Electrically controlled Aloe-vera extraction release from polyacrylamide hydrogel

S. Niamlang[1], T. Buranut[1], A. Niansiri[1], and A. Sirivat[2]

[1]***Abstract*— *Aloin which is the active compounds that decrease pain and inflammation and stimulate skin growth and repair are selected as the model drug in this work. From the low content of active compound (<5 %v/v), the development of controlled Aloe-vera extraction system is required to increase the efficiency of drug therapeutic. The development of control-released Aloe-vera extraction, aloin from polyacrylamide hydrogel system as transdermal drug delivery patch was studied. The apparent diffusion coefficients, D_{app}, hydrogel pore size and the release mechanisms of aloin/polyacrylamide hydrogels, aloin/PAAM, were investigated in the effect of crosslinking ratio of hydrogel. The pore size of crosslinked polyacrylamide hydrogel increases with decreasing amount of crosslinker. The amount of aloin release and D_{app} increase with increasing hydrogel pore size. For larger pore size of hydrogel system, aloin can easily diffuse out than smller pore size hydrogel system. Thus, the amount of aloin released and D_{app} can be controlled by controlling the hydrogel pore sized.*

Keywords— polyacrylamide hydrogels,Aloin, diffusion coefficients, electrically controlled drug release

1. INTRODUCTION

The controlled drug release technology was interested because it is highly beneficial for controlled the drugs into the body and it can be rapidly metabolize and eliminate from the body after administration. Hydrophobic drugs are also difficult to administer because of the molecules in these drugs are not soluble in water, so they are not readily transported into the body. One of the most recent approaches to overcome this is to conceal the hydrophobic drug molecule inside a larger host molecule that is soluble in water. Hyper-branched polymers are one of substances that are used as host molecules. Polymers are generally used in many applications because of their unique properties such as low density, low cost, and process ability. If these properties could be combined with their electrical properties, this would useful in several applications[1].

Hydrogels, consisting of tri-dimensional structures formed by crosslinking hydrophilic polymeric chains, possess the ability to swell in solution in response to the chemical nature of the media, the pH, the ionic strength, the electric field, and temperature [1].

The Aloe-vera extraction (Aloin, Aloe-emodin and Aloesin) which is the active compounds that decrease pain and inflammation and stimulate skin growth and repair are selected as the model drug in this work. From the low content of active compound (<5 %v/v) in Aloe vera, the development of controlled Aloe-vera extraction system is required to increase the efficiency of drug therapeutic [2].

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In this work, the release characteristic of Aloe-vera extraction, aloin from PAAM hydrogel system was investigated at various hydrogel pore sizes in with and without applied electric field strength. The rate and amount of drug release will be controlled by controlling the hydrogel pore size. These aloin/PAAM hydrogel system might increase the therapeutic efficiency and valuable of Aloe-vera extraction.

2. METHODOLOGY

Materials

Aloein (AR grade, Fluka), was used as the model drug. Acrylamide, AAM (AR grade, Fluka), N,N′ methylenebisacrylamide, (N,N´-MBA) (AR grade, Fluka), tetramethylenediamine, TEMED (AR grade, Fisher Scientific), and ammonium peroxodisulfate (AR grade, Fluka) were used as the monomer, crosslinker, catalyst, and initiator, respectively.

Preparation of Aloein-Loaded Polyacrylamide Hydrogel (Aloein/PAAM)

The 0.2 %w/w Aloein-loaded PAAM hydrogels (based on the weight of the acrylamide monomer) were prepared by the free-radical polymerization of 2.32 g of acrylamide in an aqueous solution of Aloein with N, N′ methylenebisacrylamide (MBA) as crosslinker [3]. Ammonium persulfate and tetramethylenediamine (TEMED) were used as the initiator and the accelerator. To study the effect of crosslinking ratio on the release of Aloin from Aloein/PAAM hydrogels, gels at various crosslink ratios (mol $_{MBA}$: mol $_{AAM}$; 0.001, 0.002, 0.005, 0.010, 0.016, 0.024; PAAM_01, PAAM_02, PAAM_03, PAAM_04, PAAM_05, PAAM_0, respectivele) were prepared at various amounts of N, N′ methylenebisacrylamide (MBA).

PAAM Characterization

To study the effect of crosslinking ratio or mesh size of hydrogel on drug delivery characteristic the hydrogel mesh sizes were determined.

The hydrogel mesh size, ξ, was calculated using the following equation:

$$\xi = v_{2,s}\left[C_n\left(\frac{2M_c}{M_r}\right)\right]^{1/2} l \qquad (1)$$

where C_n is the Flory characteristic ratio for PAAM (8.8), and l is the carbon-carbon bond length (=15.4 Å) [4].

Drug Release Studies

The diffusion through a pig skin was carried out in order to study the release characteristics of the drug from a Aloin/PAAM hydrogel. A pig skin was placed on top of the acetate buffer solution on a custom built modified Franz diffusion cell. The nylon net was allowed to come into equilibrium and in contact with the acetate buffer (pH 5.5) in the receptor chamber; the buffer was magnetically stirred throughout the experiment period (48 h) at a thermostatically maintained temperature (37 ± 2 ˚C). The Aloin/PAAM hydrogel with particular crosslinking ratios (mol $_{MBA}$: mol $_{AAM}$ = 0.002, 0.005, 0.016, or 0.024) were placed between the copper cathode and the net, which was mounted onto the receptor compartment. To study the effect of electric field strength on the release of the Aloin from the Aloin/PAAM hydrogels, the cathode electrode (copper electrode) was connected to a power supply, which provided various electrical voltages across the hydrogel, the pigskin, and the buffer solution. The anode electrode pin was positioned in the buffer solution. The amount of the drug in the withdrawn solution sample was determined using a UV spectrophotometer. The experiments were carried out in triplicate and the data were reported as average values.

3. RESULTS AND DISCUSSION

PAAM characterization

PAAM was polymerized through free radicalization and subsequently crosslinked at 27 ˚C [3]. The calculated mesh sizes of PAAM hydrogel is PAAM_01, 292 ± 8 Å; PAAM_02, 183 ±16 Å; PAAM_03, 161 ± 8 Å; PAAM_04, 148 ± 3 Å; PAAM_05, 119 ± 10 Å; PAAM_06, 99 ± 2; as the crosslinking ratio decreases, the mesh size increases.

Effect of crosslinking ratio

The amount of aloin released through pigskin was reported as the amount of aloin release from aloin/PAAM as shown in Fig.2. Evidently, the amount of aloin released from aloin/PAAM through the pigskin is greater at a given time for samples with a lower crosslinking ratio as shown in Figure 1 [4].

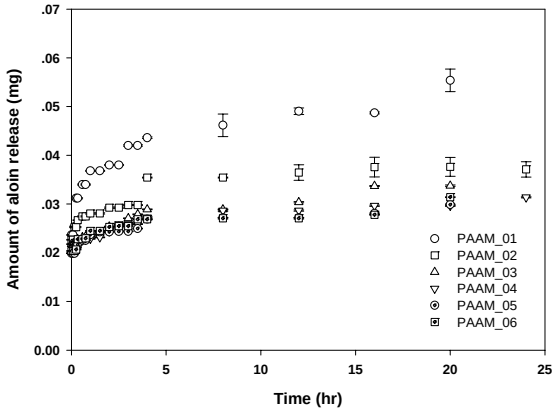

Figure 1 Amount of Aloin release from Aloin/PAAM hydrogel at time t vs. t (hr) at various crosslinking ratio, pH of 5.5, E= 0 V and at 37 ˚C.

Effect of electric field strength

Figure 2 shows the amounts of Aloin released from Aloin/PAAM versus time at various electric field strengths, 0–0.1 V. Each sample was attached to the negatively charged electrode (cathode). From Figure 2, it is evident that the amount of Aloin released from Aloin/PAAM is greater at a higher electric field strength due to three driving forces; electrostatic force, modified the pathway of pigskin and expansion of PAAM hydrogel. As the electric field was applied, the electrons push the anionic out and generate small path way in pig skin. Thus higher electric field strength, higher amount of aloin were released. The third driving force originates from the direct expansion of the PAAM hydrogel pore size due to the electric field [5].

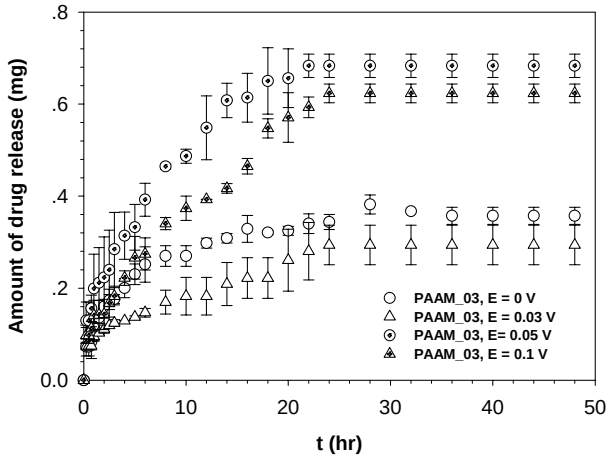

Figure 2 Amount of Aloin release from Aloin/PAAM hydrogel (PAAM_03)at time t vs. t (hr) at various electric field strength, field pH of 5.5, and at 37 ˚C.

Drug Release Kinetics

We next investigate the effects of the electric field strength on the release kinetic of Aloin from Aloin/PAAM hydrogel. Drug release kinetics can be analyzed by plotting the amount of drug released versus square root of time according to the Higuchi's equation [6,7]]

$$Q = 2C_0(Dt/\pi)^{1/2} \quad (2)$$

where Q is the amount of drug released per unit area, C_0 is the initial drug concentration in the gel, and D is the diffusion coefficient of the diffusant. In Figure 3 D_{app} of Aloin release from Aloin/PAAM hydrogels (PAAM_03) through the pigskin are plotted versus mesh size, at 37 °C as determined from data of Figure 1 and 2 using eq. 2.

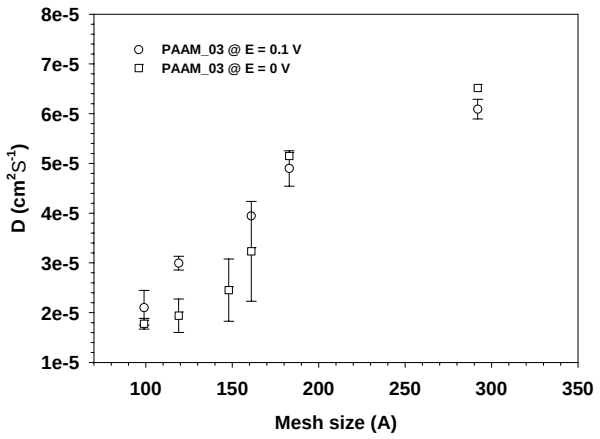

Figure 3 The apparent diffusion coefficient, D_{app} of Aloin from Aloin/ PAAM hydrogel vs. Mesh size at pH 5.5, and at 37 °C.

D_{app} of Aloin from Aloin/PAAM increase monotonically with increasing mesh size and electric field. In general, we may conclude that the diffusion coefficient of a drug in a transdermal delivery system depends on drug size, electric field (driving force).

4. CONCLUSIONS

The Aloin /PAAM hydrogels were prepared by varying the crosslinking ratio to study the release mechanisms and the apparent diffusion coefficient, D_{app}, of the aloin from Aloin/ PAAM hydrogel with and without an electric field. With the absence of electric field, the amount of aloin release increase with decreasing cronsslinking ratio due to the larger mesh size of hydrogel. Regarding the effect of electric field strength, the amountof aloin released increase with increasing electroc field strength due to three driving forces; electrostatic force, modified the pathway of pigskin and expansion of PAAM hydrogel. D_{app} of Aloin from Aloin/PAAM hydrogels system increases with increasing electric field strength and hydrogel mesh size.

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