

EFFECTS OF HEMATOCRIT ON FILTRATE FLUX OF MICROPOROUS GLASS MEMBRANES FOR BOVINE BLOOD

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Introduction

Microporous glass (MPG) membranes are superior to polymer membranes in resistance to heating, and thus are sterilized by autoclave or γ -rays without difficulty.³⁾ These membranes have the advantages of rare occurrence of hemolysis and excellent filtration characteristics because of their limited distribution of pore diameter.^{3,4,6)} Filtrate flux for bovine blood with a hematocrit of 30% and a protein concentration of 65 kg/m^3 increases with the pore diameter of microporous glass membranes at pore diameters of below $1 \mu\text{m}$ and remains constant at a pore diameter of above $1 \mu\text{m}$ at a wall shear rate of 2000 s^{-1} .⁵⁾ Maximal filtrate flux is reached as transmembrane pressure increases, and is then followed by a slight decrease in filtrate flux of MPG MB5 and MB10 membranes.⁵⁾

Filtrate flux for test solutions containing particles of microfiltration membranes depends on the volume ratio of the particles to the solution, which is referred to as hematocrit when formed elements-containing blood is used as a test solution. The hematocrit of bovine blood is much higher than the particle concentration in industrial microfiltration.

This paper describes effects of hematocrit on filtrate flux for bovine blood of microporous glass membranes with varying pore sizes at varying wall shear rates and

transmembrane pressures.

1. Materials and Methods

Membranes Plasma separation experiments were made with tubular MPG MB5, MB10 and MB15 membranes of pore diameters of 0.46, 0.94 and $1.49 \mu\text{m}$ respectively. The microporous glass membranes were prepared from $\text{Na}_2\text{O}-\text{B}_2\text{O}_3-\text{SiO}_2-\text{Al}_2\text{O}_3-\text{CaO}$ glass by the method of phase separation.²⁾ **Table 1** summarizes technical data for the membranes tested.

Filtration Test The authors made crossflow filtration experiments with bovine blood in an experimental apparatus shown in **Fig. 1** at a temperature of 310 K to determine the filtrate flux of the tubular microporous glass membranes. Feed was supplied with a roller pump to the membranes at transmembrane pressures ranging from 3 to 13 kPa and wall shear rates from 500 to 2000 s^{-1} . The bovine blood used has a protein concentration of 65 kg/m^3 and hematocrits of 10, 30 and 50%.

2. Results and Discussion

Figure 2 shows the effects of transmembrane pressure on filtrate flux for bovine blood with hematocrits of 10, 30 and 50% of the MPG MB15 membrane at wall shear rates of 2000, 1000, 500 s^{-1} respectively. Filtrate flux of the MPG MB15 membrane at a wall shear rate of 2000 s^{-1} increased

Table 1. Technical data on tubular microporous glass membranes

Membrane	No. of tubes	Tube length [mm]	Surface area [mm ²]	Inner diameter [mm]	Wall thickness [mm]	Porosity [%]	PWP* [mm ³ m ⁻² s ⁻¹ Pa ⁻¹]	Dp** [μm]	σg*** [—]
MPG MB5	7	150	4750	1.44	0.25	48	64	0.46	1.17
MPG MB10	7	150	4090	1.24	0.25	50	137	0.94	1.16
MPG MB15	7	150	4220	1.28	0.25	52	245	1.49	1.15

* Pure water permeability is abbreviated as PWP.

** Dp is mean pore diameter.

*** σg is the geometric standard deviation of pore diameter distribution.

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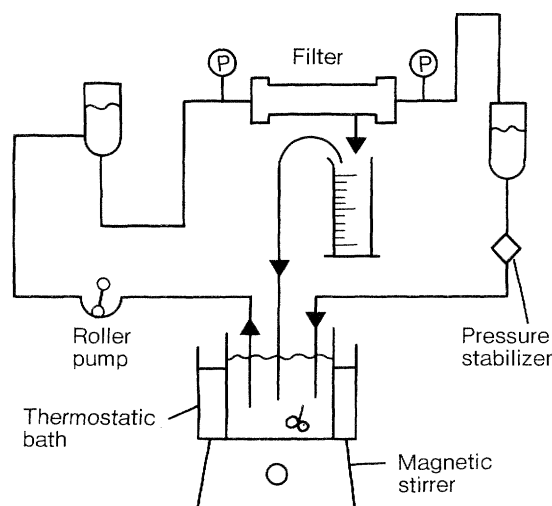


Fig. 1. Schematic of experimental apparatus for blood filtration

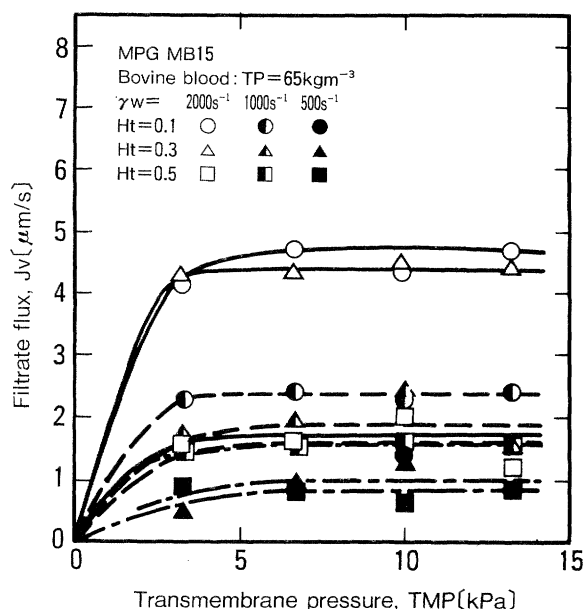


Fig. 2. Effects of transmembrane pressure on filtrate flux for bovine blood with hematocrits of 10, 30 and 50% of MPG MB15 membrane at a temperature of 310 K and wall shear rates of 500, 1000 and 2000 s^{-1}

with transmembrane pressure at transmembrane pressures below 3.3 kPa and was insensitive to transmembrane pressure at transmembrane pressures above 3.3 kPa. Figure 2 shows that filtrate flux for bovine blood with hematocrits of 10 and 30% significantly decreases with decreasing wall shear rate. Filtrate flux remained nearly constant at a hematocrit of 50% and wall shear rates of 2000 and 1000 s^{-1} . Filtrate flux decreases with decreasing wall shear rate at each hematocrit and a wall shear rate of 500 s^{-1} . Filtrate flux at a wall shear rate of 500 s^{-1} was also insensitive to transmembrane pressure at transmembrane pressures above 3.3 kPa.

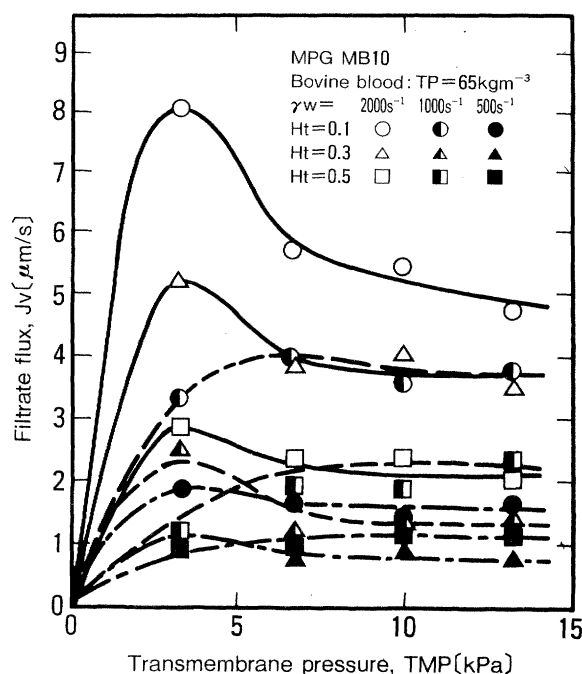


Fig. 3. Effects of transmembrane pressure on filtrate flux for bovine blood with hematocrits of 10, 30 and 50% of MPG MB10 membrane at a temperature of 310 K and wall shear rates of 500, 1000 and 2000 s^{-1}

Figure 3 shows effects of transmembrane pressure on the filtrate flux of the MPG MB10 membrane. The MPG MB10 membrane has values for filtrate flux different from those of the MPG MB15 membrane. Filtrate flux increased with transmembrane pressure at transmembrane pressures below 3.3 kPa and a wall shear rate of 2000 s^{-1} followed by slight decreases in filtrate flux at transmembrane pressures above 3.3 kPa, finally reaching a limiting filtrate flux. The ratio of maximal filtrate flux to limiting filtrate flux increased with decreasing hematocrit. Maximal filtrate flux was observed also at wall shear rates of 1000 and 500 s^{-1} except at a hematocrit of 50%. The limiting filtrate flux at each hematocrit becomes comparable to those at other hematocrits as the wall shear rate decreases.

Figure 4 shows the effects of transmembrane pressure on filtrate flux of the MPG MB5 membrane. Figure 4 shows that the MPG MB5 membrane has the same tendency as the MPG MB10 membrane at a wall shear rate of 2000 s^{-1} for maximal filtrate flux to occur, followed by a decrease in filtrate flux, finally reaching limiting filtrate flux except at a hematocrit of 50%. Filtrate flux remained constant at transmembrane pressures above 6.7 kPa. There were no differences among hematocrits in filtrate flux at a wall shear rate of 500 s^{-1} .

These results may be caused by a combination of formation of a polarization layer with red blood cells, compaction of red blood cells accumulated on membrane surfaces, and pore plugging with red blood

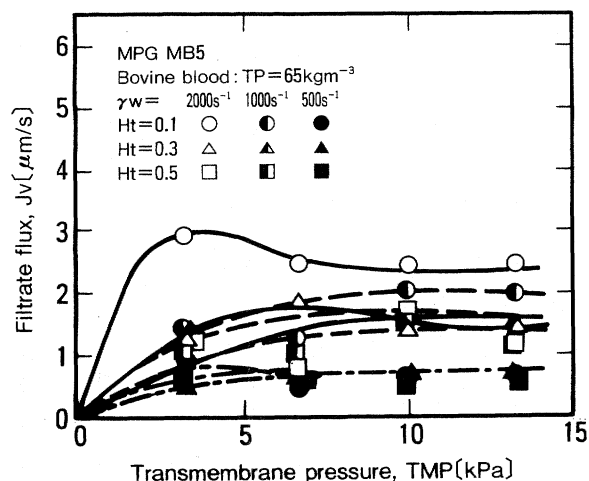


Fig. 4. Effects of transmembrane pressure on filtrate flux for bovine blood with hematocrits of 10, 30 and 50% of MPG MB5 membrane at a temperature of 310 K and wall shear rates of 500, 1000 and 2000 s^{-1}

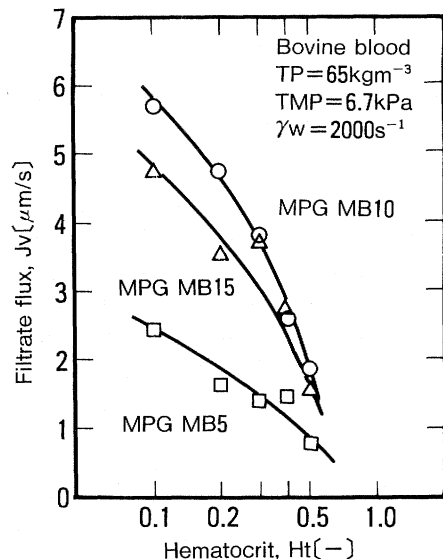


Fig. 5. Filtrate flux for bovine blood of MPG MB5, MB10 and MB15 membranes at a temperature of 310 K, a transmembrane pressure of 6.7 kPa and a wall shear rate of 2000 s^{-1} as a function of hematocrit

cells.

According to the ultrafiltration theory, filtrate flux decreases linearly with the increasing logarithm of solute concentration of feed solution.¹⁾ Figures 5 and 6 show filtrate flux data for the MPG MB5, MB10 and MB15 membranes at varying wall shear rates as a function of hematocrit. No filtrate flux decreased linearly with increasing logarithm of hematocrit at any pore diameter or wall shear rate. These results are not in accord with the ultrafiltration theory. The ratio of filtrate flux at a hematocrit of 10% to that at a hematocrit of 50% increased with wall shear rate. This indicates that the behavior of red blood cells

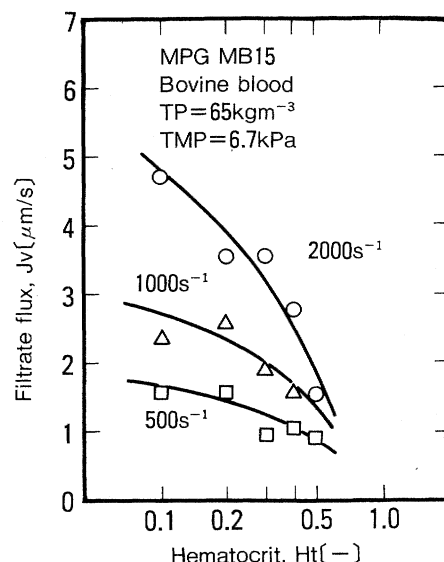


Fig. 6. Filtrate flux for bovine blood of MPG MB15 membranes at a temperature of 310 K, a transmembrane pressure of 6.7 kPa and wall shear rates of 500, 1000 and 2000 s^{-1} as a function of hematocrit

having deformability in flowing blood strongly affects filtration characteristics, which also depend on transmembrane pressure, wall shear rate, and the pore size of the microporous glass membranes.

Conclusions

Different filtration characteristics are attained for microporous glass membranes of pore diameters of 0.46, 0.94 and 1.49 μm . The ultrafiltration theory is incapable of accounting for the dependence of filtrate flux for bovine blood on its hematocrit.

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