Production of antioxidant enriched cranberry juice by electrodialysis with filtration membrane: impact of process on juice composition

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ABSTRACT
Cranberry juice is recognized for its nutraceutical properties. Recently, it was demonstrated that it is possible to enrich a cranberry juice in antioxidants from another cranberry juice by an electrodialysis with filtration membrane (EDFM) process. In order to transpose this technology on an industrial scale for the production of an antioxidant enriched cranberry juice, the present work aimed to study, during consecutive EDFM treatments, the evolution of raw and enriched cranberry juices composition. The anthocyanin concentrations and the antioxidant capacity of the enriched juice increased respectively of 19.41% and 23.74%, while the anthocyanin concentrations and antioxidant capacity of the raw juice remained constant throughout treatments.

Keywords: Cranberry; electrodialysis; filtration membrane; anthocyanins; antioxidant capacity.

INTRODUCTION
Cranberry is recognized for its high antioxidant potential. So, the enrichment of a cranberry juice with polyphenols, such as anthocyanins and proanthocyanidins, would be particularly interesting for the ever growing nutrition-health market. To answer the consumer demands for healthy products, the food industry is looking for innovative technologies for their manufacture. Bazinet et al. [1] demonstrated that it is possible to enrich a cranberry juice in antioxidants from another cranberry juice by electrodialysis with filtration membrane (EDFM). This process is inexpensive, easy to use and environmentally friendly. Nevertheless, in this first preliminary work on the subject, it was demonstrated that if used as is this technology has the disadvantage to generate a raw juice impoverished in antioxidants with an unsatisfactory color and taste. In order to transpose this technology at an industrial scale for the production of an antioxidant enriched cranberry juice, Bazinet et al.[1] proposed the integration of EDFM to the conventional process used for cranberry juice production, in a way avoiding the generation of a source juice impoverished in polyphenols. However, the effectiveness of such a process was not demonstrated.

In this context, the objectives of this work were 1) to validate the feasibility of the integrated proposed process, 2) to study the composition evolution of source and enriched cranberry juices during consecutive EDFM treatments 3) to study the EDFM parameters evolution.

METHODS
EDFM treatments were performed in batch process using a constant voltage difference of 30 V. In order to evaluate the feasibility of EDFM treatment for the production of a polyphenol-enriched cranberry juice, 300 mL of cranberry juice were circulated in the compartment on the cathode side and 3L of cranberry juice in the compartment on the anode side. The cranberry juices were circulated three times (3 cycles). The duration of the treatment was 2 h. Conductivity and pH of cranberry juices were recorded throughout the process as well as the global system resistance. Anthocyanin, proanthocyanadin, organic acid, mineral contents (Na, K, P, Ca, Mg, Cu) juice color parameters (L*, a* and b*) and °Brix were determined before treatments and following each cycle on both treated cranberry juices and on a control juice.
RESULTS AND DISCUSSION

Juice parameters evolution

The general trends in the different juices were that the anthocyanin contents increased in the enriched juice all along the treatment, while at the same time the concentration of anthocyanins were constant whatever the cycle. Total anthocyanin concentration in the enriched juice increased from 136.4 ± 7.1 to 162.9 ± 8.0 g/L during treatments corresponding to a 19.4% enrichment value. However, total concentration in the raw juice remained constant at 125.9 ± 6.3 g/L throughout the treatment. The increases in the concentration of the individual anthocyanins varied between 18.8 and 22.4%. The concentrations of anthocyanins in the enriched juice increased during the process and according to the number of cycle, but these concentrations in all the cases became significantly different from control juice and all other juices starting from cycle 3. Proanthocyanidin concentration of both juices remained also constant which suggests that the duration of treatments was too short to allow the migration of these molecules.

Organic acid concentrations remained constant and were preserved in treated cranberry juices except for citric acid concentration. Citric acid concentration in the enriched juice decreased during treatments from 1159.1 ± 61.7 to 1074.4 ± 66.3 mg/100mL of juice corresponding to a loss of 7.3%, while citric acid concentration in the 3L juice remained constant. The citric acid has a pKa (3.14) lower than those of other organic acids. At the cranberry juice pH (pH 2.60), this compound will be the most dissociated acid and should then migrate more than the other acids, its negatively charged conjugated base will migrate towards the anode. Citric acid is also known to migrate easily during electromembrane processes [2].

EDFM treatments did not have a significant effect on the pH of the enriched and raw cranberry juices. The mean pH of enriched and raw juices was 2.6 ± 0.1 and 2.9 ± 0.1 respectively. Soluble sugars (Brix) in juices remained constant at 6.9 ± 0.5 throughout treatments. Color parameters for the enriched juices remained constant during all cycles of EDFM. For the raw juice, a* parameter values obtained following the second and third cycle were higher than for the control and the enriched juice.

The evolution of the mineral concentrations as a function of time was different according to the type of juice treated and the type of mineral. In raw juice, the concentration of the 6 minerals was constant all along the 3-cycle EDFM treatments and except for potassium; these concentrations were similar to the ones of the control juice. In the enriched juice, the concentrations of sodium, magnesium and calcium increased very slightly; these variations were statistically different for magnesium after 2 cycles and after 3 cycles for calcium. Potassium is the ion with the highest concentration in the cranberry juice and the cation with the highest electrophoretic mobility [3,4]. In addition, these results indicated that the phosphorous was used as a counter-ion to the potassium when necessary for maintaining the electroneutrality on both side of the EDFM.

EDFM parameters evolution

The mean global system resistance increased from 50.3 ±1.5 Ω to 83.0 ± 4.0 Ω during the first cycle and from 65.3 ± 2.4 Ω to 87.3 ± 10.3 Ω during the second and third cycle. The increase in the global system resistance was higher during the first 15 min of treatments and then reached a plateau. This could be due to water dissociation at membrane interfaces following the first 15 min of treatments as previously suggested by Bazinet et al. [1]. The decrease in the global system resistance at the beginning of each cycle might also be due to a fouling of the membranes. During each cycle, the decrease in the electrical conductivity of ion-exchange membranes resulted in an increase of the system resistance. This decrease in conductivity may be explained by a masking of charged sites of membranes by molecules of opposite charges. The EDMF process for cranberry juice enrichment presented an energy consumption (all cycle averaged) of 27.7 ± 11.2 kWh/kg total anthocyanins migrated.
CONCLUSION
Results obtained in this study showed the effectiveness of the process to increase the antioxidant capacity and polyphenol content of a cranberry juice and confirmed the possibility to use EDFM process for the production of an antioxidant-enriched cranberry juice fraction from a large juice source. The model proposed for the integration of an EDFM system to the process used for the production of cranberry juices can be transposed at an industrial scale. However, prior to the development of an industrial process, it will be essential to carry-out a study on the fouling of the membranes and determine the evolution of membrane parameters such as the streaming potential determination and the identification of the molecules interacting with the different types of membranes.

REFERENCES