Hydrogel film of polyethylene oxide-polypropylene glycol diacrylate for wound dressing application

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Abstract. Hydrogel polymer receives more attention in medical and other applications due to its biocompatibility properties and swelling ratio. Hydrogel has an ability to absorb and retain water, a property which is very useful for medical applications. We developed polyethylene oxide (PEO)-polypropylene glycol diacrylate (PPGDA) hydrogel film through electron beam irradiation for wound dressing application. Various compositions of PPGDA/PEO (0%, 5%, 10%, 15% and 20%) were irradiated using electron beam to obtain the optimum composition for a better hydrogel characteristic. The PPGDA content in the hydrogel film influences the level of swelling capacity, gel fraction and mechanical strength. The results show that 20% PPGDA content of hydrogel film has the highest mechanical strength (6.2 N/mm²). The composition of 20% PPGDA hydrogel film also has the highest gel fraction (79%). However, the hydrogel prepared using that composition has the lowest swelling ratio (300%). Based on the results, 20% PPGDA hydrogel film is very potential for wound dressing application with high mechanical strength and ideal water vapor transmission rate.

1. Introduction
Wound dressing accelerates wound healing and protect the wound surface. It absorbs the exudate to speed up its healing. Nowadays, hydrogel material especially hydrogel film has been used as a wound dressing materials. Hydrogel is a perfect dressing to accelerate autolytic debridement of necrosis and slough due to the ability to absorb and retain water inside [1-4]. An ideal wound dressing must initiate an appropriate environment to speed up healing process, easy to be applied, and require fewer dressing changes, so it take shorter nursing time [2]. Hydrogel film has low mechanical strength caused the limited use of this type of dressing in wound healing applications. Therefore, the hydrogel film from polyethylene oxide (PEO) and polypropylene glycol diacrylate (PPGDA) produced via electron beam irradiation is expected to have a better tensile strength and vapor transmission rate.

Various polymers can be polymerized by crosslinking to form hydrogel film [5]. Polyethylene oxide demonstrates the excellence as a good biocompatible material [6]. However, PEO hydrogel without any addition materials is easily be broken and has low tensile strength [7-9]. As a non-polar polymer, PEO shows a strong interaction with protein [10]. It has been applied for various medical applications [11, 12] and it has recently been used as a wound dressing [13-15].
PPGDA is a polymer which is soluble in water and non-hazardous to the body. It has been used in various biomedical applications, including oral insulin delivery and bone regeneration applications [16, 17]. Nevertheless, very few researches have noted the application of this polymer as a wound dressing matter.

There are several functions of an electron beam which is irradiated on the polymers, namely crosslinking, grafting and degradation [18]. Moreover, in the electron beam system, the change of the intensity of energy or dose can be run without any difficulties. Furthermore, irradiated polymers are safe and free from unwanted initiators or accelerators in the cross-linked polymers [15]. The mechanical strength of cross-linked hydrogel and the water vapor transmission rate of PPGDA/PEO cross-linked hydrogels are expected to be higher than pure PEO hydrogel films.

2. Materials and methods

2.1. Materials
Polyethylene oxide and Polypropylene glycol diacrylate were bought from Sigma-Aldrich, Singapore.

2.2. Production of hydrogel films
Polyethylene oxide (PEO) (Mn 6x10^5) and Polypropylene glycol diacrylate (PPGDA) (Mn 750) were used for production of the hydrogels. PPGDA was purified by passing through Alumina column to remove monomethyl ether hydroquinon inhibitor. The mixture of PPGDA and PEO (5% w/w) was stirred at ambient temperature for one day. Various percentages of PPGDA (0%, 5%, 10%, 15% and 20%) were prepared in the same way. The certain thickness of hydrogel films was made by pouring the PPGDA/PEO aqueous solution into a petri dish. The solution was dried for one day at 50°C in the oven. Finally, the dry films were irradiated using electron beam (EB) at 300 kGy after vacuum sealing with polyethylene bag.

2.3. Gel fraction
The gel fraction of hydrogel film was measured from the weight ratio of the insoluble dry film after soaking in the water and the initial weight of dry film. The dry PPGDA/PEO film was soaked into distilled water at 50°C for one day after irradiation. The gel fraction can be calculated using equation (1).

\[ \text{Gel fraction} = \left( \frac{W_c}{W_o} \right) \times 100 \% \] (1)

where \( W_c \) and \( W_o \) are the weight of insoluble dry gel and the initial weight of a dry film [19].

2.4. Swelling ratio
The weight of swollen hydrogel was measured at certain time intervals until the hydrogel reached the equilibrium. The dry PPGDA/PEO film was weight immediately after irradiation as an initial weight. The swelling ratio (SR) was measured using equation (2).

\[ \text{SR} = \left( \frac{W_t}{W_o} \right) \times 100 \% \] (2)

where \( W_t \) and \( W_o \) are the weight of swollen hydrogel at time \( t \) and that of the dry PPGDA/PEO film, respectively.

2.5. Mechanical strength
The mechanical properties of PPGDA/PEO hydrogel film were measured using universal tensile instrument (UTM Taiwan) with an extension rate of 10 mm/min.
2.6. Water vapor transmission rate
The transmission rate of water vapor of cross-linked hydrogel film was measured using equation (3).

\[ \text{WVTR} = \frac{(W_2-W_1)}{S} \text{[g m}^{-2}\text{h}^{-1}] \]  

(3)

where \( W_1 \) and \( W_2 \) are the weight of the whole cup at the first and the second hours, respectively, and \( S \) is the surface area of the sample. A round shape of dry film was put on the top of a cup and placed in an incubator of 90% RH at 40°C. Then the whole cup was weight at the first and second hours.

3. Results and discussion

3.1. The effect of PPGDA percentage on gel fraction and swelling properties
Figure 1(a) indicates that the gel fraction of cross-linked hydrogel increased linearly with increasing the weight percentage of the PPGDA in a mixture after 5 minutes. It shows that PPGDA enhance the degree of crosslinking due to the lower viscosity of PPGDA. Figure 1(b) indicates that all composition of hydrogel films absorb water very quickly and get an equilibrium state within 5 minutes. The swelling ratio decreased with increasing content of PPGDA from 800% at 0% of PPGDA to 300% at 20% of PPGDA. This result reveals that the higher content of PPGDA can decrease the swelling ratio due to the crosslinking of PPGDA together with radicals in PEO backbones via radical polymerization.

![Figure 1](image_url)

**Figure 1.** The effect of PPGDA percentage on gel fraction (a) the swelling ratio over time (b).

3.2. Mechanical strength
Figure 2 shows the tensile strength of PPGDA/PEO cross-linked hydrogel film. The tensile strength increased linearly from 5% to 20% content of PPGDA and reached the maximum value (0.65 MPa) at 20% of PPGDA. The result indicates that mechanical strength of PPGDA/PEO cross-linked hydrogel film are high enough to be applied as a wound dressing.
3.3. Water vapor transmission rate (WVTR)

Figure 3 demonstrates that the WVTR is remain stable for all compositions of PPGDA. However, the average of WVTR of various compositions of PPGDA/PEO (25 g m⁻² h⁻¹) is higher than of pure PEO hydrogel film (15.89 g m⁻² h⁻¹). The different type of wound need different type of dressing. High exudate wound need the wound dressing which has high water vapor transmission rate to evaporate more exudate from wound. The ideal dressing should have WVTR higher than normal skin (8.5 g m⁻² h⁻¹).

4. Conclusions

The PPGDA/PEO hydrogel film could be prepared by e-beam irradiation at 300 kGy. The increasing content of PPGDA in PPGDA/PEO hydrogel film was able to increase the mechanical strength. These results proved that the content of PPGDA influence the properties of cross-linked hydrogel film. The findings also proved that confirmed that PPGDA/PEO hydrogel film has a great potential for future use in wound dressing application.
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