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Research Article

Simulated Moving Bed Technology for the Separation of Fructose from Date Syrup

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Abstract

In North African countries, common or second quality dates are not harvested, but rather left to rot, although they are rich in fructose and glucose, sugars which offer more interesting nutritional properties than sucrose used as common table sugar. The recovery of fructose and glucose from these common dates requires the development of an efficient industrial process capable of separating both sugars. The objective of this study was therefore to test the Continuous Chromatographic Simulated Moving Bed technology (SMB) for the separation of both sugars from date syrup and the production of 90% High-Fructose-Syrup (HFS-90). Consisting of four adsorption columns, a laboratory SMB system was used to test the effect on separation of: date syrup sugar concentrations of 37, 26 and 22 %; Feed or syrup and Eluent or distilled water flow rate. After running 27 different combinations of operating parameters, the Feed and Eluent flow rates of 0.45 and 3.2 pore volume/h (pv/h), respectively, produced the highest fructose concentration, but HFS-90 was produced only with the date syrup at 22 % sugar. Accordingly, the SMB process is a promising industrial technology for the recovery of fructose and glucose from date pulp syrup. Optimal operating parameters need optimization depending on date syrup sugar concentration.

Keywords: *Common dates syrup, simulated moving-bed technology and fructose.*

1. Introduction

In Tunisia, an important tonnage of common or second quality dates is left to rot every year when these could be used for their glucose and fructose content. Palm tree plantations in Tunisia cover 33 000 ha and account for 3.5 million trees representing over 250 cultivars (Rhouma, 1994). Only the dates of best quality are harvested to be consumed fresh while the rest is left to rot despite its high glucose and fructose content (Mohamed and Ahmed, 1983; (Al-Eid, *et al*, 1999), (Al Eid, 2006). Accordingly, these second quality dates could be valorised to produce 35 000 tons of sugar of which 15 000 tons is fructose, the sweetest of all naturally occurring sugar. Only half the mass of fructose is required to give the same sweetness as glucose, thus reducing the calorie intake of desserts and sweetened beverages by almost 50 % (Al-Farsi, *et al*, 2005), (Sardesai and Waldshan, 1991).

Fructose is a hexose with a 5-member hemiketal ring known as a furanose. Present in corn syrup produced from corn starch, fruits and honey, fructose is widely used as an alternative sweetener by the pharmaceutical industry for diabetic patients because it slows intestinal track absorption and, for children, it improves iron absorption. Its high sweetening capacity benefits obese persons, stimulates the growth of the probiotic bacteria *Bifidobacteria* in the large and small intestines, and prevents colon cancer (Gill, *et al*, 2003), (Singh, *et al*, 2007). The ingestion of small amounts of fructose can also improve glucose homeostasis (Vaisman, *et al*, 2006).

High-Fructose-Syrup with 90% fructose (HFS-90) is valued as a sweetener by the food and pharmaceutical industries because of its offers a high osmotic pressure and solubility, is better digested in the digestive track and does not crystallize in food products. Presently, the bulk of HFS-90 is produced from the continuous isomerization of glucose achieved through the use of the enzyme glucose isomerase, in a packed-bed reactor (Tomotani and Vitolo, 2007).

Once hydrolyzed, date syrup must be processed to separate fructose from glucose, a technology lacking development. In batch operations, Al Eid (2006) extracted fructose from date syrup by means of column chromatography. The process performance depended on the sugar concentration of the date syrup, the separation temperature, the flow rate and the elution volume (Al Eid, 2006). As compared to a continuous

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process, batch systems are usually more expensive due to their high solvent consumption and low productivity (Schramm,*et al*, 2003). The Continuous Chromatographic Simulated Moving Bed technology (SMB) is a system allowing for the continuous separation of compounds, while using less solvent than regular batch chromatography (Bae and Lee, 2006). Developed in the 1960's for the separation of sugars from molasses, this technology has now been applied to pharmaceutical ingredients and several industrial processes (Miller, *et al*, 1999). During the last decade, SMB was successfully used to separate similar challenging chemicals and for chemical separation processes requiring a high energy level, such as distillation and crystallization (Azevedo and Rodrigues, 2000). Also, SMB was widely applied by the petro-chemical industry in applications such as the separation of p-xylene from its isomers on zeolites (Blehaut and Nicoud, 1998).

The SMB technology is a chromatography-based technique consisting in simulating the counter-current motion of a solid adsorbent relative to a mobile phase. In this process, a liquid (mobile phase) flows against a solid (stationary phase), which enhances the separation potential and allows for process continuity. Four columns are required to operate four liquid streams, namely two inlet streams (Feed and Eluent) and two outlet streams (Extract and Raffinate). Each two sets of streams, the inlets and outlets, are operated against each other, thus requiring four columns with a packed resin connected in a loop assembly. The position of each stream is switched one column ahead in the direction of fluid flow, and at regular time intervals, to simulate counter-current column movement (Azevedo and Rodrigues, 2000). The separation efficiency of SMB is sensitive to the flow rate of the Feed and Eluent streams, and the flow position switching interval (Yu, *et al*, 2003).

In view of its industrial potential, SMB could be applied to recover fructose from glucose from secondary dates. The objective of the present project was therefore to investigate the impact of various operating conditions on the efficiency of SMB for the continuous separation of fructose and glucose after the hydrolyzing the sugars of date syrup. The project tested the following operating conditions: the date syrup sugar concentration; the Feed flow rate for the date syrup, and; the counter-current Eluent flow rate for the distilled water. Collected at the exit of the SMB system, the Extract was produced by the Eluent and contained the separated fructose while the Raffinate was produced by the Feed and contained the other sugars, consisting mostly of glucose in this case.

2. Materials and Methods

2.1Experimental materials and equipment

The SMB separation experiment was initially conducted using date syrup (Table 1). The date syrup was produced by mixing equal masses of fresh common Menakher variety dates and distilled water in an Erlenmeyer flask which was then submerged in hot water at 75°C for 120 min and screened using 2 mm cellulose fibre to remove all lumps and prevent column blockage. The syrup was hydrolyzed using the Amberlite FPC12 H resins at 40 °C (Rohm and Haas, Philadelphia, USA) to obtain uniquely fructose and glucose. The date pulp and syrup were characterized using standard methods (Table 1).

Table1. Typical characteristics of date pulp

Parameter	Al-Aid(2006)	Al-Hooti *et al.* (2002)				Experimental dates	
	Date syrup	Date pulp	Date pulp	Date syrup	Date syrup	Pulp	Syrup
Moisture content (%)	13.5	11.53±0.1	11.55±0.19	16.25	16.76	23±0.4	25
Reducing sugars[a] (%)		87±1.15	88.02±1.06				
- glucose	39			38.45	38.02	30	26
- fructose	41	NA		39.69	39.12	29	24
Non reducing sugars[a] (%)	1					3	3.07
Proteins[a] (N x 6.25, %)	2.2	2.03±0.11	2.60±0.07	1.22	1.68	1.7±0.8	NA
Fat (%)	NA	NA	NA	NA	NA	1.0	NA
Variety	*Khalas*	*Safri*	*Birhi*	*Safri*	*Birhi*	*Menakher*	
Origin	Saudi Arabia		Saudi Arabia			Tunisia	

[a] on a wet basis.
NA- not available

The experimental SMB system is illustrated in Fig. 1. The four B-685 Medium-Pressure Chromatography Columns (C1, C2, C3 and C4; Buchi Labottechnik AG, Flawil, Switzerland) measuring 250 mm in length and 10 mm in inside diameter, were packed with resin and connected in series. Each column had a specific inlet and outlet stream, which could be rotated by a four port valve system to either introduce (Feed F or Eluent El) or remove (Extract E or Raffinate R) the stream. Each inlet and outlet streams were pumped by means of peristaltic pump (Buchi Chromatography B-688 Pump, Flawil, Switzerland). The system was operated at a temperature of 25 °C.

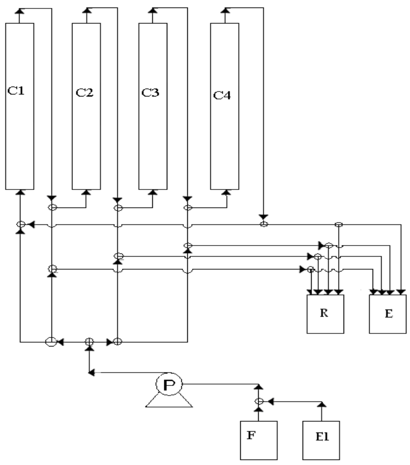

Fig. 1. The SMB system used for fructose separation, where C1, C2, C3 and C4 are the experimental columns measuring 0.25 m in length and 10 mm in inside diameter, F is the Feed (hydrolized date syrup), El is the Eluent (distilled water), E is the extract (liquid with the separated fructose), R is the Raffinate (liquid with residual sugars such as glucose), and P is the pump.

The Eluent was deionized water and the separation columns were packed with the resin Amberlite CR1320 Ca (Rohm and Haas, Philadelphia, USA) made of polystyrene containing a strong cation exchange gel matrix with Ca2+. The resin had a particle size of 300-350 µm, an exchange capacity of over 150 Cmol+/Kg and a heat tolerance of up to 120° C. The polystyrene cation-exchange resin complex preferentially adsorbs fructose by means of its calcium ions (Kurup, *et al*, 2005). The chromatographic separation process is achieved by the Ca2+ ions forming a weak complex with fructose, which results in the preferential retardation of fructose while glucose is carried away by the mobile phase (Al Eid, 2006). The strongly adsorbed component (fructose) was collected in the Extract stream, whereas a weaker adsorbed component (glucose) was collected in the Raffinate stream (Matijaš ević and Vasić -Rač ki, 2000).

2.2 Separation experiment

For all experiments, the four SMB columns were initially filled with syrup and the recovery of fructose was initiated, before fully operating the system. This initial step consisted in feeding the syrup into the column assembly until Raffinate (R) was observed to flow out of the third column (C3). At that point, the first column (C1) was washed with the Eluent (El). When the Raffinate (R) reached the fourth column (C4), the second column (C2) was washed with Eluent (El). At this point, the SMB system was operated continuously, and the third column (C3) could be fed while the first column (C1) was washed with the Eluent (El). Then, syrup was fed into the fourth column (C4) while washing the second column (C2) and so forth. For each column operation, three consecutive 3 ml samples of the Raffinate and the later Eluent with mostly fructose were collected to quantify both their glucose and fructose content. One full trial consisted in the consecutive feeding and washing of all four columns, after the initial filling operation. Each full trial took 4 to 5 hours and was repeated three times, after carefully washing all columns with deionized water.

Each trial consisted in testing the effect on fructose and glucose separation of: date syrup concentration, syrup Feed and distilled water Eluent feeding rates. The Feed rate has an impact on the distribution of the liquid inside the columns while the syrup composition tested the effect of fructose and glucose concentration on the optimal time required to maximize the contact between the liquid and solid phases over the full length of the columns.

2.3 Experimental design

For each trial, common date syrup was used. To produce the valued High-Fructose-Syrup (HFS), one date variety (*Menakher*) was used. Combinations of three different sugar concentrations of date syrup solutions (22, 26 and 37%), three different Feed flow rate (0.45, 1 and 1.9 pore volume/hour or pv/h) and three different Eluent flow rate (3.2, 8.5 and 14.7 pv/h) were tested. The experimental plan is a (3x3x3) factorial experiment (Table 2).

Table 2 Experimental design

Syrup					
syrup	Glucose g/L	Fructose g/L	Feed flow rate pv/h	Eluent flow rate pv/h	Elution volume pv
Synthetic	120	260	4.9-6.8	31.7-109	1.8-17.2
Synthetic	50	540	0.7-8.3	8.1-71.7	0.1-26.5
Synthetic	260	70	2.2-11	18.3-104.1	1.7-14
Synthetic	340	240	1.6-13.1	17.9-103.3	1.1-46.2
Date	260	240	3.7	34.2	2.3
Date	260	240	0.029-1.9	0.011-14.7	

2.4 Analytical procedures

All chemical tests were conducted according to AOAC (1995) and AOAC (2000) and triplicate values were expressed along with their standard mean error (M ± SME). The moisture content was measured gravimetrically by drying the sample in an oven at 103 °C until a constant weight was reached. Ash was then determined by burning in a muffle furnace at 500 °C for 4 h. Total nitrogen was determined by the Kjeldahl method (Kjeltec Auto 1030 Analyzer Manual, 1987) and proteins were calculated using the accepted conversion factor of 6.25 (CAC/GL 2-1985, Egan, Kirk, & Sawyer, 1993; Egan *et al*., 1981), assuming negligible amounts of ammonium. Fat was measured by extracting with light petroleum ether, and then removing the solvent by distillation. The residue was dried at 103 °C.

Total sugars and reducing sugars were determined according to Mahadevan and Sridhar (1986). Date pulp was soaked in alcohol and the total and reducing sugars were determined by spectrophotometry (model 6300 VIS, Gerber Instruments, Germany) at an absorbance wavelength of 490 nm and 575 nm, respectively. Non reducing sugars were determined by calculating the difference. Commercial grade glucose and fructose were used as reference standard (Rahman, *et al*, 2007).

2.5 Statistical analysis

In this experiment, the full factorial design was used with three replications. The ANOVA and LSD procedures were used to identify the significant parameters. To select the best values for any particular experiment in a full factorial design, sets of linear combinations giving the best estimators were considered. Statistical significance was set at ($p < 0.05$) and tested using the software SPSS (Predictive Analytics Company, Chicago, USA) for Windows software, Version 13.0.

Multivariate Proc GLM was performed to predict the effect on sugar concentration of the operational parameters (date sugar concentration, Feed and Eluent flow rates) including their interactions, using the statistical software package SPSS (Predictive Analytics Company, Chicago, USA) for Windows software. The predictive regression model was based on the following equation:

$$E[Y/\chi_1,\chi_2,\chi_3] = \beta_0 + \beta_1\chi_1 + \beta_2\chi_2 + \beta_3\chi_3 + \beta_{12}\chi_1\chi_2 + \beta_{13}\chi_1\chi_3 + \beta_{23}\chi_2\chi_3 + \beta_{123}\chi_1\chi_2\chi_3 \quad (1)$$

where Y is the outcome of interest, namely the glucose or fructose concentration; β_0 is the intercept; $\beta_1, \beta_2, \beta_3$ are the linear coefficients; $\beta_{12}, \beta_{13}, \beta_{23}, \beta_{123}$ are the interaction coefficients; χ_1 is the date syrup concentration in %; χ_2 is the Feed flow rate in pv/h and $\chi_3$is theEluent flow rate in pv/h. The simulated results were illustrated using the software *Table Curve 3D*, version 4.0 (SYSTAT Software Inc., Illinois, Chicago, USA).

3. Results and discussions

3.1 Date pulp and syrupcharacteristic

Data concerning the fruit pulp composition and principle characteristics are presented in Table 1. The date fruit pulp from the Menakher variety had a moisture content of 23%. The total sugars, proteins and fat contents were found to be 62, 1.7 and 1.0 %, respectively, indicating that besides moisture, dates are rich in sugars. Al-hooti, *et al*, (1995) analyzed the date fruit pulp from the Birhi and Safri varieties which had an even lower moisture content of 11.55 and 11.53 %, respectively. Accordingly, these varieties offered more sugar at 88.0 and 87.5 %. Their ash, protein and pectin contents were 2.08 and 2.16, 2.60 and 2.03, and 0.56 and 0.44%, respectively.

For the date pulp used in the present experiment, the sugars consisted mainly of fructose and glucose at 290 and 300 g/kg wet basis (Table 1). According to Al-Farsi, *et al*, (2005), fructose and glucose are the main sugars found in the three Omani date varieties: the Khalas variety offering 622 g/kg of fructose and glucose, followed by the Fard variety offering 567 g/kg and the Khasab variety offering 561g/kg, on a wet basis. According to Djerbi (1994) the proportion of fructose and glucose varies according to the date variety and the stage of maturation.

The sugar content of the experimental date syrup is presented in Table 2. The cooking of dates with an equal mass of distilled water produced date syrup with 75 % total solids, of which 24 % was fructose and 26 % was glucose on a wet basis. Clearly, most of the total solids were sugars because of their high concentration in the date pulp itself, as also found by Al Aid (2006).

3.2 Experimental SMB separation performance

A process for separation of fructose and glucose from an aqueous solution of date syrup was carried out by means of SMB technology. Based on the experimental design, 27 experimental runs were performed, where each run was repeated 3 times. Table 3 presents the average fructose and glucose concentration in the Extract and Raffinate, respectively for each experimental separation run. All values were expressed in pore volumes/hour (pv/h) to represent a dimensionless flow rate through the columns. In general, the Raffinate and Extract were rich in glucose and fructose, respectively, indicating that the polystyrene cation-exchange resin complex could effectively separate these fractions.

Run conditions were compared to maximize the glucose in the Raffinate and the fructose in the Extract (Table 3). The best result was obtained with run 19 using a Feed flow rate of 0.45pv/h and an Eluent flow rate of 3.2pv/h with a 22% date syrup sugar concentration. The purity of glucose and fructose, in their individual fractions for run 19, were 83.3 % and 90.9 %, respectively.

Despite the 87 % concentration of fructose in the Extract of run 10, which was almost as high as that of run 19, the Raffinate glucose concentration was only 68.7% compared to 83.3 % with run 10. Also, run 18 produced a Raffinate glucose concentration of 84.7%, but an Extract fructose concentration of only 79.3%, compared to 83.3 % with run 10.

In this experiment and as illustrated in Table 4, all experimental test parameters namely date syrup sugar concentration, Feed and Eluent flow rates, and their interactions, were found to significantly affect the Extract fructose and Raffinate glucose concentrations ($p < 0.01$). Therefore, the predictive software, SPSS, used all main test parameter effects and their interaction to simulate a wider range of SMB response.

Table 3: Average fructose and glucose concentrations in the extract and raffinate, respectively.

Date syrup %*	Flow rate (pv/h)		Sugar concentration			
	Feed	Eluent	Glucose - rich fraction		Fructose - rich fraction	
			Glucose g/L	Fructose g/L	Glucose g/L	Fructose g/L
37	0.45	3.2	69.0	31.0	26.5	73.5
37	0.45	8.5	81.3	18.7	22.5	77.5
37	0.45	14.7	72.5	27.5	17.4	82.6
37	1.0	3.2	62.4	37.6	32.9	67.1
37	1.0	8.5	79.6	20.4	24.2	75.8
37	1.0	14.7	52.6	47.4	41.9	58.1
37	1.9	3.2	54.1	45.9	16.3	83.7
37	1.9	8.5	78.0	22.0	27.5	72.5
37	1.9	14.7	73.5	26.5	18.5	81.4
37	0.029	0.011	95.5	4.5	53.0	47.0
22	**0.45**	**3.2**	**83.3**	**16.7**	**9.1**	**90.9**
22	0.45	8.5	72.8	27.2	21.3	78.7
22	0.45	14.7	62.5	37.5	34.2	65.8
22	1.0	3.2	76.9	23.1	24.4	75.6
22	1.0	8.5	73.5	26.5	18.7	81.3
22	1.0	14.7	69.0	31.0	35.5	64.5
22	1.9	3.2	69.4	30.6	34.5	65.5
22	1.9	8.5	75.2	24.8	37.5	62.5
22	1.9	14.7	72.7	27.3	29.4	70.6
22	**0.01**	**0.018**	**99.4**	**0.60**	**0.28**	**99.7**
26	0.45	3.2	68.7	31.3	13.0	87.0
26	0.45	8.5	74.7	25.3	29.6	70.4
26	0.45	14.7	71.9	28.1	43.2	56.8
26	1.0	3.2	71.4	28.6	39.8	60.2
26	1.0	8.5	81.3	18.7	35.9	64.1
26	1.0	14.7	78.7	21.3	45.4	54.6
26	1.9	3.2	68.2	31.8	34.6	65.4
26	1.9	8.5	56.5	43.5	27.7	72.3
26	1.9	14.7	84.7	15.3	20.6	79.3
26	**0.037**	**0.034**	**99.8**	**0.20**	**0.4**	**99.6**

Note: * % sugar concentration of the date syrup, with a fructose to glucose ratio of 24 to 26.
The Eluent volume was 3.2 pv.

Table 4: Statistical analysis for date syrup

Source	Type III Sum of Squares	df	Mean Square	F	Significance
Corrected Model	8899.737[a]	35		58.040	
Intercept	79821.685	1	254.278	18219.538	0.00
Date syrup	675.814	3	79821.685	51.419	0.00
Flow F	1252.087	2	225.271	142.896	0.00
Flow El	167.743	2	626.044	19.144	0.00
Date syrup * Flow F	706.565	6	83.871	26.879	0.00
Date syrup * Flow El	2527.188	6	117.761	96.879	0.00
Flow F * Flow El	604.532	4	421.198	96.140	0.00
Date syrup* Flow F * Flow El	2965.808	12	151.133	34.479	0.00
Error	315.439	72	247.151	56.413	0.00
Total	89036.861	108	4.381		
Corrected Total	9215.177	107			

a. R^2 =0.96 and Adjust R^2 =0.95

3.3 Simulating optimal SMB separation values

Figures 2, 3 and 4 illustrate the simulated separation efficiency for high (37%), medium (26%) and low (22%) date syrup sugar concentrations, respectively, as estimated from the experimental data.

For the date syrup with 37 % sugar (Figures 2a and b), the Raffinate glucose level and the Extract fructose level are illustrated as a function of various Eluent and Feed flow rates (pv/h). A low Feed flow rate of 0.50 pv/h and a high Eluent flow rate of 12.5 pv/h gave the highest glucose and fructose concentrations of 85 %. In this case, the same Feed and Eluent flow rate optimized the separation of both fructose and glucose.

For the date syrup with 26 % sugar concentration (Figures 3a and b), the Raffinate glucose concentration was optimized at 85 % with high Feed and Eluent flow rates of 2.0 pv/h and 12.5 pv/h, respectively. Under such operating conditions, the Extract fructose concentration of 82 % was not optimized. Rather, the optimal Feed and Eluent flow rates for an Extract fructose concentration of 90 % were 0.50 pv/h and 5 pv/h, respectively, while the Raffinate glucose concentration was mediocre at 67 %.

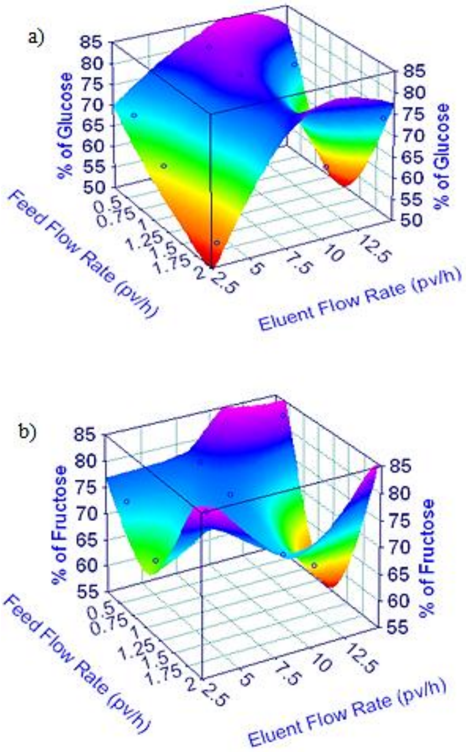

Fig. 2 Separation efficiency with a high date syrup concentration of 37%, as function of Feed (date syrup) and Eluent (distilled water) flow rate.

For the date syrup with 22 % sugar concentration (Figures 4a and b), both a Raffinate glucose and Extract fructose concentration of 85 and 95 % were reached, respectively, when the Feed and Eluent flow rates were 0.5 pv/h and 5 pv/h.

Accordingly, both date syrups with 37 and 22 % sugar required operating conditions simultaneously optimizing the separation of glucose and fructose, while the 26 % date syrup required different operating conditions. Nevertheless, the date syrup with 37 % sugar required a low and high Feed and Eluent flow rate, respectively, while the date syrup with 22 % sugar concentration required both a low Feed and Eluent flow rate. For the date syrup with 26 % sugar, the optimal separation efficiency in terms of Feed and Eluent flow rates changed for glucose and fructose. A HFS-90 was achieved only with the lowest date syrup sugar concentration of 22 %.

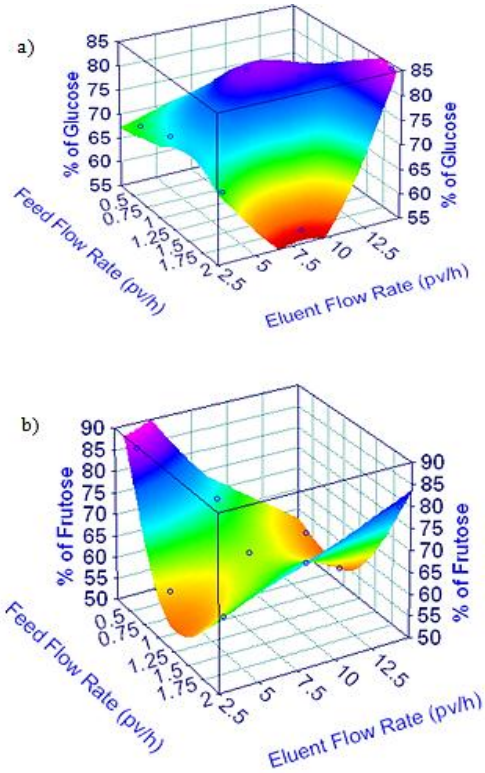

Fig. 3 Separation efficiency with a medium date syrup concentration of 26%, as function of Feed (date syrup) and Eluent (distilled water) flow rate.

These results suggest that the slower Feed flow rate increased the retention time distribution (RTD) in the column promoting the formation of a complex between the fructose and resin calcium ions. In addition, a reduced Eluent flow rate produced higher quality fructose syrup as a result of a longer contact time and absorption level by the column media. In the case of the more concentrated date syrup, a higher Eluent flow rate promoted more turbidity and improved the recovery efficiency of the fructose. The counter-current chromatography SMB technology is therefore a promising technology for the separation of fructose and glucose, as long as the right operational parameters are defined based on date syrup sugar concentration.

3.4 Operating conditions for industrial standard grades of High-Fructose-Syrup

From the results obtain, the SMB technology can be designed for the processing of date syrup at the industrial level. With a HFS-90, low glucose levels of less than 10% are tolerated (Borges da Silva, *et al*, 2006). Besides HFS-90, other standard commercial grades are marketed, namely, HFS-42, HFS-55 and HFS-90, containing respectively 42, 55 and 90 % fructose, with the remaining sugars being mainly glucose (Zhang, *et al*, 2004). The SMB technology can produce the sweeter HFS-90 grade from date syrup diluted to 22 % sugar, and a Feed and Eluent flow rate of 0.45 and 3.2 pv/h.

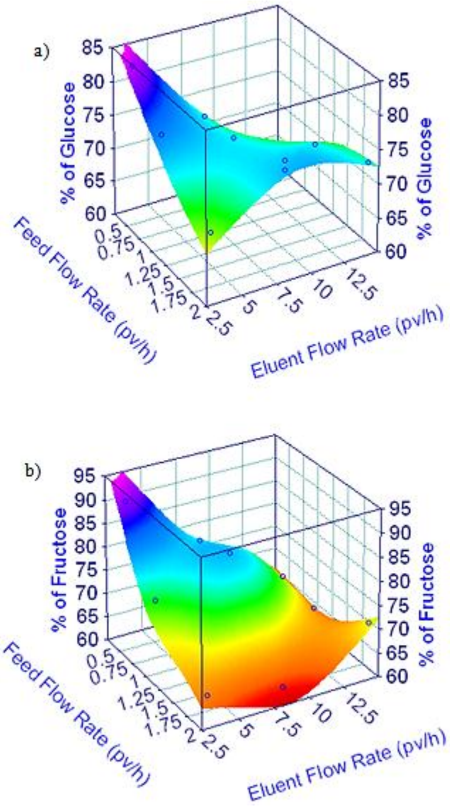

Fig. 4 Separation efficiency with a medium date syrup concentration of 22%, as function of Feed (date syrup) and Eluent (distilled water) flow rate.

A technico-economic study needs to be conducted to compare the feasibility of production high fructose syrup by either SMB or by enzymatic process. The enzymatic process converting glucose to fructose is the method presently used.

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Conclusions

The present project investigated the operating conditions (Feed and Eluent flow rates) required for the continuous separation of glucose and fructose from 36, 27 and 22 % sugar date syrup using the Continuous Chromatographic Simulated Moving Bed technology (SMB).

The results demonstrated that SMB is a technology which can effectively separate glucose from fructose when fed date syrup. To obtain the highest fructose concentration regardless of sugar content, the optimal separation conditions were found to be 0.45 and 3.2 pore volumes per hour (pv/h) for the Feed and Eluent flow rates, respectively. With the 22 % sugar date syrup, these operating conditions produced the valued High-Fructose-Syrup of 90 %.

The SMB technology is governed by many variables which are challenging to optimize. Therefore, it is a common practice to operate SMB units using conditions which are far from being economical, to deal with uncertainties in the system and to minimize the effect of disturbances (Abel, Erdem, Amanullah, Morari, Mazzotti & Morbidelli, 2005). Further work is proposed to use an on-line optimization control scheme allowing for the exploitation of the full economic potential of the SMB technology for the separation of fructose from glucose.

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