

Membrane Technology

A Practical Guide to Membrane Technology and Applications in Food and Bioprocessing

Z. F. Cui

S. Muralidhara

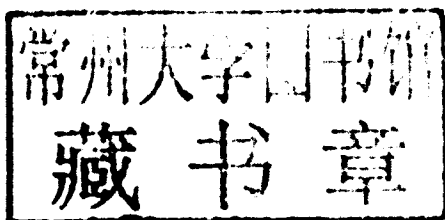


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A Practical Guide to Membrane Technology
and Applications in Food and Bioprocessing

Edited by

Z.F. Cui and H.S. Muralidhara



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Membrane Technology

Separation and purification are key to many manufacturing processes in the food, bio-processing and pharmaceutical industries. Furthermore, these processes are becoming increasingly important for the growth of industries such as bioenergy, biotechnology and nanotechnology. The multiple steps involved in separation/purification processing often require substantial up-front capital and significant operating costs. Thus the efficiency and productivity of separation technology can be critical to both the profitability and sustainability of an enterprise.

Recent developments in membrane technology, especially the development of novel membrane processes, are the most growing areas of process technology. There are several excellent books published in the general areas of membrane science and membrane technology, but there is minimal focus on the applications of membrane technology in food and pharma areas, even though they have grown steadily during the last two decades. For example, one of the major applications in the food industry is the use of reverse osmosis membranes to extend the evaporation capacity and reduce the overall energy costs, thus lowering the carbon footprint for the overall process.

The idea for this book, which focuses on the practical applications of membranes in food and bioprocessing, came out of a North American Membrane Society (NAMS) meeting in Chicago, Illinois, USA, in 2006, when both editors held a workshop on “Fundamentals and Applications of Membrane Technology in Food/Bio-processing”. With our combined experience in food technology and bioprocessing, we felt that a book dedicated to the practical aspects and challenges of utilizing membranes effectively in an industrial setting would be an extremely useful tool for any one in membrane processing and practice. The idea gained even more momentum when Elsevier conducted a market study and subsequently expressed its interest in publishing a book on the topic.

In many ways editing this book has been a privilege and a unique experience. Thanks firstly to our excellent contributors without whose support, this book would not have materialized. It is most fitting that this technological work is published from contributors around the globe and is founded on the spirit of free enquiry coupled with hard work and imagination. It has indeed been a great pleasure to be in touch with all contributors during the last 3 to 4 years. Thanks also for their patience and understanding.

We would be utterly remiss if we did not acknowledge those people who have provided us with the inspiration, motivation and never-ending encouragement throughout the course of this work.

Dr Murali would like to acknowledge Mr Ronald Christenson, former Chief Technology Officer, Cargill Inc; his wife Ponnamma; his children Shubha and Shilesh, their spouses Chuck Harris and Nupur Parikh and his two lovely grandchildren Reya and Azad; all his teachers and mentors during his entire career; and his parents who would have been both excited and extremely proud to see this book published.

Dr Cui wishes to thank his wife, Dr Jing Yu, for her unreserved support over decades, his mother for her love, and his children, Jenny and Michael, for “keeping him happy”. He would like to thank those who inspired and encouraged him to embark on a career in the “membrane world”. Such a list would be long, and here just name a few: Tony Fane, John Howell, Norman Li and Bill Eykamp.

In setting our goal of bringing this book to fruition, we kept in mind these words from Robert Frost in *The Road Not Taken*:

*“Two roads diverged in a wood and I-
I took the one less travelled by,
And that has made all the difference”*

ZFC and HSM

About the Editors

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Fundamentals of Pressure-Driven Membrane Separation Processes

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1.1 INTRODUCTION

Membrane processes are one of the fastest growing and fascinating fields in separation technology. Even though membrane processes are a relatively new type of separation technology, several membrane processes, particularly pressure-driven membrane processes including reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF), and microfiltration (MF), are already applied on an industrial scale to food and bioproduct processing.

The concept of membrane processes is relatively simple but nevertheless often unknown. Membranes (*lat.: membrana = thin skin*) might be described as conventional filters (like a coffee filter) but with much finer mesh or much smaller pores to enable the separation of tiny particles, even molecules! In

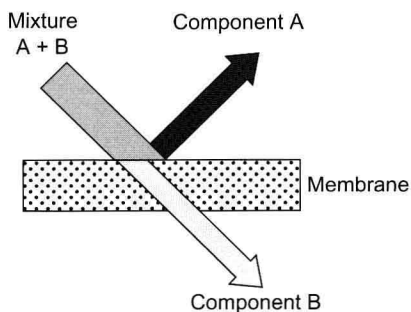


FIGURE 1.1 Basic principle of porous membrane processes. (Above is idealized; complete separation is not achieved in practice.)

general, one can divide membranes into two groups: porous and nonporous. The former group is similar to classical filtration with pressure as the driving force; the separation of a mixture is achieved by the rejection of at least one component by the membrane and passing of the other components through the membrane (see Fig. 1.1). However, it is important to note that nonporous membranes do *not* operate on a size exclusion mechanism. It should be pointed out that this chapter focuses on pressure-driven membrane processes using porous membranes for its close relevance to food and bioproduct processing.

Membrane separation processes can be used for a wide range of applications and can often offer significant advantages over conventional separation such as distillation and adsorption since the separation is based on a physical mechanism. Compared to conventional processes, therefore, no chemical, biological, or thermal change of the component is involved for most membrane processes. Hence membrane separation is particularly attractive to the processing of food, beverage, and bioproducts where the processed products can be sensitive to temperature (vs. distillation) and solvents (vs. extraction).

1.2 PROCESSES

1.2.1 Process Classification

There are four major pressure-driven membrane processes that can be divided by the pore sizes of membranes and the required transmembrane pressure (TMP): MF (0.1–5 μm , 1–10 bar), UF (500–100,000 Da, 1–100 nm, 1–10 bar), NF (100–500 Da, 0.5–10 nm, 10–30 bar), and RO (<0.5 nm, 35–100 bar). Figure 1.2 presents a classification on the applicability of different membrane separation processes based on particle or molecular sizes. RO process is often used for desalination and pure water production, but it is the UF and MF that are widely used in food and bioprocessing.