吴文福[1]，陈俊轶[1]，成荣敏[2]，毕宏达[3]

1. 130022 2. 130012
3. 130062

Design-Expert 8.05
p=0.000 1<0.01
R^2=0.939 8 81 11 min
0.802 5 3.25 1 > > >
1.081 mg/g 1.084 mg/g
P<0.05
P<0.05

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Wu Wenfu, Chen Junyi, Cheng Rongmin, Bi Hongda. Optimization of microwave-assisted extraction parameter for unsaturated fatty acids in raw potato flours and its application[J]. Transactions of the Chinese Society of Agricultural Engineering (Transactions of the CSAE), 2018, 34(6): 278 284. (in Chinese with English abstract) doi 10.11975/j.issn.1002-6819.2018.06.035 http://www.tcsae.org

0

2015 2020
660 hm^2

[1]

[2-3] [4]

[5]

10 mm×10 mm×10 mm
50 1 m/s 0.1 g/g
0.150 mm

1.1.2
97 % α- 97% *aladdin*
97 % (
) 99.99%

1.1.3
TANK
6890N JDKY-I
OS-200 TG16K
SC-15
CHD100
IKA MD200

1.2

1.2.1 试验设计

Design-Expert 8.05 Central Composite Design
[22]
4
1
1

Table 1 Factors and Levels of Extraction Conditions Encoding

Level	Factors			
	Extraction temperature X_1/	Extraction time X_2/min	Proportion of acetone volume X_3	Liquid –solid ratio X_4/(mL·g^{-1})
–2	65	10	0.00	1.5
–1	70	15	0.25	2
0	75	20	0.50	2.5
1	80	25	0.75	3
2	85	30	1.00	3.5

1.3

6.000 0 ± 0.000 5 g
1 X_3 X_4 9~21mL
180 rpm 10 min
1 X_1 X_2
3 000 r/min

1.4

1.4.1

1
20 80 1 h

1.4.2 标准曲线的绘制及样品测定

3
GC
1 3
Y =418.6X −4.477 R^2=0.991 9
1
Y =299.4X −5.214 R^2=0.991 3 2
α- $Y_{α\text{-}}$ =542.1$X_{α\text{-}}$ −3.976 R^2=0.993 5
3
Y X
mg/g
GC FID HP-5
30 m×0.32 mm×0.25 μm 200
20 1 290 1 μL
150 1 min 20 /min 200
1 min 3 /min 230 1 min 20 /min
240 1 min 1.2
mL/min

2

2.1 ANOVA

1 2 3
4 2 3
ANOVA 3
P =0.000 1<0.01
R^2=0.939 8
P=0.625 1>0.05
Optimazation-Numerical
81 11 min 0.802
5 3.25 1 Optimazation- Numerical-Solutions
1.084 mg/g
1.3
1.4 3
1.081 mg/g 1.084 mg/g
P P
> > >
X_1 X_2 X_3 X_4 X_3X_4 X_1^2 X_2^2 X_3^2
X_4^2 P<0.05

[23]

2

Table 2 Design scheme and results of experiment

Test number	X_1	X_2	X_3	X_4	Mass fraction of sum of unsaturated fatty acids/(mg·g^{-1})
1	–1	–1	–1	–1	0.707 3
2	1	–1	–1	–1	0.781 0
3	–1	1	–1	–1	0.683 4
4	1	1	–1	–1	0.745 6
5	–1	–1	1	–1	0.887 6
6	1	–1	1	–1	0.955 9
7	–1	1	1	–1	0.826 5
8	1	1	1	–1	0.904 5
9	–1	–1	–1	1	0.747 4
10	1	–1	–1	1	0.866 6
11	–1	1	–1	1	0.734 8
12	1	1	–1	1	0.819 8
13	–1	–1	1	1	0.984 3
14	1	–1	1	1	1.040 4
15	–1	1	1	1	0.953 9
16	1	1	1	1	1.002 9
17	–2	0	0	0	0.818 0
18	2	0	0	0	1.012 5
19	0	–2	0	0	0.995 6
20	0	2	0	0	0.822 2
21	0	0	–2	0	0.638 1
22	0	0	2	0	0.992 5
23	0	0	0	–2	0.760 2
24	0	0	0	2	1.040 9
25	0	0	0	0	1.034 8
26	0	0	0	0	0.968 9
27	0	0	0	0	0.991 9
28	0	0	0	0	0.942 0
29	0	0	0	0	0.990 6
30	0	0	0	0	0.931 4

2.2

Y X_1 X_2 X_3 X_4

4 1

$$Y= -5.082\ 07+0.117\ 73* X_1+0.032\ 533* X_2+1.247\ 36* X_3+0.419\ 63* X_4+0.077\ 928*X_3X_4-7.125\ 37\times10^{-4}* X_1^2-7.764\ 84\times10^{-4}* X_2^2-0.684\ 74* X_3^2-0.085\ 994* X_4^2 \quad (4)$$

1a 1e

[24]

[25-26] 1b

[27-28]

20.70

1.58

[13]

1d

1f

56

1.5

3

Table 3 Regression model coefficient test

Source of variation	Sum of square	Degrees of freedom	F F value	P P value
Model	0.38	14	16.74	< 0.000 1
X_1	0.040	1	24.6	0.000 2
X_2	0.017	1	10.71	0.005 1
X_3	0.20	1	120.8	< 0.000 1
X_4	0.062	1	38.53	< 0.000 1
X_1X_2	1.163×10^{-4}	1	0.086	0.773 4
X_1X_3	4.913×10^{-4}	1	0.27	0.613
X_1X_4	4.589×10^{-5}	1	0.038	0.847 2
X_2X_3	2.385×10^{-4}	1	0.17	0.689 8
X_2X_4	1.234×10^{-4}	1	0.062	0.806 4
X_3X_4	1.518×10^{-3}	1	4.78	0.048 4
X_1^2	8.704×10^{-3}	1	5.33	0.035 6
X_2^2	0.010	1	6.32	0.023 8
X_3^2	0.050	1	30.64	< 0.000 1
X_4^2	0.013	1	7.38	0.015 9
Residual	0.024	15		
Lack of Fit	0.015	10	0.83	0.625 1
Pure Error	9.241×10^{-3}	5		
Cor Total	0.41	29		

2.3

4

96.54% 100.85%

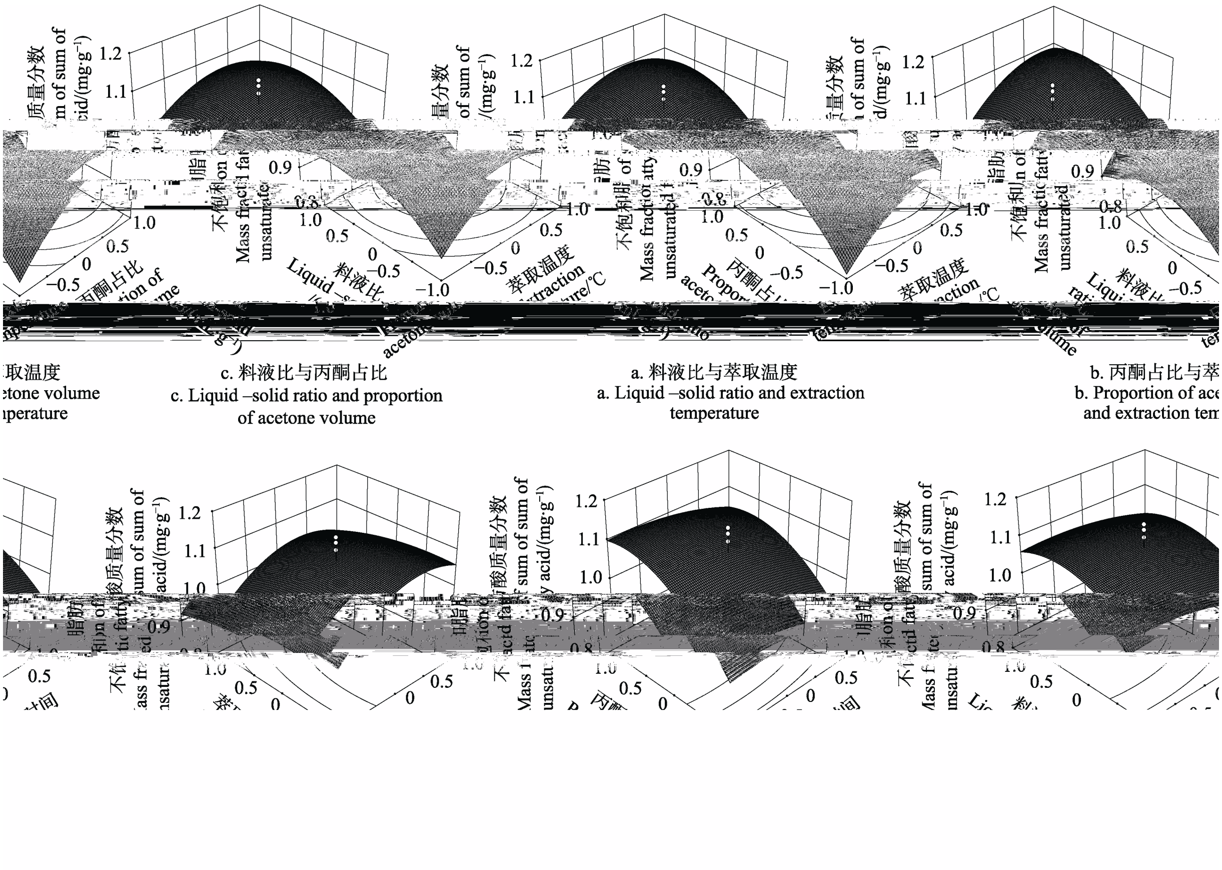

图 1 各因素对马铃薯生全粉中不饱和脂肪酸质量分数影响的响应面图

Fig.1 Response surface of various factor on the quality score of unsaturated fatty acids in raw potato flours

4

Table 4 Recall experiment results

Test Items	Sample bottom value/(mg·g^{-1})	Add amount/mg	Measurements/(mg·g^{-1})	Recovery rate/%
Linoleic acid	0.586	0.163	0.752	100.85
Oleic acid	0.101	0.188	0.279	96.54
α- Alpha-linolenic acid	0.07	0.173	0.245	100.82

3

81

11 min 0.802 5 3.25 1

50 60

70 80 90 0.1 g/g

[29]

5

Duncan

$P<0.05$

$P<0.05$ 2

[30] A

α- [31-32]

5

Table 5 Test results for mass fraction of unsaturated fatty acids in raw potato flours

/(mg·g^{-1})

Type	Temperature/				
	50	60	70	80	90
Linoleic acid	0.696±0.002	0.727±0.003	0.831±0.007	0.947±0.003	1.059±0.002
Oleic acid	0.277±0.002	0.291±0.002	0.298±0.009	0.320±0.002	0.412±0.001
α- Alpha-linolenic acid	0.083±0.002	0.086±0.003	0.091±0.004	0.090±0.002	0.092±0.002
Sum of unsaturated fatty acids	1.056±0.002	1.104±0.005	1.220±0.011	1.357±0.006	1.563±0.004

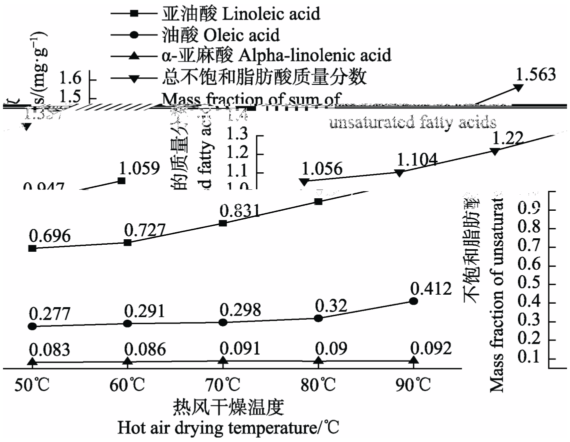

图 2　马铃薯生全粉中不饱和脂肪酸质量分数随热风干燥温度的变化趋势图

Fig.2　Changes in quality score of unsaturated fatty acids in raw potato flours with hot air drying temperature

5

1 Design-Expert 8.05 P=0.000 1<0.01 R^2=0.939 8 P=0.625 1>0.05

2 81 11 min 0.802 5 3.25 1 > > > 1.084 mg/g 1.081 mg/g 96.54% 100.85%

3 P<0.05 P<0.05

A

[ ]

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Optimization of microwave-assisted extraction parameter for unsaturated fatty acids in raw potato flours and its application

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Abstract: In 2015, the Ministry of Agriculture of the People's Republic of China formally put forward the strategy of using potatoes as the staple food. Potato is one of the most productive crops in China. However, fresh potato is easy to go moldy in storage. Fatty acid is an important component for quality of food. Most of the fatty acid in potato is unsaturated fatty acid which is the necessary nutrient of the human body and has an important physiological function. In this research, we have conducted an orthogonal experiment to determine extraction temperature, extraction time, the proportion of acetone and the solid-liquid ratio for microwave-assisted extraction of unsaturated fatty acid from raw potato flours. The content of unsaturated fatty acid in each group of experiment was tested by the gas chromatographic method. After all the data were acquired, the microwave-assisted extraction process of the unsaturated fatty acid in the raw potato flours was optimized by virtue of Design-Expert 8.05 Analysis and Response Surface Method. Then the optimized program was used for studying the influence of the hot air drying temperature on the content of unsaturated fatty acid of potato. The results allowed us to develop the extraction model (P=0.000 1<0.01 R^2=0.939 8) of unsaturated fatty acids in raw potato flours . By use of the model, the optimum extraction technology of unsaturated fatty acids in raw potato flours was obtained and they were, the extraction temperature was 81 , the extraction time was 11 min, the volume ratio of acetone in the extraction solvent was 0.802 5, and the solid-liquid ratio was 3.25:1. The effects of various factors on the content of the unsaturated fatty acids were as follows: the volume ratio of acetone > the solid-liquid ratio > the extraction temperature > the extraction time, and the predicted value of the content of unsaturated fatty acid in the raw potato flours was 1.084 mg/mL. After getting the average value from three replicated tests for the optimal extraction process, the actual value of the content of the unsaturated fatty acid in the raw potato flours was 1.081 mg/g, which confirmed the predicted response value. In the application of optimization scheme, the drying of raw potato flours was operated by making use of different temperature (50, 60, 70, 80 and 90), and the determination showed that, with the increase of the drying temperature, the content of total unsaturated fatty acids had been increased (P<0.05), therein, the content of linoleic acids had also been increased significantly (P < 0.05), and the content of oleic acids and linolenic acids had been also increased, which has been not increased significantly by comparing with the content of linoleic acids. Such change can be attributed to two reasons: on the one hand, the lipolysis had produced the glycerol and fatty acid, on the other hand, the fatty acid has constantly been biosynthesized. Through the research on the influence of hot air drying temperature on the quality of raw potato flours, the optimal hot air drying temperature was obtained according to the index of content of unsaturated fatty acid to realize the optimal quality of raw potato flours after drying so as to promote the strategy of taking potato as the staple food.

Keywords: microwave; partition; optimization; response surface; raw potato flours; unsaturated fatty acid; methyl esterification.