EFFECT OF MONOSODIUM GLUTAMATE ADDITIVE ON PERFORMANCE OF DIALYSIS MEMBRANE

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ABSTRACT

A novel dialysis membrane with monosodium glutamate (MSG) as an additive has been fabricated and its performance evaluated in terms of urea clearance. Nine formulations of casting solutions had been designed with 20% cellulose acetate, and different ratio of formic acid/MSG. The result shows that MSG based membrane with the 6 wt% of MSG, achieved the best urea clearance, 53.20%. SEM images illustrated that the increment of MSG in casting solution tend to promote macrovoids formation and finally transit to finger like structure. However, when the amount of MSG is further increased beyond 6 wt%, the urea clearance reduced and the macrovoids structure disappeared. Thus, enlarged finger like structure favors the dialysis process.

Key words: Dialysis membrane, monosodium glutamate, cellulose acetate.

1. INTRODUCTION

The demand for dialysis membranes in Malaysia is increasing in the future. According to New Straits Times on 15 September 2006, Malaysia government spends more than RM500 million annually for patients with kidney problems and 70% of the expenditure are for patients, undergoing dialysis treatment. Nevertheless, the dialysis technology in Malaysia is still dependent very much depends on foreign countries.

Recently Idris et al., 2006, studied the effect of different molecular weight PEG additives on cellulose acetate asymmetric dialysis membrane performance and the results revealed that low concentration of PEG, less than 5 wt% in the dope solution strongly enhanced the urea clearance while too concentration amount of additives more than 10% reduced the membrane performance. In this study, only PEG is used as additives.

Effect of dialysis dose and membrane flux on mortality and morbidity among patients had been studies by Eknoyan et al., 2002.There are 15 clinical centers associated with 72 participating dialysis units involved in this study. The results indicate that neither an increased dose of dialysis nor use of high flux membrane improves the mortality and morbidity among patients. However, it also reduces hospitalization rate or maintains serum albumin levels when compared to a standard dose and use of low flux membrane. Besides, the total urea clearance is similar for both low flux and high flux dialysis treatment. But, Eknoyan et al., 2002 did not mention the types of used membranes in dialyzers; it may influence the survival rate.

Based on the research done by Liu et al., 2003, it was found that the bore liquid composition had a clear influence on BSA retention and pore size of polyethersulfone (PES) membrane with PEG 400 as an additive. 100% BSA retention is achieved when pure water or bore liquid with 30%PEG and 70% water is used. The increment of NMP and PEG in bore liquid reduces the diffusion rate of the water, and thus promotes the presence of larger pore presence. However, these membranes were not tested in terms of urea clearance.

Based on literature reviews, PVP and PEG are the most favorable additives in membrane fabrication due to the hydrophilic characteristic (Idris et al., 2006; Kim et al., 1998; Qian et al., 2007). Monosodium glutamate (MSG) is a well known as a food additive, highly hydrophilic due to the hydroxyl group in the structure, easy to get and cheap. However, the effect of MSG had not been studied in membrane performance. Thus, objective of this study is to investigate the influence of MSG as an additive in the membrane's morphology and the performance of the membranes are evaluated on the urea clearance.

2. THEORY

2.1 DIFFERENT PREPARATION PARAMETERS AND THEIR EFFECTS ON MEMBRANE MORPHOLOGIES AND PERFORMANCE

According to Strathmann, 1985 the performance and morphologies of membrane is affected by

- the selection of the polymer-solvent-bore liquid system
- the effect of additives
- polymer concentration in the casting solution

2.1.1 The selection of polymer-solvent-coagulant system

The selection of the polymer-solvent-bore liquid affects the morphologies of membrane can be explained in term of solubility. When the solubility parameter disparity of solvent and polymer is smaller, the compatibility of solvent and polymer is better but a longer time is required to remove the solvent from the polymer structure. Thus, the precipitation of the polymer becomes slow. As a conclusion, if all other parameters are kept constant, the tendency for change from a sponge to a finger structure membrane increases when the compatibility of solvent and polymer decrease. The same phenomena occurred for the compatibility between polymers and bore liquid (Strathmann, 1985).

The solvent-bore liquid interaction is also an important parameter in determining the morphologies of membrane. When the system which have a large mixing heat of a solvent and precipitant, precipitation rates become high and a tendency to form finger-structured membranes increase (Strathmann, 1985).

2.1.2 The effect of additives

The effect of additives to the casting solution or bore liquid on the membrane structure depends on how far the additives affect the precipitation rate. If the additives in the casting solution increase the rate of precipitation, finger structure is favorable. But, if the additives, for instance benzene is present in the casting solution, it will tend to reduce the rate of precipitation and therefore favor a sponge structure (Strathmann, 1985).

2.1.3 The effect of the polymer concentration in the casting solution on the membrane structure.

A low polymer concentration in the casting solution tends to precipitate forming a finger like structure whilst high polymer concentration tends to form a sponge-structured membrane. These phenomena can be explained by the initiation and propagation of fingers. When the polymer concentration is high in the casting solution and thus produces a higher polymer concentration at the point of precipitation, it will tend to increases the strength of the surface layer of polymer first precipitated, and finally tend to prevent initiation fingers. The increasing viscosity of the casting solution has the same effect (Strathmann, 1985).

3. EXPERIMENTAL

3.1 MATERIALS

Cellulose acetate with the average molecular weight of 30,000 Da (Sigma–Aldrich) was used as the membrane-forming polymer. The solvent used is formic acid with analytical purity of 85% (Merck Co.) and distilled water was used as coagulant. Monosodium glutamate (MSG) was used as the additive. Experiments were performed using urea with molecular weight of 60.02 obtained from Sigma–Aldrich. Urea Nitrogen Rate Reagent Set (Eagle Diagnostics) had been used to analyze the urea concentration.

3.2 PREPARATION PROCESS

The dope solutions with the composition as shown in Table 1 were prepared by continuous stirring in polymer reaction vessel. Digit sense temperature controller was used to control the temperature. The temperature of the dope solution was kept at 70°C with continuous stirring so as to dissolve the cellulose acetate (CA) and monosodium glutamate (MSG) in 85% formic acid (FA). Dissolution time takes 4 hours.

TABLE 1. Composition of Dope Solutions

No	CA (wt %)	FA (wt %)	MSG (wt %)
A	20	80	0
1	20	79	1
2	20	78	2
3	20	77	3
4	20	76	4
5	20	75	5
6	20	74	6
7	20	73	7
8	20	72	8

3.3 MEMBRANE CASTING

Membrane is casted by using a casting knife of 200 μm thickness. The cast polymer solution film is immersed into a water bath for complete the phase separation. After that, membranes are post treated by hot water (90°C) in a beaker, followed by immersion in methanol to remove excess formic acid.

3.4 MEMBRANE TESTING

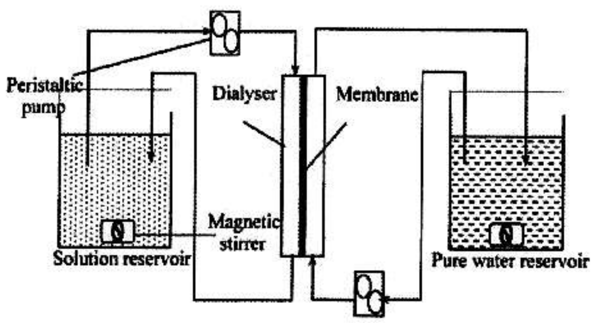


FIGURE 1. Schematic diagram of single membrane dialysis system, Idris et al., 2006

The figure above shows the test system used to evaluate the performance of the dialysis membrane in terms of urea clearance The flow rate of the testing solution on the reservoir side was maintained at 50 mL/min while on the pure water reservoir side was maintained at 100 mL/min. The temperature is maintained at 37±2°C by using Digi-sense temperature controller, which is around the human body temperature. Samples are collected at both reservoirs at 30 min intervals for 3.5 hours. Then, the urea concentrations of the samples are measured by Urea Nitrogen Rate Reagent Set (Eagle Diagnostics). The formulation of membrane which achieved the best urea clearance was then tested with BSA.

3.5 SCANNING ELECTRON MICROSCOPE (SEM)

Cross section image of the flat sheet dialysis membrane would be obtained using SEM Model SUPRA 35VP. The membranes would be snapped under liquid nitrogen, which generally will give a consistent and clean cut. To obtain better image resolutions, membrane is then sputter coated with thin film of gold. The membrane was mounted on a brass plate using double sided adhesion tape in a lateral position.

4. RESULTS AND DISCUSSION

4.1 MEMBRANE PERFORMANCE IN TERM OF UREA CLEARANCE

The results in terms of urea clearance of the membrane prepared are tabulated in Table 2. The table showed that the increment of MSG in dope solution improved the dialysis membrane performance in terms of urea clearance. It believed that the MSG, a hydrophilic additive played a key role in changing the membrane performance. As the concentration of MSG in the casting solution increases, the solute clearance increases, but up to a certain point. This observation is totally in contrast with several previous studies by Baker, 2006 and Idris et al., 2006, where high amounts of hydrophilic PEG additives, deteriorate the performance of dialysis membranes.

TABLE 2. Experiment Result

Number of Dope Solution	Cellulose acetate (wt %)	Formic acid (wt %)	Monosodium glutamate (wt %)	Urea clearance (%)
A	20	80	0	48.73
1	20	79	1	19.15
2	20	78	2	27.90
3	20	77	3	30.43
4	20	76	4	36.17
5	20	75	5	39.02
6	20	74	6	53.20
7	20	73	7	46.93
8	20	72	8	38.11

This can be explained by SEM cross section images in Fig 3 and Fig 4. The addition of 2 wt% MSG apparently promotes the formation of macrovoids within the support layer as depicted in Fig 4 (a). When the concentration of MSG increases to 4wt% and 6 wt%, the macrovoids structure disappears and formation of finger like structure seem to occur as depicted in Fig 4(b) and (c). The SEM pictures also reveal that the size of the finger like structure seems to be enlarged as the amount of MSG increases from 4wt% to 6wt%. From the result of urea clearance, this enlarged finger like structure seems to be favorable in dialysis process. However when the concentration of MSG is reaches beyond 6wt% the finger like structure disappears and thus, the solute clearance decreased. The results indicate that the optimum concentration for the MSG is 6wt%. In addition, it is also observed that the skin layer thickness decreases when the concentration of MSG reaches 6wt% concentration. This explains for the excellent performance at 6wt% MSG concentration. The urea clearance achieved is 53.20%. Compared to previous work done by Idris et al., 2006 using also cellulose acetate dialysis membrane containing PEG additives, the highest urea clearance obtained was only 40.37%.. Barzin et al., 2006, achieved 48% urea clearance with their polysulfone membranes containing PVP additives. This study thus reveals that MSG based membrane could be an attractive alternative additive due to the high solute clearance attained.

Apparently the addition of MSG has an influence on both the morphology of membranes. A very dense spongy structure is observed when no MSG is used as depicted in Fig 3. However, small amount of MSG (1 wt% to 6 wt%) added seem to promote instantaneous demixing forming finger like structure which seems to be favorable in dialysis membranes. The MSG seems to encourage the mechanism of phase inversion transit from delayed demixing to instantaneous demixing, consequently promotes the formation of macrovoids and finger like structures. On the contrary, when high amounts of MSG (8 wt%) was added into casting solution, MSG seem to promote delayed demixing, hence spongy structure obtained as illustrated in Fig 4(d).

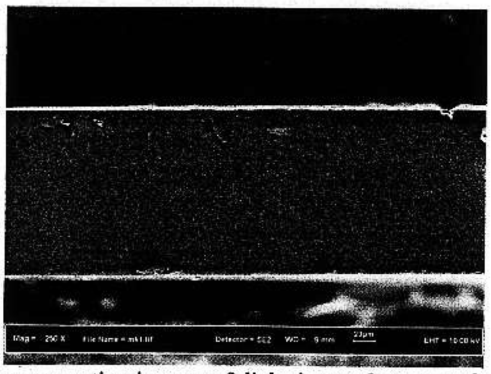
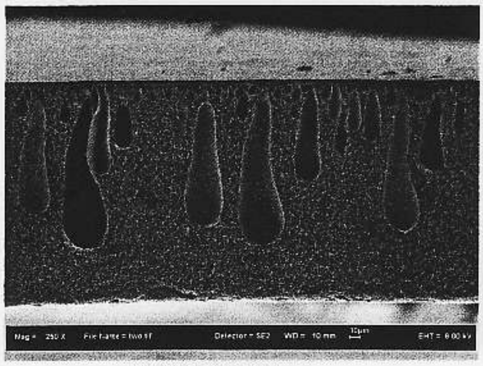
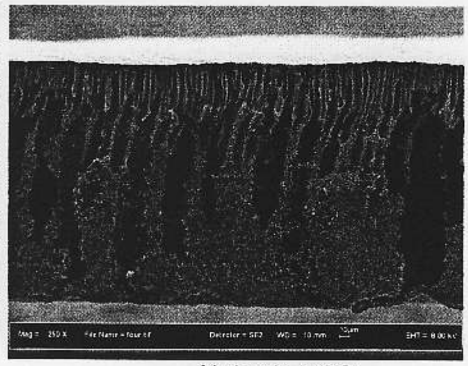


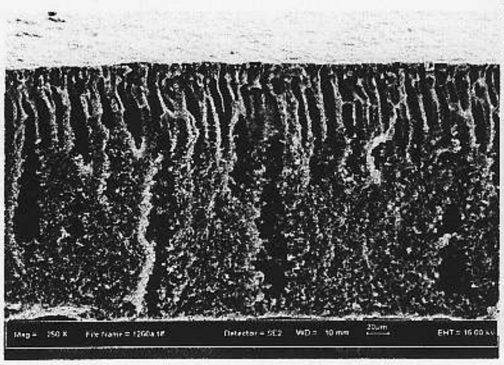
FIGURE.3. SEM cross-section images of dialysis membrane produced without MSG



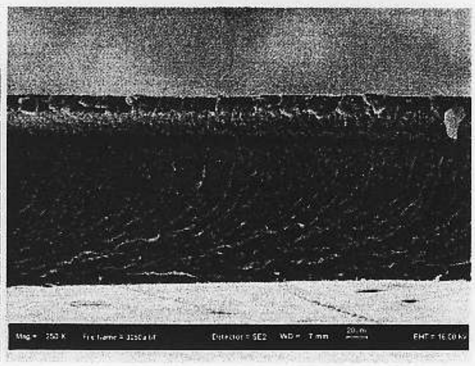
a) 2 wt% MSG



b) 4 wt% MSG



c) 6 wt% MSG



d) 8 wt% MSG

FIGURE 4. SEM cross-section images of dialysis membrane produced: (a) 2 wt% MSG; (b) 4 wt% MSG; (c) 6 wt% MSG and (d) 8 wt% MSG

Previous study by Smolders et al., 1992 reported that the occurrences of macrovoid can be explained by nucleation theory where macrovoids formation is dominated by the ratio of influx of the coagulant liquid (nonsolvent) and the influx of solvent from casting solution into the nonsolvent droplet in casting solution. It is possible that MSG in casting solution promotes the formation of nuclei with high solvent concentration. Thus the size and the number of macrovoids increased as the amount of MSG increase in casting solution. However, when the concentration of additives is too high, the viscosity of dope solution increased. Hence, when concentration of additives goes beyond 6wt%, the influx of the solvent (formic acid) from polymer solution into the nonsolvent droplet decreased. The absent of nuclei with high solvent concentration resulting a spongy like structure. Results seem to suggest that macrovoids are favorable in dialysis process shown by the increase in urea clearance in Table 2

5. CONCLUSION AND RECOMMENDATION

The effect of MSG as an additive on performance of flat sheet dialysis membrane has been investigated. MSG-based membrane achieved the best urea clearance of 53.20% with 6 wt% MSG. The membrane performance deteriorated when the MSG is further increased beyond 6wt%. MSG can be considered as a complicated modifier for membranes, as it's capability to promote either instantaneous demixing or delayed demixing is strongly dependent on the concentration of MSG in the dope solution. Based on the results of urea clearance, MSG can be considered as a good additive to fabricate dialysis membrane. Thus, further research on the use of MSG as an additive for other polymers, such as PES and PS can be considered.

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