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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, 53.2%. SEM images illustrated that the increment of MSG in casting solution tends to promote macrovoids formation and finally transits 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 very much dependent on foreign countries.

Recently Idris et al [1], 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, enhanced the urea clearance. However when the concentration of PEG was further increased to greater than 10 wt%, the membrane performance deteriorated. In this study, only PEG was used as additives.

Effect of dialysis dose and membrane flux on mortality and morbidity among patients had been studied by Eknoyan et al [2]. There are 15 clinical centers associated with 72 participating dialysis units involved in this study. The results indicated that neither an increased dose of dialysis nor use of high flux membrane improved the mortality and morbidity among patients. However, the results showed that the hospitalization rate was reduced and the serum albumin level was maintained when compared to the standard dose and use of low flux membrane. The total urea clearance was similar for both low flux and high flux dialysis treatment. But, Eknoyan et al [2] did not mention about the type of membranes used in the dialyzers that might influence the survival rate.

Based on the research done by Liu et al [3], it was found that the bore liquid composition had an influence on BSA retention and pore size of polyethersulfone (PES) membrane with PEG 400 as an additive. 100% BSA retention was achieved when pure water was used as the bore fluid. However when a mixture of 37 wt% PEG, 37 wt% NMP (N-methylpyrrolidone) and 26 wt% water was used as the bore liquid, the BSA retention achieved was only 55%. The increment of NMP and PEG in bore liquid reduces the diffusion rate of the water, and thus promotes the formation of larger pores. 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 [1, 4, 5]. Monosodium glutamate (MSG) is well known as a food additive. It is highly hydrophilic due to the hydroxyl group in the structure, easy to get and cheap. Despite of its advantages, the effect of MSG on the performance of membranes has not been studied. Thus, objective of this study is to investigate the influence of MSG as an additive on the morphology of the membrane and the performance of the membranes are evaluated base on the urea clearance.

2. Theory

2.1. Different preparation parameters and their effects on membrane morphologies and performance

According to Strathmann [6], 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

2.2. The selection of polymer-solvent-coagulant system

The selection of the polymer-solvent-bore liquid affecting 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 a change from a sponge to a finger structure membrane increases when the compatibility of solvent and polymer decreases. The same phenomena occurred for the compatibility between polymers and bore liquid [6].

The solvent-bore liquid interaction is also an important parameter in determining the morphologies of membrane. The precipitation rates become high and a tendency to form finger-structured membranes increases when a system has a large mixing heat of a solvent and precipitant [6].

2.3. The effect of additives

The effect of additives to the casting solution or bore liquid on the membrane structure depends on the extent of additives influence on 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 [6].

2.4. 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, thus forming a finger like structure. High polymer concentration on the other hand, 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, this produces a higher polymer concentration at the point of precipitation; it will tend to increase 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 [6] to form a sponge structured membrane.

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 was 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 various compositions as shown in Table 1 were prepared by continuous stirring in polymer reaction vessel. The temperature is controlled by the digital sense temperature controller. The temperature of the dope solution was kept at 70^{o}C with continuous stirring to ensure the cellulose acetate (CA) and monosodium glutamate (MSG) were completely dissolved in 85% formic acid (FA). The dissolution is completed in 4 hours.

3.3 Membrane casting

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

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

3.4. Membrane testing

Figure 1 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 were collected at both reservoirs at 30 min intervals for 3.5 hours. Then, the urea concentration of the sample was measured using Urea Nitrogen Rate Reagent Set. The formulated membrane which achieved the best urea clearance was then tested with BSA.

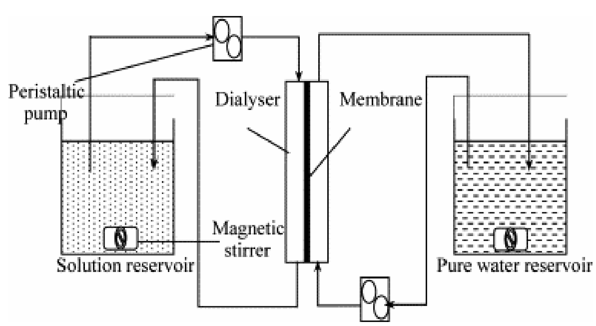


Fig. 1. Schematic Diagram of Single Membrane Dialysis System [1].

3.5. Scanning electron microscope (SEM)

Cross section image of the flat sheet dialysis membrane was obtained using SEM Model SUPRA 35VP. The membrane was snapped under liquid nitrogen to produce a consistent and clean cut. To obtain better image resolution, membrane was then sputter coated with thin film of gold before mounted on a brass plate using a double sided adhesion tape in a lateral position.

4. Results and Discussion

Membrane performance in term of urea clearance

The results in terms of urea clearance of the membranes prepared are tabulated in Table 2. The table shows that the increment of MSG in dope solution has improved the dialysis membrane performance in terms of urea clearance. It is believed that the MSG, a hydrophilic additive, has 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 in contrast with several previous studies by Idris et al [1] and Bakir [7] where high amounts of hydrophilic PEG additives, had deteriorated the performance of dialysis membranes.

Table 2. Experiment Results.

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

Figure 2 depicts the SEM cross section image of the dialysis membrane produced without any additives. A dense spongy structure without the presence of any macro void is observed. The addition of 2 wt% MSG apparently promotes the formation of macrovoids within the support layer as depicted in Fig. 3(a). When the concentration of MSG increases to 4 wt% and 6 wt% consecutively, the macrovoids structure disappears and formation of finger like structure seem to occur as depicted in Figs. 3(b) and (c) respectively. The SEM pictures also reveal that the size of the finger like structure seems to be enlarged as the amount of MSG increases from 4 wt% to 6 wt%. 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 increased to above 6 wt% the finger like structure disappears and thus, the solute clearance decreased. The results indicate

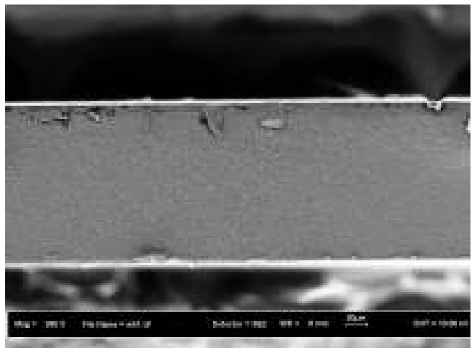
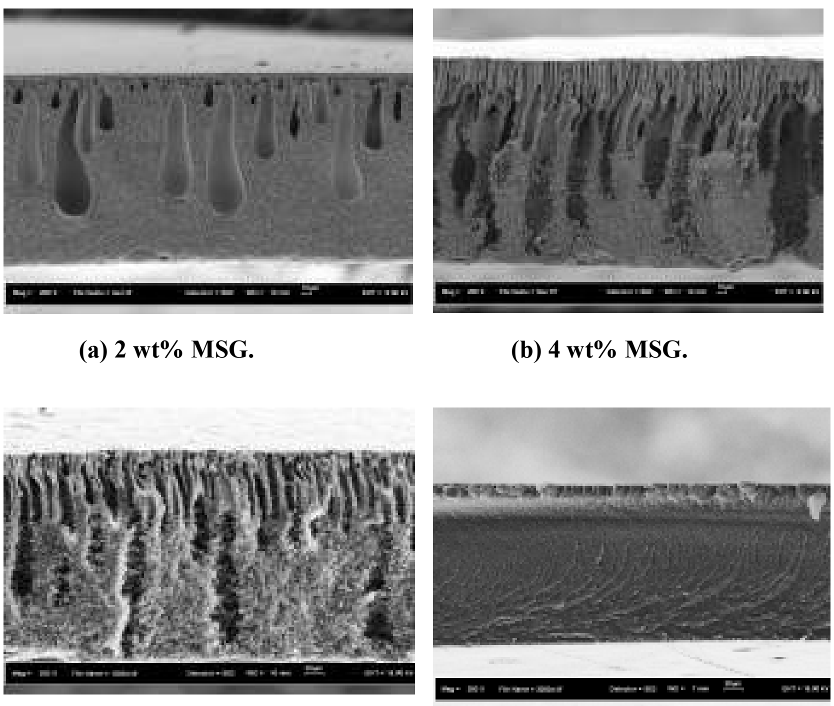


Fig.2. SEM Cross-Section Images of Dialysis Membrane Produced without MSG.



(a) 2 wt% MSG. **(b) 4 wt% MSG.**

(c) 6 wt% MSG. **(d) 8 wt% MSG.**

Fig. 3. 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.

that the optimum concentration for the MSG is 6 wt%. In addition, it is also observed that the skin layer thickness decreases when the concentration of MSG reaches 6 wt% concentration. This explains for the excellent performance of the membrane at 6 wt% MSG concentration. This membrane urea clearance has achieved 53.2% compared to the previous work done by Idris et al [1]. Their cellulose acetate dialysis membrane containing PEG additives had obtained a urea clearance of only 40.37%. Other research worker includes Barzin et al [8] achieved 48% urea clearance with their polysulfone membranes containing PVP additives. The result from the current study had revealed that MSG based membrane could be an attractive alternative additive due to the high solute clearance attained.

Apparently the addition of MSG does not only affect the performance of membranes but also 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 amounts 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 the casting solution, MSG seems to promote delayed demixing, hence the spongy structure is obtained as illustrated in Fig. 3(d).

Previous study by Smolders et al [9] 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 increased in casting solution. However, when the concentration of additives was too high, the viscosity of dope solution increased. Hence, when concentration of additive goes beyond 6 wt%, the influx of the solvent (formic acid) from polymer solution into the nonsolvent droplet decreased. The absence of nuclei with high solvent concentration promotes the spongy like structure. These results suggest that macrovoids are favorable in dialysis process as shown by the increase in urea clearance (see Table 2).

5. Conclusion

The effect of MSG as an additive on the performance of flat sheet dialysis membrane has been investigated. MSG-based membrane achieved the best urea clearance of 53.2% with 6 wt% MSG. The membrane performance deteriorated when the MSG is further increased beyond 6 wt%. MSG can be considered as a complicated modifier for membranes, as its 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.

Acknowledgements

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