1. Introduction

Peanut sprouts prepared from the germination of peanut kernels have been used in the diet as health food for several centuries. It has been reported that peanut sprouts are rich in flavonoid and resveratrol which may contribute to disease preventive and health promoting properties (Randhir, Lin, & Shetty, 2004). Resveratrol (3,5,4'-trihydroxy stilbene) is a major polyphenol present in the peanut sprouts and synthesised by several plants as a defence response to situations of stress such as UV irradiation, microbial infection and mechanical damage (Pezet et al., 2003). Over the past three decades, resveratrol has received especial interest based on a number of associated health benefits. Numerous health benefits impacting cardiovascular disease (Goldberg, Hahn, & Parkes, 1995; Hung, Chen, Huang, Lee, & Su, 2000; Soleas, Diamandis, & Goldberg, 1997; Szkdelska & Szkudelski, 2010), various cancers (Athar et al., 2007; Delmas, Lancon, Colin, Jannin, & Latruffe, 2006; Liu, Pan, Yang, & Liu, 2003; Van Ginikl et al., 2007), diabetes mellitus (Thirunavukarasu et al., 2007) and ageing (Joseph, Fisher, Cheng, Rimando, & Shukitt-Hale, 2008; Stefani et al., 2007; Wong et al., 2009) have been linked with resveratrol. However, resveratrol recovered as an extracts from some plants are not suitable for their applications in the pharmaceutical and food industries owing to high levels of impurities as well as the overall low concentration of resveratrol in the extracts (Medina Bolivar et al., 2007). Therefore, it is indispensable to separate resveratrol for in-depth pharmacological research and effective applications in medical practice and dietary supplements.

There are several methods available in the literature for the separation of resveratrol such as liquid–liquid extraction, chromatography, ion exchange and adsorption (Börnsen, Mohr, & Widmer, 1995; He, Wang, Zhuang, & Lu, 2012; Li, Geng, Liu, Zhang, & Kang, 2006; Liang, Liang, Shu, & Ri, 2013; Takagai et al., 2005; Wang, Liu, & Chen, 2012). Comparatively, adsorption seems to be the most suitable method, owing to its prominent advantages of the procedural simplicity, less labour intensity, lower yielding cost, easier scale-up and higher purification efficiency. Macroporous resins are durable non-polar and polar polymers having a high adsorption capacity with possible recovery of the adsorbed molecules, relative low cost and easy regeneration (Scordino, Di Mauro, Passerini, & Maccarone, 2004). Macroporous resins adsorption is one of the most important adsorption methods. At present, it has been widely used for the separation and purification of many secondary metabolites from aqueous solutions as well as from non-aqueous systems through electrostatic force, hydrogen bonding interaction, complexation, and size sieving action (Fu et al., 2006), including licorice flavonoids and glycyrrhizic acid (Fu et al., 2005), scutellarin (Gao, Huang, & Liu, 2007), madecassoside and asiaticoside (Jia & Lu, 2008), rosavin (Ma et al., 2009), lycopene (Liu, Liu, Chen, & Di, 2010a), chlorogenic acid (Zhang, Yang, Zhao, & Liu, 2008), genistein and apigenin (Liu et al., 2010c). However, there is no report on

**ARTICLE INFO**

**Abstract**

In the present study, the separation and purification characteristics of resveratrol from extract of peanut sprouts (PSE) on 11 macroporous adsorption resins were investigated. The results showed that ADS-5 offered better adsorption and desorption capacity for resveratrol than other tested resins. From the static experiments with ADS-5 resin, we found that the experimental data fitted best to the pseudo-second-order kinetics model and Langmuir isotherm model, and the adsorption was a spontaneous and endothermic process. The separation and purification parameters of resveratrol from PSE were optimised by dynamic adsorption/desorption experiments with the column packed with ADS-5 resin. Under the optimal conditions, after one run treatment with ADS-5 resin, the content of resveratrol in the product was increased 17.9-fold from 1.32% to 23.60%, with a recovery yield of 88.33%. The results demonstrated that ADS-5 resin was a promising basis for large-scale preliminary separation and purification of resveratrol from PSE.

**Keywords:**

Resveratrol, Purification, Macroporous adsorption resin, Peanut sprout extract

---

**Corresponding author. Tel./fax:** +0517 83591165.  
**E-mail address:** j1c2x3@gmail.com (C. Jiang).

---

**Received 15 August 2012**

**Received in revised form 25 July 2013**

**Accepted 31 July 2013**

**Available online 9 August 2013**

**Article history:**

**Contents lists available at ScienceDirect**

**Food Chemistry**

**journal homepage: www.elsevier.com/locate/foodchem**

---

**© 2013 Elsevier Ltd. All rights reserved.**

**0308-8146/$ - see front matter **

---

**Macroporous adsorption resin**

**Purification**

**Resveratrol**

**Preliminary separation and purification of resveratrol from extract of peanut (Arachis hypogaea) sprouts by macroporous adsorption resins**

Qingping Xiong, Qianga Zhang, Danyan Zhang, Yingying Shi, Changxing Jiang,*, Xiaojuan Shi

College of Life Science and Chemical Engineering, Huaian Institute of Technology, Huaian 223003, Jiangsu, PR China

School of Chinese Materia Medica, Guangzhou University of Chinese Medicine, Guangzhou 510006, Guangdong, PR China
using macroporous adsorption resins to separate and purify resveratrol from PSE.

In the present study, a simple and efficient process was developed for preliminary separation and purification of resveratrol from PSE with the optimal resin. Firstly, 11 macroporous resins with different chemical and physical properties were used to select the optimum resin by comparing their ratios and capacities of adsorption/desorption for resveratrol. Then various parameters influencing the adsorption and desorption of resveratrol were optimised in batch experiments. The adsorption kinetics, isotherms and thermodynamics of interactions for resveratrol onto the optimal resin were investigated with the aim to improve the sorption process and to predict the resin performances. The information in this study is significant for resin selection and process optimisation in separating and purifying resveratrol from PSE.

2. Materials and methods

2.1. Materials and reagents

The fresh peanut sprouts used in the experiment were purchased from Huaqin Vegetable Product Market (Huaqin, China). Resveratrol (3,5,4'-trihydroxy stilbene, 98%) was purchased from Sigma–Aldrich (St. Louis, MO, USA). Methanol of chromatographic grade was purchased from J&K Chemical Co., Ltd. (Beijing, China). Acetic acid of chromatographic grade was purchased from Dima Technology INC. (USA). Ethanol was analytical grade obtained from Shanghai Chemical Reagents Co. (Shanghai, China). Deionized water was purified by a Milli-Q Water Purification system (Millipore, MA, USA).

2.2. Adsorbents

Macroporous adsorption resins including ADS-21, ADS-7, S-8, ADS-17, AB-8, X-5 and ADS-5 were purchased from Nankai Hecheng S&T Co., Ltd. (Tianjin, China). NKA-9, NKA-II, D101 and HPD-600 resins were obtained from Changzhou Bonchem Co., Ltd. (Hebei, China). The macroporous resins were pre-treated with 1 M HCl and 1 M NaOH solutions successively to remove the monomers and porogenic agents trapped inside the pores during the synthesis process, and then dried at 60 °C under vacuum. Prior to adsorption experiments, pre-weighed amounts of resins were soaked in 95% ethanol and subsequently washed by deionized water thoroughly.

2.3. Preparation of PSE

Briefly, the fresh peanut sprouts were collected and washed carefully with cold water. After removing the impurities, the peanut sprouts were crushed by a high speed disintegrator (HX-200A, Yongkang Hardware and Medical Instrument Co. Ltd., China) and the homogenate was kept in petroleum ether for 12 h. After standing for 180 min, the final concentrations of resveratrol were determined by HPLC, the procedure was repeated three times. The static desorption experiments were determined by HPLC, the procedure was repeated three times. The static desorption experiments were studied according to the follows: after adsorption equilibrium was reached, the resins were first filtrated from the solutions, and then adequately washed by deionized water. Subsequently, 100 mL ethanol–water (70% v/v) solution was added to 250 mL flasks containing the adsorbate-laden resins. The flasks were continually shaken at 180 rpm in a constant temperature (45 °C) water-bath shaker (SHZ-82B, Jiangsu Zhengjiang Instruments Co. Ltd., China) for 12 h. After standing for 180 min, the final concentrations of resveratrol solution were determined by HPLC, the procedure was repeated three times. The static desorption experiments were studied according to the follows: after adsorption equilibrium was reached, the resins were first filtrated from the solutions, and then adequately washed by deionized water. Subsequently, 100 mL ethanol–water (70% v/v) solution was added to 250 mL flasks containing the adsorbate-laden resins. The flasks were continually shaken at 180 rpm in a constant temperature (45 °C) for 12 h. Then the corresponding resveratrol contents were determined by HPLC. The optimal resin was preliminarily evaluated by their ratios and capacities of adsorption/desorption, and the equations were as follows:

\[
\text{Adsorption capacity } q_e = \frac{(C_0 - C_1) \times V_1}{W} \quad (1)
\]

\[
\text{Adsorption rate } E(\%) = \frac{C_0 - C_1}{C_0} \times 100 \quad (2)
\]

\[
\text{Desorption rate } D(\%) = \frac{C_2 \times V_2 \times 100}{(C_0 - C_1) \times V_1} \quad (3)
\]

\[
\text{Desorption capacity } q_d = \frac{C_2 \times V_2}{W} \quad (4)
\]

where, \(q_e\) is adsorption capacity (mg/g); \(E\) is adsorption rate (%); \(D\) is desorption rate (%); \(q_d\) is desorption capacity (mg/g); \(C_0\) and \(C_1\) are the initial and equilibrium concentration of resveratrol solutions (mg/L); \(C_2\) is the concentration of desorption solution (mg/L); \(V_1\) is the volume of resveratrol solution used in the study (L); \(V_2\) is the volume of desorption solution (L); and \(W\) is the weight of dry resin (g).

2.5. Static adsorption and desorption tests

2.5.1. Screening of the optimal macroporous adsorption resins

The static adsorption/desorption experiments were carried out as follows: pre-weighed amounts of hydrated resins (equal to 1.0 g dry resin) and 100 mL sample solution with the concentration of 0.33 mg/mL for resveratrol were added into a 250 mL conical flask with stopper. The flasks were continually shaken at 180 rpm in a constant temperature (45 °C) water-bath shaker (SHZ-82B, Jiangsu Zhengjiang Instruments Co. Ltd., China) for 12 h. After standing for 180 min, the final concentrations of resveratrol solution were determined by HPLC, the procedure was repeated three times. The static desorption experiments were studied according to the follows: after adsorption equilibrium was reached, the resins were first filtrated from the solutions, and then adequately washed by deionized water. Subsequently, 100 mL ethanol–water (70% v/v) solution was added to 250 mL flasks containing the adsorbate-laden resins. The flasks were continually shaken at 180 rpm in a constant temperature (45 °C) for 12 h. Then the corresponding resveratrol contents were determined by HPLC. The optimal resin was preliminarily evaluated by their ratios and capacities of adsorption/desorption, and the equations were as follows:

\[
\text{Adsorption capacity } q_e = \frac{(C_0 - C_1) \times V_1}{W} \quad (1)
\]

\[
\text{Adsorption rate } E(\%) = \frac{C_0 - C_1}{C_0} \times 100 \quad (2)
\]

\[
\text{Desorption rate } D(\%) = \frac{C_2 \times V_2 \times 100}{(C_0 - C_1) \times V_1} \quad (3)
\]

\[
\text{Desorption capacity } q_d = \frac{C_2 \times V_2}{W} \quad (4)
\]

where, \(q_e\) is adsorption capacity (mg/g); \(E\) is adsorption rate (%); \(D\) is desorption rate (%); \(q_d\) is desorption capacity (mg/g); \(C_0\) and \(C_1\) are the initial and equilibrium concentration of resveratrol solutions (mg/L); \(C_2\) is the concentration of desorption solution (mg/L); \(V_1\) is the volume of resveratrol solution used in the study (L); \(V_2\) is the volume of desorption solution (L); and \(W\) is the weight of dry resin (g).

2.5.2. Adsorption kinetics

The adsorption kinetics curves of resveratrol on the preliminarily selected resin were performed as follows: adding pre-treated
resin (equal to 1.0 g dry resin) and 100 mL sample solution to a 250 mL conical flasks with a lid. The flasks were shaken at 180 rpm in a constant temperature (45 °C), and then the contents of resveratrol in the adsorption process at different time intervals until equilibration were determined by HPLC.

2.5.3. Adsorption isotherms and thermodynamics

The adsorption isotherms and thermodynamics on optimal resin were obtained as follows: the 100 mL resveratrol solutions with different initial concentrations contacted with pre-treated resin (equal to 1.0 g dry resin) in shakers at temperatures of 25, 35 and 45 °C, the equilibrium adsorption isotherms and thermodynamics of resveratrol on the optimal resin were obtained at different temperatures.

2.6. Dynamic adsorption and desorption tests

Dynamic adsorption and desorption tests were carried out on lab-scale glass columns (15 mm × 500 mm) packed with the optimal resin (equal to 5.0 g dry resin). The bed volume (BV) of the wet-resin was 20 mL and the packed length of resin bed was 155 mm. The adsorption process was performed by loading resveratrol solution described as Section 2.3 onto the pre-treated glass column at the constant flow rate. The effluent was collected by auto-partial collector. The concentrations of resveratrol in the aliquots of 5 mL effluents collected at 10 mL interval were determined by HPLC. Whilest adsorptive equilibrium, the adsorbate-la-den column was firstly washed with deionized water, and then desorbed with ethanol solution. One part of the eluent was directly analysed by HPLC, and the other was further concentrated using evaporator and dried under vacuum to calculate purity of product. Several variables, such as the feeding volume and flow rate for adsorption process, different proportions of ethanol–aqueous solutions in the process of desorption, and the eluent volume and flow rate for desorption process were systematically investigated.

2.7. Statistical analysis

The data were presented as mean ± standard deviation (SD) and evaluated by one-way analysis of variance followed by the Duncan’s multiple-range tests. Difference was considered to be statistically significant if \( P < 0.05 \). All statistical analyses were carried out by SPSS for Windows, Version 11.5 (SPSS, Chicago, IL).

Fig. 1. Adsorption/desorption capacities and desorption ratio of resveratrol on different resins.

Fig. 2. The adsorption kinetics curve (A), equilibrium adsorption isotherms (B) and linear correlations on the basis of the Langmuir (C) and Freundlich (D) models for resveratrol on ADS-5 resin.
3. Results and discussion

3.1. Selection of optimal resin

The adsorption characteristics of macroporous adsorption resins are in close relation to chemical features and physical properties of resins. The selection of proper resins should be in accordance with the structures and polarities of resins, such as their pore diameters, pore volumes and surface areas. According to the rule “likes dissolve likes”, the resins with lower polarity exhibited better adsorption abilities to low-polarity and non-polar substances. As shown in Fig. 1, the adsorption capacities of resveratrol on ADS-21, ADS-7, ADS-5 and S-8 resins were considerably higher than those of other resins (P < 0.05), however, the desorption capacities of resveratrol on the polar ADS-21, ADS-7 and S-8 resins were rather low, resulting in the low desorption ratio (47.6%, 54.3% and 42.1%, respectively). The reason was probably that the polar resins possessed a strong affinity for resveratrol via surface electrical property, hydrogen bonding interactions, the desorption capacities of resveratrol on the resins were not notable. On the contrary, the desorption ratio of non-polar ADS-5 resin towards resveratrol were higher than other three selected resins, probably due to the differences of ADS-5 resin in surface area, pore diameter and polar. The resin of ADS-5 had higher surface area (500–600 m$^2$/g) than other resins, which caused higher adsorption capacity of resveratrol. On the other hand, it had non-polar and bigger average pore diameter (20.0–30.0 nm) than other resins, this property helped to the process of desorption of resveratrol. Therefore, ADS-5 resin was chosen for the following dynamic adsorption/desorption experiments.

3.2. Adsorption kinetics of resveratrol on ADS-5 resin

Adsorption kinetics of resveratrol on ADS-5 resin was investigated at 45℃. The adsorption kinetics curve was obtained, as shown in Fig. 2A. It showed that the adsorption capacity of resveratrol on ADS-5 resin increased with the extension of adsorption time. The adsorption capacity of resveratrol almost achieved a maximum when the adsorption time was 80 min. After this point, the adsorption capacity started to maintain a dynamic equilibrium with increasing the adsorption time. Therefore, a 80-min adsorption time was chosen for the further adsorption equilibrium experiments.

In order to illustrate the adsorption mechanism better, the following kinetics models were employed to describe adsorption process: pseudo-first-order, pseudo-second-order and intra-particle diffusion kinetics models. The pseudo-first-order and pseudo-second-order model could be expressed as Eqs. (5) and (6), respectively.

$$\log(q_e - q_t) = \log q_e - \frac{k_1 t}{2.303} \tag{5}$$

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{t}{q_e} \tag{6}$$

where $k_1$ and $k_2$ are the first and second order rate constant, respectively. $q_t$ and $q_e$ were the amounts of adsorbed resveratrol on the ADS-5 resin surface at equilibrium and at any time $t$, respectively. From Eq. (6), $q_t$ and $k_2$ values could be obtained from the intercept and slope of the linear plot of $t$ versus $q_e^{1/2}$.

All of the parameters mentioned above were determined as shown in Table 1. The obtained correlation coefficients indicated that both pseudo-first-order model and pseudo-second-order model could describe these kinetic parameters, it could be seen that the correlation coefficients for the pseudo-first-order kinetic model was lower. And the results of pseudo-second-order kinetics showed that the linear fit with extremely high correlation coefficients ($R^2 > 0.99$) to be close to 1. Moreover, the calculated $q_e$ values were in good agreement with the experimental data. These results showed that the rates of adsorption conform to pseudo-second-order kinetics.

3.3. Adsorption isotherms and thermodynamics of resveratrol on ADS-5 resin

To understand better the adsorption characteristic of resveratrol on ADS-5 resin, sample solutions with various concentrations of resveratrol (0.077–0.44 mg/mL) were shaken with ADS-5 resin at three different temperatures of 25, 35 and 45℃. Equilibrium adsorption isotherms were obtained at three different temperatures of 25, 35 and 45℃. As shown in Fig. 2B, the adsorption capacity of resveratrol increased with the increase of the initial concentration, and reached the saturation plateau when the initial concentration of resveratrol was 0.33 mg/mL. Hence, the initial concentrations of resveratrol in the sample solution for separation and purification were selected as 0.33 mg/mL.

Adsorption data (equilibrium resveratrol concentration versus quantity adsorbed) gives the information about the affinity between solutes and adsorbents (Scordino et al., 2004). For interpretation of the adsorption experimental data above, the Langmuir and Freundlich isotherms were used to reveal the linearity fitting and to describe how solutes interact with the resins.

The model of Langmuir and Freundlich could be expressed as formula (7) and formula (8), respectively.

$$\frac{C_e}{q_e} = \frac{1}{q_m} + \frac{1}{q_mK_L}C_e \tag{7}$$

$$\log q_e = \log K_F + \frac{1}{n} \log C_e \tag{8}$$

where $q_e$ and $C_e$ are the equilibrium concentrations of resveratrol in the adsorbed (mg/g) and liquid phases (mg/mL), respectively. $q_m$ and $K_L$ are the Langmuir constants which are related to the adsorption capacity and energy of adsorption, respectively. $K_F$ and $n$ are the Freundlich constants which are related to adsorption capacity and intensity, respectively.

Table 1: Adsorption kinetic parameters of pseudo-first order and pseudo-second order model.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Adsorption Kinetic Parameters</th>
<th>Pseudo-first order model</th>
<th>Pseudo-second order model</th>
</tr>
</thead>
<tbody>
<tr>
<td>$q_e$ (mg/g)</td>
<td>$k_1$ (g/mg min)</td>
<td>$R^2$</td>
<td>$q_e$ (mg/g)</td>
</tr>
<tr>
<td>15.01</td>
<td>0.025</td>
<td>0.9904</td>
<td>33.56</td>
</tr>
</tbody>
</table>

Table 2: Langmuir, Freundlich and thermodynamic parameters of resveratrol on ADS-5 resin at different temperatures.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Adsorption Parameters</th>
<th>Thermodynamic Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>$q_m$ (mg/g)</td>
<td>$K_L$ (L/mg)</td>
<td>$R^2$</td>
</tr>
<tr>
<td>25</td>
<td>35.21</td>
<td>1.514</td>
</tr>
<tr>
<td>35</td>
<td>42.74</td>
<td>3.121</td>
</tr>
<tr>
<td>45</td>
<td>43.87</td>
<td>3.334</td>
</tr>
</tbody>
</table>
The parameters $q_m$, $K_d$, $K_f$, $n$, and $R^2$ were given in Table 2, and the graphical presentations for Langmuir and Freundlich adsorption isotherm were given in Fig. 2C and D. In general, the resveratrol adsorption data fitted the Langmuir and Freundlich equations equally well with correlation coefficients close to unity, where the Langmuir equation gave a better fit, indicating that the Langmuir isotherm could reasonably explain the adsorption process, suggesting the monolayer coverage of resveratrol onto the ADS-5 resin. Within the ranges of temperatures studied, the adsorption capacities (Fig. 2B) and the Langmuir equilibrium constant $K_L$ (Table 2) increased with the increasing temperature at the same sample initial concentration, implying that the thermal motion of the solute molecules increased with the increase of temperature, which was beneficial for resveratrol to reach and adsorb on the surface and inner of the ADS-5 resin. However, there was no significant difference at 35 and 45 $^\circ$C ($P > 0.05$). Thus, 35 $^\circ$C was selected in the following experiments in view of the lower energy consumption.

In adsorption processes, thermodynamic parameters values are the actual indicators for practical application (Hamdaoui & Naffrechoux, 2007). Thermodynamic parameters such as free energy ($\Delta G^o$), enthalpy ($\Delta H^o$), and entropy ($\Delta S^o$) change of adsorption can be determined from the following equations (Mathews, Sabina, Zuker, & Turner, 1999):

$$\Delta G^o = -RT \ln K_L$$  \hspace{1cm} (9)

$$\ln K_L = \frac{\Delta S^o}{R} - \frac{\Delta H^o}{RT}$$  \hspace{1cm} (10)

where $\Delta G^o$, $\Delta H^o$, and $\Delta S^o$ are changes in Gibbs free energy [kJ/mol], enthalpy [kJ/mol] and entropy [J/mol K], respectively. $K_L$, $R$ and $T$ are the Langmuir equilibrium constant, the gas constant (8.314 J/mol K), and the absolute temperature (K), respectively.

As shown in Table 2 the negative values of $\Delta G^o$ indicated that the adsorption was a spontaneous process. The value of $\Delta H^o$ was positive, indicating that the adsorption process was endothermic and relatively higher temperature was favourable to the adsorption process. The results were in good accordance with the analytical results of the adsorption isotherms test.

3.4. Dynamic adsorption/desorption of resveratrol on a ADS-5 resin column

3.4.1. Effects of volume and flow rate of sample solution on adsorption

It has been reported that the adsorption function of macroporous adsorption resin was determined by surface adsorption, sieve classification, surface electrical property and hydrogen bonding interactions etc. (Fu et al., 2006; Liu et al. 2010b). When the adsorption reaches the break point, the adsorption affinity decreases, even disappears, and the solutes leak from the resin. Therefore, it is very significant to set up the dynamic leakage curve in order to calculate the processing volume of sample solution and the appropriate sample flow rate. The dynamic leakage curves of resveratrol on ADS-5 resin were obtained based on the volume of effluent liquid and the resveratrol concentration herein. As shown in Fig. 3A. The best adsorption performance was obtained at the lowest flow rate (1.0 BV/h), which is likely due to better particle diffusion in sample solutions. An even lower flow rate prolonged the working period (Ma et al., 2009). When the flow rate was faster, leading to incomplete adsorption of resveratrol on ADS-5 resin. However, there was no significant difference at adsorption flow rate 1.0 and 2.0 BV/h for the adsorption capacities ($P > 0.05$). Taking it into consideration that a lower flow rate prolonged the working time for industrial production, 2.0 BV/h was selected as the
appropriate sample flow rate for further experiments. Under this condition, the processing volume of sample solution on ADS-5 resin was approximate 3 BV.

3.4.2. Effects of volume and flow rate of elution on desorption

In order to decrease the consumption of reagents and make the desorption more efficient, the effects of the volume and flow rate of eluent on desorption capacity were investigated by dynamic desorption curves. The dynamic desorption curves were obtained based on the volume of eluent and the concentration of solute herein. The results were shown in Fig. 3B. It indicated that increasing flow rate had a negative effect on dynamic desorption capacity of adsorbate on resins. The best desorption performance was obtained at the lowest flow rate 2.0 BV/h. However, there was no significant difference amongst desorption flow rate 2.0, 3.0, and 4.0 BV/h for the desorption capacities of resveratrol (P > 0.05). In view of the shorter working time and lower volume consumption, the proper desorption flow rate was 4.0 BV/h. Under this condition, resveratrol was completely desorbed when the volume of elution was approximate 8 BV.

3.4.3. Effects of concentration of ethanol–aqueous solutions on desorption

When the adsorption of resveratrol on the ADS-5 resin was completed, it was very important to select an appropriate reagent to desorb resveratrol from resin effectively. Considering the structure and property of resveratrol, the different concentration of ethanol–aqueous solutions was carried out with isocratic modes at the flow rate of 4.0 BV/h and eluent volume of 8 BV. The desorption solution was analysed by HPLC and then dried under vacuum. The dried product was weighed and the contents and recovery yield of resveratrol were calculated. The dynamic desorption tests were repeated for 5 times. As shown in Table 3, in the desorption process, the desorption ability of different eluents changed with the ethanol concentration. The mass of dried residue and resveratrol in elution solution increased, when the concentration of ethanol solution increased. Nevertheless, statistic analysis showed that the resveratrol desorbed was no significant difference (P > 0.05), when the ethanol concentration was over 60%. Furthermore, the content of resveratrol in dried residue reached a peak value (23.60 ± 0.48%) at 60% ethanol–aqueous solution. Thus, in desorption process, 60% ethanol–aqueous solution was suitable for desorption of resveratrol.

3.5. Comparison of characterisation of samples before and after purification with ADS-5 resin

Taking account of the above experiments of influential factors, the appropriate separation and purification of resveratrol from PSE on ADS-5 resin were confirmed as follows: for adsorption the volume and flow rate of samples were 3 BV and 2.0 BV/h, respectively, and for desorption resveratrol-loaded resin column was washed by 8 BV 60% ethanol–aqueous solution, the flow rates were 4.0 BV/h. After treatment with ADS-5 resin at the optimal conditions, the content of resveratrol in the product was increased 17.9-fold from 1.32% to 23.60%, with a recovery yield of 88.33%. The results demonstrated that ADS-5 resin was a promising basis for large-scale preliminary separation and purification of resveratrol from PSE.

4. Conclusions

In this study, the preliminary separation and purification of resveratrol from PSE was achieved successfully. According to the results, ADS-5 was selected as a suitable resin for resveratrol separation and purification, due to its higher adsorption/desorption capacity and desorption ratio. From the static experimental results with ADS-5 resin, it was found that the experimental data fitted best to the Langmuir isotherm model and pseudo-second-order kinetics model coupled better correlation coefficients. Meanwhile, adsorption isotherms were also found that the initial concentrations of resveratrol in the sample solution 0.33 mg/mL and temperature 35 °C were selected as optimal conditions. The negative ΔG° implied that the adsorption process was spontaneous, the positive ΔH° indicated that the adsorption was an endothermic process. Based on the dynamic adsorption/desorption experiments through column packed with ADS-5 resin, the best parameters were as follows: for adsorption the volume and flow rate of samples were 3 BV and 2.0 BV/h, respectively, and for desorption resveratrol-loaded resin column was washed by 8 BV 60% ethanol–aqueous solution, the flow rates were 4.0 BV/h. After treatment with ADS-5 resin at the optimal conditions, the content of resveratrol in the product was increased 17.9-fold from 1.32% to 23.60%, with a recovery yield of 88.33%. The results demonstrated that ADS-5 resin was a promising basis for large-scale preliminary separation and purification of resveratrol from PSE.

Acknowledgement

This work is supported by the Natural Science Foundation of Jiangsu Province of China (BK2008194).

References


