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STUDIES ON THE CONCENTRATION OF APPLE

JUICE BY REVERSE OSMOSIS

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ABSTRACT

The Reverse Osmosis (RO) process and its food industry applications were reviewed. Because most of the work published in the literature on the concentration of fruit juices by RO was empirical, it was decided to select one fruit juice (apple juice) and study the retention of certain components (namely sugars and acids) when that juice was concentrated by RO.

A method was developed for the analysis of sugars and non-volatile organic acids in apple juice. In this method, acids were precipitated as their lead salts from fruit ethanolic extracts, and the sugars in the remaining supernatant and washings were participated into aqueous methanol. These preparations with internal standards were then dried and converted to their trimethylsilyl derivatives for analysis by gas-liquid chromatography. The method provided a rapid and simple procedure for the concurrent separation, identification and quantitative analysis of sugars and non-volatile acids in apple juice.

A pilot-plant scale Abcor TM5-14 RO module was used in this study so that the results obtained could be applied to industrial processing. Preliminary experiments were conducted with dilute salt solutions to ensure that the membrane performed satisfactorily, and to monitor any changes in the operating characteristics of the membrane as the experimental work progressed. These data provide the common means for comparing different RO systems. The results obtained established that the membrane performed satisfactorily, and that the membrane characteristics (Permeate flux and % Rejection) responded as expected to changes in the operating parameters of pressure, temperature, flow rate, concentration and operating time. The membrane characteristics did not alter significantly over the time during which the experiments reported here were carried out.

A current theory (the Kimura-Sourirajan analysis) was used in an attempt to predict the membrane performance of the RO module when the system sodium chloride-water was used as test solution. The Kimura-Sourirajan analysis had previously led to the development of a set of basic transport equations which, together with the correlations of the RO experimental data, enabled the prediction of membrane performance from a minimum of experimental data. The application of this analysis to the RO system under study did not establish any significant correlations between the solute transport parameter (D_{AM}/KS), and feed concentration and operating pressure; neither were the average mass-transfer coefficient values (k) significantly correlated with feed flow rate. Experimental results obtained suggested a more complex relationship between these parameters, and the narrow range of feed flow rates under which the RO system was able to be operated meant that the Kimura-Sourirajan analysis could not be used to meaningfully predict the performance of the membrane.

A further attempt was made to predict membrane performance from a knowledge of the Taft numbers of the sugars and acids present in the juice. Experiments carried out on model solutions of sugars and acids present as single components or as complex mixtures confirmed the Taft number as a criterion for predicting the organic rejection of the RO membrane. It was also established that molecular weight was indicative of solute rejection, higher molecular weights gave higher rejection by the membrane. Results obtained further confirmed the fact that the mechanism of solute rejections by RO cellulose acetate membranes involved both preferential absorption and capillary flow of solutes through the membranes.

Finally, actual apple juice was concentrated by RO and the results obtained on permeate flux and solute rejection confirmed those found previously with model solutions of sugars and acids. It was established that apple juice (initial concentration 11°Brix) could be concentrated to 35°Brix at 7C

and 99 atm pressure without any significant loss of sugars and organic acids. Experiments were also carried out to assess the advantage of operating at a higher temperature (20 C), since any increase in flux would be desirable from a commercial point of view. The end-to-end flux of the TM5-14 module was found to be $16.4 \text{ l/m}^2\text{hr}$ at 20 C compared to $11.7 \text{ l/m}^2\text{hr}$ at 7 C when single strength apple juice was concentrated to 35°Brix under maximum pressure (99 atm), an increase in flux of 40%.

The pilot plant data thus obtained for the RO module were applied to a study of the feasibility of using RO as a pre-concentration step prior to evaporation. An RO plant comprising of 296 modules (membrane area 308 m^2) with a permeate flux of $20.7 \text{ l/m}^2\text{hr}$ was found to be feasible for concentrating the juice from 11°Brix to 20°Brix in 7.5 hours.

The economy of such a process was also assessed, and compared with that obtained by using a triple effect APV plate evaporator.

A comparison of the concentration costs (\$ /tonne of water removed) of the two systems revealed that RO was more than twice as expensive than evaporation (\$122 compared to \$51) for 900 operational hours per year, thus confirming results from the published literature, which also suggested that the cost of RO was competitive with plate evaporation when operated year round (6,300 hours/year). The results found in this study indicated that the annual operating costs for RO (\$142,200) were almost twice as high as the equivalent for plate evaporation (\$71,500). As well, the capital investment for RO was substantially higher than that for the equivalent plate evaporator (\$700,000 compared to \$282,300), thus making RO very unattractive for short seasonal operation.

Thus it is concluded that the use of RO as a preconcentration technique in apple juice processing will never be realised unless capital costs are reduced considerably and operating hours are

increased substantially. On the basis of this study, it is not financially economical for the Apple and Pear Board in Hastings to consider RO for the preconcentration of apple juice when the capacity of their present evaporator is no longer adequate.

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"Đường không khó vì ngăn sông cách núi, mà khó vì lòng người ngại núi e sông"

Tặng Ba tôi và người Mẹ quá cố

Dan Le Van
September, 1978

TABLE OF CONTENTS

	<u>Page</u>
ACKNOWLEDGEMENTS	vi.
LIST OF FIGURES	ix.
LIST OF TABLES	xi.
CHAPTER 1 "A review of Reverse Osmosis and its food industry applications"	1
1. Introduction	2
2. Osmosis and Reverse Osmosis	2
3. Membranes	4
4. Advantages of Reverse Osmosis	5
5. Review of food industry application	6
6. Review of fruit juice concentration by Reverse Osmosis	9
7. Conclusion	29
CHAPTER 2 "The development of a method for analysing sugars and non-volatile organic acids in New Zealand Granny Smith Apples"	21
<u>Section I</u> "A review of the possible methods"	22
1. Introduction	22
2. Possible methods	22
<u>Section II</u> "Analysis of sugars and non-volatile organic acids in Granny Smith apples by gas-liquid chromatography"	24
1. Introduction	24
2. Experimental materials and methods	25
3. Results and discussion	30
CHAPTER 3 "Membrane characteristics and prediction of membrane performance"	49
<u>Section I</u> "Membrane characteristics"	50
1. Mechanism of Reverse Osmosis	50
2. Concentration polarisation	51
3. Description and operation of the TM5-14 module	51
4. Experiments with dilute salt solutions	55
5. Results	58
6. Discussion	65
7. Conclusion	66

	<u>Page</u>
<u>Section II</u> "Prediction of membrane performance using the Kimura-Sourirajan analysis"	68
1. Introduction	68
2. Experimental procedure	68
3. Results	81
4. Discussion	91
5. Conclusion	93
<u>Section III</u> "Use of Taft numbers to predict membrane performance"	94
1. Introduction	94
2. Experimental	102
3. Results	106
4. Discussion	109
5. Conclusion	111
CHAPTER 4 "Reverse Osmosis of apple juice"	112
1. Introduction	113
2. Experimental	113
3. Results	115
4. Discussion	121
5. Conclusion	122
CHAPTER 5 "Economic evaluation of Reverse Osmosis"	123
1. Introduction	124
2. Current evaporation system	124
3. Proposed Reverse Osmosis system	125
4. Size of RO plant required	128
5. Design of module configuration	132
6. Costing of feasible module configuration	135
7. Cost of equivalent evaporator	137
8. Discussion	139
APPENDIX I Sample calculation of 'A'	143
APPENDIX II Data for the system (NaCl-H ₂ O) at 25 C	144
APPENDIX III Sample calculation of ($D_{AM}/K\delta$)	145
APPENDIX IV Sample calculation of 'k'	147
BIBLIOGRAPHY	148

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1	Osmosis	3
2	Reverse Osmosis	33
3	Lactose production	8
4	Glc separation of TMS ethers of GS apple sugars on SE-52 column	32
5	Glc pattern of organic acids in GS apples	33
6	Glc pattern of organic acids in GS apples	34
7	Calibration curves of sugar standards	38
8	Calibration curves of acid standards	39
9	Glc pattern of sugar standards	41
10	Glc pattern of TMS derivatives of acid standards	42
11	Flow diagram for the Reverse Osmosis pilot plant	52
12	Effect of operating pressure on membrane performance	60
13	Effect of concentration on membrane performance	61
14	Effect of recirculation rate on membrane performance	62
15	Effect of operating time on membrane performance	63
16	Effect of temperature on membrane performance	64
17	Reverse osmosis process under steady state conditions	69
18	Effect of operating pressure on the pure water permeability constant A	88
19	Effect of feed concentrations on the solute transport parameter	89
20	Effect of feed flow rate and feed concentration on the average mass transfer coefficient for the system sodium chloride-water	90

<u>Figure</u>		<u>Page</u>
21	Permeate flux versus concentration at $P = 99$ atm	119
22	End-to-end flux versus $^{\circ}$ Brix for single strength apple juice at $P = 99$ atm	120
23	Flow rate versus pressure drop for TM5-14 and TM5-20 tubular RO modules	127
24	Number of modules required as a function of final juice concentration and hours of operation.	131
25	Flow path through feasible RO module configuration design.	134
26	Dewatering costs for plate evaporator and reverse osmosis at 1,800 operational hours per year	141
27	Dewatering costs for plate evaporator and reverse osmosis at 6,300 operational hours per year.	141

LIST OF TABLES

<u>Table</u>		<u>Page</u>
I	Characteristics of hyperfiltration and ultrafiltration	4
II	Some advantages of Reverse Osmosis over traditional methods in food processing	6
III	Typical osmotic pressures for different foods	11
IV	Relative retention time of TMS derivatives of sugars on SE-52	35
V	Relation retention time of TMS derivatives of non-volatile organic acids on SE-52	35
VI	K factors for crystalline sugars and acids as their TMS derivatives	37
VII	Recovery of sugars by direct injection from various amounts input	40
VIII	Recovery of acids by direct injection	43
IX	Individual recovery by analytical procedure from 4 synthetic mixtures at a $W_1:W_s = 1.0$	44
X	Total sugar recovery by analytical procedure from mixtures A,B,C and D at a $W_1:W_s = 1.0$	44
XI	Recovery analysis of mixtures of acids at a $W_1:W_s = 1.0$ by lead salt method	45
XII	Quantitative determination of sugars in Granny Smith apples by glc	48
XIII	Quantitative determination of organic acids in Granny Smith apples	48
XIV	Characteristics of the TM5-14 module	55
XV	Typical performance of the AS-197 membrane	55
XVI	Material balance for the RO module run with fresh water. $T = 25\text{ }^{\circ}\text{C}$	58
XVII	Effect of operating pressure on membrane performance - $RR = 5\text{ l/min}$; $T = 25\text{ }^{\circ}\text{C}$	58

<u>Table</u>		<u>Page</u>
XVIII	Effect of concentration on membrane performance - RR = 8 l/min; P = 75 atm; T = 25 C	58
XIX	Effect of recirculation rate on membrane performance - P = 60 atm; T = 25 C	59
XX	Effect of operating time on membrane performance - RR = 5 l/min; C = 0.5% NaCl; P = 77 atm and T = 25 C	59
XXI	Effect of feed temperature on membrane performance - R = 5 l/min; P = 77 atm; T = 25 C	59
XXII	Effect of pressure on the pure water permeability constant A	81
XXIII	Effect of changing feed flow rates and feed concentrations on permeate flow and permeate concentration - P = 54.4 atm	83
XXIV	Effect of changing feed flow rates and feed concentrations on permeate flow and permeate concentration - P = 92.5 atm	84
XXV	Effect of feed concentration on the solute transport parameter - P = 54.4 atm	85
XXVI	Effect of feed concentration on (D_{AM}/K) P = 92.5 atm	85
XXVII	Effect of feed concentration on the mass transfer coefficient k - P = 54.4 atm	86
XXVIII	Effect of feed concentration on the mass transfer coefficient k - P = 92.5 atm	87
XXIX	Relative retention time and K factors of TMS derivatives of sugars and acids (food grade) on SE-52 column	106
XXX	Reverse osmosis of glucose, FR = 5 l/min; P = 77 atm	106
XXXI	Reverse osmosis of fructose, FR = 5 l/min; P = 77 atm	107
XXXII	Reverse osmosis of sucrose, FR = 5 l/min; P = 77 atm	107
XXXIII	Reverse osmosis of mixture of sugars, FR = 5 l/min; P = 77 atm	107

<u>Table</u>		<u>Page</u>
XXXIV	Reverse osmosis of malic acid, FR = 5 l/min; P = 77 atm	108
XXXV	Reverse osmosis of citric acid, FR = 5 l/min; P = 77 atm	108
XXXVI	Reverse osmosis of mixture of acids, FR = 5 l/min; P = 77 atm	109
XXXVII	Reverse osmosis of mixture of sugars and acids, FR = 5 l/min; P = 77 atm	109
XXXVIII	Characteristics of the apple juice studied	115
XXXIX	Permeate flow and rejection characteristics of single strength apple juice	115
XL	Permeate flow and rejection characteristics of diluted apple juice concentrate	116
XLI	Sugars and acids of permeate and concentrate obtained from concentrating single strength apple juice	116
XLII	Sugars and acids of permeate and concentrate obtained from concentrating diluted apple juice concentrate	117
XLIII	Concentration of single strength apple juice; P = 99 atm	117
XLIV	Concentration of dilute apple juice concentrate; P = 99 atm	118
XLV	Effect of cooling temperature on concentration of single strength apple juice; P = 99 atm	118
XLVI	Material balances for preconcentration by RO from 11°Brix to various concentrations in 7.5 hours	130
XLVII	Cost estimates for the RO concentration of 136,000 l of apple juice from 11°Brix to 20°Brix in 7.5 hours	136
XLVIII	Cost estimates for the evaporating concentration of 68,000 l of apple juice from 11°Brix to 72° Brix in 7.5 hours.	138