that the UV absorbance, browning intensity, and antioxidant activities as well as the emulsifying activity and emulsion stability of the Maillard reaction products (MRPs) were increased in accordance with the raise of microwave treatment power and time. The reaction time of microwave treatment is much shorter than those using traditional methods, suggesting that microwave irradiation is a novel and efficient approach to promote the Maillard reaction (MR).

The high-molecular-weight melanoids prepared from glucose and different amino acids (asparagine, glycine, and arginine) have been found to possess a higher browning degree, reducing power, and antioxidant activity [7]. Yen and Tsai [8] evaluated the antioxidant activity of partially fractionated MRPs prepared by refluxing glucose and tryptophan at pH 11.0 and 100°C for 10 h, and the results showed that, compared with low-molecular-weight fractions, the high-molecular-weight fractions achieved a higher reducing power and antioxidant activity. Therefore, the preparation of high-molecular-weight MRPs might be an alternative method to develop valuable high antioxidant products.

Response surface methodology (RSM) is of considerable value for the improvement and optimization of complex processes that elucidate the causality between explanatory variables and response variables [9]. Furthermore, RSM is one of the best experiment design methods to reduce the number of experimental trials needed to evaluate multiple parameters and their interactions to provide sufficient information for statistically acceptable results [10, 11]. The objective of the present study is to optimize the Maillard reactions between L-arabinose and glycine using microwave heating to develop high antioxidant MRPs. The relationship between browning degree and reducing power of the MRPs will also be evaluated.

Microwave radiation uses a heating mechanism that rotates and vibrates the electric dipole of target molecules. The reaction time of microwave treatment is much shorter than those using traditional methods. This study applies the microwave heating energy to the L-arabinose and glycine in the mixed solvent propylene glycol and ddH₂O. Short reaction time and less on the substrate concentration have better reducing power and emulsifying ability.

2. Materials and Methods

2.1. Chemicals. Glycine of food grade was purchased from Shanghai Weihong Bio-Sci and Tech Co., Ltd. (Shanghai, China) and L-arabinose from Jinan Shengquan Biotechnology Co., Ltd. (Jinan, China). All other chemicals were of analytical grade and purchased from Shanghai Chemical Reagent Co., Ltd. (Shanghai, China).

2.2. Preparation of Maillard Reaction Products (MRPs). Based on our preliminary experiments, a L-arabinose: glycine ratio of 2:1 (w/v) and substrate concentration of 10% (w/v) were used in the Maillard reaction. This reaction model system has been reported by Peterson, Tong, Ho, and Welt [12] and modified in this study. Briefly, L-arabinose (2g) and glycine (1g) were dissolved in a certain amount of ddH₂O and propanediol. The pH of the solution was adjusted with 5M NaOH and 1M HCl; 27 ml solutions were transferred to a 100 ml beaker and heated in a microwave oven with 500 W of power level (Galanz WD800-T model, 2450 MHz, 800W, 305mm × 508mm × 395mm, Shunde, China) for a certain time. After heating, samples were collected and placed in an ice bath to cool down to stop the reaction before they were stored at a 4°C fridge. These samples were referred to as MRPs.

2.3. Determination of Browning Degree (BD). Samples of 1.0 ml MRPs were diluted to 100-fold with the addition of ddH₂O. The browning degree was determined by measuring the absorbance at 420 nm using a UV-Visspectrophotometer [13, 14] (UV-2100 UNICO spectrophotometer, Jiangsu Scientific Instruments and Materials Co., LTD, Jiangsu, China).

2.4. Experimental Design. According to our prior experimental findings, the most influential factors on the BD and RP of MRPs are heating time (factor A: 5 min, 7 min, 9 min), volume ratio of propylene glycol to ddH₂O (factor B: 0.5, 1, 1.5 v/v), and pH (factor C: pH 8, pH 10, pH 12). The effects of interactions of these three factors were also considered in the RSM experimental design. The “Design-Expert” software (version 8.0.6, Stat-Ease, Inc., Minneapolis, USA) was used to generate the Box-Behnken experimental designs. The independent variables were heating time (A), volume ratio of propylene glycol to ddH₂O (B), and pH (C). Each independent variable had coded levels of −1, 0, and 1 and was constructed based on a 3³ factorial design. Five replications of the central points were run, leading to 17 sets of experiments, allowing each experimental response to be optimized. The experimental designs of the coded factors and actual levels of variables are shown in Table 1. The two responses (Y) were browning degree (Y₁, A₁₂₀nm) and reducing power (Y₂, A₇₀₀nm). The response functions Y₁ and Y₂ were related to the coded variables (A, B, C) by a second-degree polynomial equation using the method of least squares:

\[
Y = a_0 + a_1A + a_2B + a_3C + a_4A^2 + a_5B^2 + a_6C^2 + a_7AB + a_8AC + a_9BC,
\]

where Y is the response calculated by the model; A, B, and C are coded variables, corresponding to heating time, volume ratio of propylene glycol: ddH₂O, and pH, respectively; \(a_1\), \(a_2\), and \(a_3\) are the linear; \(a_4\), \(a_5\), and \(a_6\) are the quadratic, and \(a_7\), \(a_8\), and \(a_9\) are the cross-product effects of the A, B, and C factors on the response.

Analysis of variance (ANOVA) was performed. ANOVA tables were generated, and the effect and regression coefficients of individual linear, quadratic, and interaction terms were determined. The statistical significance of the regression coefficients was determined by using the F-test, and the
applicability of the model was checked with significant coefficients of determination ($R^2$) and the coefficient of variation (CV) values. The optimal processing conditions were obtained by using graphical and numerical analysis based on the criterion of desirability.

2.5 Qualitative Analysis of Volatiles Compounds MRPs by GC/MS. A manual solid-phase microextraction (SPME) device and divinylbenzene/carbo-xen/polydimethylsiloxane (DVB/CAR/PDMS) fibres (100 μm film thickness) were obtained from Supelco Co. (Bellefonte, PA, USA). The fibre was conditioned for 1 h at 270°C as recommended by the manufacturer. Five milliliters of MRPs was placed in a 10-ml vial closed by a PTFE/silicone septum (Supelco). Before the extraction process, a time of 30 min at 40°C was requested for headspace equilibration. After 1 h of fibre exposure in the sample headspace, the fibre was thermally desorbed in a gas chromatography (GC) injection port for 20 min. The injector was set at 250°C and operated in a splitless mode for 3 min. The GC/MS analyses were carried out using an Agilent 7890A gas chromatograph (NYSE: A, USA), equipped with an FID and coupled to a quadrupole Agilent 5975C Network mass selective detector (NYSE: A, USA). The gas chromatography was equipped with a fused silica capillary column HP-INNOWAX (PEG, 60 m × 0.32 mm i.d. film thickness = 0.25 μm, NYSE: A, USA). The carrier gas was helium (head pressure for both columns = 25 psi); oven temperature was programmed from 60 °C (2 min) to 200°C at 2°C/min and then at 5°C/min to 230°C and held isothermal for 5 min. The FID temperature was set at 250°C, and the temperatures of the ion source and the transfer line were 170 and 280°C, respectively. Energy was set at 70 eV and mass range of 35 to 350 amu. Qualitative method is done by comparing the spectrum of the detected substance with the standard spectrum in the NIST 05al and Wiley 7n databases (Agilent, USA). By comparing retention time with standard products, the results were compared with the retention index (RI) of standard substances, and those without standard substances were compared with RI in the reported literature.

2.6 Determination of Reducing Power (RP). The reducing power of the MRPs was determined according to the method previously reported [14, 15] with slight modification. Samples of 1 ml MRPs (100-fold dilution) were mixed with 1.0 ml of 0.2 M sodium phosphate buffer (pH 6.6) and 1.0 ml of 1% potassium ferricyanide (K3Fe(CN)6) in a test tube and sealed. The reaction mixtures were incubated in a water bath at 50°C for 20 min, followed by rapid cooling to 25°C. The solution of 1.0 ml was further mixed with 1.0 ml ddH2O and 200 μl 0.1% FeCl3 (w/v), and the absorbance was read at 700 nm with a spectrophotometer. The reducing power of MRPs was expressed as absorbance ($A_{700}$) using the mean values of three determinations.

2.7. DPPH Radical Scavenging Activity of MRPs. DPPH radical-scavenging activity of MRPs was determined according to the method of Yen and Hsieh [16] with a slight modification. An aliquot of 80 μl MRP sample was diluted with 320 μl of ddH2O and 2 ml of 0.12 mM DPPH in methanol was added. The solution was then mixed vigorously and allowed to stand at room temperature in the dark for 30 min. The absorbance of mixtures was measured at 517 nm on the UNICO UV-2100 spectrophotometer. The control was prepared in the same way, except that ddH2O was used instead of MRP samples. For the blank sample, the assay was conducted in the same way, but methanol was added instead of DPPH solution. The percentage of DPPH radical-scavenging activity is calculated as follows:

$$\text{radical scavenging activity (\%)} = \left(1 - \frac{A_{\text{sample} (517\text{nm})}}{A_{\text{control} (517\text{nm})}}\right) \times 100 \tag{2}$$

2.8. Determination of Emulsifying Ability of MRPs. Emulsifying ability of MRPs was determined according to the method reported by Pearce and Kinsella [17] with minor modifications. Five milliliters of corn oil were added to 15 ml of MRPs solution (1 mg/ml, ddH2O) and homogenized (FA25 Model homogenizer, Fluko Equipment Shanghai Co., Ltd, China) at 13,000 rpm at 25°C for 1 min to form an emulsion. The emulsion of 5 ml was transferred into a test tube and diluted with 5 ml of 0.1% sodium dodecyl sulfate solution. The absorbance at 500 nm of the diluted emulsion was measured with the UNICO UV-2100 spectrophotometer against a blank (ddH2O). The data of emulsifying ability were expressed as absorbance units ($A_{500}$) at 500 nm and were shown as mean values of the three determinations.

### Table 1: Experiment design and results of RSM.

| Run | A/Time(min) | B/Ratio | C/pH | BD/$A_{420nm}$ | RP/$A_{700nm}$ |
|-----|-------------|---------|------|----------------|--------------|
| 1   | −1          | −1      | 0    | 0.112          | 0.032        |
| 2   | 0           | 0       | 0    | 0.369          | 0.238        |
| 3   | 0           | 0       | 0    | 0.387          | 0.255        |
| 4   | −1          | 1       | 0    | 0.1           | 0.02         |
| 5   | 1           | 1       | 0    | 0.265          | 0.184        |
| 6   | 1           | 0       | −1   | 0.254          | 0.159        |
| 7   | 0           | 1       | 1    | 0.343          | 0.221        |
| 8   | 0           | −1      | 1    | 0.358          | 0.232        |
| 9   | 1           | −1      | 0    | 0.307          | 0.195        |
| 10  | 0           | 0       | 0    | 0.383          | 0.254        |
| 11  | −1          | 0       | −1   | 0.087          | 0.011        |
| 12  | 0           | −1      | −1   | 0.289          | 0.196        |
| 13  | 1           | 0       | 1    | 0.376          | 0.247        |
| 14  | 0           | 0       | 0    | 0.38           | 0.25         |
| 15  | 0           | 1       | −1   | 0.206          | 0.139        |
| 16  | 0           | 0       | 0    | 0.375          | 0.244        |
| 17  | −1          | 0       | 1    | 0.15           | 0.064        |

$\text{CV}\%$ = 3.4 5.01

*a BD, browning degree as absorbance of 420 nm; b RP, reducing power at an absorbance of 700 nm.*
2.9. Data Processing. Data were processed using software such as SPSS 20.0 and Design-Expert 8.0.6.

3. Results and Discussion

3.1. Mathematic Model of Maillard Reaction. RSM experiments of L-arabinose/glycine were carried out in a random order. Values obtained from the Maillard reaction system are given in Table 2 and 3, respectively. The ANOVA confirmed the adequacy of the statistical models since their Prob > F values were less than 0.05 and statistically significant at the 95% confidence level. The models presented high determination coefficients ($R^2$) and low coefficients of variation (CV). These values are listed as follows: $R^2 = 0.9967$ and CV% = 3.4 for BD; $R^2 = 0.9957$ and CV% = 5.01 for RP. These results indicated a good precision and reliability for the experiment. The fitted model equations are as follows:

$$Y_1 = 0.38 + 0.082 \times A - 0.016 \times B + 0.045 \times C$$
$$- 0.014 \times A \times B + 0.023 \times A \times C$$
$$+ 0.017 \times B \times C - 0.12 \times A^2$$
$$- 0.046 \times B^2 - 0.034 \times C^2,$$  \hspace{1cm} (3)

$$Y_2 = 0.23 + 0.054 \times A + 0.022 \times B + 0.051 \times C$$
$$- 0.023 \times A \times B + 0.046 \times A \times C - 0.03 \times B \times C$$
$$- 0.081 \times A^2 - 0.016 \times B^2 - 0.080 \times C^2.$$  \hspace{1cm} (4)

3.1.1. Optimization for Browning Degree. As shown in Table 2, the browning degree (BD) of MRPs was positively related to the linear effect of heating time (Time), volume ratio of propylene glycol to ddH$_2$O (ratio), and pH (pH) ($p < 0.05$). The interaction effects of heating time and

| Source | Sum of Squares | df | Mean Square | F-value | p value |
|--------|----------------|----|-------------|---------|---------|
| Model  | 0.19           | 9  | 0.021       | 234.03  | <0.0001 |
| A$^b$  | 0.071          | 1  | 0.071       | 787.45  | <0.0001 |
| B      | 2.89E-03       | 1  | 2.89E-03    | 32.09   | 0.0008  |
| C      | 0.019          | 1  | 0.019       | 212.32  | <0.0001 |
| AB     | 2.25E-04       | 1  | 2.25E-04    | 2.5     | 0.1579  |
| AC     | 8.70E-04       | 1  | 8.70E-04    | 9.67    | 0.0171  |
| BC     | 1.16E-03       | 1  | 1.16E-03    | 12.84   | 0.0089  |
| A$^2$  | 0.074          | 1  | 0.074       | 821.59  | <0.0001 |
| B$^2$  | 0.0011         | 1  | 0.0011      | 118.24  | <0.0001 |
| C$^2$  | 3.67E-03       | 1  | 3.67E-03    | 40.78   | 0.0004  |
| Residual | 6.30E-04    | 7  | 9.00E-05    |         |         |
| Lack of fit | 4.33E-04    | 3  | 1.44E-04    | 2.94    | 0.1626  |
| Pure error | 1.97E-04  | 4  | 4.92E-05    |         |         |
| Cor total | 0.19         | 16 |             |         |         |

*df is the degree of freedom; $^A$ reaction time; $^B$ volume ratio of propylene glycol: distilled-deionized water; C, pH.

Table 3: Variance analysis of the reducing power experiment.

| Source | Sum of Squares | df | Mean Square | F-value | p value |
|--------|----------------|----|-------------|---------|---------|
| Model  | 0.12           | 9  | 0.014       | 182.03  | <0.0001 |
| A$^b$  | 0.054          | 1  | 0.054       | 720.17  | <0.0001 |
| B      | 1.04E-03       | 1  | 1.04E-03    | 13.77   | 0.0075  |
| C      | 8.39E-03       | 1  | 8.39E-03    | 111.58  | <0.0001 |
| AB     | 2.50E-07       | 1  | 2.50E-07    | 3.33E-03| 0.9556  |
| AC     | 3.06E-04       | 1  | 3.06E-04    | 4.08    | 0.0833  |
| BC     | 5.29E-04       | 1  | 5.29E-04    | 7.04    | 0.0328  |
| A$^2$  | 0.05           | 1  | 0.05        | 660.8   | <0.0001 |
| B$^2$  | 4.27E-03       | 1  | 4.27E-03    | 56.84   | 0.0001  |
| C$^2$  | 1.58E-03       | 1  | 1.58E-03    | 20.98   | 0.0025  |
| Residual | 5.26E-04    | 7  | 7.52E-05    |         |         |
| Lack of fit | 3.21E-04    | 3  | 1.07E-04    | 2.09    | 0.2441  |
| Pure error | 2.05E-04  | 4  | 5.12E-05    |         |         |
| Cor total | 0.12         | 16 |             |         |         |

* df is degrees of freedom. $^A$ reaction time; $^B$ volume ratio of propylene glycol to distilled-deionized water; C, pH.
Figure 1: Three-dimensional figures of interactive effects of heating time (time), volume ratio of propylene glycol to ddH₂O (ratio), and pH (pH) on browning degree (BD) of an L-arabinose/glycine Maillard reaction system.
constant volume ratio of propylene glycol to ddH2O is (Figure 1(a)). The variation is curvilinear in nature. 

The reducing power (RP) of the MRP has a positive linear effect on the variation in heating time, volume ratio of propylene glycol to ddH2O, and pH, as shown in Table 3. The quadratic effects also have a significant effect on the RP of MRP. The interaction terms of the variables of volume ratio and pH were found to have significant effects on RP.

Figure 2(a) presents the value of RP with the variation of heating time and the volume ratio of propylene glycol to ddH2O at a given pH. The RP value increased rapidly with the heating time at a given volume ratio and pH, while at a fixed volume ratio and heating time, the RP value slightly increased with increased pH values (Figure 2(b)). However, the RP value increased slightly at the beginning and decreased slowly with the variation in the volume ratio at a fixed heating time and pH Figure 2(c).

It has been widely recognized that melanoids from Maillard reactions possess high reducing power [18, 19]. The present experimental results showed that the browning degree and reducing power of MRP from the L-arabinose/glycine system have a good positive correlation with each other (higher browning degree and higher reducing power) and are consistent with the reported results of Yamaguchi, Koyama, and Fujimaki [7].

### 3.1.2. Reducing Power

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### 3.1.3. Optimization and Experimental Validation

The optimal processing parameters were obtained from SRM to the preparation of L-arabinose/glycine MRP with high browning degree and reducing power. Browning degree can be optimized from the contour plot figures of Figure 1(a)–1(c). The pH region is in the range of 8–12, the volume ratio of propylene glycol to ddH2O is 0.5–1.5, and the heating time is 5–9 min. The model describing the optimum conditions for BD was as follows: a heating time of 7.44 min; a volume ratio of propylene glycol to ddH2O of 0.93; and a pH of 10.44. Reducing power can be optimized from contour plots of Figure 2(a)–2(c), and the model describing the optimal conditions for RP were the same to those of BD: a heating time of 7.44 min; a volume ratio of propylene glycol to ddH2O of 0.93; and a pH of 10.44. The highly coincident data also suggested that the BD and RP of the MRP are positively correlated with each other. Therefore, the responses (Y1 and Y2) of the optimal conditions for both BD and RP could be expressed using the same model. The responses (Y1 and Y2) calculated from the final polynomial functions were a BD of 0.405 at 420 nm and a RP of 0.268 at 700 nm. The Maillard reaction conditions were experimentally validated, and the results were a BD of 0.461 ± 0.02 at 420 nm and a BD of 0.319 ± 0.01 at 700 nm. Based on the relative deviation values of BD (SD% = 3.96) and RP (SD% = 3.61), it could be tentatively concluded that the methodology employed for the optimization of the Maillard process conditions was satisfactory and that the surface responses obtained by the full experimental design were suitably validated.

### 3.2. HS-SPME GC-MS Analysis Results of MRP

Table 4 shows the volatile chemicals of MRP produced by microwave heating under the optimum Maillard reaction conditions obtained by the SRM design. The major compounds identified in the MRP sample were pyrazines (peak area = 21.27%), furans (peak area = 4.49%), alcohols (7.8%), pyrroles (peak area = 10.34%), acids (peak area = 12.88%), ketones (3.51%) and phenols (peak area = 16.97%). The types of pyrazines of the result are more than the ascorbic acid/glycine Maillard reaction [20]. And alkylated pyrazines are an important group of flavor compounds, which contribute substantially to the unique roasted aroma of various food products [21]. Pyrazines came from the Maillard reaction involving glycine [22]. Pyrroles were the key antioxidant activity compounds [23]. So the MRP has the pyrazines characteristics of pyrazines flavor and fine antioxidant activity.

### 3.3. Emulsifying Ability Analysis of MRP

The emulsifying ability of MRP was 0.367 absorbance at 500 nm by microwave heating under the optimal Maillard reaction conditions, which was very close to the emulsifying ability of the casein-glucose Maillard reaction product (the emulsifying ability was 0.397 absorbance at 500 nm) reported by Gu, Abbas, and Zhang [24]. So the MRP has a good emulsifying ability like the casein-glucose Maillard reaction product. We can also conclude that some hydrophilic and lipophilic substances must be formed by the reaction products. If it can
Figure 2: Three-dimensional figures of interactive effects of heating time (time), volume ratio of propylene glycol to ddH₂O (ratio), and pH (pH) on reducing power (RP) of an L-arabinose/glycine Maillard reaction system.
| Serial number | Compound name                             | Cas     | Fragrance description       | Peak area (%) | RI     |
|---------------|-------------------------------------------|---------|----------------------------|---------------|--------|
| 1             | N-Methylpyrrole                           | 96-54-8 | Smoky, herbal              | 0.20          | 1145   | 1246   |
| 2             | 1-Pentanamine                             | 17839-26-8 | -                       | 0.20          | -      | 1301   |
| 3             | 2-Methyltetrahydrofuran-3-one             | 3188-00-9 | Bread, butter             | 0.78          | 1270   | 1380   |
| 4             | Pyridimamine                              | 146580-32-7 | -                       | 0.20          | -      | 1384   |
| 5             | 2-Methylpyrazine                          | 109-08-0 | Nutty, cocoa              | 0.20          | 1267   | 1385   |
| 6             | Hydroxyacetone                            | 116-09-6 | Pungent, caramellic       | 3.32          | 1301   | 1422   |
| 7             | Pyrazine, 2,6-dimethyl-                    | 108-50-9 | Coffee buttermilk        | 0.78          | 1340   | 1444   |
| 8             | 2,3-Dimethylpyrazine                      | 5910-89-4 | Peanut butter            | 1.17          | 1355   | 1461   |
| 9             | 2-Ethyl-6-methylpyrazine                  | 13925-03-6 | Roasted potato          | 0.39          | 1389   | 1497   |
| 10            | 2-Ethyl-5-methylpyrazine                  | 13360-64-0 | Coffee bean              | 0.39          | 1395   | 1503   |
| 11            | 2,3,5-Trimethylpyrazine                   | 14667-55-1 | Nutty, baked potato     | 5.85          | 1414   | 1517   |
| 12            | DL-2-octanol                              | 123-96-6 | Fresh, woody herbal       | 0.20          | -      | 1525   |
| 13            | 2-Propylpyrazine                          | 18138-03-9 | Green vegetable        | 0.20          | 1430   | 1528   |
| 14            | 2-Ethyl-3,6-dimethylpyrazine              | 27043-05-6 | Burnt coffee            | 3.51          | -      | 1555   |
| 15            | 1-Acetoxy-2-propanol                      | 1331-12-0 | -                        | 7.02          | -      | 1650   |
| 16            | Pyrazine, 2-ethyl-3,5-dimethyl-            | 248-182-2 | Burnt coffee            | 3.32          | -      | 1671   |
| 17            | 2-Methyl-5-propylpyrazine                 | 29461-03-8 | -                        | 0.98          | -      | 1746   |
| 18            | Pyrazine, 2-methyl-5-propyl-              | 2884-14-2 | -                        | 0.20          | -      | 1787   |
| 19            | Pyrazine, 3,5-diethyl-2-methyl-           | 18138-05-1 | Nutty meaty              | 0.78          | -      | 1602   |
| 20            | 3,5-Dimethyl-2-propylpyrazine             | 32350-16-6 | Hazelnut               | 0.39          | -      | 1644   |
| 21            | Propanoic acid                            | 79-09-4 | Pungent acid              | 0.39          | 1526   | 1647   |
| 22            | 2,3-Dimethyl-5-n-propylpyrazine           | 32262-98-9 | -                        | 0.59          | -      | 1650   |
| 23            | 2,3,5-Trimethyl-6-propylpyrazine          | 92233-82-4 | -                        | 0.98          | -      | 1678   |
| 24            | 1-Acetoxy-2-propanol                      | 1331-12-0 | -                        | 7.02          | -      | 1862   |
| 25            | 2-Acetylpyrrole                           | 1072-83-9 | Musty nut skin           | 0.98          | -      | 1787   |
| 26            | 1-Dodecanol                               | 112-53-8 | Earthy, soapy            | 0.78          | 1973   | 2074   |
| 27            | 2-Pentadecanone                           | 2345-28-0 | Fresh jasmine            | 0.20          | 2031   | 2133   |
| 28            | 4-Hydroxy-4-methyl-2-pentanone            | 123-42-2 | Phenolic camphor         | 16.58         | 1920   | 2024   |
| 29            | 4-Hydroxy-4-methyl-2-pentanone            | 123-42-2 | Phenolic camphor         | 16.58         | 1920   | 2024   |
| 30            | 2,4-Di-tert-butylphenol                   | 96-76-4 | Phenolic                 | 0.39          | 2315   | 2252   |
| 31            | N-Hexadecanoic acid                       | 57-10-3 | Fatty                    | 6.63          | 2931   | 2319   |
| 32            | Cyclohexadecane                           | 295-65-8 | -                        | 1.76          | -      | 2293   |
| 33            | Dodecenoic acid                           | 143-07-7 | Bay oil                  | 2.34          | 2503   | 2400   |
be separated and identified, one may be able to get good emulsifier. MRPs have a more broad application area.

3.4. Changes in DPPH Radical-Scavenging Activity. The DPPH radical was scavenged by MRPs by the donation of hydrogen to form a stable DPPH-H molecule. And the color changed from purple to yellow by the acceptance of a hydrogen atom from MRPs, and it became a stable diamagnetic molecule [25]. As shown in Figure 3, it can be observed that DPPH radical-scavenging activity of the MRPs of L-arabinose-glycine and D-glucose-glycine is positively related to the linear effect of heating time (Time), volume ratio of propylene glycol to ddH2O (ratio), and initial pH (pH) (p < 0.05). MRPs derived from L-arabinose and D-glucose had similar activities. However, a slightly greater activity was found with MRP derived from L-arabinose-glycine with more volume.

4. Conclusion
The response surface methodology has been demonstrated as a useful tool to optimize the reaction conditions of heating time, volume ratio of propylene glycol to ddH2O, and pH to improve the browning degree and reducing power in the L-arabinose/glycine Maillard reaction product. The coefficients of determinations and $R^2$ values showed a good fit of the models with the experimental data at the 95% confidence level. The different conditions for Maillard reaction revealed that heating time had the significant effect on browning degree and reducing power using microwave heating, while the other two variables (volume ratio of propylene glycol to ddH2O and pH) had an optimum zone for emulsifying ability and DPPH scavenging ability. These results were well fitted with the experimental data, and the obtained models have the potential to be used to maximize the antioxidant activity of the Maillard reaction products.

The peak area of pyrazines is 21.27%, and alkylated pyrazines are the unique roasted aroma of various food products, so the main flavor of MRPs is roasted aroma. MRPs have better reducing power and emulsifying ability. The reaction time of microwave treatment is much shorter than those using traditional methods, so microwave irradiation is a highly efficient approach to promote MR and has huge potential in MR. This study provides a new direction for the development of sweet flavor.

Data Availability
The data used to support the findings of this study are included within the article.

Conflicts of Interest
The authors declare that they have no conflicts of interest.

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