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Effect of gamma irradiated super water absorbent from sago waste on vegetables

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Abstract

Super water absorbent (SWA) has the ability to absorb water hundreds of times bigger than its own weight and potentially can be used as a water retainer in agriculture. Other than holding water, SWA can release water to the soil, which is required by the plants. In this study, SWA from sago waste has been successfully prepared using the gamma radiation technique and the properties of SWA such as FTIR, gel fraction and swelling have been carried out. Performance of SWA from sago waste as a water retainer has been carried out with mustard and Chinese kale with three different compositions (0.1, 0.3 and 0.5%) of SWA mixed with the soils. The effects of SWA on the plants such as height of plants and weight of plants have been determined. Generally, the height and weight of the plants were at the highest at 0.1% of SWA content in the soil.

1. Introduction

Mukah which is located in Sarawak, Malaysia, has the largest sago palm plantation areas. Currently, more than 40,000 tons of sago starch has been exported to different countries and the value is expected to increase every year as well as the amount of waste generated (Amin *et al.*, 2019). Sago waste or residue from sago production was usually discharged into the river, which contributed to water pollution (Ngaini *et al.*, 2014). Sago waste is mostly made out of starch approximately 65.7% and lignocellulosic components which can be transformed into other useful products such as biosorbents, biogas, animal feed and compost and also biodegradable composite material (Rasyid *et al.*, 2020) and (Awg-Adeni *et al.*, 2010). Besides, sago waste has been also widely used in studies as a heavy metal remover (Quek *et al.*, 1998) and fermentable sugar (Kumoro *et al.*, 2008). Thus, sago waste was used in this study to produce a product, which can benefit humans as well to protect the environment. Sago waste was mixed with other polymers and introduced to gamma radiation for crosslinking or grafting to take place to produce super water absorbent (SWA).

Rather than synthesizing new materials using chemical or enzymatic techniques, radiation processing has been widely used due to its simple processing. The radiation technique is effective, environmental-friendly and more convenient compared to other conventional techniques such as chemical processes, which require initiators and produce waste from the processing. It also has been proven that radiation processing can also be used to prepare super water absorbents or super absorbents (Kiatkamjornwong and Suwanmala, 1998; Chen *et al.*, 2004; Suwanmala *et al.*, 2014).

In this study, the use of sago waste as a super water absorbent and potentially to be used in agriculture as a water retainer and might be useful during drought season will be evaluated and reported. Super water absorbent were given that name due to their capability to absorb water a hundred times compared to their weight. SWA prepared from sago waste has the potential to be used in agriculture, the food industry, bioengineering and biomedicine and some other applications.

2. Materials and methods

2.1 Materials

Sago waste was obtained from Ng Kia Seng Kilang Sagu Industries Sdn. Bhd. Batu Pahat, Johor. Carboxymethyl cellulose was purchased from Acros Organic, (USA). Industrial-grade acrylic acid was obtained from LG Chem. Ltd. Korea while industrial-grade potassium hydroxide (KOH) was purchased from Tessenderlo Group, France. All materials were used as received without further purification.

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2.2 Preparation of super water absorbent

Carboxymethyl cellulose was prepared by dissolving it in water and stirring for 45 mins. Acrylic acid was then added to the solution and continued stirring for 30 mins. This solution was poured into the basin containing sago waste and mixed for 45 mins. KOH later was added and mixed again for another 30 mins. The mixture was then packed into plastic bags and sealed prior to irradiation. These mixtures were irradiated at 15, 20, 25, 30 and 35 kGy from Co-60 source facility at Sinagama, Malaysian Nuclear Agency. Upon completion of the irradiation process, the mixtures, which now became SWA were dried in the oven at 70°C until reached constant weight. The dried SWA were ground to have a smaller size of SWA.

2.3 Characterization of super water absorbent

2.3.1 Gel fraction

The SWA samples were put into tea bags and weighed accurately. The tea bags were soaked in distilled water and autoclave for 15 mins at 121°C. The samples were then dried in the oven at 60°C until they reached constant weight (Idris, 2008). The estimation of gel fraction was measured by the insoluble part after immersion in water. A minimum of five specimens was tested for each sample and averages were calculated. The gel fraction was calculated using Equation 1.

$$\%\ \text{Gel fraction} = \frac{W_2}{W_1} \times 100 \qquad (1)$$

Where W_1 is the initial weight of the sample and W_2 is the weight of insoluble part after immersion.

2.3.2 Degree of swelling

Swelling performance of SWA when exposed to irradiation was done by immersing known weight of the sample in distilled water at room temperature for 24 h. Excessive water remain on the sample was removed by dapping with tissue paper and immediately weighed (Chowdhury *et al.*, 2015). Swelling degree of samples was calculated using Equation 2.

$$Swelling\ (\%) = \left(\frac{W_S - W_D}{W_D}\right) \times 100 \qquad (2)$$

Where W_S and W_D represent the weight of swollen and dried sample, respectively.

2.3.3 Scanning electron microscopy

The morphology of the samples was investigated by scanning electron microscopy (SEM), FEI Quanta 400. Prior to the scanning process, the samples were freeze-dried (Epsilon 1.8) at -75°C. The freeze-dried method on the samples is considered the best method to observe the pore morphology or inter-polymer network (IPN) of hydrogel. The dried samples were gold sputter-coated before being analysed by SEM. SEM images were obtained from the fractured surface of dried samples.

2.3 Pot experiment with mustard and Chinese kale

Approximately 1 kg of soil was used in each pot (poly bag). The 600 g of soil was first poured into the pot. Then SWA after swell was added (0.1%, 0.3% and 0.5%) and later pot were filled with another 400 g of soil and ready for plant transfer. Mustard and Chinese kale which have been germinated for 2 weeks have been chosen by similar height and transferred into each pot. Each pot will have one plant. Pot experiments were to study the effect of the application of SWA on the growth of mustard and Chinese kale and were conducted under a controlled environment.

3. Results and discussion

Figure 1 shows the FTIR spectra of sago waste and super water absorbent from sago waste that has been irradiated by gamma irradiation. At around peak 3294 cm^{-1} there were wide bands for both spectra of sago waste and SWA, which indicate the absence of O-H groups in the cellulose molecule (Kunusa *et al.*, 2021). However the intensity of the O-H peak of the sago waste spectrum reduced when compared with the SWA spectrum due to the substitution of O-H groups with the C=O group of acrylic acid during the making of SWA where acrylic acid was involved in the process. Acrylic acid has also been grafted to sago waste based on new absorption bands at around 1550 cm^{-1} and 1400 cm^{-1} which indicated of C=O from acrylic acid (Yacob *et al.*, 2014).

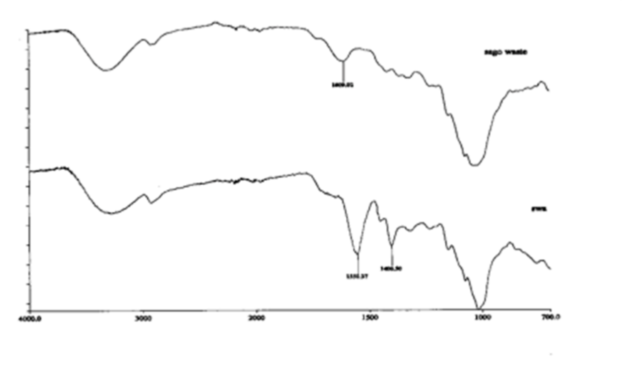

Figure 1. FTIR spectra of sago waste and super water absorbent (SWA).

Cross-sectional images of sago waste SWA after irradiation are shown in Figure 2. From these images, can be seen that the sago waste mixture that is exposed to irradiation will form three three-dimensional (3D) networks (Yacob *et al.*, 2014) to form SWA. This 3D network porous structure was formed due to a crosslinking process that took place under irradiation (Talip and Mahmud, 2017). This porous structure in the

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irradiated SWA will help to absorb and retain water. The bigger the pore size, the more water can be absorbed.

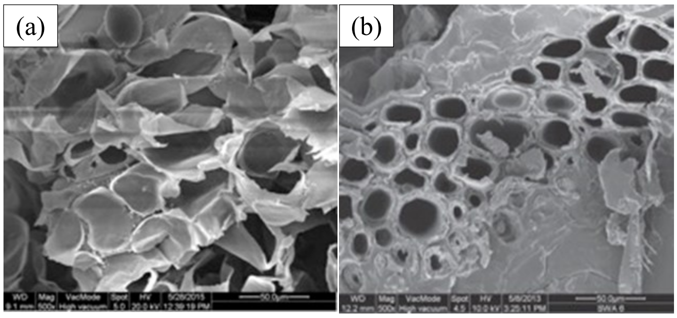

Figure 2. SEM images of (a) sago waste and (b) SWA.

Super water absorbent has the ability to absorb water hundreds of times more than its original weight. The water will be absorbed and retained in the 3D network form in the SWA structure. Swelling characterization on the SWA will give information on how much water has been absorbed by the SWA. Figure 3 and Figure 4 show the gel fraction and swelling of the SWA when irradiated at different gamma irradiation doses. SWA when further exposed to gamma irradiation, particularly at a dose of 25 kGy, the gel fraction gives the highest reading at around 145% and at higher doses the gel fraction was decreased. It shows that at 25 kGy, the crosslinking to form a 3D network has formed at the highest and at that particular irradiation dose, the density of the network became higher (Suwanmala *et al*., 2014)

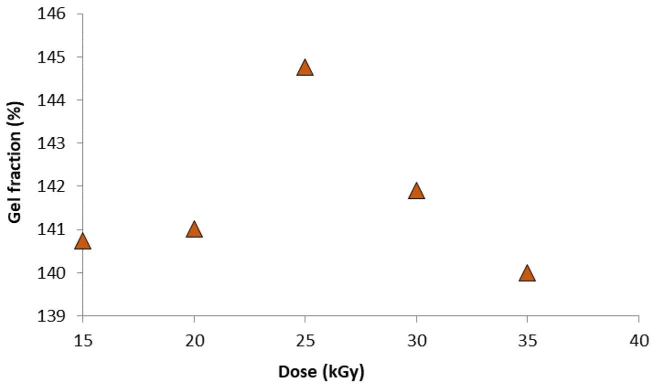

Figure 3. Gel fraction of SWA irradiated at various dose.

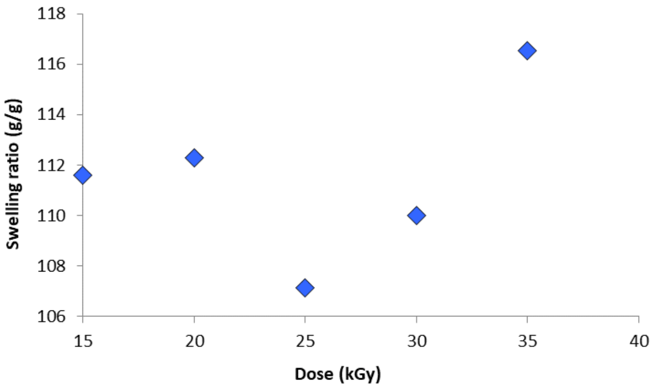

Figure 4. Swelling degree of SWA irradiated at various dose.

The gel fraction of SWA is illustrated in Figure 3. The results of gel fraction will affect the ability of SWA to absorb water by the creation of a 3D network (crosslink) in the SWA. The formation of crosslink occurs by the water radiolysis where, free radical is created by the absorption of rays by water molecules and activated state of H^- and OH^- radicals to form crosslink bonds (Ghobashy *et al*., 2020). The formation of the network can also occur by the recombination of polymer chains which can happen with the same polymer chain (intra molecules) or with different polymer chains (inter molecules) (Yang *et al*., 2010; Talip, 2019).

As seen in Figure 3 and Figure 4 at a dose of 25 kGy, SWA gives the highest value of gel fraction but the lowest value of swelling. This is due to the density of the crosslink network in the SWA. When crosslink is too much it will affect the pore sizes in the SWA. More pores will occur but in smaller sizes. Therefore, less water can be absorbed by the SWA.

To choose the optimum irradiation dose for preparing SWA by choosing the highest value of swelling. Therefore there will be more water that can be absorbed, retained and later released into the soil for the uptake of the plants.

The presence of SWA in the soil did improve the growth of mustard and Chinese kale as can be seen in Figure 5. With 0.1% SWA concentration, it gave the highest value in the weight of mustard and Chinese kale. The increasing weight of mustard and Chinese kale at 0.1% SWA concentration compared to the control (no SWA) is about 35% and 21%, respectively. It shows that having SWA in the soil will improve the growth of the plant. From this data, it can be concluded that SWA not only can absorb water but at the same time can release water to the soil to be taken by the plant for their growth. Other researchers obtained similar results where, SWA has the ability to absorb water and can improve irrigation systems (Ghobashy *et al*., 2020). As SWA concentration increased, the weight of the plant reduced. SWA at only 0.1% content in the soil is the optimum concentration and can improve the growth significantly.

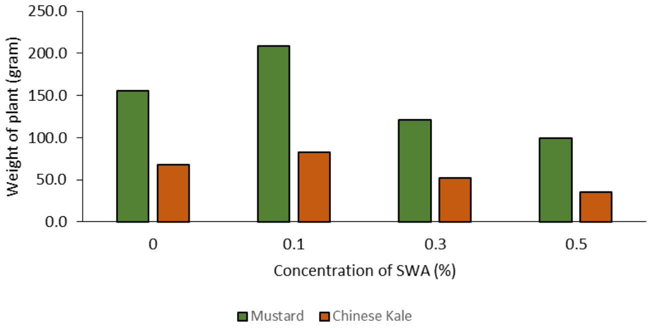

Figure 5. Weight of mustard and chinese kale with different concentration of SWA in the soil.

Figure 6 shows the heights of mustard and Chinese

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kale with different concentrations of SWA in the soil. For mustard, the content of SWA does not affect the height of mustard. While for the Chinese kale, SWA concentration at only 0.1% improved significantly when compared with the control (0% SWA). Images of the plants with SWA and without SWA (control) in the soil are shown in Figure 7.

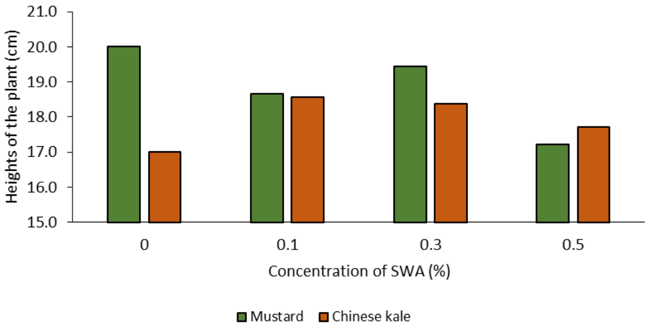

Figure 6. Heights of mustard and chinese kale with different concentration of SWA in the soil.

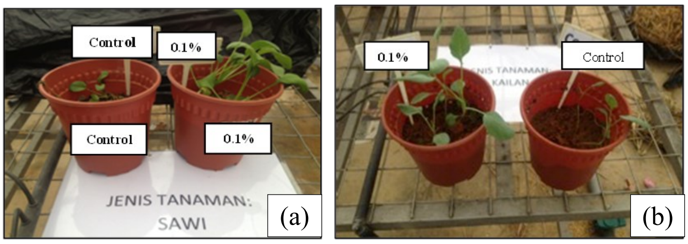

Figure 7. Images of (a) mustard and (b) chinese kale with and without SWA in the soil.

4. Conclusion

Super water absorbent from sago waste has been successfully prepared. Gel fraction and swelling degree depended on the dose of gamma irradiation. The swelling property of SWA is dependable on the gel fraction of the sample. The higher the value of gel fraction may result in a lower degree of swelling and the capability of SWA to hold or retain water is lower. This is due to the density of 3D networking formed in the structure. SWA is suitable to be used in agriculture as a water retainer or soil conditioner as SWA can hold and release water to be taken from the plants. Only the 0.1% concentration of SWA in the soil can improve significantly the weight and the height of the plant studied. SWA can be used in the agricultural sector and may reduce the amount of water used and might as well reduce the cost of irrigation systems.

Conflict of interest

The authors declare no conflict of interest.

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