Characterization of DNA Transport through a Semipermeable Membrane with the Effect of Surfactants

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ABSTRACT

In current advances of biotechnology, various models of introduction of DNA into cells to alter their gene expression have important biomedical and bioengineering applications. However, the molecular mechanisms underlying how DNA's cross cell and nuclear membranes are poorly understood.

Surfactants are known to influence functions of many proteins in membranes, cells and tissues; however, the natural configurations of DNA's are more stable and are expected to behave differently compared to proteins, especially proteins with smaller size. Information for surfactants on DNA transport is nearly non-existent.

We previously systematically reported how surfactants of different hydrophilicities affected three metabolically important enzymes (namely, glutamate dehydrogenase (GDH), lactate dehydrogenase (LDH), and malate dehydrogenase (MDH)) of various molecular masses and their transport behaviors through a semipermeable membrane at a pH range (6.5-7.4) and concentrations relevant to body functions. In this study, we employed a similar approach to investigate how membrane pore size, surfactant properties (anionic, cationic, size, non-ionic), pH, would affect the membrane transport of herring DNA. All these factors would modulate DNA transport to certain extent.

Results of this research study would have many implications and applications in bioengineering and cell signaling, further research is on-going and needed.

Keywords: surfactant, DNA, membrane, permeation, transport

1. INTRODUCTION

In the past years, there is an increasing interest in the application of artificial membranes with biomedical and biotechnological purposes. The idea lies in the utilization of these artificial membranes to mimic the function of biological channels, such as those found in living cells. Since most of our body functions are the result of the interactions of different membrane systems, a clear understanding of how important components (proteins, ions, or DNA) for our correct body

functions permeate through our cells, and the mechanisms to control the selectivities and permeabilities of those species across these membranes may help to design more efficient and advance membrane systems, such as those in hemodialysis, detoxification of body fluids, and artificial organs. Likewise, the pharmaceutical industry may take advantage of this knowledge in the separation of these species that they rountinely carry out.

Unlike the already published research work with respect to either DNA permeation or use of DNA to modify the permeation of certain species through a semipermeable membrane, which used DNA as driving force for the application of an external potential in order to change the permeation rate of other species; our work focused on acquiring a better understanding of surfactants effect on DNA permeation in our body functioning. Thus, since surfactants are naturally-created in our body, they may by themselves alter the DNA molecular transport in our body, leading to either beneficial or adverse health effects.

We have, systematically and stepwise, studied how 2 cationic surfactants of different molecular weight, a non-ionic, and 2 anionic surfactants of different hydrophobicities might influent the interfacial mass transport of DNA coming from herring sperm through a semipermeable, artificial membrane at three different pHs that are important to human body functions. We consider that the results obtained from this experimental approach would help to design more effective treatment applications involving either DNA alone or with other compounds, such as proteins that are having important influence on DNA.

2. MATERIALS AND METHODS

The DNA for this study of molecular transport came from Herring sperm (Sigma), the DNA contained 6.1 % of sodium. The cationic surfactants used were C-573 (low molecular weight) and C-581 (high molecular weight) (Cytec Industries, Inc.). The anionic surfactants were IB-45 (hydrophilic) and TR-70 (hydrophobic) (Cytec Industries, Inc.). Non-ionic surfactant was Triton-X 100 (Sigma). Experiments setup and surfactant concentrations were similar to studies that we previously reported [1,2].

3. RESULTS

3.1 Effect of pH

Similar to the effect that we observed for protein transport, .the DNA that we used also revealed pH differential by passive permeation; the permeation rate increased with the increase of pH value, as it is shown in Figure 1 below.

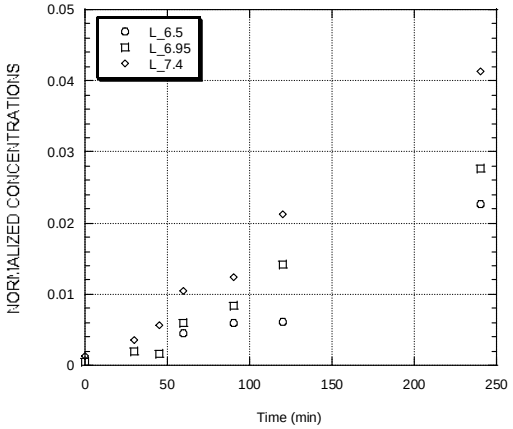

Figure 1: Effect of pH on DNA in the absence of surfactant with 1 micron membrane.

3.2 Effect of Surfactants

As shown in Figure 2, effect of surfactants to DNA permeation appeared to be random initially. This may be due to the fact that only a small amount of DNA was able to pass through the pores when 1 micron of membrane was used in the experiments, the relatively error was high in the initial measurements at time interval of less than 120 minutes. At the time interval of 240 minutes, the differential mass permeabilities were becoming more obvious. The non-ionic surfactant, Triton-X 100, appeared to impede the DNA permeability, as well as the hydrophobic surfactant, TR-70. Both cationic surfactants and the hydrophilic anionic surfactant, IB-45, increased the permeability of DNA, this observation was consistent with what we had reported for the effect of these surfactants to proteins' permeabilities: cationic surfactants behave similarly as hydrophilic anionic surfactant.

3.3 Effect of Membrane Pore Size

As shown in Figure 3, the pore size of the membrane had definitive effect to the interfacial transport of DNA. For the membrane pore size of 0.03 μ, there was no detectable DNA permeated from the high concentration cell to the low concentration cell after 240 minutes. For the pore

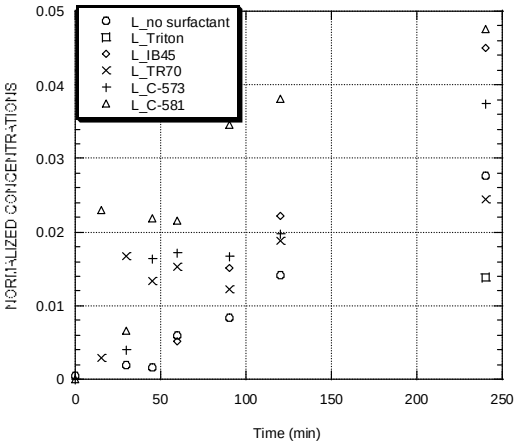

Figure 2: Effect of various surfactants on DNA permeation at pH 6.95 with 1 micron membrane.

size between 0.1 to 1 µ, the overall mass permeated from high to low concentration for the interfacial transport was about the same, although mass permeated for the membrane with the 1 µ-pore was slightly higher in spite of the fact that the pores were 10 times larger than the 0.1 µ membrane. As expected, the 5 µ membrane allowed much higher DNA permeated through the system. One might presume that the molecular radius of the DNA is much smaller than 5 µ and thus the DNA can easily pass through the membrane channels. However, the microfluidic phenomenon and how the DNA interacts with the membrane within the channel, when the pore size is minimal, remain interesting.

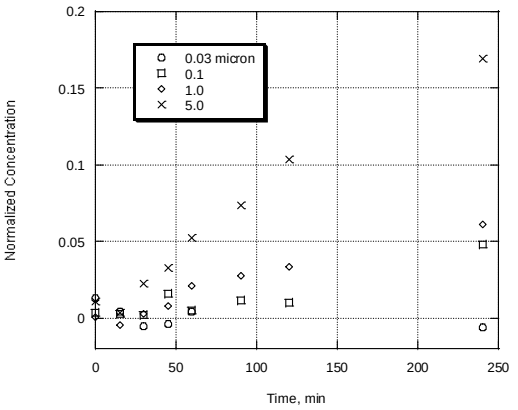

Figure 3: Permeability of DNA through different pore sizes of membrane at pH 6.95 in the absence of surfactant.

4. CONCLUSIONS

Interfacial DNA transport between cells and organs is not well understood, and is very important in tissue engineering and other bioengineering applications. Our exploration toward this interesting, yet challenging, field is just the beginning of many discoveries to be awarded.

5. REFERENCES

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