Adsorption equilibrium of fructose, glucose and sucrose for cationic resins in the sodium and potassium form

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INTRODUCTION

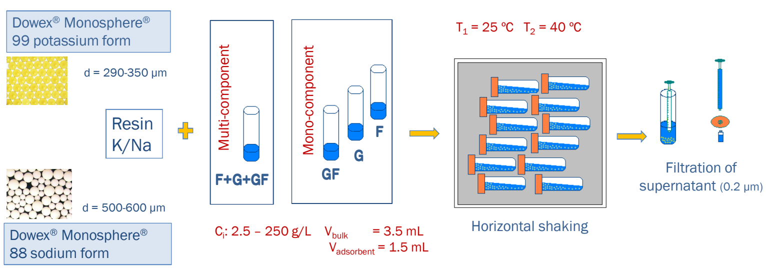
- Separation of glucose from mixtures of fructose and sucrose in molasses is a major challenge in industrial sugar chromatographic separations.
- Sulfonated poly(styrene-co-divinylbenzene) (PS-DVB) ion exchange resins are the most frequently used for sugars separation, generally in a cationic form. The cation of the resins used in this study complex with the hydroxyl group of the sugar adsorbed leading to a selective adsorption. Thus, the conformation of the sugar determines its relative affinity for the resin and its distribution coefficient.
- The separation process is usually carried out at high temperatures. However, this implies high energy costs and high levels of hydrolysis.
- The knowledge of the adsorption isotherms of the sugars in a mixture is a very important parameter for the selection of the adsorbent to be used in the chromatographic separation.

OBJECTIVE

- In this study, the adsorption isotherms of glucose (G), fructose (F) and sucrose (S) in mixtures of mono and multi-component at 25 and 40ºC were determined for two resins of PS-DVB in the sodium and potassium forms.

EXPERIMENTAL METHODOLOGY

Static Method



- Sugars were quantified by High Performance Liquid Chromatography (HPLC)

- Equilibrium loading
  q (mg_sugar/g_adsorbent)

$$q = \frac{(C_i - C_f)V}{m}$$

C_i – Initial concentration (mg/mL)
C_f – Final concentration in bulk (mg/mL)
V – Volume of sugar solution (mL)
m – dry adsorbent mass (g)

- Adsorption Isotherm Model

$$q = k.C_f$$

k – distribution coefficient (mL/g_{ads})

- Selectivity (α):

$$\alpha = \frac{k_F}{k_G} = \frac{k_G}{k_S} = \frac{k_F}{k_S}$$

- For testing the equality of the distribution coefficient a factorial design was set up as an analysis of covariance at a 5% significance level . SPSS version 17 was used.

RESULTS AND DISCUSSION

Adsorption Isotherms

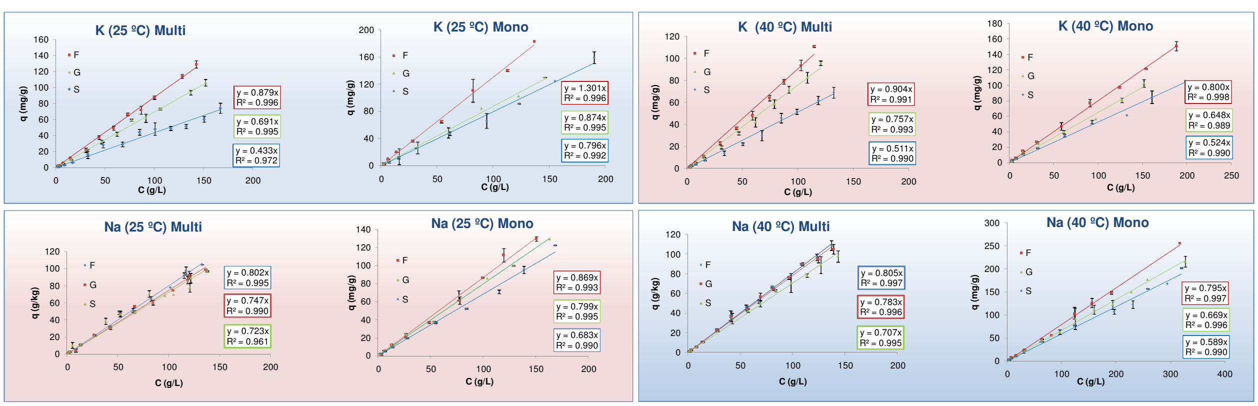
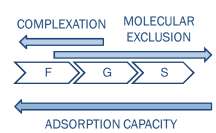


Table 1. Variation of distribution coefficient (k) from F, G, and S with resin (K/Na), component (mono/multi) and temperature (25/40ºC) Increase (green) Equal (yellow) Decrease (orange)

	K resin				Na resin				25ºC		40ºC	
	25ºC	40ºC	Mono	Multi	25ºC	40ºC	Mono	Multi	Mono	Multi	Mono	Multi
	Mono ->Multi	Mono ->Multi	25->40	25->40	Mono ->Multi	Mono ->Multi	25->40	25->40	K->NA	25->40	25->40	25->40
F	Decrease	Increase	Decrease	Increase	Decrease	Equal	Decrease	Equal	Decrease	Decrease	Equal	Decrease
G	Decrease	Increase	Decrease	Increase	Equal	Decrease	Decrease	Equal	Decrease	Increase	Equal	Equal
S	Decrease	Equal	Decrease	Increase	Equal	Decrease	Decrease	Equal	Decrease	Increase	Increase	Increase

Table 2. Selectivity (α) between sugars:

Resin	K		Na	
T (ºC)	25	40	25	40
F/G	1,28	1,18	1,07	1,03
G/S	1,56	1,49	1,04	1,10
F/S	2,00	1,76	1,11	1,13



Component

- The presence of additional sugars (multi-component) decreased the distribution coefficient, although, for the potassium resin at 40ºC a synergetic effect was found.

Temperature

- In the mono-component mixtures the increase of temperature lead to a decrease of the distribution coefficient, therefore, the capacity of both resins decreased. Nevertheless, the capacity in multi-component mixtures was not significantly affected by the temperature in the sodium resin, and for the potassium resin a small increase in the adsorption was observed.

Selectivity

- The sugars that demonstrated lower selectivity values were F/G since these sugars have the same molecular weight. S/F selectivity showed a higher value as compared to the S/G one because of the complex that is formed between the fructose and the resin.
- For both resins, selectivity decreased with the increase of the temperature. Nevertheless, the selectivity for the potassium resin was higher than the selectivity of the sodium resin.

CONCLUSIONS

- In our case study, the potassium resin appears to be the most suitable adsorbent for an industrial purpose, being the best results achieved for an operational temperature of 25 ºC.

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