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CONCENTRATION OF PINEAPPLE JUICE BY

REVERSE OSMOSIS

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SUMMARY

Pineapple juice was concentrated from 130 g/kg to 250 g/kg soluble solids in pilot scale tubular and plate-and-frame reverse osmosis units. Factors investigated were clarification operating temperature, membrane types, flow rate, pressure and concentration level. Permeate flux averaged 20 L/m^{2}h, and was affected by all factors except clarification. Losses of soluble components into the permeate were very slight, and flavour of the reconstituted juice was comparable with single strength juice. It was concluded that pineapple juice could be concentrated up to 250 g/kg soluble solids at 6000 kPa pressure, 40^{o}C, and a velocity of 3 m/sec, with good qual ity retention.

INTRODUCTION

Queensland pineapple production for the year ending 31 March, 1986, was 142000 t (ABS 1988). Pineapple juice provides the major processing outlet, accounting for about 70% of the State's fruit juice output. Most juice is concentrated by vacuum evaporation to reduce storage and transport costs. In recent years, reverse osmosis (R.O.) has found increasing application for concentrating food liquids, particularly dairy products (Schmidt, 1987). Advantages include lower energy consumption and better product quality retention.

There have been a number of publications on fruit juice concentration by R.O. These have included apple juice (Sheu and Wiley 1984; Chua et al 1987; Paulson 1985), orange juice (Papanicolaou et al 1984), mandarin juice (Fukutani and Ogawa 1983), tomato juice (Robe 1983; Watanabe 1982; Gheradi et al 1986), grapefruit and lemon juices (Braddock et al 1988). However, information on pineapple juice concentration by R.O. is lacking. The aim of this research was to measure the effects of juice pre-treatment, operating temperature, membrane type, flow rate, pressure and degree of concentration on pineapple juice R.O.

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MATERIALS AND METHODS

Juice concentration

Commercial pasteurised pineapple juice (120 g/kg soluble solids) was obtained from a Queensland processor. A portion of the juice was clarified by recirculation through an "Omess" diatomaceous earth filter ("Fibrocel" 6F precoat and "Hyflo" filter medium) and stored in 20 L PVC drums at-18°C. The remainder was frozen as a cloudy juice. Samples were thawed at 5°C prior to concentration by reverse osmosis.

Twenty litre juice samples were concentrated in a PCI (Patterson Candy International) tubular pilot reverse osmosis unit fitted with thin film ZF99 membranes (surface area 0.9 m^2). Product was recirculated at 6000 kPa/25°C until a soluble solids level of 250 g/kg was reached. For the membrane comparison trial, a laboratory scale DDS (De Danske Sukkerfabrikker) plate-and-frame reverse osmosis unit, fitted with thin film HR95 or HR98 membranes (surface area 0.36 m^2), was used.

Membranes were cleaned after runs with NaOH (1 g/L) and "Ultrasil" detergent (2.5 g/L) (40°C/3000 kPa) for 30 mins. When not in use, the membranes were preserved in $Na_2S_2O_5$ solution (1 g/L) and stored at 5°C.

Permeate flux rates, product temperatures and soluble solids were measured at 5 min intervals during each experiment. Samples of juice, concentrate, and permeate were stored in lacquered cans at -18°C for later analyses.

Experiments

(1) Clarification Two treatments, cloudy and clarified juices, were replicated over 9 runs.

(2) Temperature Four temperature treatments (10°C, 25°C, 40°C, and 55°C) were each replicated over 4 runs using cloudy juice.

(3) Membrane type Three membrane types (ZF99 in a PCI unit, HR98 and HR95 in a DDS unit) were replicated over 6 runs.

(4) Flow rate Four velocities (1, 1.5, 2 and 3 m/sec) were replicated over 6 runs.

(5) Pressure and concentration Six pressure-concentration treatments (4000 kPa - 200 g/kg, 5000 kPa - 200 g/kg, 6000 kPa - 200 g/kg, 5000 kPa-250 g/kg, 6000 kPa - 250 g/kg, and 6000 kPa - 300 g/kg) were replicated over 3 runs.

Analytical methods

Samples of juice, permeate, and concentrate from all runs were tested for acidity, soluble solids, ascorbic acid (vitamin C), and yeast and mould count. Permeate samples were also tested for calcium and potassium levels.

Organoleptic assessments

Samples of frozen concentrate were thawed at 5°C, and reconstituted with distilled water to the original juice soluble solids level. A taste panel of 15 adults selected from laboratory staff rated the juices for flavour on a 9-point hedonic scale.

RESULTS

(1) Clarification There were no differences in permeate flux rates when concentrating clarified and cloudy juice. Slight membrane fouling occurred during the first few minutes of operation, but original flux was completely restored with the standard cleaning procedure.

(2) Temperature Permeate flux increased with temperature, and decreased with increasing soluble solids (Fig. 1). Losses of acid and soluble solids, were very slight and there was no loss of ascorbic acid at any temperature. Yeast and mould counts ranged from 390 to greater than 3000 CFU/mL, and decreased with increasing operating temperature. Permeate calcium levels ranged from 0.25 to 0.85 mg/L, while potassium ranged from 4.39 to 5.87 mg/L. Concentration increased as operating temperature increased. Temperature did not significantly affect flavour scores ($P<0.05$), and quality was comparable to frozen single strength juice (the control). The only volatile flavour components found in the permeate were traces of ethanol and methyl-3-methyl thiopropionate. Their levels increased with temperature.

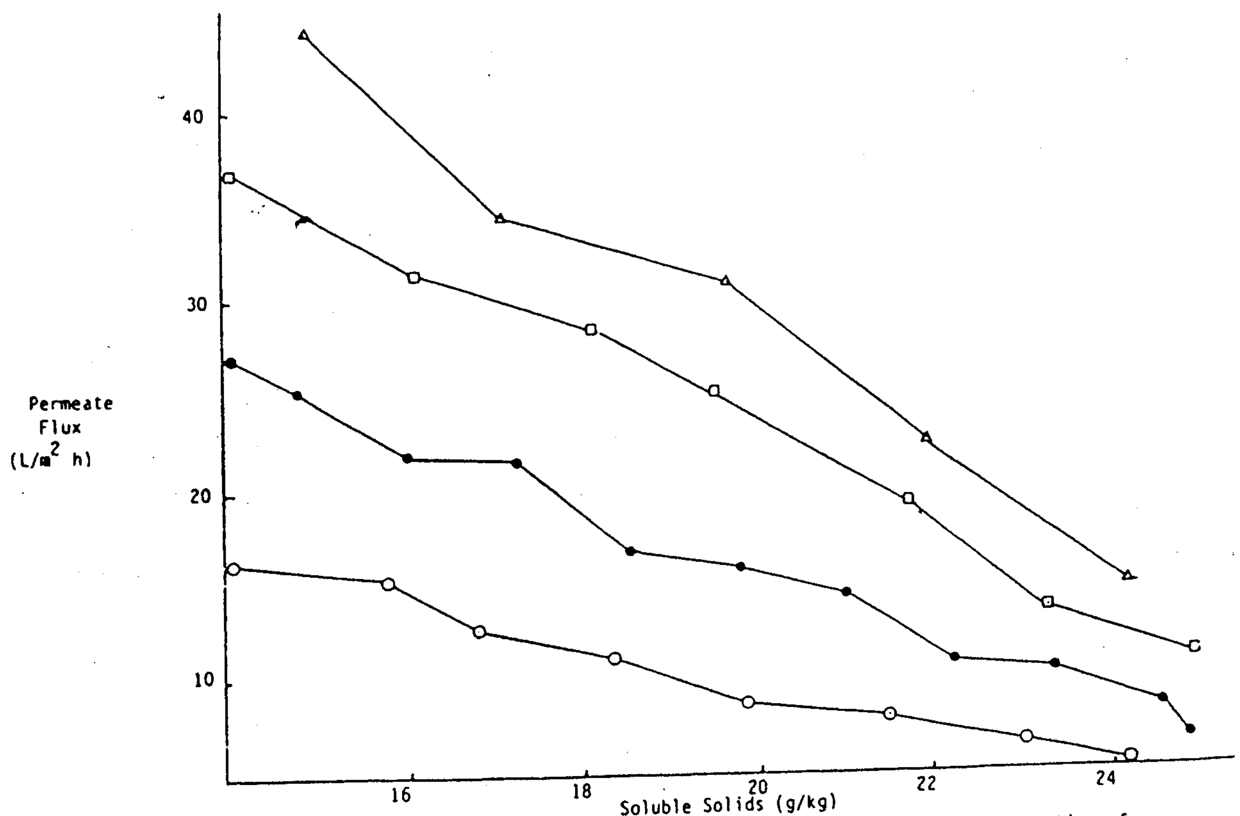

Figure 1. Effect of operating temperature on permeate flux during concentration of pineapple juice by reverse osmosis in a PCI tubular unit. Temperatures are 10°C (○), 25°C (●), 40°C (□), and 55°C(△).

(3) Membrane type Permeate flux decreased most rapidly with the ZF99 membrane, followed by HR98 and HR95 membranes. Losses of acid and soluble solids were greatest with the HR95 membrane and least for ZF99 membranes, although the magnitude of loss was very slight (Table 1). Flavour effects were not significant (P<0.05).

Table 1. Effect of membrane type on permeate flux, acid and soluble solids during pineapple juice concentration by reverse osmosis

Membrane Type	Acid (g/kg)	Soluble Solids (g/kg)	Permeate Flux (L/M^2h)
HR95 (DDS)	0.07 a	1.8 a	16.2 a
HR98 (DDS)	0.04 b	0.8 ab	16.0 a
ZF99 (PCI)	0.02 c	0 b	18.0 b
Standard error	0.004	0.3	0.9

* Means followed by a common letter are not significantly different (p>0.05)

(4) Flow rate Permeate flux decreased as flow velocity decreased below 2 m/s, but there was little difference between 2 m/s and 3 m/s velocities (Fig. 2). Membrane fouling was not a problem at any velocity.

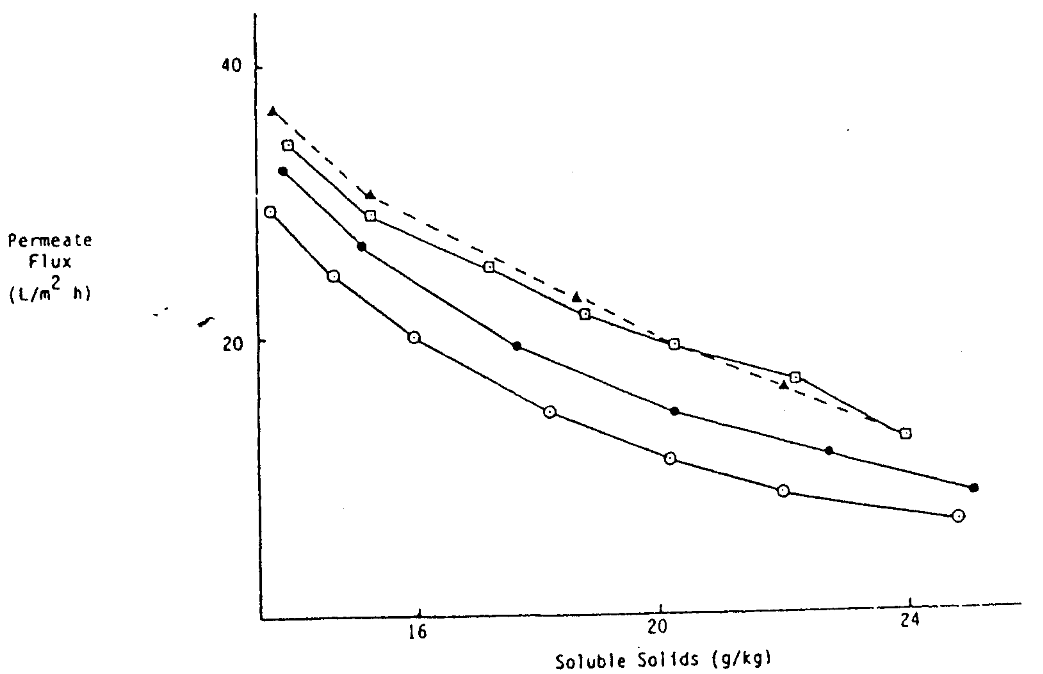

Figure 2. Effect of flow rate on permeate flux during concentration of pineapple juice by reverse osmosis in a PCI tubular unit. Velocities are 1 m/s (○), 1.5 m/s (●), 2 m/s (▲), and 3 m/s (□).

(5) Pressure and concentration Permeate flux rate was highest for the 6 000 kPa - 200 g/kg combination and lowest for the 4 000 kPa - 200 kPa treatment. Co ncentration beyond 250 g/kg soluble solids was very slow.

There was no loss of soluble solids or ascorbic acid into the permeate, at any combination of pressure and temperature. Acid losses were very slight in all cases (0.01-0.03 g/kg). Permeate calcium and potassium levels decreased as operating pressure increased, and all concentrations very low (0.1-0.6 mg/L Ca, 5.7-6.4 mg/L K). Flavour scores of the reconstituted juices averaged 6.4, and were not significantly affected by pressure and degree of concentration.

DISCUSSION

This study indicates that pineapple juice can be concentrated by R.O. without requiring any clarification. Fukutani and Ogawa (1983a) found that clarification of Satsuma mandarin juice, prior to R.O., gave higher permeate flux rates, than with cloudy feed juice. The discrepancy may be due to different pulp characterstics of the two juices. As pineapple juice is not clarified commercially, this would make R.O. more feasible for pineapple concentrate.

Overall, R.O. concentration at higher temperatures did not adversely affect the product quality or permeate flux rates. This agrees with the findings of Sheu and Wiley (1984) who concentrated apple juice at 40°C, and reported a 3-4% increase in processing capacity for every 1°C increase in operating temperature. The decrease in concentrate ascorbic acid level at 55°C was presumably due to accelerated breakdown or oxidation, rather than migration across the membrane. The absence of ascorbic acid in the permeates is in agreement with the findings of Braddock et al(1988) and Papanicolaou et al (1984) who reported good ascorbic acid retention in citrus juices. Losses of some volatiles during R.O. did not appear to affect the sensory quality of reconstituted pineapple juice. Similar findings have been reported for tomato juice (Gherardi et al 1986) and citrus juice concentration (Braddock et al 1988).

Permeate fluxes and losses of soluble components correlated with membrane retentive properties. Temperature effects were similar for each membrane type, which concurs with the literature (Fukutani and Ogawa 1983b). As anticipated, operating pressure increased permeate flux and reduced run times. Fukutani and Ogawa (1983b) also reported that pressure had the greatest effect on permeation rate, in Satsuma mandarin juice followed by temperature. Difficulty in concentrating to a soluble solids level of 300 g/kg was probably due to the high osmotic pressure of pineapple concentrate. Sheu and Wiley (1984) reported that apple juice R.O. was most efficient up to 200-250 g/kg soluble solids, and therefore was limited to preconcentration.

CONCLUSION

Cloudy pineapple juice can be concentrated to 250 g/kg soluble solids in either tubular or plate-and-frame type reverse osmosis units. Optimum conditions are:- 40°C operating temperature, 6000 kPa pressure, 3 m/s flow rate. Losses of soluble components into permeate are very slight. Organoleptic quality of the reconstituted juice is comparable with single strength juice.

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