STUDIES ON THE CONCENTRATION OF APPLE JUICE BY REVERSE OSMOSIS

A thesis presented in partial fulfilment
of the requirements for the degree
of Master of Technology in
Food Technology at
Massey University.

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1978

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 snalysis 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 ($D_{AM}/K\delta$), 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^{o}Brix) could be concentrated to 35^{o}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 l/m^2hr at 20 C compared to 11.7 l/m^2hr 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 l/m^2hr 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.

ACKNOWLEDGEMENTS

I wish to thank the following people:

My supervisor, Mr. G.L. Robertson, for his valuable assistance and encouragement throughout the course of this study, and without whose help this thesis would never have been completed.

Mr. M. Gyde of the Apple and Pear Board Ltd., Hastings, for providing the apple juice used in this study.

Dr. G.M. Wallace, Mr. M.J. Reeves, Dr. I.W. Boag, Mr. B. Imison and Mr. F.B. Walter, for helpful discussions on some aspects of the work.

Messrs. T.M. Gracie, G. Burton and Miss S. Quin, for technical assistance.

Khanh, Long and Sharon for their encouragement.

Mrs. M.M. Garden and Mrs. M. Booker for typing this thesis.

This study was supported by a Brooker Research Award, a Faculty grant, and a Colombo Plan Award. The reverse osmosis module was purchased in part from a University Grants Committee grant-in-aid awarded to Mr. G.L. Robertson.

"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

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