# CHAPTER III

# LITERATURE REVIEW

## 3.1 Bacterial cellulose membrane

Bacterial cellulose was produced by *Acetobacter* species, displays unique properties, including high mechanical strength, high water absorption capacity, high crystallinity with an ultra-fine, and highly pure fiber network structure. It is expected to be a new commodity biochemical with diverse applications, if its mass production process could be improved, especially via submerged fermentation technology. It has already found application as a food matrix (nata de coca) and as dietary fiber, as a temporary dressing to heal skin burns, as an acoustic or filter membrane, as ultra-strength paper and as a reticulated fine fiber network with coating, binding, thickening and suspending characteristics.

Dubey et al. (2002) studied pervaporation of binary water-ethanol mixtures through bacterial cellulose membrane. The permeate flux, selectivity, PV separation index (PSI), solubility, and degree of sorption were studied as a function of increasing ethanol concentration in the feed. From this studied, it was found that as the water content in the feed mixture increased, the degree of sorption (Q) also increased. It indicated that the membrane was a hydrophilic membrane. Similarly at concentration of water did not exceed 60 wt%, increasing water concentration in the feed, the flux increased; however, the selectivity decreased. If the concentration of water exceed 60 wt%, a reversal in the phenomenon occurs, viz., the flux decreased with slightly increased in the selectivity.

Pandey et al. (2005) studied on pervaporative characteristics of bacterial cellulose membrane. Five binary mixtures systems were chosen, Ac/$H_2O$, HCHO/$H_2O$, EtOH/$H_2O$, EG/$H_2O$, Gly/$H_2O$ for the study of permeate flux, selectivity, pervaporation separation index (PSI), solubility, and degree of sorption as a function of increasing concentration of organics in the feed. Gly/$H_2O$ binary mixtures system showed the highest selectivity and degree of sorption but the lowest flux. The highest flux but lower selectivity was observed in EtOH/$H_2O$ binary mixtures system. From studying influenced of temperature for EtOH/$H_2O$ binary mixtures system, it was found that temperature increased, the flux also increased but the selectivity decreased.

## 3.2 Alginate membrane

Among the hydrophilic polysaccharide type polymers, alginate membrane has gained special interest for pervaporation system because it showed the highest flux and separation factor. However, a very high hydrophilicity of alginate resulting from both of its carboxyl and hydroxyl groups, leads to a significant swelling of membrane in aqueous solution, followed by a remarkable decline of selectivity and mechanical strength. To overcome these drawbacks, several researchers have modified the alginate membranes for the effective dehydration performance (Kalyani et al., 2008).

Kanti et al. (2004) studied dehydration of ethanol through blend membranes of chitosan and sodium alginate by pervaporation. This membranes made by blending 84% deacetylated chitosan and sodium alginate biopolymers followed by crosslinking with glutaraldehyde. The blend membrane had more the tensile strength at break than either chitosan or sodium alginate. The enhancement attributed to the ionic-crosslinking of membrane.

Kalyani et al. (2008) studied pervaporation separation of ethanol–water mixtures through sodium alginate membranes. A sodium alginate dense membrane was prepared by the casting and drying of sodium alginate solutions on an acrylic plate, followed by crosslinking with phosphoric acid. The results of this work showed that the membrane containing 3 wt% of sodium alginate showed the highest selectivity of 2,182 with a substantial flux of 0.035 $kg/m^2$ h. With the increasing feed water concentration, the membrane performance was found to be affected substantially by increase in the extent of swelling of the polymer, which resulted in a rise in flux but a reduction in selectivity.

## 3.3 Other membranes

In the recent years, a significant development of membranes in the pervaporation of the ethanol-water mixture has been reported.

Shieh et al. (1998) studied chitosan/n-methylol nylon 6 blend membranes for the pervaporation separation of ethanol-water mixtures. Blend membranes of chitosan and n-methylol nylon 6 were prepared by solution blending. The permeability as a function of the feed concentration for the chitosan membrane had a different trend from the n-methyllol nylon 6 membrane. The permeability of the chitosan membrane decreased with increasing ethanol concentration, whereas the permeability of the n-methyllol nylon 6 membrane increased. The blend membranes had the opposite influence on pervaporation performance at the feed solution of high and low water content (90 and 5 wt%). At a feed solution of high water content, the permeability increased with an increase in chitosan content and showed a maximum separation factor at the chitosan content around 60 wt%. At the feed solution of low water content, the permeability decreased, while the separation factor increased, with an increase in chitosan content.

Chen et al. (2001) studied pervaporation separation water/ethanol mixture through lithiated polysulfone membrane. The separation performance of water and ethanol strongly depended on the degree of lithiation of polysulfone membrane. The water permeation rate decreased but separation factor increased with increasing the degree of lithiation of polysulfone membrane up to 0.75. Beyond the degree of substitution 0.75, the permeation rate increased but separation factor decreased with increasing the substitution. The effect of lithiation on separation performance was due to the improvement of diffusion selectivity lithiated membrane.

Jiratananon et al. (2002) studied pervaporation dehydration of ethanol-water mixtures with chitosan/hydroxyethylcellulose (CS/HEC) composite membranes. Composite hydrophilic pervaporation membranes were prepared from chitosan blended with hydroxyethylcellulose using cellulose acetate as a porous support. The results of this work showed that an increase of temperature, feed flow rate and feed concentration enhanced flux but reduced separation factor. Operating the pervaporation system at low permeate pressure could increase both flux and separation factor.

Nomura et al. (2002) studied selective ethanol extraction from fermentation broth using a silicalite membrane. From the comparison of the pervaporation of ethanol solution with that of the fermentation broth, it was found that the separation factor from the fermentation broth was much higher than that from ethanol solution. The ethanol flux from ethanol solution and fermentation broth are almost same, while the water flux from fermentation broth are less than those from ethanol solution.

Ahn et al. (2006) studied pervaporation of an aqueous ethanol solution through hydrophilic zeolite membranes. The effect of a concentration of ethanol at the feed side and temperature were studied on the permeation flux and the separation factor of water with respect to ethanol. The separation factor obtained with the NaA zeolite membrane was found to be 1,000 times larger than that obtained with the NaY zeolite membrane. However, the water flux through the NaA zeolite membrane was observed to be lower by 1/2 through the NaY zeolite membrane. The water flux significantly increased as the temperature increased for both the NaA and the NaY zeolite membranes. However, for feed with ethanol concentration below 80 wt% the ethanol flux was not much changed through the NaA zeolite membrane as the temperature increased. On the other hand, the ethanol flux through the NaY zeolite membrane rapidly increased even below 80 wt% of ethanol as temperature increased.

Li et al. (2006) studied Chitosan-poly (vinyl alcohol)/poly (acrylonitrile) (CS–PVA/PAN) composite pervaporation membranes for the separation of ethanol–water solutions. The results of this work showed that the degree of swelling in water decreased rapidly and the degree of swelling in ethanol seems to remain the same with the increase of ethanol concentration in the feed solution. In addition, the degree of swelling in water was larger than in ethanol. Therefore, these membranes had a greater interaction with water than with ethanol. Furthermore, ethanol concentration in the CS-PVA/PAN composite membrane was less than CS homogeneous membrane. This illustrated that the CS-PVA/PAN composite membrane was more suitable than the CS homogeneous membrane for the separation of ethanol-water.

Chen et al. (2007) studied pervaporation and characterization of chitosan membranes crosslinked by 3-aminopropyltriethoxysilane. Chitosan–silica hybrid membranes (CSHMs) were prepared by chitosan (CS) crosslinked with 3-aminopropyl-triethoxysilane (APTEOS). The results showed that there were strong hydrogen bond and covalent bond formed in the CSHMs matrix. The crystallinity of the CSHMs was lower than CS, and silica was well distributed in the CSHMs matrix. The CSHMs exhibited a low degree of swelling in ethanol/water mixture. Both the solubility and diffusion selectivity increased with increasing ethanol content. The rate of increase in the solubility selectivity was faster than the rate of decrease in the diffusion selectivity with increasing the feed temperature. These caused the permeate ethanol content to decrease with increasing either the feed ethanol content or the feed temperature. Both the permeation flux and water permselectivity increased with increasing APTEOS content.

**Table 3.1** Studies on pervaporation of ethanol-water mixtures

| No. | Membrane | Ethanol in feed (%) | thickness (μm) | Permeate pressure (mmHg) | Temperature (°C) | Total flux ($g/m^2h$) | Selectivity | Reference |
|---|---|---|---|---|---|---|---|---|
| 1 | BC | 70 | 100 | 1 | 70 | 112 | 287.0 | Dubey et al. (2002) |
| 2 | BC | 60 | 80 | 1 | 35 | 614 | 12 | Lokesh et al. (2004) |
| 3 | BC | 95 | 80 | 2 | 24 | 750 | 1.6 | Dubey et al. (2005) |
| 4 | CS/BC | 95 | 200 | 2 | 24 | 214 | 9.2 | Dubey et al. (2005) |
| 5 | CS/HEC | 95 | 110 | 3 | 60 | 220 | 16,606.0 | Jiraratananon et al. (2002) |
| 6 | CS/MN6 | 95 | 10 | 3 | 60 | 350 | 560.0 | Shieh et al. (1998) |
| 7 | SA/GL | 90 | - | - | 40 | 290 | 120.0 | Yeom et al. (1996) |
| 8 | CS/SA | 95 | 25 | 0.05 | 30 | 550 | 436.3 | Kanti et al. (2004) |
| 9 | P/SA | 95 | 70 | 0.5 | 30 | 240 | 2182.0 | Kalyani et al. (2008) |

BC = Bacterial cellulose membrane, CS = Chitosan, HEC= Hydroxyethycellulose, MN6= *N*-methylol nylon 6 membrane, SA = Sodium alginate, GL=Glutaraldehyde and P= Phosphoric acid