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สมดุลกรด-เบส

+++ pH (intracellular fluids) 6.8-7.8

pH $\text{HCO}_3^- - \text{H}_2\text{CO}_3$ () $\text{HPO}_4^{2-} - \text{H}_2\text{PO}_4^-$ ()

HA + $\text{HCO}_3^- \rightleftharpoons \text{A}^- + \text{H}_2\text{CO}_3$

B + $\text{H}_2\text{CO}_3 \rightleftharpoons \text{BH}^+ + \text{HCO}_3^-$

HA + $\text{HPO}_4^{2-} \rightleftharpoons \text{A}^- + \text{H}_2\text{PO}_4^-$

B + $\text{H}_2\text{PO}_4^- \rightleftharpoons \text{BH}^+ + \text{HPO}_4^{2-}$

70 H^+ 0.1 CO_2 15

2 pH

H^+

2

_____ (erythrocyte) 1 5

2×10^5

pH 7.4

H_2CO_3 HCO_3^-

$7.4 = 6.1 + \log \left(\frac{[\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} \right)$

pK_a 6.38 25°C

37°C $\text{pK}_a' = 6.1$

$[\text{HCO}_3^-]/[\text{H}_2\text{CO}_3] = 20$ CO_2 HCO_3^- $1.2 \times 10^{-3} \text{ M}$

0.024 M $0.024/1.2 \times 10^{-3}$ 20

HCO_3^- , OH^- ,

Cl^- K^+ Na^+

oxyhemoglobin

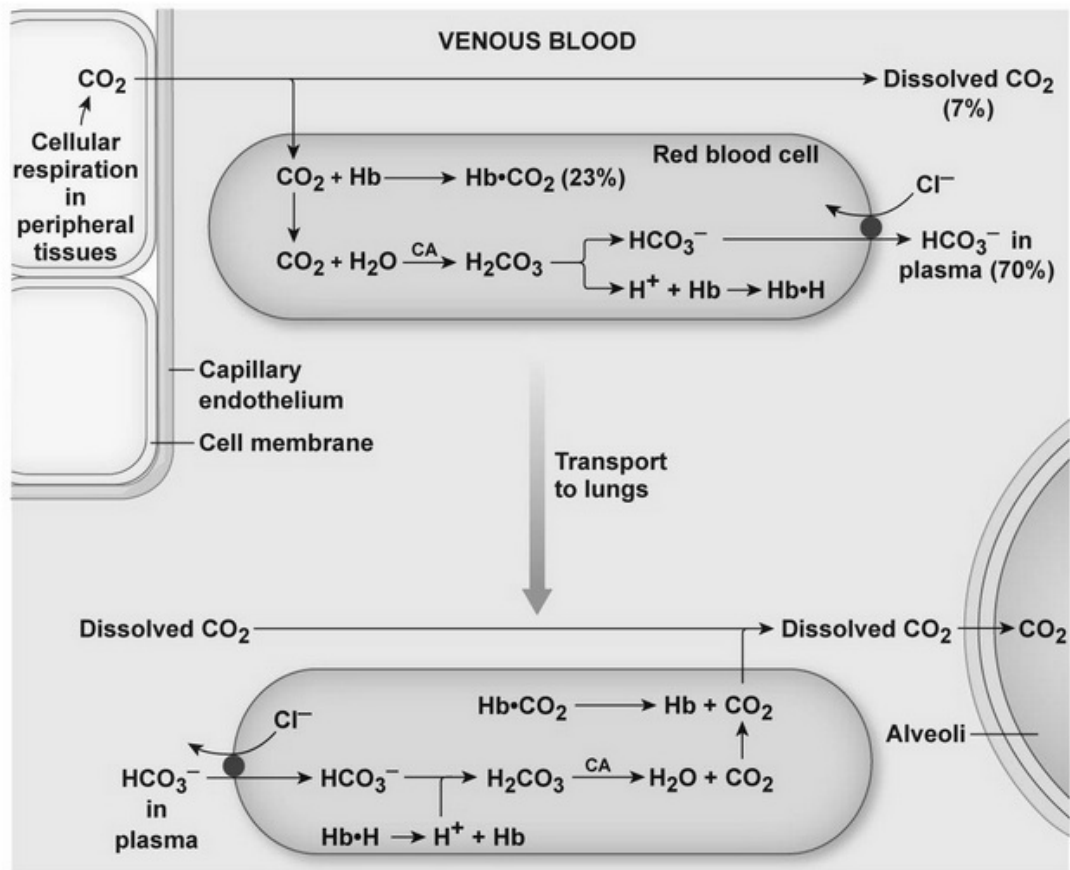
myoglobin

$\text{HHb} \rightleftharpoons \text{H}^+ + \text{Hb}^-$ $\text{pK}_a = 8.2$

$\text{HHbO}_2 \rightleftharpoons \text{H}^+ + \text{HbO}_2^-$ $\text{pK}_a = 6.95$

pH = 7.25 (pH) HHbO_2 65%

10% HHb



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_____ The pH of blood plasma is 7.40. Assuming the principal buffer system is HCO₃⁻/H₂CO₃, calculate the ratio [HCO₃⁻]/[H₂CO₃]. Is this buffer more effective against an added acid or an added base?

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เทอร์โมไดนามิกส์ของการขนส่งไอออนและอิเล็กตรอน

+++

+++

A

activity gradient

$$\Delta G_m = \Delta G_{m,in} - \Delta G_{m,out} = RT \ln a_{in}/a_{out}$$

$$a_{in} < a_{out}$$

z

$\Delta\phi$

$zF\Delta\phi$

F

$$F = 96.485 \text{ kC mol}^{-1}$$

$$\Delta G_m = RT \ln([A]_{in}/[A]_{out}) + zF\Delta\phi$$



298 K

K⁺

20

Na⁺

10

$$\Delta G_m = 0$$

$$\Delta\phi = -(RT/zF) \ln([A]_{in}/[A]_{out}) \quad z = +1 \quad K^+ \quad Na^+$$

$$[K^+]_{in}/[K^+]_{out} = 20$$

$$\Delta\phi = -\{(8.3145 \text{ J K}^{-1} \text{ mol}^{-1}) \times (298 \text{ K}) / 9.648 \times 10^4 \text{ C mol}^{-1}\} \ln 20 = -7.69 \times 10^{-2} \text{ V} = -76.9 \text{ mV}$$

$$1 \text{ V} = 1 \text{ J C}^{-1}$$

$$[Na^+]_{in}/[Na^+]_{out} = 0.10$$

$$\Delta\phi = -\{(8.3145 \text{ J K}^{-1} \text{ mol}^{-1}) \times (298 \text{ K}) / 9.648 \times 10^4 \text{ C mol}^{-1}\} \ln 0.10 = +5.91 \times 10^{-2} \text{ V} = +59.1 \text{ mV}$$



Na⁺

$$[Na^+]_{in}/[Na^+]_{out} = 0.1$$

$$\Delta\phi = +50 \text{ mV}$$



$$\Delta G_m < 0$$

passive transport

active transport

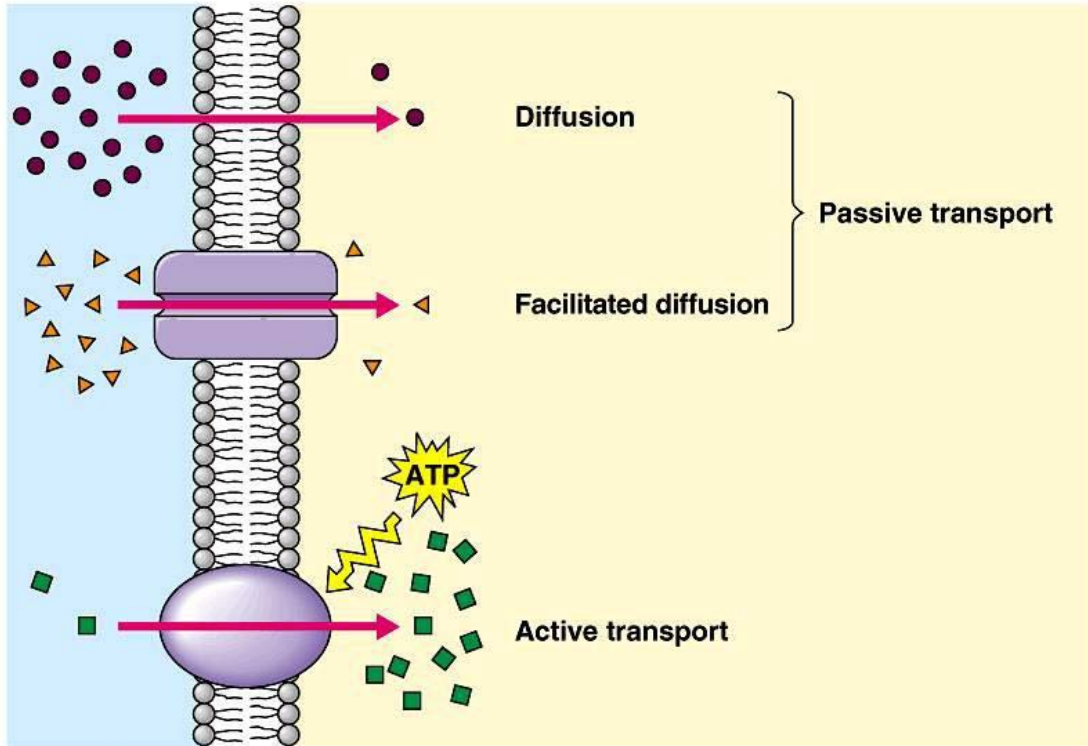
ATP

$$\Delta G_m = RT \ln([A]_{in}/[A]_{out}) + zF\Delta\phi + \Delta_r G^{ATP}$$

+++

+++

permeability barrier



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แบบฝึกหัด	K ⁺	Na ⁺							
50 mM				K ⁺	Na ⁺	20 mM	400 mM	440 mM	
									-70 mV
			1						37
			$\Delta G_m = RT \ln([A]_{higher}/[A]_{lower}) + zF\Delta\phi$						
	K ⁺								Na ⁺ = 12 kJ mol ⁻¹
									$\Delta G_m = 0.97 \text{ kJ mol}^{-1}$

Comparison of different methods for deacidification of clarified passion fruit juice

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Abstract

The high acidity of passion fruit limits its addition in food preparation. In order to ease the uses of this juice to formulate high aroma and flavour products, its citric acid content must be decreased. Various methods such as calcium salts precipitation, ion-exchange resins and electrodialysis with homopolar and bipolar membranes were investigated to increase the pH of a clarified passion fruit juice from 2.9 to 4.0. Each deacidification process was compared in terms of characteristics of deacidified juices such as concentration of inorganic and organic ions, colour and flavour. The deacidification by precipitation using CaCO_3 was not recommended because of CO_2 release. The ion-exchange process gave a poor quality juice in terms of organoleptic characteristics. Electrodialysis with homopolar membranes induced an increase in the sodium concentration. Precipitation with $\text{Ca}(\text{OH})_2$ and electrodialysis with bipolar membrane were the most suitable processes in terms of sensorial properties of juices treated. The physico-chemical analyses showed an increase in the calcium concentration with the use of $\text{Ca}(\text{OH})_2$ that could cause some precipitation problems in the final product. Inorganic anions were eliminated together with citrate by using electrodialysis and resins. Nevertheless, electrodialysis with bipolar membranes presented great advantages: it was a continuous process without reagent addition moreover allowing the production of a valuable solution of citric acid.

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Keywords: Passion fruit juice; Deacidification; Precipitation; Ion-exchange resin; Conventional electrodialysis; Bipolar electrodialysis

1. Introduction

Passiflora edulis v. flavicarpa or passion fruit is used for production of concentrated juice (Serna & Chacon, 1988). Export of this juice at 50 °Brix (500 g kg⁻¹ of total soluble solids) is a very important source of income in several South American countries such as Ecuador, Brazil, Peru and Colombia. In Ecuador, the principal exporter country (Loeillet, 1999), the passion fruit occupied in 2000 the second place in exports with 26 000 tons of concentrated juice (US\$ 28 million).

The juice quality could be improved by a reduction of its acidity that would facilitate its use in many food products (Adhikary, Harkare, Govindan, & Nanjundawamy, 1983; Bhatia, Dang, & Gaur, 1979; Couture &

Rouseff, 1992; Goloubev & Salem, 1989; Johnson & Chandler, 1985, 1986; Lue & Chiang, 1989; Scott, 1995).

In previous studies, ion-exchange (IE) and electrodialysis (ED) processes were investigated for deacidification of clarified passion fruit juice (Vera, Dornier, Ruales, Reynes, & Vaillant, 2003; Vera, Ruales, et al., 2003). Ten weakly basic resins were tested and their performances compared. The most suitable resins were Amberlite IRA95 and Duolite A378, because they gave the highest content of juice treated with the lowest content of soda required for regeneration. Concerning the electrodialysis process, different ED designs using homopolar or bipolar membranes were investigated. Among the three anion exchange membranes studied, the AXE01 membrane was selected for its deacidification rate, current efficiency and energy consumption. Moreover, its use was authorized in the food industry.

The aim of this paper is to compare both the above physico-chemical techniques with the conventional

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chemical method based on precipitation of calcium citrate, obtained by addition of calcium hydroxide or calcium carbonate to the clarified juice.

In order to avoid microorganism growth and spoilage, the increase in pH value was limited to 4.0 for all deacidified juices. Then, the physico-chemical and sensorial properties of juices treated were analysed and compared to those of fresh juice.

2. Materials and methods

2.1. Passion fruit juice

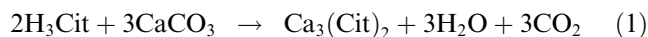
The fruits (*Passiflora edulis v. flavicarpa*) were obtained at Quevedo (Ecuador) and treated as previously described (Vera, Dornier, et al., 2003). After an enzymatic treatment, the juice was clarified to avoid fouling of the resins and ion-exchange membranes by using crossflow micro-filtration.

The characteristics of the clarified passion fruit juice after pretreatment are given in Table 1. Citrate and potassium ions were the most abundant anion (91%) and cation (94%), respectively.

2.2. Deacidification by precipitation of calcium citrate

The reagents, CaCO_3 and $\text{Ca}(\text{OH})_2$, were products of analytical degree from Sigma. The amounts required for

precipitation of calcium citrate were calculated from Eqs. (1) and (2). For 0.1 dm^3 of clarified juice, 3.61 and 3.15 g of CaCO_3 and $\text{Ca}(\text{OH})_2$ were necessary, respectively



The clarified juice was slowly added to the reagent (CaCO_3 or $\text{Ca}(\text{OH})_2$) until the pH reached 4.5. At this pH, the addition of juice was stopped because the calcium citrate is soluble at lower pH values. Then, the mixture was maintained for 24 h at 4°C , and the precipitated calcium citrate was separated by filtration with Whatman paper No. 40 (retention of $8 \mu\text{m}$).

Finally, the deacidified juice was mixed with clarified fresh juice in order to adjust the pH to 4.0.

2.3. Deacidification by ion-exchange resins

The operating conditions of deacidification by ion-exchange resins were described in a previous paper (Vera, Dornier, et al., 2003). A column 1.7 cm in diameter and 60 cm long, with a bed volume of 50 cm^3 was used. Among the most suitable resins tested, the macroporous weakly basic resin, Amberlite IRA95 from Rohm and Haas, was chosen to compare ion exchange with others processes. The resin matrix consisted of styrene divinylbenzene. The tertiary amine functional groups were equilibrated in the OH^- form before use.

2.4. Deacidification by electrodialysis

Electrodialysis experiments were performed using a laboratory cell of two stack designs:

- ED3C, the stack was equipped with homopolar membranes comprising three compartments, C1 and C2 being two distinct compartments in this case (Fig. 1),
- EDBM2C, the stack was equipped with homopolar and two bipolar membranes comprising two compartments (Fig. 2).

Each ED unit had the same compartment spacing of 0.8 cm and the same electrode surface of 20 cm^2 , corresponding to the effective area of each membrane.

The ion-exchange membranes were commercial ED membranes, Selemion CMV (Asahi Glass) as cation exchange membrane (CEM), Neosepta AXE01 (Tokuyama Co.) as anion exchange membrane (AEM), and Neosepta BP-1 (Tokuyama Co.) as bipolar membrane (BM).

The characteristics of solutions circulating in a batch mode in all compartments are given in Table 2.

Table 1

Characteristics of the clarified passion fruit juice

Density (kg m^{-3})	1050 ± 0.13^a
Viscosity (mPa s)	1.3
pH	2.93 ± 0.03^a
Colour	
<i>L</i>	30.8 ± 0.56^a
<i>a</i>	-1.4 ± 0.07^a
<i>b</i>	5.0 ± 0.25^a
Total soluble solids (g kg^{-1})	132 ± 1^b
Total sugars (g kg^{-1})	85.2 ± 2^b
Titration acidity	
(g citric acid per kg)	43.3 ± 1^a
(meq kg^{-1})	680 ± 20^a
Citric acid (g kg^{-1})	36.8 ± 1.3^a
Malic acid (g kg^{-1})	2.8 ± 0.1^a
Tartaric acid (g kg^{-1})	0.09 ± 0.08^a
Total minerals (g kg^{-1})	4.1 ± 0.2^a
Chloride (mg kg^{-1})	90 ± 15^a
Phosphate (mg kg^{-1})	455 ± 24^a
Sulphate (mg kg^{-1})	194 ± 21^a
Potassium (mg kg^{-1})	3206 ± 144^a
Calcium (mg kg^{-1})	50 ± 16^a
Magnesium (mg kg^{-1})	126 ± 11^a
Sodium (mg kg^{-1})	34 ± 5^a

Values expressed as $x \pm$ standard deviation.

^a Replications = 8.

^b Replications = 2.

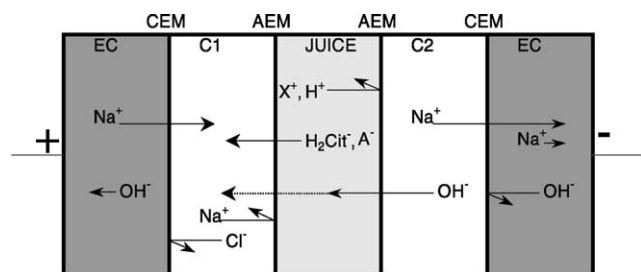


Fig. 1. Configuration of the ED3C cell. C1 and C2 are separated compartments, the two EC are connected (AEM and CEM: anion- and cation-exchange membrane, respectively).

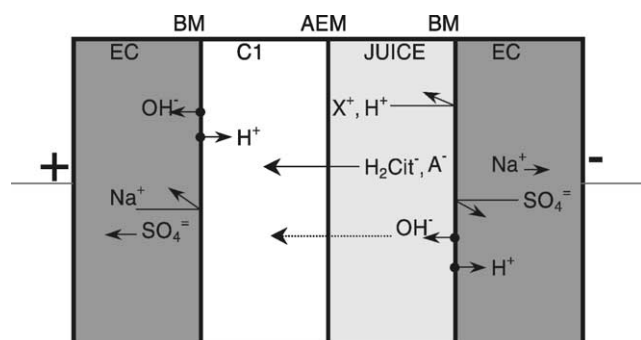


Fig. 2. Configuration of the EDBM2C cell. The two EC compartments are connected (AEM and BM: anion-exchange and bipolar membrane, respectively).

ED operations were carried out at constant current density of 400 A m^{-2} . Voltage, conductivity and pH were monitored during all the experiments. ED operations were continued until pH 4.0 was reached in the juice.

2.5. Analytical procedures

Amount of total soluble solids was determined by refractometry with an Atago hand refractometer. Colour was measured with a Minolta CR-A70 colorimeter in the L , a , b space. Colour variation was calculated according to Eq. (3) using the non-treated sample as a reference solution

$$\Delta E = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{1/2} \quad (3)$$

Table 2
Solutions and flow rates in the different compartments of the electro dialysis cells

	Juice compartment	C1 compartment	C2 compartment	Electrode compartment
ED3C	Clarified juice 0.5 dm^3 $3.6 \text{ dm}^3 \text{ h}^{-1}$	0.1 N NaCl 2.5 dm^3 $3.6 \text{ dm}^3 \text{ h}^{-1}$	0.2 N NaOH 2.5 dm^3 $3.6 \text{ dm}^3 \text{ h}^{-1}$	0.1 N NaOH 1 dm^3 $10.2 \text{ dm}^3 \text{ h}^{-1}$
EDBM2C	Clarified juice 0.5 dm^3 $3.6 \text{ dm}^3 \text{ h}^{-1}$	$0.5 \text{ N H}_3\text{Cit}$ 2.5 dm^3 $3.6 \text{ dm}^3 \text{ h}^{-1}$	–	$0.2 \text{ N Na}_2\text{SO}_4$ 1 dm^3 $10.2 \text{ dm}^3 \text{ h}^{-1}$

Acidity was assayed by titration with 0.1 N NaOH and expressed as grams of citric acid or meq per kg of juice. The cation and anion concentrations were measured by ICP and HPLC, respectively.

Sensory analyses were done by a panel of 15 semi-trained members in a cabin under green light. Triangular tests that are the most widely used of all the different tests (Jellinek, 1985) were carried out to compare the aroma of the fresh juice with the deacidified juices. To avoid perturbations in the aroma perception, the pH of deacidified juices was adjusted back to its initial value with citric acid. Then, all the samples were prepared with 18% w/w juice and 2% w/w sucrose, before testing.

Ranking tests in order of degree of preference were directly done with the deacidified juices. The 19 panelists received five random sorted samples of deacidified juice treated by five different methods, and they were asked to order the samples by their degree of preference. Then, samples were ranked from 1 to 5, with 1 as the least liked sample and 5 as the most liked sample. Final rank was calculated as the addition of the rank given for each sample by the 19 panelists.

3. Results and discussion

The juice acidity was mainly due to the presence of citric acid (H_3Cit) which has three acid functions: $\text{p}K_1 = 3.1$, $\text{p}K_2 = 4.7$, $\text{p}K_3 = 6.4$ (Merck Index, 1983). The value of the initial pH (2.93 ± 0.03) was close to the $\text{p}K_1$ of citric acid. Therefore, in the fresh juice, H_3Cit and H_2Cit^- were the major species of citric acid, each one being close to 50%.

The performances of each deacidification process were compared in terms of characteristics of deacidified juices such as concentration of inorganic and organic ions, colour and flavour.

3.1. Deacidification by precipitation of calcium citrate

This method increased successfully the pH of the juice. However, a major problem is the juice loss in the precipitate which contained a moisture content of 70% and 76% by using CaCO_3 and Ca(OH)_2 , respectively.

That induced a juice loss of 19% and 27% with CaCO_3 and Ca(OH)_2 , respectively.

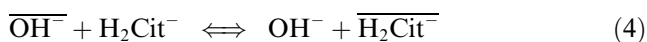
The use of CaCO_3 induced a release of CO_2 making foam which hindered the mixture of CaCO_3 and juice. This explains the lower content of precipitate obtained with the latter reagent, 23% compared to 32% obtained with Ca(OH)_2 .

Moreover, precipitation of calcium citrate requires an accurate control of pH which must be maintained at values higher than 4.5 during the experiment, the adjustment of pH to 4.0 being made by addition of fresh juice. Consequently, stability and re-precipitation problems could occur in the final product.

3.2. Deacidification by ion-exchange resins

Deacidification by ion-exchange resins was previously studied (Vera, Dornier, et al., 2003). All the resins tested gave similar results in terms of physico-chemical properties and sensorial analysis of deacidified juice. To select the best resin, the production of deacidified juice has been related to the soda consumption used for regeneration. Taking into account these considerations, the most efficient resins were the Amberlite IRA95 and Duolite A378. The results obtained with the Amberlite IRA95 resin were used in the present paper to compare the performances of ion exchange with other processes.

The resin used was in OH^- form and the ion-exchange equilibrium was described by the following equation:



Consequently, the pH at the column outlet was initially higher than 6 and decreased with the volume of juice treated. The experiment was stopped when pH 4.0 was reached.

3.3. Deacidification by electrodialysis

The principle of the two electrodialysis configurations used is the extraction of citrate anions from the juice and their replacement by hydroxyl ions provided either by the NaOH solution in the C2 compartment (ED3C, Fig. 1) or by the bipolar membrane sandwiched between the juice and electrode compartments (EDBM2C, Fig. 2). In the latter configuration, citric acid was formed in the C1 compartment by citrate ions extracted from the juice and protons provided by the second

bipolar membrane separating the C1 and electrode compartments.

The ED3C configuration led to NaOH consumption in the C2 compartment, while the EDBM2C configuration avoided the reagent consumption.

In the two cases, the cations in the juice were not eliminated because the juice circulated between two anion exchange membranes. On the other hand, all organic and inorganic anions were partially extracted.

The performances of the two ED operations are compared in Table 3. The EDBM2C configuration leads to a higher energy consumption required by the water splitting in the bipolar membranes. Note that these values of energy consumption only aim to make comparison for two laboratory scale cells. But we can suppose that this classification will be confirmed in industrial trials.

3.4. Comparison of the properties of juices deacidified by various methods

Physico-chemical and sensorial analyses were performed on the juices deacidified by the various methods investigated and compared to those of fresh juice.

3.4.1. Physico-chemical properties of deacidified juices

Table 4 shows that titrable acidity and total soluble solids varied up to 30% according to the deacidification method applied. Resin treatment induced the greatest change in total soluble solids and colour.

Fig. 3 shows the variation in anion concentration. In all the deacidified juices, a decrease in the citrate and malate concentrations was obtained. The precipitation of calcium citrate is the most selective technique where citrate ions were preferentially eliminated, the chloride, sulphate and phosphate concentration remaining unchanged. Nevertheless, the use of CaCO_3 induced a lower elimination of citrate and malate ions, 40% and 12.5%, respectively, than with Ca(OH)_2 where it attained 65% and 32%, respectively. This result is in agreement with the lower content of precipitate obtained with CaCO_3 than with Ca(OH)_2 , as previously noticed.

The gap between the extraction ratios of organic anions was lower with the other methods, about 65% and 53% for citrate and malate, respectively. Moreover, the inorganic anions were partially extracted together with organic ions when using resin and electrodialysis.

Table 3
Comparison of performances of the two electrodialysis configurations tested

	Time to obtain pH 4.0 in the juice (min)	Current efficiency for citric acid (%)	Deacidification rate ($\text{eq h}^{-1} \text{m}^{-2}$)	Energy consumption (kWh dm^{-3} of juice)
ED3C	496	33	4.9	0.38
EDBM2C	549	31	4.6	0.50

Table 4
Physico-chemical analysis of the juices deacidified by different methods

Deacidification method	pH	Titrable acidity ^a		Total soluble solids ^b (g kg ⁻¹)	Colour ^c			
		(g citric acid per kg)	(meq kg ⁻¹)		<i>L</i>	<i>a</i>	<i>b</i>	ΔE
CaCO ₃	4.0	13.5 ^d	210 ^d	130 ^d	30.90 ^d	-1.50 ^d	5.14 ^d	0.2
Ca(OH) ₂	4.0	10.4 ^e	160 ^e	112 ^e	31.00 ^d	-1.46 ^{de}	4.94 ^d	0.2
IRA95	4.0	10.8 ^e	170 ^e	100 ^f	31.66 ^d	-1.49 ^d	4.09 ^e	1.5
ED3C	4.0	12.3 ^f	190 ^f	111 ^e	30.33 ^d	-1.26 ^f	4.62 ^{de}	0.5
EDBM2C	4.0	12.0 ^f	190 ^f	111 ^e	31.26 ^d	-1.30 ^{ef}	4.94 ^d	0.4

Maximum error on the measure: ^a2%, ^b1%, ^c5%.

^{d,e,f}Homogeneous groups determined by one-way ANOVA analysis with 95% of confidence.

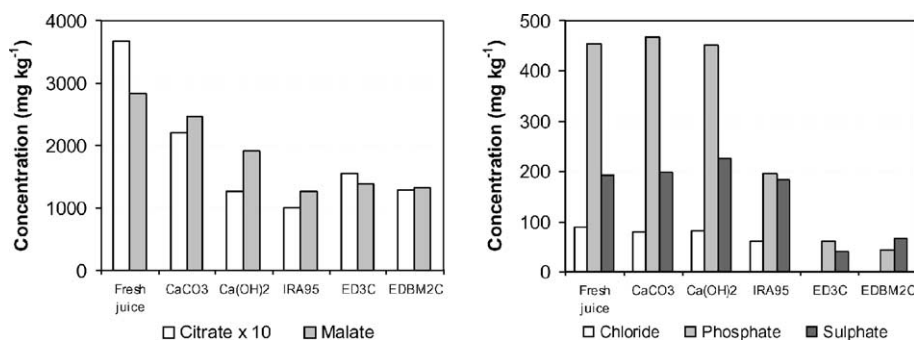


Fig. 3. Anions concentrations variation.

In the latter method, the elimination of anions is related to their mobility both in the solutions and membrane, and consequently the extraction of inorganic anions is easier than that of organic anions. Almost all the chloride ions were eliminated and about 90% and 70% of phosphate and sulphate ions were extracted, respectively.

Fig. 4 shows the variation in cation concentration. The potassium and magnesium concentrations were not affected whatever the methods used, while the calcium and sodium concentrations were significantly increased by using the precipitation method and electro dialysis with three compartments, respectively.

The calcium amount in the juice reached 48% and 25% of cations after using CaCO₃ and Ca(OH)₂, respectively, compared to 1% in the untreated juice. This

increase was due to an incomplete precipitation of added calcium ions.

The sodium concentration was increased from 1% to 9% by ED3C treatment because of NaOH and NaCl dialysis arising from adjacent compartments. Indeed, it is well known that a concentration gradient between ion-exchange membranes induces a dialysis phenomenon.

There was no change in the cation concentration by using resins and electro dialysis with bipolar membranes.

To conclude, the method based on precipitation of calcium citrate leads to a selective decrease in the citrate concentration and an increase in the calcium one, the use of Ca(OH)₂ giving better performances than CaCO₃. Ion exchange with resins and electro dialysis induce an extraction of inorganic anions together with organic

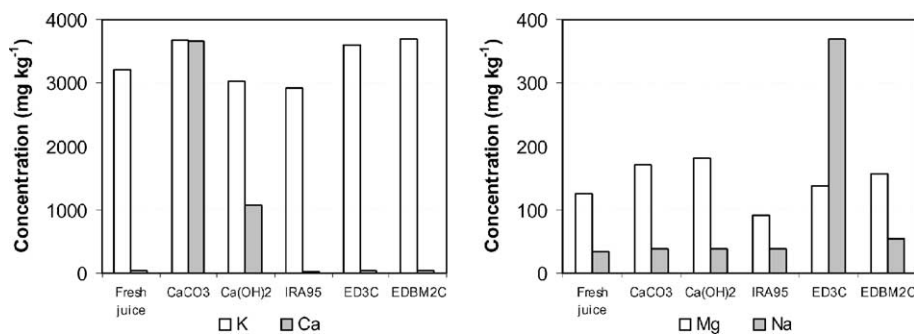


Fig. 4. Cations concentrations variation.

Table 5
Results of triangular test between treated juices and fresh juice

	CaCO ₃	Ca(OH) ₂	IRA95	ED3C	EDMB2C
Number of tests ^a	12	15	11	14	12
Number of good answers	3/12	7/15	4/11	8/14	6/12
Minimum number of good answers required to find a difference between the samples compared	8/12	9/15	7/11	9/14	8/12

^a Replications = 1.

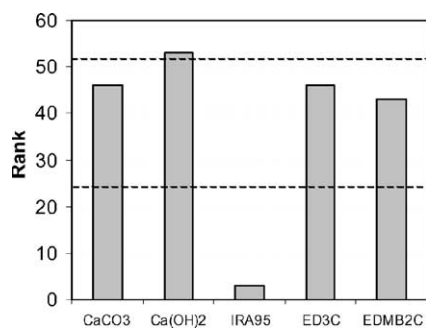


Fig. 5. Degree of preference with passion juices deacidified by different methods ($\alpha \leq 0.05$).

ones, without change in the cation concentration, except for electro dialysis with homopolar membranes where the sodium concentration is significantly increased.

3.4.2. Sensory properties of deacidified juices

The triangular tests did not highlight significant differences between the deacidified juices and the fresh juice (Table 5).

To classify the deacidified juices, a ranking test in order of degree of preference was done by directly tasting the deacidified juices. The results of rank sums required for significance at the 5% level ($\alpha \leq 0.05$) were depicted by Fig. 5. The rank position of samples within the range delimited by dashed lines is not significant (Jellinek, 1985). Nevertheless, one can conclude that the juice treated by ion-exchange resin was highly significant as the sample liked least, the precipitation method with calcium hydroxide giving the most liked sample by a narrow margin.

4. Conclusion

All the methods tested allowed the deacidification of the clarified passion fruit juice in which pH was increased from 2.9 to 4.0. Nevertheless these methods have some different advantages and disadvantages.

The deacidification by precipitation using CaCO₃ is not recommended, because problems induced by the liberation of CO₂, foam making and poor pH control, occurred during the precipitation phase. The use of Ca(OH)₂ is easier and gives a good quality product.

Besides, citric acid could be recovered as a by-product by dissolving the precipitated calcium citrate in sulphuric acid, and converting the calcium citrate into calcium sulphate and citric acid (Milsom & Meers, 1985). However, the application of the precipitation method has two limitations: the legislation of some countries and the fact that consumers prefer natural products, without chemical addition. It is also necessary to take into account that this method induces an increase in the calcium concentration and could cause some precipitation problems in the final product.

The ion-exchange process does not seem to be a good option, because of changes in the organoleptic characteristics of juice treated and the large amounts of effluent produced during the regeneration phase of resins.

The deacidification by electro dialysis has some advantages over the above methods, especially electro dialysis with bipolar membrane which is a continuous process without added reagents, giving a high quality juice in terms of physico-chemical and sensorial analyses. It was observed that there was (i) no change in the cation concentration, (ii) slight colour variation and (iii) good flavour. Only organic and inorganic anions were partially eliminated. Nevertheless, electro dialysis is more expensive than the other techniques but the citric acid simultaneously produced during the deacidification could improve the cost of this technique. Therefore, ED on BM could be a promising alternative to the conventional calcium precipitation process for the deacidification of the passion fruit juice. Further studies are necessary under conditions similar to the industrial ones which are more favourable than those carried out in a laboratory cell.

Acknowledgements

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