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Swelling Properties of Gamma Irradiated Starch Based Hydrogel Dressing

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Abstract

Sago starch is used as biopolymer and biocompatible to the human skin. The hydrogel is prepared by mixing the solution of sago starch (SS) with polyvinyl alcohol (PVA) solution and finally this solution is subjected to the gamma irradiation. The effect of sago starch and gamma irradiated doses on swelling properties are evaluated. The swelling behaviours of samples are discussed through swelling, equilibrium degree of swelling (EDS) and equilibrium water content (EWC). The hydrogels produced from this method is observed high in transparency and swelling behaviour as well as high water absorbency.

Keywords: *Gamma Ray, Sago Starch, Polyvinyl Alcohol and Wound Healing Dressing.*

1. Introduction

Wound healing is a dynamic process and the performance requirements of a dressing can change as healing progresses. However, it is widely accepted that a warm, moist environment encourages rapid healing and most modern wound care products are designed to provide these conditions. Fluid balance in burn injury is very important since heavy loss of water from the body by exudation and evaporation may lead to a fall in body temperature and increase in the metabolic rate. Besides this, dressing should have certain other properties like ease of application and removal, and proper adherence so that there will not be any area of non-adherence left to create fluid-filled pockets for the proliferation of bacteria. Numerous wound dressing materials are available and are also being investigated. Hydrogels combine the features of moist wound healing with good fluid absorbance and are transparent to allow the monitoring of healing [1]. Hydrogel is a three-dimensional polymeric network that has chemical or physical crosslinking among a macromolecule chain to form this network [2].

Both natural and artificial polymers are utilized to reconstitute dermis. Between these two types of material, naturally natural polymers are more desirable to be administered as wound healing dressings due to their generally low toxicity and biocompatibility [3,4]. Sago starch is intended to be applied to produce wound dressing material by gamma irradiation due to sago's properties as a polysaccharide and its abundant availability in the Malaya Peninsula, rendering it a relatively low cost for production and utilization. Sago starch alone cannot be crosslink to form hydrogel since it is degradable upon irradiation. It need medium or material that can be crosslink and the formation of semi-gel form from sago starch will assist in handling prior for irradiation. Since sago starch dissolved in hot aqueous solution, the suitable material is the water-soluble polymer such as polyvinyl alcohol (PVA) [5]. Not requiring chemicals such as initiators or crosslinkers in addition to low costs are only a few of the advantages of the gamma irradiation technique, making it a candidate to be used for the preparation of hydrogel due to the polymer solution undergoing a crosslinking process upon radiation which results in a gel like material [6]. Therefore, this paper reports on swelling properties of starch hydrogel which produced through gamma irradiation method.

2. Materials and Methods

2.1 Materials

Polyvinyl alcohol 1500 and Sago starch was bought from Hup Seng Heng shop.

2.2 Samples Preparation

Prior to the wound hydrogel dressing production, sago starch solution was prepared by mixing of 4 gram sago starch with 100ml water at 90°C for 1hours. Also, prior to hydrogel production, PVA solution was prepared through mixing the 10 gram PVA and 100 ml water for 4 hours at 90°C with keeping stirring. Solution of PVA was left for 2 days to remove the bubble. Then, amount of 30, 50 and 70 wt% sago starch (SS) solution are mixed with 70, 50 and 30 wt % polyvinyl alcohol (PVA) solution respectively and subjected to the gamma irradiation at different dose (15, 25 and 35 kGy). Finally, irradiated solutions were left in oven at 45°C for overnight.

2.3 Swelling Capacity

A completely dry, pre-weighed disc-shaped SS/PVA hydrogel was weighed and then immersed in excess distilled water. The SS/PVA hydrogel was removed from the water and weighed after excessive water on the surface was blotted. Data presented in this experiment was the mean values of triplicate measurements. Results were calculated for swelling kinetics according to the following Equation 1:

$$Q=(M_t-M_d)/M_d\times100 \qquad (1)$$

Where,
Q is the swelling ratio,
M_t is the mass in the swollen state at time t and
M_d is the mass in the dried state.

2.4 Equilibrium Degree of Swelling and Water Content

In this work, the effect of SS content on equilibrium degree of swelling (EDS) and equilibrium water content (EWC), as important swelling characteristics of hydrogels, were measured. These characteristics indicated the ability of wound dressing in absorption of wound fluids and exudates. The desirable and ideal values of EDS and EWC for a wound dressing strongly depend on the type and condition of the wound, for instance, a full-thickness wound with a large amount of exudates needs to a dressing with high value of EDS or EWC [7].

The EDS and EWC were determined by immersing the dry SS/PVA hydrogel in excess distilled water for 48 hours when the swelling process not able to continue and reach to equilibrium state. The samples were periodically weighed after the excess surface water was removed. The EDS and EWC were calculated according to the following Equation 2 and 3 respectively:

$$EDS\ \%=(M_s-M_d)/M_d\times100 \qquad (2)$$
$$EWC\%=(M_s-M_d)/M_s\times100 \qquad (3)$$

Where,
M_s is the mass in the swollen state an
M_d is the mass in the dried state.

3. Results and Discussion

2.1 Swelling Capacity

Swelling ratio has been widely used as a simple method to characterize water absorption [8]. Fig 1(a)-(c) show the swelling ability of SS/PVA hydrogel with different content of sago starch at different dosage of irradiation at room temperature, measurement were every 2 hours. Most of the produced hydrogels, regardless of the composition and irradiation doses, shows very significant swelling for the first 2 hours of measurement. This drastic swelling capability occurs because most O-H groups of the produced hydrogels are first hydrated by water molecules during the swelling process, which makes the hydrogels absorb more water during this time of measurement [9].

It is observed that in Fig 1, from 2 to 10 hours at 15, 25 and 35 kGy , the samples with 50 and 70 wt % of SS increased slightly and reached to equilibrium after 10 hours, whereas sample with 30 wt % of SS at 15 kGy increased sharply and showed constant increment, but it did not achieve the equilibrium Compared to other samples with 50 and 70 wt % SS (50 PVA and 30 wt % PVA respectively), the sample with 30 wt % SS (70 wt % PVA) has more hydrophilic groups to absorb water and does not reach the equilibrium because it still contains O-H groups to be hydrated by water molecules [10].

Also, as can be seen from Fig 1 (a)-(c), the swelling ability was higher for sample with 30 w/t % of SS compared to samples with 50 and 70 w/t % of SS. Generally, it is clear that starch amount plays an important role in influencing the swelling ratio of SS/PVA hydrogel. Swelling capacity decreases with the increase of starch content. This is because instead of water molecules, the hydrogel networks start to be occupied by starch molecules, whereas the networks become more occupied by smaller starch molecules due to the degradation of starch molecules into smaller fragments upon irradiation [11, 12].

Moreover, swelling ability of all samples at 15 kGy was higher than the same sample at 25 and 35 kGy, and the lowest swelling ability was observed for 25 kGy. The swelling ability of SS/PVA hydrogel was influenced by radiation doses. The swelling ratio decreased with increasing irradiation doses, where at higher doses, the mobility of polymer chain is obstructed by the formation of tighter structure and more crosslinks, hence the penetration of water in the hydrogel structure is reduced [13].

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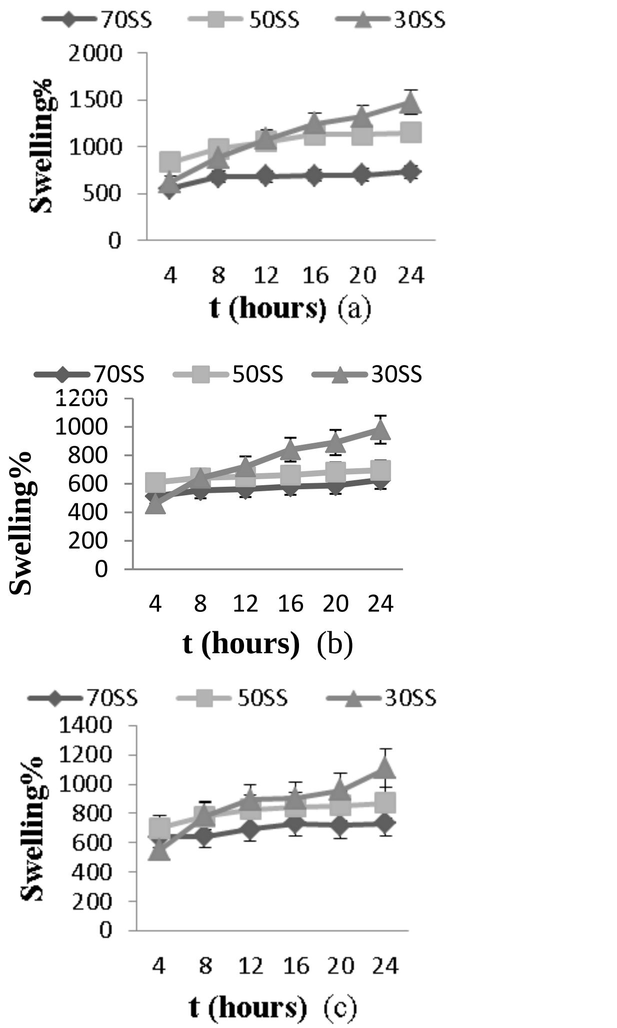

Fig 1. Effect of SNP and Temperature on Swelling Capacity of SS/PVA Hydrogel at (a) 16 ºC (b) 26 ºC (c) 36 ºC

3.2 Equilibrium Degree of Swelling and Water Content

The ability of SS/PVA hydrogel to absorb and hold water inside the polymeric networks can be examined after 48 hours as the swelling stops. EDS and EWC are two important keys to investigate the absorbing property of SS/PVA hydrogel. Figure 2 shows the maximum absorption after 48 hours based on different amount of SS and various doses of gamma ray at room temperature. EDS values changed by changing the dose from 15 to 35 kGy. The EDS reduced significantly from 15 to 25 kGy for SS/PVA hydrogels with 30 and 50 wt % of SS from 1469 to 980% and 1150 to 695% respectively. The SS/PVA hydrogel with 70 wt % of SS decreased slightly from 736 to 627%. However, the EDS increased slowly from 25 to 35 kGy. It was observed from Figure 2 that the effect of radiation dose on EWC was similar to EDS. The highest value of EWC of SS/PVA hydrogel was 93.62%, which belonged to 15 kGy with 30 wt % SS. It can be observed from the result of EDS and EWC that doses have similar effects on SS/PVA hydrogel. It can be related to crosslinking formation during irradiation. At low dose of irradiation, less crosslinking occurs, which creates more pores that can hold more water. At higher dose of irradiation, the pores inside the hydrogel reduce as more crosslinking occur, which decreases the hydrophilic group number of hydrogel and swelling ratio [14, 15].

Content of SS and irradiation dose have similar effects on the values of EDS and EWC. This is because smaller starch molecules from the degradation of sago starch occupy the free volume where water can be held. When these amount of smaller molecules increases in the free volume, there is insufficient space to take water, and also poor hydrophilicity of starch decreases EDS and EWC [16, 17].

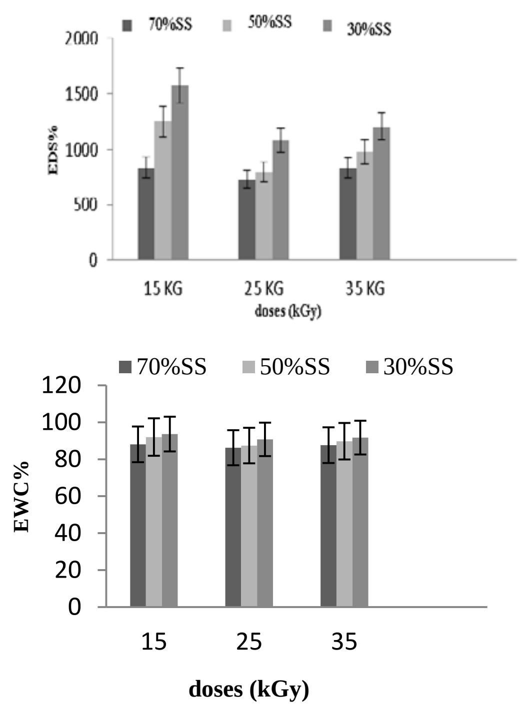

Fig 2. Effect of SNP and Temperature on (a) EDS and (b) EWC

4. Conclusions

In the present work, it was prepared a superabsorbent hydrogel by gamma irradiation with different dosages onto sago starch and PVA for wound healing dressing. It is found that swelling and absorbing behaviour is affected by doses and amount of sago starch. The optimum reaction conditions to obtain maximum water absorbency (1469 %) were found to be: sago starch/PVA with 30/70 concentration by 15 kGy.

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