



**UNIVERSITY OF PANNONIA**  
DOCTORAL SCHOOL  
OF CHEMICAL ENGINEERING AND MATERIAL SCIENCES

**BERRY JUICE CONCENTRATION WITH MILD  
MEMBRANE SEPARATION TECHNOLOGY**

PHD THESES

SUBMITTED BY:  
**ANDRÁS BOÓR**  
ENVIRONMENTAL ENGINEER

SUPERVISORS:  
**DR. KATALIN BÉLAFI-BAKÓ**  
PROFESSOR

**DR. NÁNDOR NEMESTÓTHY**  
ASSOCIATE PROFESSOR

**Veszprém**  
2017

## INTRODUCTION

The development of science and technology provides new and innovative approaches in every field of life; the food industry is not an exception either. During my experiments, my aim was to concentrate the juice from cornelian cherry, blackthorn, rowanberry and elderberry fruits by a mild membrane technology. As a first step, I produced juice from the wild and colorful berries. Then, the liquid content of the juices was reduced through membrane, with the help of selective transportation. For this purpose, I used the combination of two membrane separation methods, the osmotic distillation (OD) and the membrane distillation (MD), together the membrane and osmotic distillation (MOD).

The experiments had proved the effectiveness of the method concerning the preservation of the inner content in the juices. By the comparison of the antioxidant capacity, polyphenol, antocianin and C-vitamin content in the re-diluted and in the original juices, I have determined that the products had preserved their inner measured values.

Further improving the procedure, I have developed a multiple-stage cascade system. I have implemented a simplified mass transfer model, by concentrating saccharose solutions, thus I have defined a mass transfer coefficient characteristic of the MOD method. Then, I have performed the concentration of the juices according to the cascade model in 2-, 3- and 4-stage systems. With the tests, I have demonstrated the efficiency of the system. Using the cascade system, the time of juice concentration had been reduced, without the regeneration of the osmotic agent ( $\text{CaCl}_2$  solution).

## **EXPERIMENTAL SYSTEMS**

To execute the mild MOD membrane technology, I used a capillary membrane module. The membrane is a polypropylene, porous and hydrophobic membrane type. The hydrophobic character is very important, due to the rejection of the water-soluble content. The module contains 34 membrane fibres, whose total transfer area is 68 cm<sup>2</sup>.

For the recirculation of the osmotic agent, I used an appropriate sized Erlenmeyer beaker, which was cooled by a cryostat on its shell side. The osmotic agent was continuously mixed by a magnetic stirrer, to prevent the crystallization of the oversaturated solution. The same cooling liquid is used for the cooling of the osmotic agent down-stream of the module, through a heat exchanger. With the help of the membrane module, all the necessary experiments could be executed for the calculation and modelling of the transport processes and the flux.

The inner contents of the juices were determined by different photometric methods, according to the literature. The determination of the C-vitamin was implemented by HPLC.

I carried out an organoleptic test on the juices, produced by MOD technology; the tests are based on the notes of Katalin Horváthné Dr. Almássy from the University of Szeged.

## RESULTS

After the harvest of the ripe berries of cornelian cherry, blackthorn, rowanberry and elderberry fruits, I investigated how to increase the liquid gain from the fruit pulps. A series of tests were carried out to find the best pectinase enzyme preparation. Due to my experiments, I proved, among the commercially available enzymes, the *Microzym 200* preparation can increase most significantly the liquid gaining from the examined four fruits at 37 °C in a dosage of 0.3 g *Microzym 200* + 30 µl cellulase / 30 g fruit mash. By its application, the liquid production yield increased from 51.6-60.5 % to 59.9-72.1 %.

Juices from these fruits were firstly concentrated by combined osmotic and membrane distillation technology (MOD). All four type of juice were concentrated to the desired concentration (over 50 % total soluble solids).

It was proved by organoleptic tests and inner content measurements, that the membrane osmotic distillation (MOD) technology is a mild concentration technique. By the comparison of the antioxidant capacity, polyphenol, antocianin and C-vitamin content in the re-diluted and in the original juices I have found, that the products had preserved 70-80 % of their inner measured values.

I have published results on a 2-, 3- and 4-stage multiple cascade MOD system firstly in the literature. Using the cascade system the time of juice concentration up to 60 % was reduced by 15-21 %, without the regeneration of the osmotic agent (CaCl<sub>2</sub> solution), to the desired weight concentration.

A simplified mass transfer model by using saccharose model solutions was constructed and mass transfer coefficients of the MOD system were determined in the given range.

My results during the experiments hopefully will contribute to increase the efficiency and mildness of the fruit processing distribution of the Hungarian food industry

# THESES

## 1. Thesis

I proved that – among the commercially available enzymes – the *Microzym 200* preparation can increase most significantly the liquid gaining from cornelian cherry, blackthorn, rowanberry and elderberry fruits at 37 °C in a dosage of 0.3 g *Microzym 200* + 30 µl cellulase / 30 g fruit mash [5]. By its application, the liquid production yield increased from 51.6-60.5 % to 59.9-72.1 %.

## 2. Thesis

Juices of cornelian cherry, blackthorn, rowanberry and elderberry fruits were firstly concentrated by combined osmotic and membrane distillation technology. During the process the average flux value was 0.4-1.5 l/m<sup>2</sup>h [1, 2, 5, 7].

## 3. Thesis

It was proved experimentally, that the membrane osmotic distillation (MOD) technology is a mild concentration technique. By the comparison of the antioxidant capacity, polyphenol, antocianin and C-vitamin content in the re-diluted and in the original juices I have found, that the products had preserved 70-80 % of their inner measured values [2, 9, 10].

## 4. Thesis

I have published results on a 2-, 3- and 4-stage multiple cascade MOD system firstly in the literature [3, 11]. Using the cascade system the time of juice concentration up to 60 % was reduced by 15-21 %, without the regeneration of the osmotic agent (CaCl<sub>2</sub> solution), to the desired weight concentration [3].

## 5. Thesis

A simplified mass transfer model by using saccharose model solutions was constructed and mass transfer coefficients of the MOD system were determined in the given range.

## **PUBLICATIONS**

### **Theses and Dissertation based Papers**

1. BOÓR A., BÉLAFI-BAKÓ K.: Concentration of cornelian cherry fruit juice by membrane osmotic distillation, *Desalination and Water Treatment*, 35, 271-274, 2011
2. BOÓR A., BÉLAFI-BAKÓ K., NEMESTÓTHY N.: Comparative study on concentration of juices from colourful wild berry fruits by membrane osmotic distillation, *Hungarian Journal of Industry and Chemistry*, 40, 53-56, 2012
3. BOÓR A., BÉLAFI-BAKÓ K., NEMESTÓTHY N.: Concentration of colourful wild berry fruit juices by membrane osmotic distillation via cascade model systems, *Journal of Membrane Science and Research*, 2, 201-106, 2016

### **Other Papers**

1. BOÓR A.: Gyümölcslevek kezelése membrán szeparációval, *Természet Világa*, 142 évf., 4. füzet, 175-176, 2011
2. BOÓR A., BÉLAFINÉ BAKÓ K., NEMESTÓTHY N.: Kókényből és húsos somból készített gyümölcslevek koncentrációja kéméletes ozmotikus - és membrán desztillációs eljárással, *Konzervújság*, 3-4 szám LX évf. 46., 2012
3. BOÓR A., BÉLAFINÉ BAKÓ K., NEMESTÓTHY N.: Direkt ozmózis, *Membrántechnika és ipari biotechnológia*, III. évfolyam 1. szám, 2-11, 2012

### **Proceedings**

1. BOÓR A., CSANÁDI ZS., NEMESTÓTHY N., BÉLAFI-BAKÓ K.: Preservation of antioxidant capacity of wild berry fruits during concentration of fruit juices by membranes, *Slovenian Chemical Days, Maribor*, pp. 123, 2010
2. BOÓR A.: Concentration of Cornelian cherry fruit juice by membrane osmotic distillation, *XXVIII. EMS Summer School, Lengyelország, Smardzewice*, 2011
3. BOÓR A.: Preservation of antioxidant capacity of cornelian cherry and blackthorn fruits during the concentration of fruit juices by mild membrane processes, *ICOM, Amszterdam, Hollandia*, 2011

4. BOÓR A.: Preservation of antioxidant capacity of wild berry fruits during the concentration of fruit juices by mild membrane processes, 1<sup>st</sup> Euro-Mediterranean Symposium for Fruit & Vegetable Processing, Avignon, Franciaország, pp. 98, 2011
5. SZIGETI M., BOÓR A., NEMESTÓTHY N., BÉLAFI-BAKÓ K.: Effective and mild osmotic distillation membrane distillation process with cascade operation, The 6<sup>th</sup> Membrane Conference of Visegrád Countries, Permea, Varsó, Polish Academy of Sciences, pp. 9, 2013
6. BOÓR A.: Kőkényből és húsos somból készített gyümölcslevek koncentrációja kéméletes ozmotikus - és membrán desztillációs eljárással, Konzervipari Napok, Nagykőrös, 2012
7. BOÓR A.: Kőkény és húsos som gyümölcslevek kezelése membrán szeparációs műveletekkel, Műszaki Kémiai Napok, Veszprém, pp. 185, 2011
8. BOÓR A., BÉLAFINÉ BAKÓ K.: Antioxidáns tartalom meghatározása kőkény (*Prunus spinosa* L.) és húsos som (*Cornus mas* L.) gyümölcsökben, Műszaki Kémiai Napok, pp. 55-58, 2010