การศึกษาการดูดซับ จลนพลศาสตร์ และอุณหพลศาสตร์ ของสารให้ความขาว**
โดยเส้นใยต้นขิงที่ผ่านการปรับสภาพด้วยกรด
Adsorption, Kinetic and Thermodynamic Studies of Whitening Agent by** the Use of Acid Treated Stem Ginger Fibers (ATSGF)

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บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อนำเส้นใยต้นขิงที่ผ่านการปรับสภาพด้วยกรด มาใช้เป็นวัสดุดูดซับวิตามิน บี 3 ซึ่งเป็นสารให้ความขาวชนิดหนึ่งที่ใช้ในเครื่องสำอาง โดยกระบวนการดูดซับแบบแบทซ์ จากการศึกษาปัจจัยต่างๆ ที่มีผลต่อการดูดซับ ได้แก่ ระยะเวลาในการเข้าสู่สมดุล ความเข้มข้นของตัวถูกดูดซับ และอุณหภูมิ พบว่าภายใต้อุณหภูมิ 30 องศาเซลเซียส เส้นใยต้นขิงที่ผ่านการปรับสภาพด้วยกรดเริ่มเข้าสู่สมดุลที่เวลา 150 นาที เส้นใยต้นขิงที่ผ่านการปรับสภาพด้วยกรดสามารถดูดซับวิตามิน บี 3 ได้มากขึ้นเมื่ออุณหภูมิสูงขึ้น ผลการศึกษาพฤติกรรมการดูดซับวิตามิน บี 3 ของเส้นใยต้นขิงที่ผ่านการปรับสภาพด้วยกรด สอดคล้องกับทั้งสมการของแลงเมียร์และฟรอยด์ลิช โดยปริมาณการดูดซับสูงสุดแบบชั้นเดียวภายใต้อุณหภูมิ 30, 40 และ 50 องศาเซลเซียส มีค่าเท่ากับ 526, 588 และ 667 มิลลิกรัมต่อปริมาณเส้นใยต้นขิงหนึ่งกรัม ตามลำดับ การศึกษาสมการทางจลนพลศาสตร์โดยใช้สมการอันดับหนึ่งเทียมและสมการอันดับสองเทียม ผลจากการทดลอง พบว่าสอดคล้องได้ดีกับสมการอันดับสองเทียมมากกว่าสมการอันดับหนึ่งเทียม การศึกษาตัวแปรต่างๆ ทางเทอร์โมไดนามิกส์ ได้แก่ ΔH°, ΔS° และ ΔG° พบว่ากระบวนการดูดซับเป็นแบบดูดความร้อน โดยเกิดการดูดซับแบบสุ่ม และกระบวนการดูดซับดังกล่าวสามารถเกิดขึ้นได้เอง ตามลำดับ ผลจากการศึกษาปริมาณการปลดปล่อย พบว่าภายใต้อุณหภูมิ

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30 องศาเซลเซียส เส้นใยต้นขิงที่ผ่านการปรับสภาพด้วยกรดที่ดูดซับวิตามิน บี 3 ความเข้มข้นร้อยละ 0.5 โดยน้ำหนักต่อปริมาตร สามารถปลดปล่อยวิตามิน บี 3 ได้เท่ากับ 120 มิลลิกรัมต่อปริมาณเส้นใยต้นขิงหนึ่งกรัม หรือคิดเป็นร้อยละ 80 ผลการศึกษาดังกล่าวแสดงให้เห็นว่าเส้นใยต้นขิงที่ผ่านการปรับสภาพด้วยกรด สามารถนำมาประยุกต์ใช้เป็นสครับขัดผิวจากธรรมชาติชนิดใหม่ในผลิตภัณฑ์เครื่องสำอางที่สามารถขจัดเซลล์ที่เสื่อมสภาพ และปลดปล่อยสารให้ความขาวให้กับผิวได้

คำสำคัญ: การดูดซับ จลนพลศาสตร์ อุณหพลศาสตร์ วิตามิน บี 3

Abstract

The objective of this work is the potential use of acid treated stem ginger fibers (ATSGF) as adsorbents for vitamin B3, which is used as a whitening agent in cosmetics. Batch adsorption experiments were conducted for this work. The parameters studied were equilibrium time, influence of adsorbate concentration and temperature. The equilibrium time of ATSGF for the adsorption of vitamin B3 at 30° C was 150 minutes. The amount of vitamin B3 sorption onto ATSGF increased with the increase in temperature. The adsorption behavior of vitamin B3 on the surface of ATSGF was fitted to Langmuir and Freundlich isotherms. The maximum monolayer adsorption capacities were found to be 526, 588 and 667 mg/g at 30, 40 and 50 °C, respectively. The adsorption kinetics were evaluated using pseudo first and pseudo second order. The kinetic results indicated that the pseudo second order equation described the adsorption kinetics data slightly better than the pseudo first order equation. The thermodynamic parameters $\Delta H°$, $\Delta S°$ and $\Delta G°$ indicated an endothermic adsorption process, which is random, and spontaneous adsorption of vitamin B3 on the surface of ATSGF, respectively. The desorption results indicated that ATSGF with adsorbed vitamin B3 (prepared at a concentration of 0.5 %w/v) can release 120 mg of vitamin B3 per gram ATSGF (or equal to 80%) at 30° C. The results of this study showed that ATSGF could be used as a natural body scrub material in cosmetic products for scrubbing and releasing the whitening agent to the skin.

Keywords: Adsorption, kKinetic, Thermodynamic, Vitamin B3

Introduction

Ginger *(Zingiber officinale)* is a herb plant in the family of Zingiberaceae like galangal, turmeric, torch ginger. Ginger is popularly known and found in South East Asia. This plant has been used as a spice for over 2000 years (Datta et al., 2011). The proximate composition of ginger is 60-70% carbohydrate, 12% water, 9% protein, 3-8% fiber, 8% ash, 3-6% fatty oil and 2-3% volatile oil (Alakali & Satimehin, 2009). Ginger plants are widely used as spice, condiment and traditional medicine. Rhizomes of ginger have been widely used for food, and leaves of ginger for medicine (Chan et al., 2008; Chan et al., 2011). It is also used industrially in the manufacture of powdered ginger for drinking. For its many advantages, ginger is grown widely, leaving a large number of stem ginger unused after harvesting the ginger rhizomes. Nowadays, a large number of plants in the family of Zingiberaceae, as low cost agricultural waste, has been used as natural adsorbent materials, such as ginger for the synthetic patent blue VF in wastewater (Ahmad & Kumar, 2008), synthetic malachite green (Ahmad & Kumar, 2010) and crystal violet dye (Kumar & Ahmad, 2011). The adsorption of aluminium salts from the waste water by turmeric has also been studied (Halim et al., 2011). Galangal can adsorb lead and zinc salts (Chairgulprasert et al., 2013). Many research studies mentioned here show that plants in the family of Zingiberaceae, especially ginger, can serve as a natural adsorbent material for some kinds of synthetic dyes and some types of heavy metal ions. A variety of natural materials have been used for scrub in cosmetic products such as luffa and grape seed. But there is no research yet about the adsorption of whitening agents by these natural materials. Stem ginger is left in large amounts as agricultural waste after harvesting the rhizome ginger. This research evaluates the use of acid treated stem ginger fibers (ATSGF) as an adsorbent for the whitening agent vitamin B3 (nicotinic acid), since this product is widely used in cosmetics and skin care products. Fibers of stem ginger with adsorbed vitamin B3 could be applied as body scrub releasing the vitamin B3 as a whitening agent. This should have a rapid whitening effect on the skin.

Experimental

1. Adsorbate

Vitamin B3 with the molecular formula $C_6H_5O_2N$ has the structure shown in Fig. 1. Fresh ginger *(Zingiber officinale)* was collected from Kanchanaburi Province, Thailand. Only stem ginger was used in this study. It was cut into small pieces and washed with distilled water to remove dirt. Finally the material was dried in an oven at 70 °C for 24 hours. The dried stem ginger waste material was converted into 12 mesh (≈1.68 mm) sized particles.

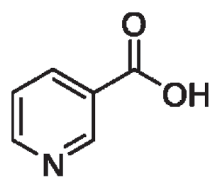

Fig. 1 Structure of vitamin B3

2. Preparation of stem ginger fibers as bio-sorbent

Small pieces of dried stem ginger waste material were weighted and soaked in 1 M H_2O_2, then heated in water at 90 °C for 2 hours, washed with distilled water and dried in an oven at 70 °C for 24 hours. Stem ginger fibers were prepared by soaking the pieces in 1 M NaOH for 2 hours at 90 °C. The bio-fibers were then washed with distilled water to eliminate excess NaOH (Syahrizul et al., 2012), and dried in an oven again at 70 °C for 24 hours. Finally, the stem ginger fibers were soaked in a mixed solution of 0.25 M H_2SO_4 and 0.25 M $ZnCl_2$ in the ratio of 1:1 for 24 hours (Kumar & Ahmad, 2011). Afterwards the fibers were washed with distilled water and dried in an oven at 70 °C for 24 hours and used as bio-sorbent material.

3. Characterization of the bio-sorbent

Point of zero charge determination

A determination of the point of zero charge (pH_z) of ATSGF was done to investigate the surface charge of adsorbents (Ahmad & Kumar, 2010). Solutions of 0.1 M KCl were prepared and the pH adjusted between 2.0 and 12.0. Then 0.5 g of ATSGF were soaked in 50 mL of the KCl solutions for 24 hours and the final pH of the solutions was measured with a pH meter. The point of zero charge was determined between x-axial as pH initial and y-axial as pH final (Sharma & UmaUpadhyay, 2009).

Morphology analysis

ATSGF before and after vitamin B3 adsorption were placed in 10 mm diameter aluminum stubs, gold coated to provide electrical conductivity. Scanning electron microscopy (JSM-7610F Field Emission Scanning Electron Microscope) analysis was used to analyze the surface morphology of ATSGF.

4. **Batch biosorption studies**

A batch method was used to study the rate and equilibrium data of the adsorption of ginger (Ahmad & Kumar, 2008; Ahmad & Kumar, 2010; Kumar & Ahmad, 2011). All experiments were performed in 125 mL Erlenmeyer flasks at 30, 40 and 50 °C. Flasks were filled with 50 mL solutions of different vitamin B3 concentrations (0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 % w/v) and 0.5 g portions of the ATSGF adsorbent were added. After shaking at 120 rpm for the equilibrium time, the suspensions were filtered and the residual amount of vitamin B3 in each solution was measured at wavelength 262 nm using an UV/VIS spectrometer (Jasco V-530). The amount of vitamin B3 adsorbed at equilibrium (q_e: mg/g) was calculated by equation (1):

$$q_e = (C_0 - C_e)V/W \qquad \text{......................(1)}$$

where C_0 (mg/L) is the initial concentration of vitamin B3 and C_e (mg/L) is the equilibrium concentration of vitamin B3, V (L) is the volume of the vitamin B3 solution and W (g) is the mass of ATSGF.

5. **Thermodynamic studies**

0.5 g samples of ATSGF were put in 125 mL Erlenmeyer flasks. Then 50 mL solutions of different vitamin B3 concentrations (0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 %w/v) were added. The experiments were performed at 30, 40 and 50 °C. Flasks were shaken at 120 rpm for the equilibrium time. After shaking, the suspensions were filtered and the residual amount of vitamin B3 in each solution was measured at wavelength 262 nm using an UV/VIS spectrometer.

6. Kinetic studies

0.5 g samples of ATSGF were put in 125 mL Erlenmeyer flasks. Then 50 mL solutions with different vitamin B3 concentrations (0.5, 1.0, and 2.0 %w/v) were added. The experiments were performed at 30 °C. Flasks were shaken at 120 rpm for different times (1, 5, 10, 30, 40, 50, 60 and 120 minutes). After shaking, the suspensions were filtered and the residual amount of vitamin B3 in each solution was measured at wavelength 262 nm using an UV/VIS spectrometer.

7. Batch desorption studies

Desorption of vitamin B3 was achieved by using 50 mL of distilled water and 0.5 g of ATSGF with adsorbed vitamin B3 at a concentration of 0.5 %w/. After shaking at different times (1, 3, 5, 15 and 20 minutes) with 120 rpm at 30 °C, the suspensions were filtered and the amount of vitamin B3 in each flask was measured by using a UV/VIS spectrometer.

Results and discussion

1. Study of the charge on the surface of ATSGF

The charge on the surface of ATSGF was evaluated by studying the point of zero charge (pH_z). Fig. 2 shows the point of zero charge (pH_z) of ATSGF at pH 7. For lower pH than the zero point charge (pH_z =7) the solution has a higher concentration of H^+ than OH^-, making H^+ ions accumulate on the adsorbent surface, hence the positive charge on the surface of ATSGF. For pH above the zero point charge (pH_z = 7) the solution has a higher concentration of OH^- than H^+ making high OH^- ions accumulate on the adsorbent surface, hence the negative charge on the surface of ATSGF (Kumar & Ahmad, 2011; Janos et al., 2003).

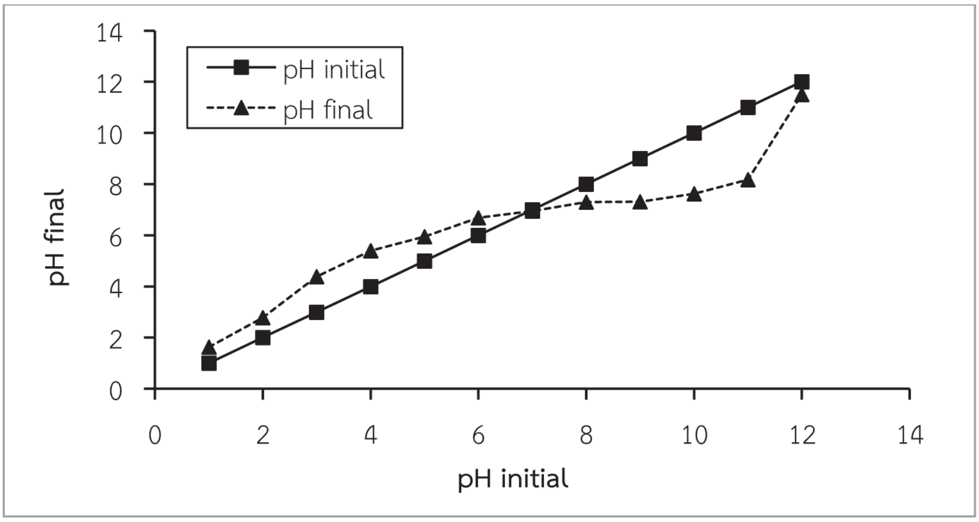

Fig. 2 Point of zero charge of ATSGF.

2. Effect of time and initial concentration of vitamin B3

This study revealed a rapid initial adsorption of vitamin B3 on the surface of ATSGF. This may be the part of vitamin B3 adsorbed at the exterior surface of the adsorbent (ATSGF) (Meikap et al., 2006). Afterwards, vitamin B3 adsorbed slower on the surface until an equilibrium time of 150 minutes. The result is shown in Fig. 3. After a short equilibrium time for each initial adsorbate concentration, the amount of adsorption increased from 114 to 150 mg/g, 175 to 241 mg/g and 255 to 378 mg/g, when the vitamin B3 concentration was increased from 0.5, 1.0 and 2.0 %w/v, respectively.

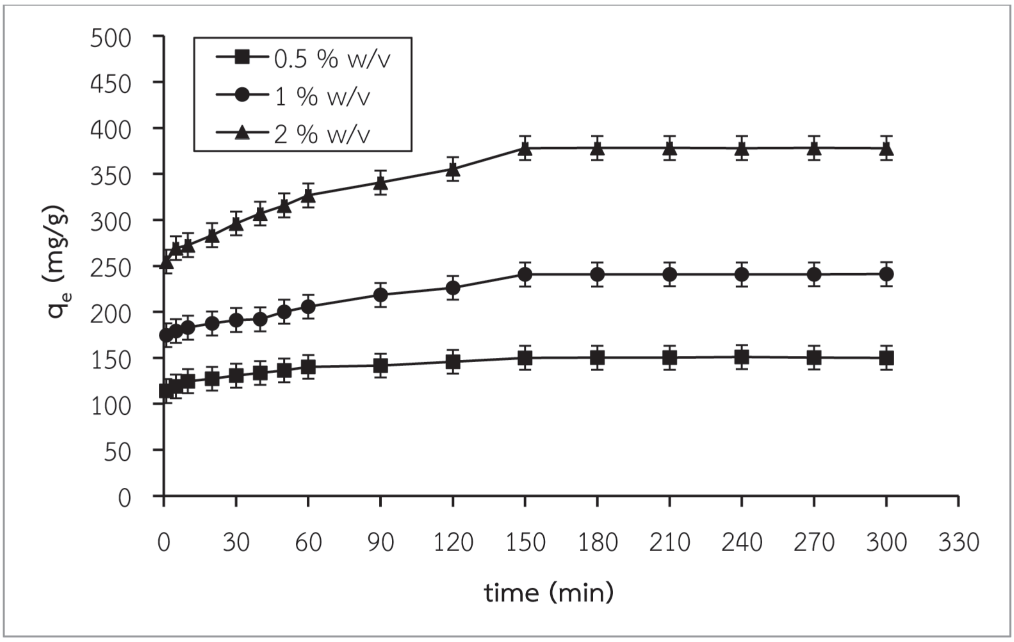

Fig. 3 Effect of time on the vitamin B3 adsorption on the surface of ATSGF at 30° C; biosorbent dosage = 0.5 g; pH = 6; and stirring speed = 120 rpm.

The effect of the initial adsorbate concentration depends on the relation between the adsorbate concentration and the available binding sites of the adsorbent surface (Etim et al., 2012). In this experiment, the amount of vitamin B3 adsorbed on the surface of ATSGF with varied concentrations of vitamin B3 (0.5, 1.0, 1.5, 2.0, 2.5, 3.0 %w/v) at 30, 40 and 50 °C showed that the adsorption capacity increased by increasing the vitamin B3 concentrations, as shown in Fig. 4. The maximum adsorption was found to be 475, 529 and 622 mg/g, respectively. When the initial concentration of adsorbate was increased, the adsorption capacity increased as well. This may happen at low concentrations when the active sites of the adsorbent surface might be low occupied by adsorbate molecules. At higher concentrations, the active sites of the adsorbent surface would be occupied by adsorbate molecules, so the adsorption process slows down significantly (Kannan & Sundaram, 2001).

3. Effect of temperature

To study the effect of temperature on the adsorption, experiments were carried out at 30, 40 and 50 °C. Fig. 4 shows the amount of adsorbed vitamin B3 by ATSGF. The results indicate that the amount of adsorption is increased by increased temperature, which points to an endothermic process (Ahmad & Kumar, 2010). Increasing the temperature may increase the mobility of adsorbate molecules resulting in an increased rate of adsorption (Aksu et al., 2008).

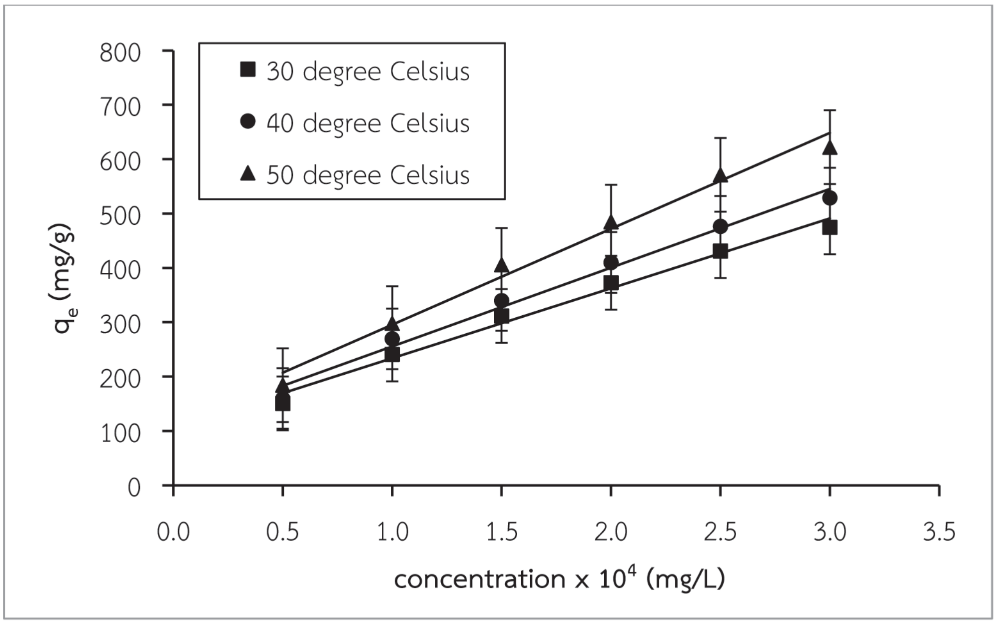

Fig. 4 Effect of initial concentration of vitamin B3 adsorption on the surface of ATSGF at 30, 40 and 50 °C; biosorbent amount = 0.5 g; pH = 6; and stirring speed = 120 rpm.

4. Adsorption isotherms

The Langmuir isotherm is used as a monolayer sorption model, while the Freundlich isotherm is a multilayer sorption model. The linear equation of the Langmuir and Freundlich models are based on the following linear equation (2) (Kumar & Admad, 2011) for the Langmuir model and the linear equation (3) (Freundlich, 1906) for the Freundlich model.

$$1/q_e = (1/q_{max}K_LC_e) + (1/q_{max}) \quad \text{.....................(2)}$$

$$\log q_e = \log K_F + 1/n \log C_e \quad \text{.....................(3)}$$

q_e (mg/g) is the amount of vitamin B3 adsorbed at equilibrium, q_{max} (mg/g) is the maximum monolayer adsorption on the surface of adsorbent, C_e (mg/L) is the equilibrium concentration of vitamin B3, K_L is the Langmuir constant, K_F the Freundlich constant which is related to the biosorption capacity, and 1/n is the Freundlich constant which refers to heterogeneity factors (Kumar & Ahmad, 2011). The K_F and n constants in the linear equation of the Freundlich model were obtained from the y-intercept and slope of the log q_e versus log C_e plot.

Langmuir and Freundlich adsorption isotherms were used for the analysis of vitamin B3 adsorbtion on ATSGF. Fig. 5 shows a straighter line with a greater correlation coefficient (R^2) than Fig. 6. Therefore, the phenomena of vitamin B3 adsorption on the surface of ATSGF corresponds slightly better to the Langmuir than the Freundlich isotherm. Table 1 shows the maximum monolayer adsorption (qmax) with 526, 588 and 667 mg/g at temperature 30, 40 and 50 °C, respectively.

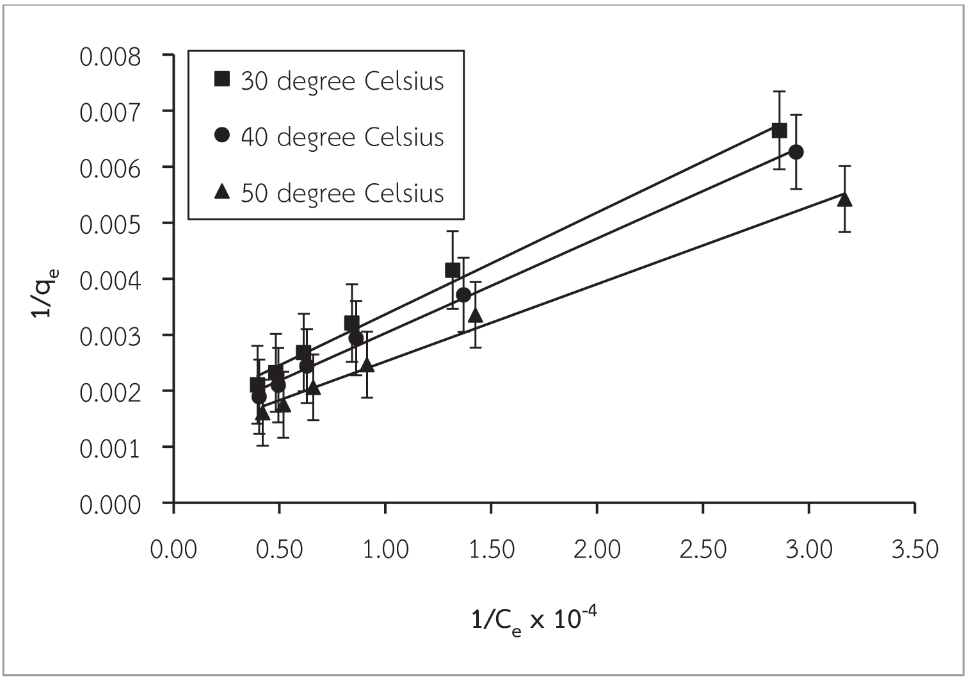

Fig. 5 Langmuir adsorption isotherm plots for the adsorption of vitamin B3 on the surface of ATSGF at different temperatures.

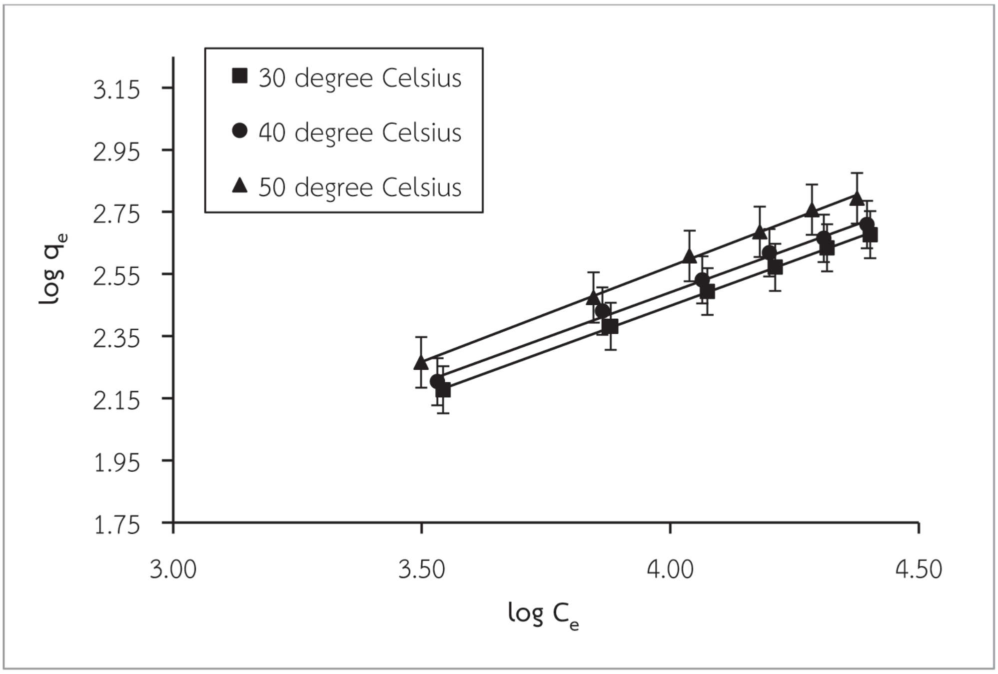

Fig. 6 Freundlich adsorption isotherm plots for the adsorption of vitamin B3 on the surface of ATSGF at different temperatures.

Table 1 Langmuir and Freundlich parameters for the adsorption of vitamin B3 on the surface of ATSGF.

Temperature (°C)	Langmuir isotherm			Freundlich isotherm			
	q_{max} (mg/g)	K_L (L/mg)	R^2	K_F (mg/g)	1/n	n	R^2
30	526	0.0001	0.9924	1.296	0.584	1.71	0.9995
40	588	0.0001	0.9922	1.452	0.582	1.72	0.9948
50	667	0.0001	0.9907	1.321	0.613	1.63	0.9984

5. Morphological analysis

Fig. 7 shows the surface morphology by SEM of ATSGF: (a) the ATSGF before the adsorption of vitamin B3 indicates that the acid treatment can clean-up the surface impurities (Huang & Huang, 1996). Part (b) shows the ATSGF after adsorption of vitamin B3.

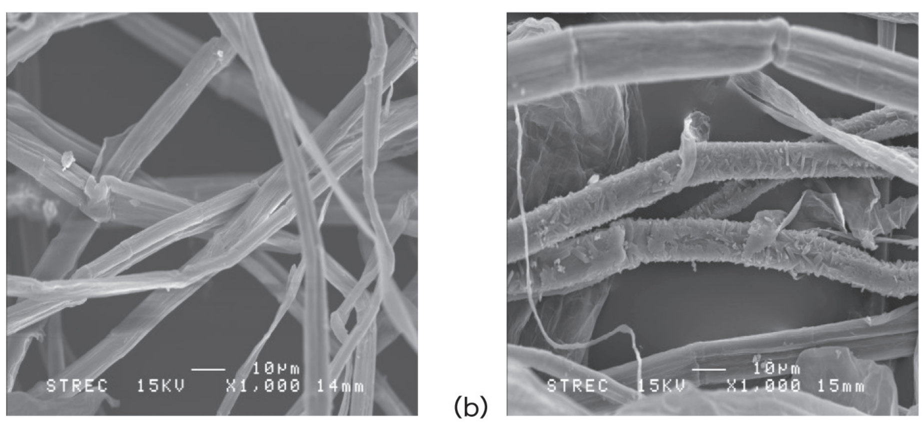

Fig. 7 SEM images of ATSGF (a) before and (b) after adsorption of vitamin B3.

6. Study of desorption

The desorption of vitamin B3 at 30 °C from ATSGF is shown in Table 2. The amount of desorbed vitamin B3 was determined by UV/VIS spectro-photometrically at 262 nm. Table 2 shows the amount of released vitamin B3 from the ATSGF. The desorption results indicated that ATSGF with adsorbed vitamin B3 at a concentration of 0.5 %w/v can release 60, 100, 120, 120 and 120 mg of vitamin B3/1.0 g of ATSGF at time of 1, 3, 5, 15 and 20 minutes, respectively. The desorption results indicated that ATSGF can release 120 mg of vitamin B3 per gram of ATSGF within a time of 5 minutes. The desorption results indicated that ATSGF could be well employed as a scrub for the release of vitamin B3.

Table 2 Desorption of vitamin B3 from the surface of ATSGF.

Concentration (%w/v)	Desorption of vitamin B3 (mg/g)				
	1 minutes	3 minutes	5 minutes	15 minutes	20 minutes
0.5	60	100	120	120	120

7. Study of thermodynamic parameters

Thermodynamic studies were performed to examine the nature of the sorption process. Thermodynamic parameters such as standard free energy change (ΔG°) is related to the spontaneous or non-spontaneous nature of a process, the standard entropy change (ΔS°) is related to the number of ways a system can disperse (which is closely related to the freedom of motion of the particles (Silberberg, 2013), and the standard enthalpy change (ΔH°) is related to exothermic or endothermic behavior (Silberberg, 2013). These parameters (ΔH°, ΔS° and ΔG°) are based on the following equations (4)-(6) (Catena & Bright, 1989; Fraji et al., 1992) for thermodynamic model.

$$K_c = C_0/C_e \quad \text{.............................}(4)$$

$$\Delta G_0 = -2.303RT \log K_c \quad \text{.............................}(5)$$

$$\log K_c = (\Delta S_0/2.303R) - (\Delta H_0/2.303RT) \quad \text{.............................}(6)$$

Where R is equal to 8.314 J/mol•K which is the gas constant, T (K) is the absolute solution temperature in Kelvin. When plotting a graph of log K_c versus 1/T, the values of ΔS° and ΔH° can be estimated from the y-intercept and the slope.

The values of thermodynamic parameters including Gibbs free energy change (ΔG°), enthalpy change (ΔH°), entropy change (ΔS°) obtained from the experimental data can be used to describe the nature of the adsorption process. In this study, the effect of temperature was studied at 30, 40 and 50 °C. The results are shown in Table 3. The negative values of ΔG° indicate the spontaneous nature of the adsorption process. Furthermore, the decrease in the values of ΔG° at higher temperature point to a more spontaneous adsorption process at higher temperatures. The positive value of ΔH° suggests an endothermic adsorption process. ΔH° in this study turned out to be 3.64 kJ/mol. The positive value of ΔS° is related to the freedom of motion of solid/liquid interfaces during the adsorption of vitamin B3 on the surface of the ATSGF (Silberberg, 2013).

Table 3 Thermodynamic parameters for the adsorption of vitamin B3 on the surface of ATSGF.

ΔG° (kJ/mol)			ΔH° (kJ/mol)	ΔS° (kJ/mol.K)
30°C	40°C	50°C		
-0.90	-1.00	-1.20	3.64	0.01

8. Study of the adsorption kinetics

Kinetic equation models were investigated to study the order of the adsorption reaction. For this evaluation, a pseudo-first order (7) and pseudo-second order equation (8) (Mckay & Ho, 1999) were applied to the experimental data. The linear equations for the pseudo-first order and pseudo-second order kinetic are:

$$\log (q_e - q_t) = \log q_e - K_1 t/2.303 \qquad \text{..............................(7)}$$

$$t/q_t = 1/K_2 q_e^{\ 2} + t/q_e \qquad \text{..............................(8)}$$

where q_e (mg/g) is the amount of vitamin B3 adsorbed at equilibrium, q_t (mg/g) is the amount of vitamin B3 adsorbed at any time t, k_1 and k_2 are the rate constants of the pseudo-first order and pseudo-second order reaction, respectively.

The reaction rate constant (k) and the value of equilibrium adsorption capacity can be studied by the kinetics of adsorption (Chowdhury et al., 2013) Table 4 shows the kinetic data for the adsorption of vitamin B3 on the surface of ATSGF. The correlation coefficient (R^2) of pseudo first order is lower than for pseudo second order. The calculated q_e values in pseudo second order correlate well with experimental q_e values. Therefore it can be concluded that the adsorption of vitamin B3 by ATSGF follows a pseudo second order kinetics, which is plausible since both the concentration of adsorbent as well as the amount of binding sites influence the speed of the adsorption process.

Table 4 Pseudo first order and pseudo second order kinetics plot for the adsorption of vitamin B3 on the surface of ATSGF.

C_0 x 10^4 (mg/L)	$q_{e\ (exp)}$ (mg/g)	Pseudo-first order kinetic			Pseudo-second order kinetic		
		$q_{e\ (cal)}$ (mg/g)	k_1 (1/min)	R^2	$q_{e\ (cal)}$ (mg/g)	k_2 (g/(mg·min))	R^2
0.5	150.0	32.4	0.017	0.9780	64.1	0.036	0.9988
1.0	241.0	70.0	0.012	0.9783	227.3	0.001	0.9955
2.0	378.0	122.2	0.014	0.9783	357.1	0.001	0.9955

Fig. 8 describes an adsorption mechanism of vitamin B3 on the ATSGF, concluded from the result of zero point of charge indicating that the ginger fiber surface contains positive charges. Therefore the negative partial charge of the oxygen atoms in vitamin B3, as well as the basic nitrogen lone-pair will be attracted to the positive charges on the surface of the ATSGF due to strong electrostatic forces.

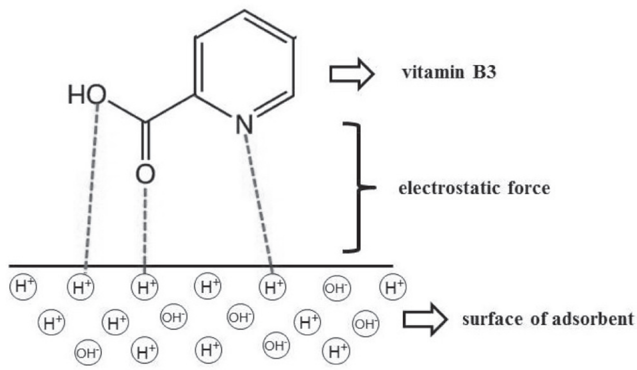

Fig. 8 Proposed mechanism for the adsorption of vitamin B3 on the surface of ATSGF.

Conclusions

In this article, acid treated stem ginger fibers (ATSGF) and its adsorption and desorption behavior towards vitamin B3 were studied. The point of zero charge (pHz) of ATSGF is at pH 7. For this study, at pH 6 the surface of ATSGF was therefore positively charged. The equilibrium time of ATSGF for the adsorption of vitamin B3 at 30° C was 150 minutes. The amount of vitamin B3 sorption onto ATSGF increased with increased temperature. The results indicated that both Langmuir and Freundlich isotherms can be used to fit the vitamin B3 adsorption onto ATSGF. The kinetic results indicated that a pseudo second order equation best describes the adsorption kinetics data. The values of $\Delta H°$, $\Delta S°$ and $\Delta G°$ indicated an endothermic, random, and spontaneous process of adsorption. The present study shows that ATSGF is an effective low cost adsorbent for the adsorption of vitamin B3. The desorption results indicated that ATSGF can release 120 mg of vitamin B3 per gram of ATSGF within 5 minutes. The desorption experiments showed that ATSGF could be used as a natural body scrub material in cosmetics for scrubbing and releasing the whitening agent to the skin.

References

Ahmad, R. & Kumar, R. (2008). Adsorption study of patent blue VF using ginger waste material. *J. Iran. Chem.* Res., 1, 85-94.

Ahmad, R. & Kumar, R. (2010). Adsorption studies of hazardous malachite green onto treated ginger waste. *J. Environ. Manage.,* 91, 1032-1038.

Aksu, Z., Tatli, A. & Tunc, O. (2008). A comparative adsorption/biosorption study of acid blue 161: effect of temperature on equilibrium and kinetic parameters. *Chem. Eng. J.,* 142, 23-39.

Alakali, J. S. & Satimehin, A. A. (2009). Moisture adsorption characteristics of ginger *(Zingiber officinale) powders. Agricultural Engineering international: the CIGR Ejournal.,* XI, 1286.

Catena, G. C. & Bright, F. V. (1989). Thermodynamic study on the effect of cyclodextrin inclusion with anilono naphthalene sulphonates. *Anal. Chem.,* 61, 905-909.

Chairgulprasert, V., Japakeya, A. & Samaae, H. (2013). Phytoremediation of synthetic wastewater by adsorption of lead and zinc onto *Alpinia galanga Willd. Songklanakarin J. Sci. Technol.,* 35, 227-233.

Chan, E. W. C., Lim, Y. Y., Wong, L. F., Lianto, F. S., Wong, S. K., Lim, K. K., Joe, C. E. & Lim, T. Y. (2008). Antioxidant and tyrosinase inhibition properties of leaves and rhizomes of ginger species. *Food Chem.,* 109, 477-483.

Chan, E. W. C., Lim, Y. Y. & Wong, S. K. (2011). Antioxidant properties of ginger leaves: an overview. *Free Radicals Antioxid.,* 6-16.

Chowdhury, S., Chakraborty, S. & Saha, P. D. (2013). Removal of crystal violet from aqueous solution by adsorption onto eggshell: equilibrium, kinetics, thermodynamics and artificial neural network modeling. *Waste & Biomass Valorization.,* 4, 655-664.

Datta, C., Dutta, A. & Dutta, D. (2011). Adsorption of polyphenols from ginger rhizomes on an anion exchange resin Amberlite IR-400- Study on effect of pH and temperature. *Procedia Food Sci.,* 893-899.

Etim, U. J., Umoren, S. A. & Eduok, U. M. (2012). Coconut coir dust as a low cost adsorbent for the removal of cationic dye from aqueous solution. *J. Saudi. Chem. Soc.,* 1-10.

Fraji, L. K., Hayer, D. M. & Werner, T. C. (1992). Static and dynamic fluorescence quenching experiments for the physical chemistry laboratory. *J. Chem. Educ.,* 69, 205-215.

Freundlich, H. M. F. (1906). Über die Adsorption in Lösungen. *Z. Phys. Chem.,* 57(A), 385-470.

Halim, A. A., Ezani, E., Othman, M. S., Awang, N. Ikram, M. & Ithnin A., (2011). Adsorption study of aluminium onto *Curcuma Longa. Aust. J. Basic & Appl. Sci.,* 5, 1170-1177.

Huang, C. & Huang, C.P. (1996). Application of Aspergillus oryzae and Rhizopus oryzae for Cu (II) removal. *Water Res.,* 30, 1985-1990.

Janos, P., Buchtova, H. & Ryznarova, M. (2003). Sorption of dye from aqueous solution onto fly ash. *Water Res.,* 37, 4938-4944.

Kannan, N. & Sundaram, M. M. (2001). Kinetics and mechanism of removal of methylene blue by adsorption on various carbons-a comparative study. *Dyes and Pigments,* 51, 25-40.

Kumar, R. & Ahmad, R. (2011). Biosorption of hazardous crystal violet dye from aqueous solution onto treated ginger waste (TGW). *Desalination,* 265, 112-118.

Langmuir, I. (1916). The constitution and fundamental properties of solids and liquids. *J. Am. Chem. Soc.,* 38 (11), 2221-2295.

Meikap, B. C., Mohanty, K., Naidu, J. T. & Biswas, M. N. (2006). Removal of crystal violet from wastewater by activated carbons prepared from rice husk. *Eng. Chem. Res.,* 45, 5165-5171.

Mckay, G. & Ho, Y. S. (1999). Pseudo-second-order model for sorption processes. *Proc. Biochem.,* 34, 451–465.

Sharma, Y. C. & UmaUpadhyay, S. N. (2009). Removal of a cationic dye from wastewaters by adsorption on activated carbon developed from coconut coir. *Energy Fuels,* 23, 2983-2988.

Silberberg, M. S. (2013). *Principle of General Chemistry* (3rd ed). New York: McGraw-Hill.

Syahrizul, M., Rohani, M., Awang, M., Aidil, M. A. A. & Ali, N. (2012). Tensile, thermal property and surface morphology of sodium hydroxide treated Alpinia galanga natural fiber. *International Annual Symposium on Sustainability Science and Management,* Terengganu, Malaysia, 1120-1123.

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