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Concentration of watermelon juice by reverse osmosis process

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ABSTARCT

Watermelon is much appreciated fruit due its good sensory characteristics such as flavour, aroma and succulence. Watermelon juice was concentrated by reverse osmosis (RO) process. RO was carried out on a pilot plant unit equipped with polyamide composite membranes with an effective permeation area of 0.72 m^2. The concentration tests were carried out in a fed batch mode at 30ºC, 60 bar transmembrane pressure and 650 l/h recycle flow rate. The medium permeate flux was 21.7 l/hm^2. The volumetric concentration factor and the soluble solids concentration factor were 4.4 and 3.6, respectivelly. The results showed an increase in the physico-chemical properties of the concentrated juice, mainly, in the lycopene content and in the antioxidant capacity.

Keywords: Lycopene; Antioxidant capacity; Membrane separation process; Fruit juice; Tropical fruit; Carothenoids

1. Introduction

Watermelon is a tropical fruit that presents excellent sensory characteristics as flavour, color, sweetness and succulence.

Recent epidemiological studies reported an inverse relationship between the consumption of fruits and the incidence of several degenerative diseases and, nowadays, watermelon is pointed out as an excellent source of lycopene, carotenoid that contributes to the antioxidant capacity of the food. The ingestion of this compound is related to the decrease of certain types of cancers, mainly the one of prostate and cardiovascular diseases caused by the cellular damages promoted by the free radicals in the organism [1].

There is a crescent demand for fruit juices with the sensory, nutritional and functional properties of fresh fruits. To increase its marketing potential the watermelon may be processed either as a fresh single strength juice or as a concentrated one. The classical concentration processes use high temperature that promotes considerable losses of many bioactive compounds. Reverse osmosis (RO) is an alternative to the conventional fruit juice concentration processes because it does not involve heating which preserves the properties of the fresh fruit as they are carried out under mild conditions [2].

The concentration of lycopene from fruit juices by membrane separation processes has already been demonstrated to be efficient so that it can be a good alternative to the industrial production [3]. In this context, the objective of this work was to evaluate the concentration of watermelon juice by RO.

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2. Materials and methods

2.1. Material

Watermelon from the *Crimson Sweet* variety was used as raw material. The juice was obtained by the depulping of the fruits in a finisher with a 0.8 mm. The juice was conditioned in polyethylene—aluminum bags and stored at 18ºC until its use.

2.2. RO process

The RO processes were carried out in a pilot plant unit model Lab Unit M-20 (DDS Danish Separation System, Denmark), with thin polyamide composite membranes presenting 98% NaCl solution rejection at 25ºC and 60 bar. The membranes were arranged in a plate and frame module, totalizing 0.72 m^2 of permeate area.

The concentration tests were carried out in a fed batch mode at 30ºC, 60 bar transmembrane pressure and 650 l/h recycle flow rate. The permeate flux and the soluble solids content were evaluated every 5 min. The processes were finished when the permeate flux became so low that the concentration process became not feasible.

The concentration processes were carried out in triplicate (RO 01, RO 02 and RO 03).

The volumetric concentration factor (VCF) is defined as the initial volume of the juice divided by the volume of retentate at a time.

2.3. Analytical methods

Samples of the watermelon juice (F) and of the retentate (R) fractions were analyzed for pH, soluble solids content (ºBrix) and total titrable acidity (g/100 g) according to AOAC [4]. Lycopene content was determined by extraction with a mixture of hexane: acetone: ethyl alcohol (2:1:1, v:v:v) followed by the absorbance measure of the hexanic phase in a spectrophotometer at 503 nm [5]. Antioxidant capacity was evaluated in the hexanic extract by using ABTS radical and Trolox as standard [6]. The color loss was determined by spectrophotometry at 734 nm after 15 min of reaction of the sample with the ABTS radical. Instrumental colour and haze evaluations were carried out in a Hunter System [7]. All the samples were analyzed in triplicate. Analysis of variance (ANOVA) was used to compare the means. Differences were considered to be significant at $p < 0.05$. The statistical analyses were performed with XLSTAT.

3. Results

Fig. 1 shows the permeate flux behavior of the processes. The average initial permeate flux was 44.3 ± 3.1 l/h/m^2. After 10 min, a reduction of 58% in the permeate flux was observed reaching an average permeate flux of 21.7 ± 5.1 $L.h^{-1}.m^{-2}$. The observed increase

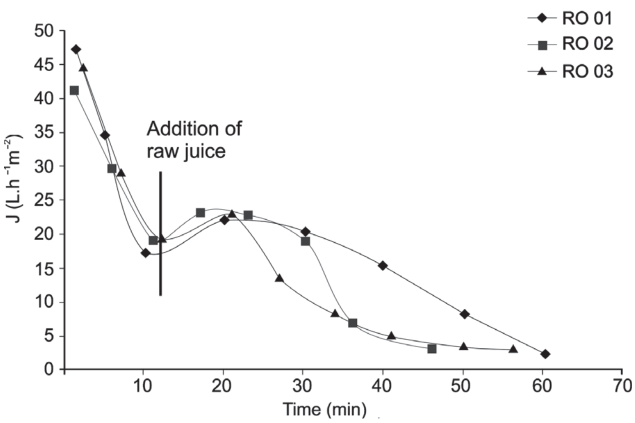

Fig. 1. Permeate flux variation during the concentration of watermelon juice by RO processes.

in the permeate flux was due to the addition of raw juice in the feed tank as the process was carried out at a fed batch mode. The RO processes showed a permeate flux decrease along time processes. This is a classical behavior in membrane separation processes and it can be attributed to the concentration polarization phenomenon that occur in the initial stages of the permeation and to the membrane fouling which, in this case, is only due to the retained solutes accumulated in the membrane surface. As composite membranes with a dense skin layer were used, the phenomena related to pore adsorption and pore-blocking are not important. At the experimental conditions used it was not possible to evaluate the concentration polarization phenomena so it was considered that the main resistances to permeation were due to membrane itself, to the increase of the osmotic pressure and the viscosity of the juice along processing, which resulted in the decrease of the driving force and in the increase of the mass transfer resistance that, consequently, decreased the permeate flux.

Although the obtained VCF was 4.4 ± 0.3, the concentrated juice reached 30º Brix, corresponding to a concentration factor of solids of 3.6. The lycopene content and antioxidant capacity raised, respectively, 3.2 and 2.4 folds in relation to the single strength juice. The observed loss in relation to VCF can be attributed to the oxidation and isomerization reactions of lycopene during the processes, which directly affect the antioxidant capacity. It must be point out that these trials were carried out in a small pilot plant so that the verified problems should not occur if the concentration was conducted at an industrial scale decreasing the negative effects of oxygen action and light exposure over lycopene. The evolution of the total soluble solids content during the processes is shown in Fig. 2.

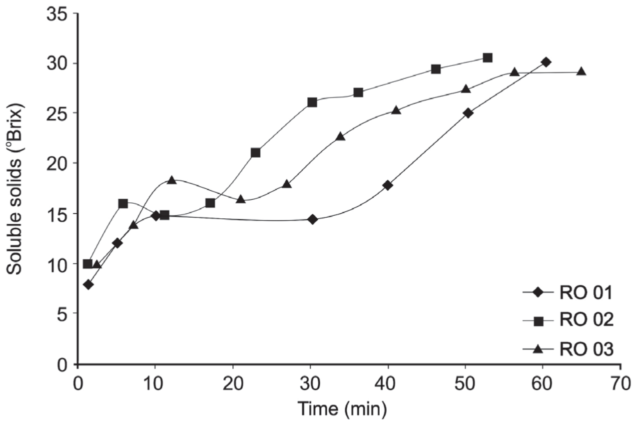

Fig. 2. Soluble solids content during the concentration of watermelon juice by RO processes.

Table 1 shows the results obtained for the feed and retentate fraction. There was a significative ($p < 0.05$) increase in the soluble solids, total solids and in the acidity content.

These results were similar to those obtained by Das Gupta and Jayarama [8] for the concentration of watermelon juice using the same RO membrane with 50 bar of transmembrane pressure. In this work, watermelon juice was concentrated from 6.5 to 24°Brix corresponding to a concentration factor of 3.7 and an increase in lycopene content of 3.1. The permeate flux obtained by these authors was 15.2 $L.h^{-1}.m^{-2}$.

In relation to instrumental colour and haze determinations, it was verified a decrease in the luminosity and an increase the haze of the concentrated juice when compared to the raw juice. The increase in "a" parameter represented an increase in the red intensity colour which can be easily explained by the concentration of the red pigment lycopene due to water remotion. The results can be observed in Table 2.

Table 1
Caracterization of the feed and retentate fractions

Analysis	Raw juice	Concentrated juice
pH	$5.43^a \pm 0.13$	$5.22^a \pm 0.03$
Soluble solids (°Brix)	$8.3^a \pm 0.3$	$29.9^b \pm 0.7$
Total titrable acidity (g/100 g)	$1.21^a \pm 0.26$	$3.55^b \pm 0.16$
Total solids (g/100 g)	$7.07^a \pm 0.01$	$29.6^b \pm 2.11$
Lycopene (μg/g)	$31.43^a \pm 6.49$	$100.87^b \pm 29.77$
Antioxidant Capacity (μmol Trolox/g)	$0.34^a \pm 0.06$	$0.81^b \pm 0.14$

Same letter (a,b) in the same line do not differ significantly ($p > 0.05$) among themselves by Tukey test.

Table 2
Caracterization of the feed and retentate fractions

Analysis	Raw juice	Concentrated juice
Luminosity	$32.74^a \pm 3.77$	4.80b ± 1.15
a	$10.56^a \pm 0.07$	19.55b ± 2.42
b	$9.80^a \pm 0.82$	0.36b ± 0.13
Haze	$85.04^a \pm 0.97$	94.30b ± 5.67

Same letter (a,b) in the same line do not differ significantly ($p > 0.05$) among themselves by Tukey test.

4. Conclusions

Watermelon juice was concentrated from 8 to 30°Brix by RO process. The quality parameters of the concentrated such as acidity, colour, total solids increased in relation to the single strengh juice. Lycopene content and antioxidant activity increased but not proportional to the VCF.

The results showed that it was possible to obtain concentrate watermelon juice by RO.

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