Adsorption isotherm, thermodynamics and kinetics studies of polyphenols separation from kiwifruit juice using adsorbent resin

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Background:

high content of polyphenols

Juice browning and severe astringency

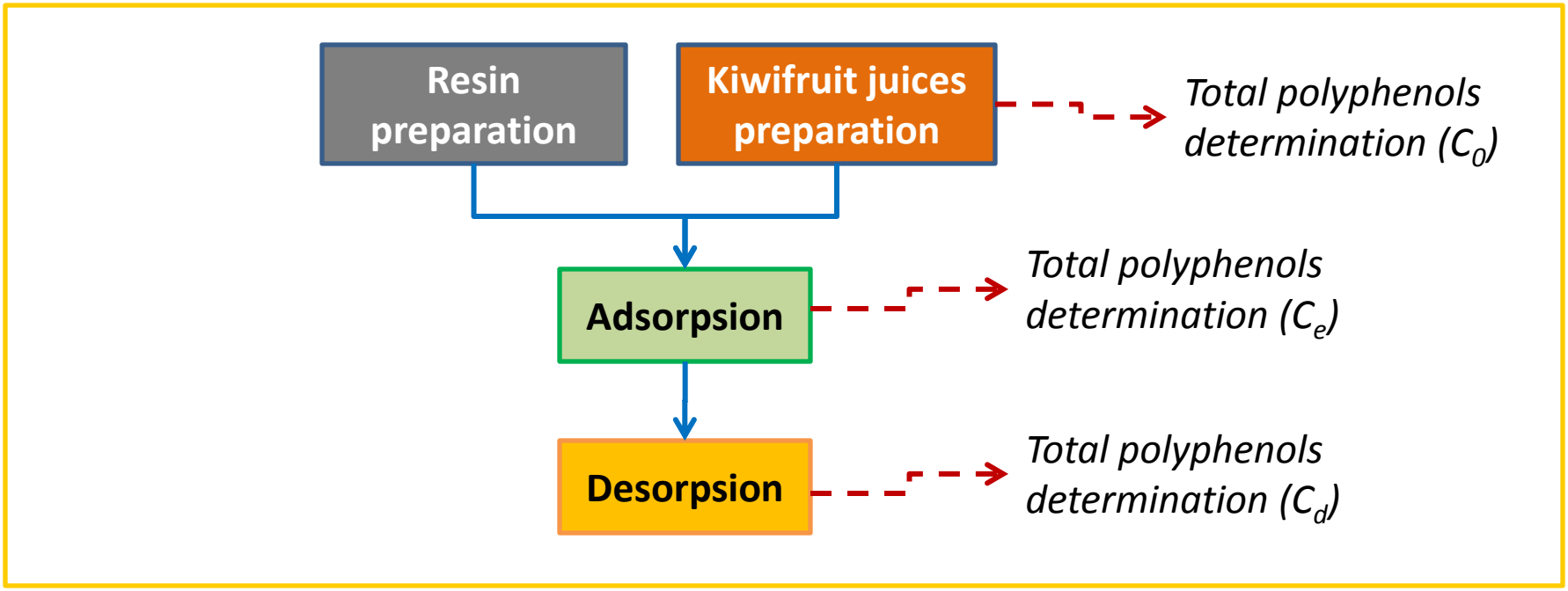
Removal polyphenols using activated carbon, resin

Study on AB-8 resin

Objective:

1. To obtain experimental equilibrium data at different temperatures and to simulate these data with isotherm models including Langmuir and Freundlich models;
2. to evaluate the thermodynamic parameters including adsorption enthalpy (DH), adsorption free energy (DG) and adsorption entropy (DS), which are basic principles in thermodynamics;
3. to obtain experimental kinetics data at optimum temperature and to simulate the data with different kinetics models;
4. to interpret the kinetics mechanism and ratelimiting step of the adsorption process

Method:



Static adsorption test | **Adsorption isotherms** | **Adsorption kinetics**

Result:

Adsorption capacity :

Table 1
Adsorption properties of AB-8 resin.

Resin	Adsorption/desorption property		
	Adsorption capacity (mg/g)	Desorption capacity (mg/g)	Ratio of desorption (%)
AB-8	55.65	54.38	97.72

The temperature of test was at 25 °C.

Adsorption isotherm :

process is endothermic

Table 2. Model fitting of polyphenol adsorption equilibrium data using Langmuir and Freundlich isotherm models

Model	Temperature (°C)	Constants			
		K_L (mL/mg)	q_m (mg/g)	R^2	
Langmuir $\frac{C_e}{q_e} = \frac{C_e}{q_m} + \frac{1}{q_m K_L}$	25	0.0019	76.3359	0.9779	
	30	0.0058	59.8802	0.9941	
	35	0.0086	63.6943	0.9692	
		K_f (mL/mg)	n	$1/n$	R^2
Freundlich $\ln q_e = \frac{1}{n} \ln C_e + \ln K_f$	25	0.6084	1.5156	0.6598	0.9773
	30	2.585	2.1901	0.4566	0.9903
	35	4.912	2.644	0.3782	0.9920

Better

Adsorption thermodynamics

Table 3
Thermodynamic parameters for polyphenols adsorption onto the AB-8 resin.

q_e (g/g)	ΔH (kJ/mol)	R^2	ΔG (kJ/mol)			ΔS (J/(mol K))		
			25 °C	30 °C	35 °C	25 °C	30 °C	35 °C
0.010	4.560	0.9923	−3.755	−5.517	−6.771	27.903	33.257	36.789
0.014	4.390	0.9924				27.332	32.696	36.237
0.018	4.263	0.9925				26.906	32.277	35.825
0.022	4.161	0.9925				26.564	31.941	35.494
0.026	4.076	0.9926				26.279	31.66	35.218
0.030	4.004	0.9927				26.037	31.422	34.984

the value of ΔG decreased with increasing temperature, indicating that the adsorption became more favorable at higher temperature

Adsorption kinetics

Table 4
Kinetic parameters for polyphenols adsorption onto the AB-8 resin.

Model	Equation	Constants	
Pseudo first-order model $ln(q_e - q_t) = ln\ q_e - k_1 t$	$\ln (q_e - q_t) = -0.0199\ t + 3.6868$	k_1 (min^{-1}) q_e (mg/g) R^2	0.0199 40.01 0.966
Pseudo second-order model $\frac{t}{q_t} = \frac{t}{q_e} + \frac{1}{k_2 \cdot q_e^2}$	$t/q_t = 0.6085\ t + 3.1579$	k_2 (g/(mg min)) q_e (mg/g) R^2	0.1173 1.6434 0.942
Intra-particle diffusion model $q_t = k_i t^{\frac{1}{2}} + I$	$q_t = 3.3479\ t^{1/2} - 11.228$ (first stage)	k_i (g/(mg $min^{1/2}$)) I (g/mg) R^2	3.3479 −11.228 0.9825
	$q_t = 1.0451\ t^{1/2} + 14.901$ (second stage)	k_i (g/(mg $min^{1/2}$)) I (g/mg) R^2	1.0451 14.901 0.9135

Conclusion:

- Freundlich equation exhibited slightly better fitting at high temperature (R^2= 0.99).
- The adsorption of polyphenols was a physical adsorption process which happened spontaneously and was endothermic in nature.
- The adsorption kinetics could be well fitted into the pseudo first-order model with a good correlation coefficient (R^2=0.966). The kinetics studies also revealed that intra-particle diffusion is not the sole rate-limiting step in the adsorption process of polyphenols onto AB-8 resin as shown by the Weber and Morris intra-particle diffusion model.