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Evaluation of the effect of ultrasonic variables at locally ultrasonic field on yield of hesperidin from penggan (*Citrus reticulata*) peels[☆]

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ABSTRACT

It has been reported that the maximum ultrasonic power depended on the distance of ultrasonic irradiation surface. Therefore, to confirm this point, an experiment for ultrasound-assisted extraction (UAE) of hesperidin from penggan peels at locally ultrasonic field was performed by response surface methodology (RSM). A three-level three-factor Box–Behnken design was applied to evaluate the effects of three independent variables including ultrasonic power, extraction time and temperature on the yields of hesperidin at high and low ultrasonic irradiation surface. The results showed that the coefficients of two mathematical-regression models by means of the second-order polynomial equation obtained at high and low ultrasonic irradiation surface was 0.9742 and 0.9745, respectively, thus indicating that quadratic polynomial model could be used to estimate the ultrasound-assisted extraction of hesperidin. By comparison of the ultrasonic irradiation surface influence, the yield of hesperidin obtained at low ultrasonic irradiation surface was much higher than the high ultrasonic irradiation surface. Moreover, the scanning electron microscopy (SEM) showed that the particles' microstructures of Penggan peel obtained at low ultrasonic irradiation surface were destroyed more heavily than high ultrasonic irradiation surface. As a result, the vicinity of ultrasonic irradiation surface can generate stronger cavitation energy.

1. Introduction

The extraction of active ingredients from vegetal materials has a long history all over the world. More recently, with the rapid development of pharmaceutical, cosmetics and food industries, making fully use of naturally bioactive products related to healthy properties have become popular. Simultaneously, finding new ways to effectively extract these bioactive components also are concerned increasingly. Moreover, the extraction efficiency is the most crucial for industrial processing, influenced by many factors such as solvent, solvent to solid ratio, extraction time, extraction temperature, extraction method (Cacace & Mazza, 2002; Vagiri, Ekholm, Andersson, Johansson, & Rumpunen, 2012; Wettasinghe & Shahidi, 1999). Therefore, it is necessary for selection of effective extraction method and optimization of extraction factors in the practical application of industrial production, which can be obtained by empirical or statistical methods.

UAE has been widely applied in extraction of a variety of biologically active compounds from plants. In ultrasonic extraction experiments, ultrasonic parameters including solvent, particle size, frequency, ultrasonic power, extraction time and temperature are measured frequently (Capelo, Maduro, & Vilhena, 2005; Tian, Xu, Zheng, & Martin Lo, 2013), Even ultrasonic devices (ultrasonic bath or probe) have an effects on the activities of cavitation bubbles. However, the most important criterion in the classification of ultrasonic applications is the energy amount of the generated sound field (Knorr, Zenker, Heinz, & Lee, 2004). Positive or negative effects when applied ultrasonic power can be observed in different reports. For example, a positive result by Zhong and Wang (2010) showed that the higher extraction efficiency of longan polysaccharides at higher ultrasonic power was obtained. In the negative cases of extraction oil from woad seeds (Romdhane & Gourdon, 2002), the yields of oil at three levels of ultrasonic power (60 W, 100 W, 170 W) were practically unchanged.

Power ultrasound has been regarded as considerable potential for industry process for many years. Measuring ultrasonic power by different methods has been reported (Romdhane, Gourdon, &

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Casamatta, 1995), which gave the similar results that maximum ultrasonic power was observed at the vicinity of irradiating surface of ultrasonic transducer, and the decrease of ultrasonic power increased with the distance between ultrasonic irradiating surface and ultrasonic transducer. This is in accordance with a visual experiment for determination of ultrasonic power using aluminum foil in application of ultrasonic horn (Laborde, Bouyer, Caltagirone, & Cérard, 1998). However, the attenuation of ultrasonic power with increase of distance of ultrasonic irradiating surface was mostly investigated in theory. In our previous studies (Ma et al., 2008), ultrasonic power has a weak effect on the yields of hesperidin from Penggan peels, the assumption of which was resulted in the longer distance between treated materials with the irradiating surface. Therefore, it is necessary to confirm the assumption by experimental data.

It is well-known that citrus fruits have been widely used in traditional Chinese medicines (Chinese Pharmacopoeia Edition Committee, 2005), which was named chenpi (dried citrus peel). Flavonoids were recognized as the primary biological compounds. In south China, Penggan is one of the most popular citrus varieties cultivated, and Penggan peel are rich in flavonoids, specially, hesperidin is the dominant flavonoid in Penggan (it is also called as Ponkan) peel (Zhang et al., 2014), which has been reported to possess a wide range of pharmacological properties. Thus they are very beneficial to human health.

Response surface methodology (RSM) has been successfully used to optimize the critical extraction parameters by estimating interactive and quadratic effects (Sahin, Aybastıer, & Esra, 2013; Tiwari, Muthukumarappan, O'Donnell, & Cullen, 2008). Box-Behnken design (BBD) is a suitable for response surface methods because it can reduce the number of effective experiments and indicate the role of each parameter (Liu, Mei, Wang, Shao, & Tao, 2014). BBD is used to determine the best combination of the variables for the response. In the paper, the effect of ultrasonic power on the extraction yields of hesperidin from Penggan peel at the different height of ultrasonic irradiation surface was performed by response surface methodology. The objection of the paper, as an example of extraction hesperidin, is to employ RSM to optimize the hesperidin extraction process from Penggan peel for maximum yield, and by comparison of the extraction yields of hesperidin under different ultrasound conditions, it is helpful to confirm that the activities of ultrasonic power depend on the distance of ultrasonic irradiation surface. Meanwhile, the locally ultrasonic irradiation effect on the extraction was evaluated by scanning electron microscopy (SEM) analysis in the aspect of Penggan peel particles' cellular structures.

2. Experimental

2.1. Apparatus

Ultrasonic extraction experiments were carried out in ultrasonic cleaning baths produced by Guangzhou Sonoc Ultrasonic Electronic Equipment Co. Ltd. (Guangzhou, China). A frequency of 20 kHz was selected. A variable power output, a digital timer, a temperature controller and a voltage meter were designed; an electric current meter was used for measuring the electrical power consumed. The bottom of water tank was made a shape of quadrangular frustum of a pyramid equipped with five same sonic generators on each side. The schematic diagram of the ultrasonic apparatus is described in previous paper (Ma et al., 2008). High performance liquid chromatographic (HPLC) was performed in a Waters 2695-2996 system (Waters, Milford, MA , USA) consisting of 515 pump and an Econosphere ODS-2 column of 250 × 4.6 mm dimension and a C-18 column (250 mm × 4.6 mm, ID 5 um) from Dikma Technologies Co. Ltd. (Dalian, China).

3. Materials and method

3.1. Materials and reagents

Fresh Penggan (*C. reticulata*) were provided friendly by Zhejiang Citrus Research Institute in Tai-zhou city, Zhe-jiang province, China. Penggan (*C. reticulata*) peels were dried in an oven with air circulation at 50 °C, the dried Penggan (*C. reticulata*) peels were grounded in laboratory with a blade mixer to pass through a 0.45–1 mm screen and were kept in labeled capped plastic inside desiccators until use.

Methanol was used to extract the hesperidin from Penggan peels. All chemical reagents used in experiments were of analytical-reagent grade (Dingguo biotechnological Co. Ltd., Beijing, China). Methanol (reagent for HPLC), glacial acetic acid (reagent for HPLC) and redistilled water were filtrated through a 0.45 um membrane before use. All HPLC reagents and the standard hesperidin were purchased from Sigma Aldrich Co. Ltd (St. Louis, MO, USA).

3.2. Extraction method

A 600 ml flask (8 cm diameter × 14.5 cm height) named as high irradiation surface and a specialized design flask (8 cm diameter × 26 cm height) named as low irradiation surface were used in extraction hesperidin, and the height of 28 cm in Fig. 1A refers to that of ultrasonic water bath. The detailed diagram of the apparatus has shown in Fig. 1. Two flasks were made by the same glass material and have the same thickness of flask wall according to our experiment demands, which were supplied by Zhejiang university chemical plant, Hangzhou, China.

The grounded powders of 1 g were loaded into flask sealed by plastic film to avoid loss of solvent and then extraction solvent was added with a solid–liquid ratio of 1:40. The sample flask was immersed into the ultrasonic cleaning bath for irradiation under different ultrasonic conditions in Table 2. Finally, extracts were filtered off through 0.45 um microporous membrane and the filtrate was collected for HPLC analyses. All samples were prepared and analyzed in triplicate, and the results were the averages of triplicate analyses.

3.3. Chromatographic analysis

The yields of hesperidin were determined according to previous method described in Ref (Nagy, Shaw, & Veldhuis, 1977) with some modification. Prepared extracts solution was filtered through a millipore membrane (0.45 μm) before injection. The mobile phase was 100% methanol (A) and 4% (by vol) acetic acid in water (B) (A:B = 37:63) at a flow rate of 1 ml/min, the column temperature was 40 °C and sample volume injected was 10 μL. The optimum detecting wavelength for hesperidin was 283 nm. Hesperidin concentration (expressed as mg/g DW) was calculated by an external standard method using calibration curves. Standard stock solution with varying hesperidin concentrations were prepared, within the range of 1–35 μg/mL the equation of linear regression was good with $R^2 > 0.998$ for all measured hesperidin. The repeatability of intraday analysis ranged from a relative standard deviation (RSD) of 0.17% to an RSD of 1.89% ($n = 3$). The detection limits and the quantification limits were 0.042 and 0.175 μg/mL, respectively.

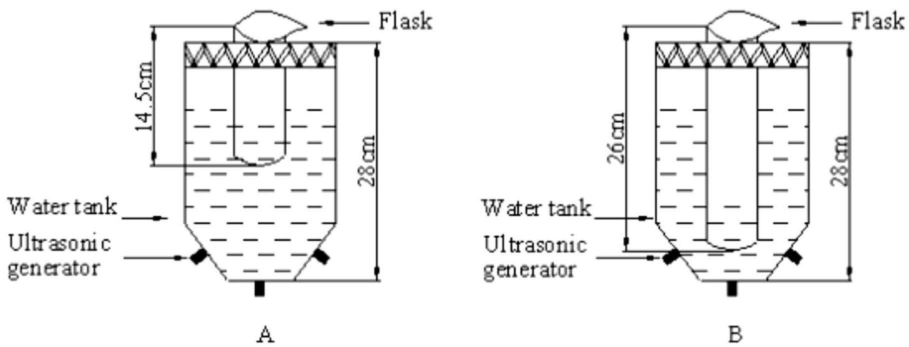

Fig. 1. The schemes for the measurements of local ultrasound-assisted extraction. (A) High irradiation surface (HRS). (B) Low irradiation surface (LRS).

3.4. Scanning electron micrographs

The samples of fresh (before drying) Penggan peel and after ultrasonic extraction were prepared to observe with SEM. Firstly, the samples were fixed in 0.025 mL/mL glutaraldehyde at 4 °C for 12 h and then rinsed with 0.1 mol/L pH 7.0 phosphoric acid for three times at intervals of 15 min the dehydration was performed through an ethanol series: 50, 70, 80, 90, 95, 100% (by vol) for 15 min, subsequently. The samples were dried in a critical-point dryer and fixed on holders with aluminum tape and then sputtered with gold and then examined by scanning electron microscopy under the high vacuum condition at the voltage of 20 kV.

3.5. Box–Behnken design

The software Design Expert (Trial version 7.1.3, Stat-Ease Inc., Minneapolis, MN, USA) was employed for experimental design, statistical analysis and building model. A Box-Behnken design with three variables at three levels (Table 1) was used to investigate responses and then to determine the optimal combination of variables. Three independent variables used in this study were ultrasonic power (X_1), extraction time (X_2) and extraction temperature (X_3). The dependent variables are the yields of hesperidin treated at different ultrasonic irradiation surface. The complete design consisted of 17 experimental points including five replicates at the center of the design in Table 2. Experiments were carried out in random order.

The variables were coded according to following equation:

$$x_i = \left(X_i - \overline{X_i}\right) \Big/ \Delta X_i \tag{1}$$

where x_i is the coded value of an independent variable, X_i is the real value of an independent variable, $\overline{X_i}$ is the real value of an independent variable at the center point, and ΔX_i is the step change value. The independent variables and their levels are showed in Table 1. The dependent variables are presented in Table 2. A quadratic equation was used for this model as follows:

$$Y = \beta_0 + \sum_{j=1}^{k} \beta_j X_j + \sum_{j=1}^{k} \beta_{jj} X_j^2 + \sum\sum_{i<j} \beta_{ij} X_i X_j \tag{2}$$

where Y is the response variable, β_0, β_j, β_{jj}, β_{ij} are the regression coefficients of variables for intercept, linear, quadratic and interaction terms, respectively. X_i and X_j are independent variables.

4. Results and discussion

4.1. Effect of ultrasonic power, time, and temperature on the yields of hesperidin from penggan peel at high irradiation surface

Based on the previous investigation (Ma et al., 2008), an available levels range for ultrasonic variables including ultrasonic power, ultrasonic temperature and ultrasonic time were selected (Table 1). The effects of ultrasonic power, ultrasonic temperature and ultrasonic time on the yields of hesperidin at high irradiation surface as well as their interactions were investigated, respectively. Fig. 2 shows the effects of ultrasonic power and ultrasonic time on the yields of hesperidin at high irradiation surface. According to response surface graph presented in Fig. 2A and B, increasing ultrasonic power did not increase the yields of hesperidin extracted. However, an increase in ultrasonic time at a fixed ultrasonic power

Table 1
Independent variables and their coded and actual values used for optimization.

Independent variables	Units	Symbols	Code levels		
			−1	0	1
Ultrasonic power	W	X_1	4	30	56
Extraction time	Min	X_2	10	25	40
Extraction temperature	°C	X_3	24	32	40

Table 2
The Box–Behnken design and experiment data for the yields of hesperidin at high irradiation surface and low irradiation surface (mg/g).

Treat	Independent variables			Dependent variables	
	Power (W)	Time (min)	Temperature (°C)	YHRS[a] (mg/g)	YLRS[b] (mg/g)
1	0	−1	1	64.71	71.73
2	0	0	0	63.59	72.77
3	0	0	0	64.05	73.41
4	−1	−1	0	61.85	65.17
5	1	0	−1	60.96	72.29
6	0	1	1	68.23	74.45
7	0	−1	−1	60.13	64.91
8	0	0	0	62.93	74.19
9	−1	1	0	65.62	68.28
10	−1	0	1	65.52	69.42
11	0	0	0	63.35	73.35
12	0	0	0	62.82	72.85
13	1	0	1	64.92	74.09
14	0	1	−1	65.37	70.51
15	1	−1	0	61.35	69.23
16	−1	0	−1	62.13	64.85
17	1	1	0	67.06	73.72

[a] The yield of hesperidin at high irradiation surface.
[b] The yield of hesperidin at low irradiation surface.

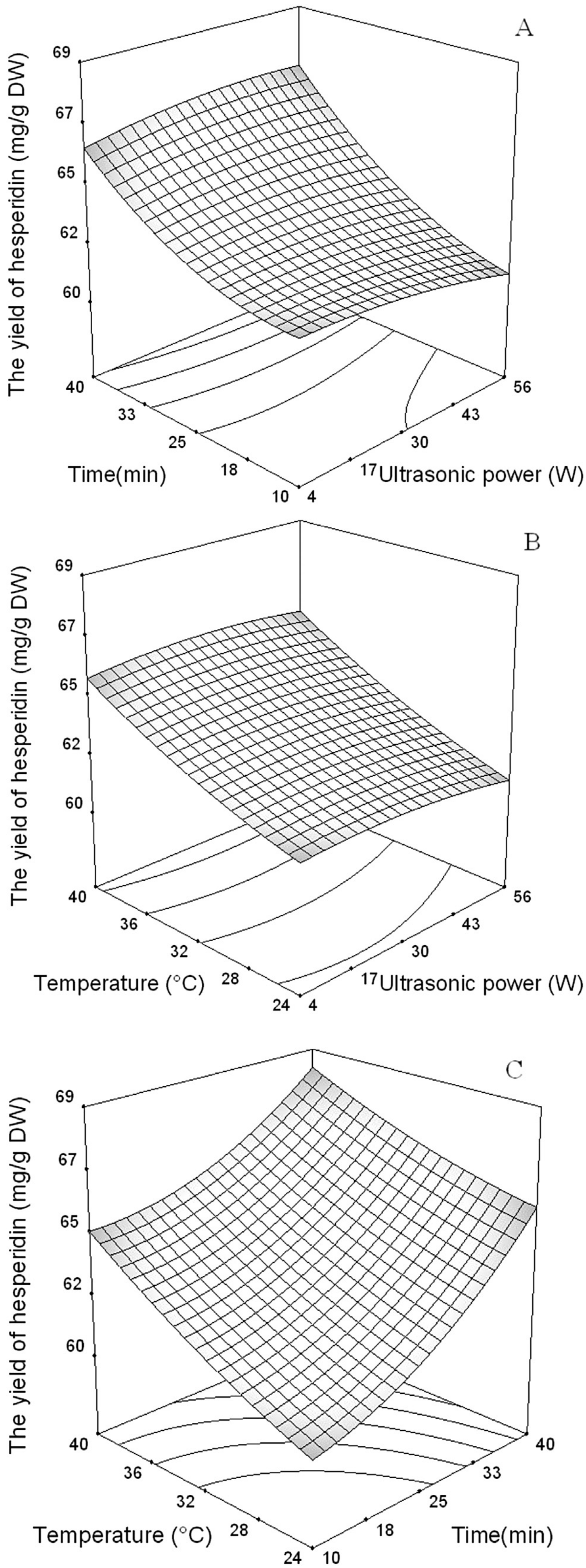

Fig. 2. Response surface plots for effect of ultrasonic power, ultrasonic time and temperature at high irradiation surface. (A) extraction temperature was constant at 32 °C. (B) ultrasonic time was constant for 25 min (C) ultrasonic power was constant at 30 W.

led to a significant increase in the yield of hesperidin, thereafter, kept a constant value. The similar phenomena were also observed for extraction temperature (Fig. 2C). The above results obtained were in agreement with the previous studies that ultrasonic power has a weak effect on the yields of hesperidin from Penggan peels (Ma et al., 2008), whereas ultrasonic time and temperature has a positive effect on the yields of hesperidin.

The optimized ultrasonic parameters at high irradiation surface were determined as: ultrasonic power 30 W, extraction time 40 min, temperature 40 °C, and the extraction yield of hesperidin obtained from the optimized ultrasonic parameters was 68.23 mg/g DW.

4.2. Effect of ultrasonic power, time and temperature on the yields of hesperidin form penggan peel at low irradiation surface

The effects of ultrasonic power, ultrasonic time and extraction temperature on the yields of hesperidin as well as their interaction at low irradiation surface are shown in Fig. 3. As shown in Fig. 3A, when extraction temperature was fixed, the yield of hesperidin increased with ultrasonic power at short extraction time, but decreased slightly when extending extraction time. Likewise, when ultrasonic time was kept constant, an increase of ultrasonic power also resulted in a marked increase in the yield of hesperidin (Fig. 3B). The effect of ultrasonic time and temperature on the yield of hesperidin was depicted in Fig. 3C; ultrasonic time exerted a quadratic effect on extraction of hesperidin, whereas temperature has a linear effect approximately.

The optimized ultrasonic parameters at low irradiation surface were determined as: ultrasonic power 30 W, extraction time 40 min, temperature 40 °C, which was found in accordance with those of high irradiation surface. However, under the optimized experiment conditions, the yield of hesperidin at low irradiation surface increased by 8.23% than that of high irradiation surface.

From above results, the effects of ultrasonic power at low irradiation surface on the yield of hesperidin in comparison with high irradiation surface were significantly positive, indicating that ultrasonic power has more highly activities in near ultrasonic irradiation surface. These results are in accordance with the previous reports (Laborde et al., 1998; Romdhane et al., 1995).

4.3. Morphological properties

Morphological properties of cell tissue of Penggan peels were observed to understand the effect of UAE on the disruption of cell structure by SEM. Cell structures of the fresh peels both under low magnification (25×) in Fig. 4A and high magnification (500×) in Fig. 4B were found to have an arrangement regularly and clearly. Moreover, the microfractures of fresh samples in Fig. 4A distinguished between the tissue of albedo composed of loosely packed, tube-like cell with the most part of the tissue volume and the oil gland surrounded by flavedo parenchymous cell. This tissue structure of Penggan peel is in agreement with earlier reports (Nagy et al., 1977). The electronic micrograph of cell tissue after UAE at high irradiation surface and low irradiation surface were described in Fig. 4C and D, respectively, which was performed at the same ultrasonic conditions (30 °C, 30 min, 8 W). The morphological properties of cell structure of Penggan peel obtained at low irradiation surface were difficult to be discerned (Fig. 4D), while only a number of pieces, at high ultrasonic irradiation surface, appeared on the surface of Penggan peel in Fig. 4C. Therefore, the consequence revealed that the cell tissue of samples at the vicinity of ultrasonic irradiation surface was easily destroyed due to highly acoustic cavitation, and thereby facilitated the release of cell contents. As a result, the extraction efficiency is greatly increased.

As have been reported earlier (Nowacka, Wiktor, Śledź, Jurek, & Witrowa-Rajchert, 2012; Sharma & Gupta, 2006; Zhang et al., 2008), ultrasonic treatment resulted in the change of the physical structure of plant materials due to cavitation energy, enhancing the penetration of solvent into cellular materials and facilitating the release of cell contents (Maricela, Vinatoru, Paniwnyk, & Mason, 2001).

4.4. Model fitting

The following mathematical models, which represented the yields of hesperidin extracted at high and low irradiation surface as a function of the independent variables in coded unit, were obtained by response surface methodology.

$$Y_{\mathrm{HRS}} = 63.35 - 0.10X_1 + 2.28X_2 + 1.85X_3 + 0.48X_1X_2 + 0.14X_1X_3 - 0.43X_2X_3 - 0.30X_1^2 + 0.92X_2^2 + 0.34X_3^2 \quad (3)$$

$$Y_{\mathrm{LRS}} = 73.31 + 2.70X_1 + 1.99X_2 + 2.14X_3 - 0.34X_1X_2 - 0.69X_1X_3 - 0.72\,X_2X_3 - 2.23X_1^2 - 1.99X_2^2 - 1.54X_3^2 \quad (4)$$

Where Y_{HRS} and Y_{LRS} are the yields of hesperidin extracted at high and low irradiation surface, respectively, whereas X_1, X_2, and X_3 are the coded variables for ultrasonic power, time and temperature, respectively.

The significance of fitness of both models was determined using p-value in Table 3. The corresponding variables will be more significant if the p-value becomes smaller than 95% confidence level (Amin & Anggoro, 2004). The p-values of two models for the yields of hesperidin at high and low irradiation surface were less than 0.0001, implying that the fitness of both models was significant. However, no significant lack of fit values for two models were exhibited, 0.3883 and 0.1319, respectively.

The coefficient of R^2 value is closer to unity, which showed the empirical model can more fit with the actual data; likewise, a smaller R^2 value indicates the less relevance of dependent variables in the model (Benito-Román, Alonso, & Cocero, 2013; Sin, Yusof, Hamid, & Rahman, 2006). Analysis of variance, the R^2 values for the yields of hesperidin at high and low irradiation surface are 0.9742 and 0.9745, respectively, indicating that the regression models adequately explained the real reaction among variables. In addition, a model experiment using the optimized ultrasound extraction conditions was performed to verify the reliability of experimental results. The yields of hesperidin extracted from real experiments at high and low irradiation surface were measured as 67.95 and 75.18 mg/g, respectively, under the same ultrasonic conditions, their predicted values observed were 67.15 and 76.24 mg/g, respectively. It was not significantly different between predicated values and experimental values within 95% confidence interval, which showed that predicted values matched well with experimental values obtained from the optimum extraction conditions, thus the mathematical-regression models from BBD should be accurate and reliable for predicting the yield of hesperidin from Penggan peel by ultrasonic-assisted extraction.

From response surface graphs, the positive effect of ultrasonic power on the yields of hesperidin from Penggan peel at low

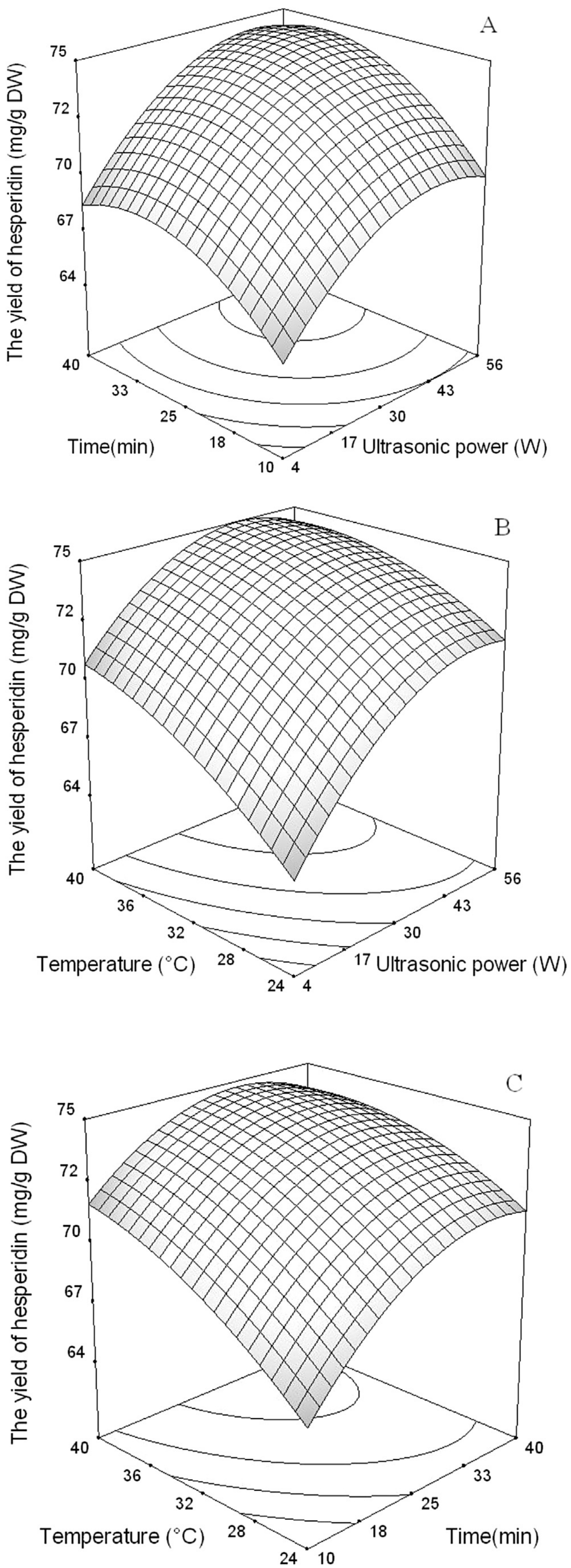

Fig. 3. Response surface plots for effect of ultrasonic power, ultrasonic time and temperature at low irradiation surface. (A) extraction temperature was constant at 32 °C. (B) ultrasonic time was constant for 25 min(C) ultrasonic power was constant at 30 W.

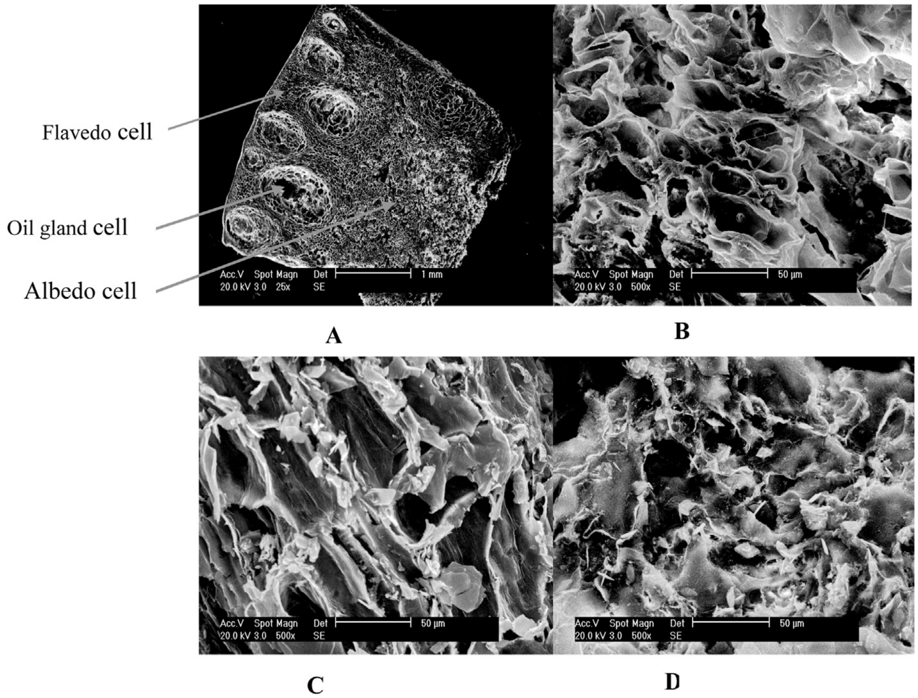

Fig. 4. Scanning electron micrographs of fresh samples of penggan peel and after ultrasound-assisted extraction at low magnification (25×, A) and high magnification (500×, B, C, D). A and B, fresh penggan peel; C, after ultrasound-assisted extraction at high irradiation surface; D, after ultrasound-assisted extraction at low irradiation surface.

irradiation surface was observed, proving the fact that ultrasonic power is effective at the vicinity of ultrasonic irradiating surface.

5. Conclusions

The effects of different ultrasonic irradiation surface on the yield of hesperidin from Penggan peel were studied. The results indicated that the extraction yield of hesperidin at low ultrasonic irradiation surface was higher than that of high ultrasonic irradiation surface. The optimized ultrasonic conditions at low irradiation surface and high irradiation surface were consistent, such as ultrasonic power 30 W, extraction time 40 min, temperature 40 °C. Under the optimal conditions, the yields of hesperidin from Penggan peel at low and high ultrasonic irradiation surface were 74.45 and 68.23 mg/g, respectively. Meanwhile, the verification experiments showed that the experimental yields of hesperidin at low and high ultrasonic irradiation surface agreed with the predicated values from fitted equations, respectively. Thus the mathematical-regression models from BBD should be reliable for predicting the yield of hesperidin from Penggan peel by ultrasonic-assisted extraction.

SEM micrograph revealed that samples irradiated by ultrasound were more seriously destroyed at low ultrasonic irradiation surface, in which the microstructure morphology of Penggan peel particles lost its typical structure due to crumble or rupture violently, confirming the fact that ultrasonic power at the vicinity of ultrasonic irradiation surface is higher. Therefore, the consideration for the design of ultrasonic device, according to the characteristics of ultrasonic variables, should be essential for practically industrial application.

Table 3
Analysis of variances for the response surface quadratic model for the yields of hesperidin at high and low irradiation surface.

Source	Sum of squares	Degrees of freedom	Mean square	*F*-value	*p*-value
High irradiation surface					
Model	75.24	9	8.36	29.42	<0.0001
Residual	1.99	7	0.23		
Lack of fit	0.98	3	0.33	1.31	
Pure error	1	4	0.25		0.3883
Total	77.23	16			
Low irradiation surface					
Model	176.47	9	19.61	29.75	<0.0001
Residual	4.61	7	0.66		
Lack of fit	3.33	3	1.11	3.44	
Pure error	1.29	4	0.32		0.1319
Total	181.09	16			

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检 索 报 告

项目名称：论文被SCI收录情况

委 托 人：西南大学柑桔研究所　　　马亚琴

日　　期：2021年08月17日

认证单位：教育部科技查新工作站N08

二 O 二O年制

<table>
<tr><td>检索项目名称</td><td colspan="4">委托人提交论文被 SCI 收录情况</td></tr>
<tr><td rowspan="2">查新机构</td><td>名　称</td><td>教育部科技查新工作站 N08</td><td>邮　编</td><td>400715</td></tr>
<tr><td>地　址</td><td>重庆市北碚区西南大学图书馆</td><td>电　话</td><td>023-68253283</td></tr>
<tr><td>委托文献目录</td><td colspan="4">Degradation behavior of polyphenols in model aqueous extraction system based on mechanical and sonochemical effects induced by ultrasound
Wang, PX; Cheng, CX; (...); Jia, M
Sep 15 2020 | SEPARATION AND PURIFICATION TECHNOLOGY 247
等 4 篇</td></tr>
<tr><td>检索的数据库范围</td><td colspan="4">1. Science Citation Index Expanded (SCIE) –1900 年至今
2. 中科院期刊分区数据在线平台升级版
3. 中科院期刊分区数据在线平台基础版</td></tr>
<tr><td>检索要点</td><td colspan="4">论文被 SCI 收录，影响因子, 中科院分区情况</td></tr>
<tr><td>检索结论</td><td colspan="4">经检索，委托人提交的 4 篇论文被 SCI 收录，影响因子、分区等检索结果详细情况见附件 1 和附件 2。
检索人（签名）：周剑　周剑
职称：研究馆员
教育部科技查新工作站 N08
2021 年 08 月 17 日</td></tr>
<tr><td>备注</td><td colspan="4">1、影响因子及分区为最新的影响因子和分区。</td></tr>
</table>

附件 1：SCI 收录情况

序号	题名	检索号	影响因子	中科院类别　分区	出版时间	语种
1	**Degradation behavior of polyphenols in model aqueous extraction system based on mechanical and sonochemical effects induced by ultrasound** **Wang, PX; Cheng, CX; (...); Jia, M** **Sep 15 2020 | SEPARATION AND PURIFICATION TECHNOLOGY 247**	000536142200014	IF_{2020}=7.312	中科院类别升级版 | 分区 大类：工程技术 | 1 区 小类：ENGINEERING, CHEMICAL 工程：化工 | 1 区	2020	英文
2	**Comparison of the effects of novel processing technologies and conventional thermal pasteurisation on the nutritional quality and aroma of Mandarin (Citrus unshiu) juice** **Cheng, CX; Jia, M; (...); Ma, YQ** **Aug 2020 | INNOVATIVE FOOD SCIENCE & EMERGING TECHNOLOGIES 64**	000564512100007	IF_{2020}=5.916	中科院类别升级版 | 分区 大类：农林科学 | 1 区 小类：E FOOD SCIENCE & TECHNOLOGY 食品科技 | 2 区	2020	英文
3	**Evaluation of the effect of ultrasonic variables at locally ultrasonic field on yield of hesperidin from penggan (Citrus reticulata) peels** **Ma, YQ; Ye, XQ; (...); Han, Z** **Mar 2015 | LWT-FOOD SCIENCE AND TECHNOLOGY 60 (2) , pp.1088-1094**	000347740800004	IF_{2015}=2.711	中科院类别基础版 | 分区 大类：工程技术 | 2 区 小类：E FOOD SCIENCE & TECHNOLOGY 食品科技 | 2 区	2015	英文
4	**Considering solubility disparity and acoustic-cavitation susceptivity of neoteric solvents to accurately predict sono-recovery yield of value-added compounds** **Wang, PX; Ma, YQ; (...); Jia, M** **Dec 1 2021 | SEPARATION AND PURIFICATION TECHNOLOGY 276**	000681684300001	IF_{2020}=7.312	中科院类别升级版 | 分区 大类：工程技术 | 1 区 小类：ENGINEERING, CHEMICAL 工程：化工 | 1 区	2020	英文