Concentration of Clarified and Pulpy Pineapple Juice by Osmotic Evaporation

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Abstract

Osmotic evaporation is a membrane concentration process in which two solutions with different concentrations are separated by a hydrophobic porous membrane. This process can be carried out at friendly temperature and pressure, presenting a great potential to be applied in fruit juice concentration. This process allows the selective water vapour extraction from a dilute aqueous solution (fruit juice) to a concentrate solution (brine), concentrating it and preventing its thermal degradation. In this work the concentration of pineapple juice by osmotic evaporation was evaluated. The experiments were carried out in a laboratory unit composed of two independent circuits, pineapple juice and brine. Calcium chloride solution is used as brine. Concentration of the single strength and clarified pineapple juices was studied. For the concentration of the single strength juice, the evaporatory flux ranged from 8.5 kg/hm2 to 5.5 kg/hm2 allowing the concentration of the juice up to 55°Brix. The concentration of the clarified juice reached 53°Brix after the osmotic evaporation. In this case, the evaporatory flux ranged from 6.6 kg/hm2 to 9.9 kg/hm2.

INTRODUCTION

Osmotic evaporation is a relatively new concentration membrane process especially attractive for the processing of heat sensitive aqueous solutions like fruit juices or pharmaceutical products. The solutions to be concentrated are separated by a porous hydrophobic membrane from an extraction medium, which could be a hypertonic solution. The hydrophobic nature of the membrane prevents the penetration of the liquid water in the interior of the membrane pores. In this process, the driving force for mass transfer is the difference in concentration across the membrane (Petrotos et al. , 2001).

Osmotic evaporation can be carried out at friendly temperature and pressure, presenting a great potential to be applied in fruit juice concentration. For fruit juice concentration, it can be reached high concentration values (60° Brix), producing concentrates with good nutritional and sensory qualities. This process has been applied to clarified juices.

Vaillant et al. (2001) used osmotic evaporation to concentrate clarified passion fruit juice up to 60 °Brix at 30°C in an industrial scale. Sensory quality and vitamin C content were well preserved in the concentrated juice.

In 2004, Rodrigues et al. evaluated the application of osmotic evaporation membrane technology to produce clarified concentrated camu-camu juice. The clarified camu-camu juice was concentrated in two steps, first concentrating up to 25°Brix, and then from 25 to 64°Brix. The ascorbic acid losses were about 3%. The osmotic evaporation process resulted in a 64°Brix camu-camu juice.

More recently, orange juice was clarified and concentrated up to 62°Brix by microfiltration and osmotic evaporation on a semi-industrial pilot scale. It was verified that during the concentration step, significant losses of vitamin C and aroma compounds occurred but the pre-conditioning of the membrane and the regeneration of the brine reduced the losses, mantainig the aroma composition similar to the original juice (CISSE et al, 2005).

This work aim to investigate the thecnical viability of obtaining concentrated pineapple juice by osmotic evaporation. The single strength juice and clarified one were evaluated.

MATERIAL AND METHODS

As raw material it was used a commercial pulpy pineapple juice at 12°Brix and 3% pulp content. The concentration experiments were carried out with the single strength juice and with the clarified one.

The pineapple juice was clarified in a microfiltration system with tubular ceramic membranes (0.1 μm as mean average pore size and 0.015 m^2 surface) at 20°C and 2 Bar transmembrane pressure.

The osmotic evaporation trials were carried out in a lab scale system consisted by two independent circuits, one for the juice and the other for the brine. Two gear pumps were used for the circulation of the solutions in each membrane side. The temperature of both circuits was controlled. A 2 L feed tank was placed on a balance connected to a computer where the decay of the juice mass was registered allowing further evaporatory flux calculations. $CaCl_2$ solutions ranging from 4.7 M to 5.3 M was used as brine. A PFTE 0.2 μm flat sheet membrane from Pall-Gelman (TF200) was used. The effective surface of the membrane was 0.005 m^2. As the membrane surface was small, the juice was concentrated in a circulation loop continuously fed by the raw juice.

Some preliminary tests were done before concentrating the pineapple juice in order to evaluate the effect of the temperature and feed velocity on evaporator flux. These experiments were carried out with the single strength pineapple juice. By these experiments the following operation conditions were fixed:

juice temperature : 35°C

brine temperature: 20°C

juice velocity: 1.25 m/s

brine velocity: 2.00 m/s

transmembrane pressure: < 0.05 Bar

The concentration of pineapple juice was carried out in two steps. At the first day the single strength or the clarified juice was concentrated by osmotic evaporation from 10-12°Brix up to 25-30°Brix during eight hours. In the second day, a juice previously concentrated by thermal evaporation at around 30°Brix was then concentrated by osmotic evaporation up to 53-60°Brix. This procedure was necessary as the amount of concentrated juice obtained during the osmotic evaporation trial was not enough to be used in a subsequent experiment.

The efficiency of the process was evaluated by the evaporator flux calculation and by the concentration factor obtained.

In order to obtain the relation between juice concentration and evaporatoy flux, some steady state experiments of osmotic evaporation were carried out using pre-concentrated juices obtained by thermal evaporation. These experiments were performed during three hours using a big volume of juice so that its concentration didn't change during the essay. Five different concentrations were evaluated ranging from 10 to 60°Brix using both single strength juice and the clarified one.

RESULTS

Tables 1 shows the juice concentration and the mean evaporator flux during the osmotic evaporation of the clarified and single strength pineapple juices. As mentioned, the juice concentration was carried out in two steps of eight hours each.

The osmotic evaporation allowed the concentration of the single strength pineapple juice from 12.5°Brix to 28°Brix at first stage and from 33°Brix to 55°Brix at the second stage. During this trials the evaporatory flux ranged from 8.5 L/hm^2 to 5.5 L/hm^2.

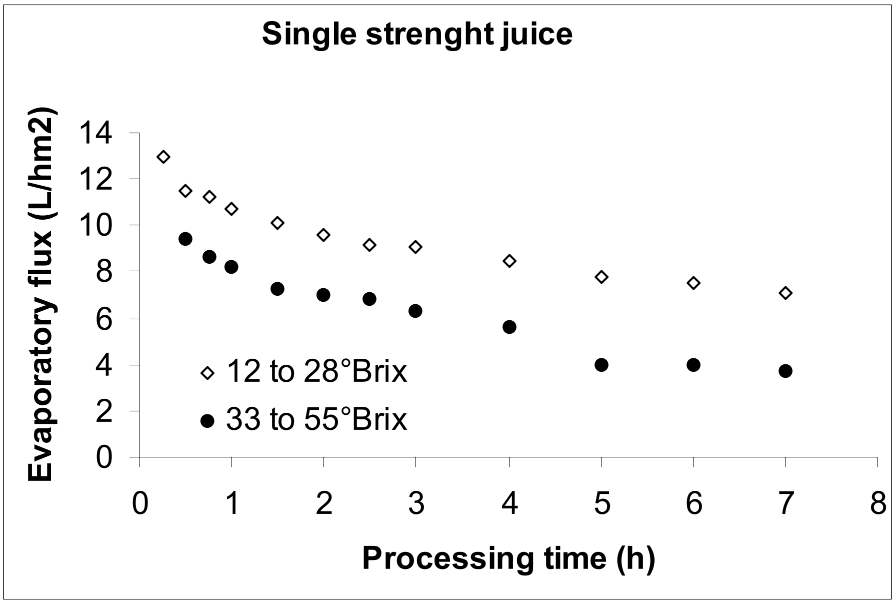
When the clarified juice was concentrated by osmotic evaporation, it was observed almost the same behaviour: the evaporatory flux ranged from 9.9 L/hm^2 to 6.6 L/hm^2 and the concentration degree reached 53°Brix.

Table 1: Total soluble solids (°Brix) and mean evaporatory flux (kg/hm^2) of the clarified juice and the single strength juice during osmotic evaporation trials.

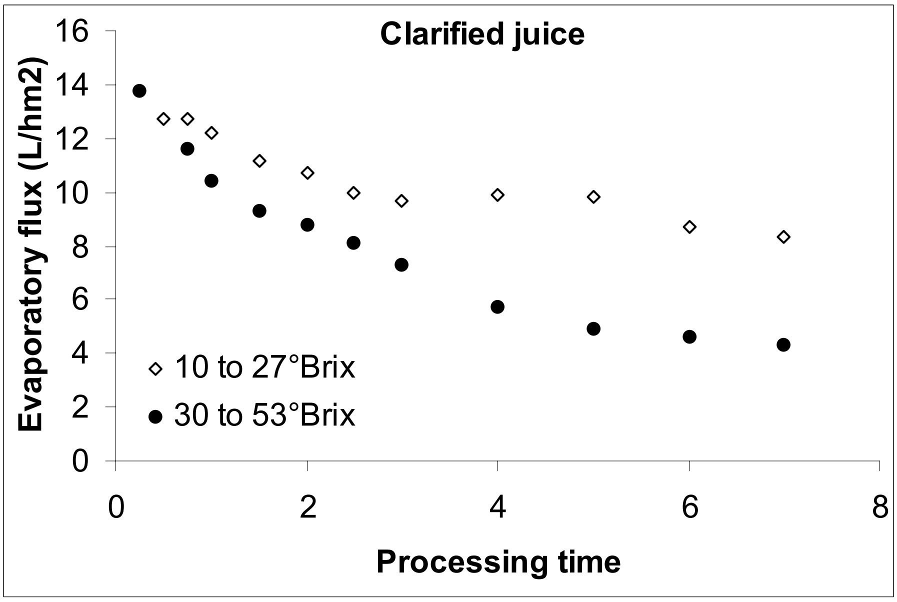
	Clarified juice			Single strength juice		
	Total soluble solids		Flux	Total soluble solids		Flux
	F	C		F	C	
First step	11	28	9.9	12.5	28	8.5
Second step	32	53	6.6	33	55	5.5

F: Feed, C: Concentrate,

As expected, the evaporatory flux was higher for the concentration of the clarified juice. The evaporatory flux decreased during the processing time (Figure 1) for both clarified or single strength juice. In general, the flux decay during membrane filtration is attributed to the polarization concentration and fouling phenomena due to solute retention on the membrane surface. However, in the case of osmotic evaporation this decay could be related to the concentration of the juice itself, resulting in the increase of the juice viscosity and consequently the increase of the resistance to mass transfer in the liquid phase and also to a decrease in the driving force.



(a)



(b)

Figure 1: Evolution of the evaporatory flux during the concentration of single strength (a) and clarified (b) pineapple juice by osmotic evaporation.

The comparison of the flux values of the first step with those of second step it can be verified that at the end of the first step the flux values are approximately 7 kg/hm2 for the single strength juice and 8 kg/hm2 for the clarified one. Nevertheless, regarding of the flux values at the beginning of the second step, the evaporatory fluxes are about 9.5 kg/hm2 for the single strength juice and 14 kg/hm2. These higher values may be attributed to the new membrane conditions as after each experiment the membrane was clean until its permeability characteristics had returned.

To understand the effect of the juice concentration on the flux behaviour, the experiments under steady state conditions when the evaporatory flux is constant were investigated (Figure 2). As expected the evaporatory flux decreased when the juice concentration increased. The same behaviour was observed for both the single strength juice and the clarified one.

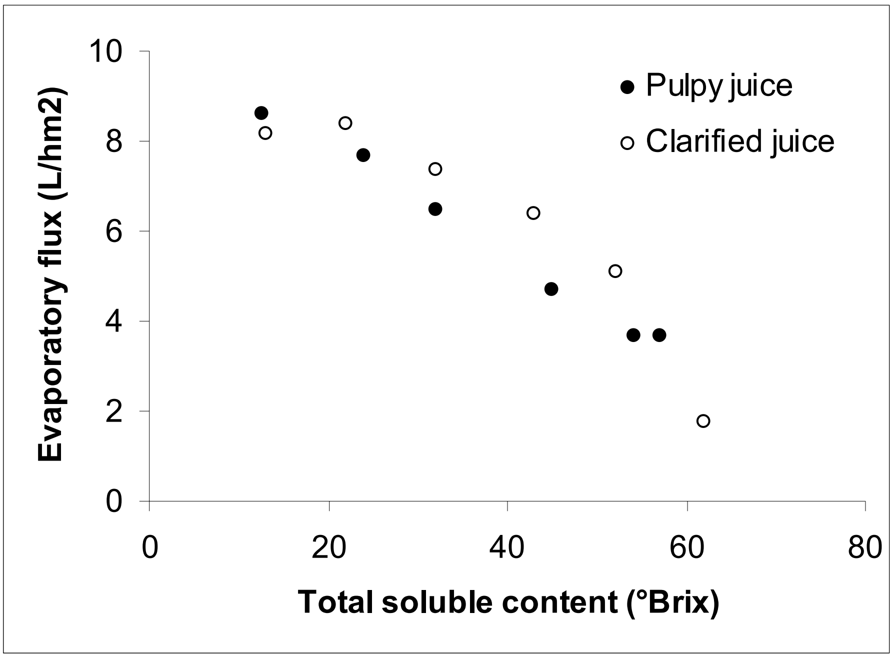


Figure 2: Evolution of evaporation flux during the concentration of clarified and pulpy pineapple juices by osmotic evaporation.

CONCLUSION

It was possible to concentrate single strength or clarified pineapple juice up to 55°Brix by osmotic evaporation. Others concentration experiments must be carry out to allow new evaluations, mainly sensorial and nutritional, in order to compare this membrane technology to the thermal concentration.

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