

## Production of Superabsorbent Biopolymer from Modified Cellulose-Based Polyvinyl Alcohol with Variation of the Number of Initiator and Crosslink Agent

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### ABSTRACT

The problems that are often encountered in the results of the development of material modification of super absorbent polymers include water absorption ability and ability swelling which is low, limited solubility in water and organic compounds, in addition to the condition of the material that is hard and brittle and not environmentally friendly, also being difficult to decompose. These conditions can be minimized and improved through modification of monomer compounds, crosslinker, and initiator in the polymerization process. The polymerization process is carried out by the method of chemical crosslinker with crosslink agent i.e. formaldehyde in the main chain (backbone), namely polyvinyl alcohol, and daughter chains, i.e. bagasse cellulose, with the help of an initiator in the form of potassium persulfate. The results of the study showed that formation of a new functional group (C-OH stretch) at 1143.30  $\text{cm}^{-1}$ ; (-OH) at 3461.03  $\text{cm}^{-1}$ ; (C-O-C) at 1200.55  $\text{cm}^{-1}$ ; (C=O) at 1529.86  $\text{cm}^{-1}$ . The highest absorption capacity reached 746.49% in the sample with 0.8 gram of initiator and crosslink 0.8 mL. Mark Swelling the highest was obtained under acidic conditions, namely pH 6 with a value of 358.30. The surface morphology of the superabsorbent, which is a dense, strong and elastic surface, is formed with pores  $\pm 11.75$  nm. The surface change proves that the grafting process and interfacial interactions of two materials are going well.

**Keywords:** polyvinyl alcohol, cellulose bagasse, initiator, crosslink agent, superabsorbent.

### INTRODUCTION

Advanced materials are the focus of development for various roles and functions in human needs. Development of modified materials in the manufacturing of super absorbent polymers (SAPs) continues to seek the best polymer materials to improve quality and quantity. SAPs or hydrogels that are good in their main characteristics must have the capacity to absorb water or water absorption capacity (WAC), high swelling ability and water resistance. These conditions allow SAPs to absorb and retain water up to 1000 times more than their own mass (Locus et al., 2018).

Problems that are often encountered in the results of the development of modifications to SAPs materials are in the form of water absorption ability and ability swelling which is low, solubility

in water and organic compounds is lacking, the condition of the material is hard and brittle and not environmentally friendly so it is difficult to decompose. These conditions can be minimized and improved through modification of monomer compounds, crosslinker, and initiator in the polymerization process. The low absorption of SAPs can be improved by choosing the right type of monomer such as polyvinyl alcohol monomer. These monomers contain many hydroxyl groups (-OH) which are expected to increase absorption by binding to water when combining with natural monomers (Mehra et al., 2021).

Solubility in water and organic compounds as well as hard and brittle materials can be increased by selecting the type crosslinker and the right initiator in the modification of the polymer structure. Crosslinker is widely used in the binding of

monomers in polymerization including formaldehyde. Selection of crosslinker is expected to be a monomer binding agent in increasing perfect solubility in polar and non-polar compounds as well as increasing the efficiency of the copolymer binding process with a low activation energy. A good initiator is a compound that can release a lot of free radical ions that help break cellulose hydrogen bonds to bind other monomers, for example, potassium persulfate.

The selection of monomer materials in the manufacture of SAPs to obtain two different monomer properties in increasing quality and quantity was modified by combining synthetic monomers and natural monomers. One of the natural monomers that contain a high percentage of cellulose compounds is bagasse. A good natural monomer in the process of making SAPs is a monomer that contains high levels of cellulose. Bagasse has great potential because it contains a percentage of cellulose content of 36.81–52.45% (Fatriasari et al., 2019). This potential has not been properly maximized by the community, especially in Ogan Ilir Regency, which still uses this potential as waste without further utilization. The cellulose content of bagasse can be maximized through the proper isolation method.

Many polymer material modifications have been carried out with the characteristics and drawbacks of each according to the raw materials used in the polymerization process. The research conducted by Zhao, et al. (2019) polymerized solutions of sulfamic acid and acrylic acid with starch to produce SAP which is highly soluble in salt ions. Li et al. (2020) said that polyvinyl alcohol (PVA) was substituted with groups styryl *pyridinium* through two ether bonds cross-linked to the SAP material through UV irradiation to produce a material with strong mechanical properties as a composite hydrogel. Khozemy et al. (2020) stated that wheat flour is used as a raw material for making SAP biodegradable through radical grafting with acrylamide using gamma rays. Mignon et al. (2017) stated that chitosan can be dimethacrylate and this main product is reacted with dimethyl aminoethyl methacrylate or dimethyl aminopropyl methacryl amide, to form good superabsorbent absorbents.

The characteristics of the superabsorbent developed produce a monomer raw material formula, crosslink agent, and different initiators to be able to create kinds of materials with high quality and low production costs. Monomer Type,

crosslink agent and good initiators are usually sold at very high production prices and nonbiodegradable. The importance of this research involves seeking an urgent solution to find an effective and efficient formulation by reducing production costs through a combination with some natural monomers, namely bagasse in the polymerization process.

## MATERIALS AND METHODS

Bagasse waste was obtained from the waste of small and medium micro enterprises in the Indralaya area, Palembang, South Sumatra. The concentration of 5% cellulose is 5 grams, and the concentration of PVA is 10%, 10 grams. Variation in the number of initiators is 0.4%; 0.6%; 0.8% and 1% while the variation in the number of crosslinkers is 0; 0.4; 0.8 and 1.2 mL

### Experimental stage

The bagasse was cut into small pieces  $\pm 1$  cm and sieved to 90 mesh, then dried in an oven at 50 °C for 3 hours. A total of 50 grams of bagasse powder was heated with 5% NaOH at 80 °C for 3 hours using a magnetic stirrer. Then the bleaching process was carried out with NaOCl for 1 hour at 60 °C using a magnetic stirrer. The residue was rinsed with distilled water until the pH was neutral.

### Superabsorbent polymer synthesis stage

The polymerization process uses 5% bagasse cellulose and 10% PVA. The ratio of cellulose and PVA raw materials in each sample is 1 : 4. The cellulose and PVA solutions are mixed with varying amounts of potassium persulfate (KPS) initiator with constant stirring for 10 minutes using a magnetic stirrer. The polymerization process goes well if it forms a hydrogel. Then the hydrogel was put into a petri dish to be dried in an oven at 60 °C for 2 hours. The dried hydrogel films were stored in a desiccator to test the superabsorbent characteristics.

### Analysis stage

Dry cellulose was weighed at 1 gram (weight A). Cellulose was placed in a three-neck-flask and then 150 mL was added and refluxed at 100

°C for 1 hour. The residue was dried in an oven until constant weight and weighed (weight B). The residue was added 150 mL of 1 N H<sub>2</sub>SO<sub>4</sub> and refluxed for 1 hour at 100 °C. The residue is dried to a constant weight and weighed (weight C). The residue was added with 100 mL of 72% H<sub>2</sub>SO<sub>4</sub> and soaked at room temperature for 4 hours. Added 150 mL of 1 N H<sub>2</sub>SO<sub>4</sub> and refluxed at 100 °C for 1 hour. The residue is filtered and washed until the pH is neutral. The residue was dried in an oven at 105 °C and weighed (weight D). The cellulose content and lignin content were calculated using the following equation:

$$\text{Cellulose rate} = \frac{\text{Weight C} - \text{Weight D}}{\text{Weight A}} \times 100\% \quad (1)$$

where: Weight A – first dry cellulose;  
 Weight B – residue oven-dried to constant weight;  
 Weight C – residue oven-dried to constant weight after addition of H<sub>2</sub>SO<sub>4</sub>;  
 Weight D – residue after drying at 105 °C.

The polymerization results were weighed at 0.1 gram. Then, they were placed in a 10 mL measuring cup and 6 mL of distilled water were added at room temperature for 24 hours. Then the liquid that was not absorbed was removed from the test tube and left with the tube upside down until no more liquid dripped. The hydrogel is then weighed. The absorption capacity is calculated using the following equation:

$$\text{Absorption capacity} = \frac{W_2 - W_1}{W_1} \times 100\% \quad (2)$$

where: W<sub>2</sub> – weight of superabsorbent polymer in condition swelling;  
 W<sub>1</sub> – weight of superabsorbent polymer in dry state.

The results of the polymerization weighed 0.1 gram. Then, it was placed in a 10 mL measuring cup and 6 mL of a solution with a pH of 6 were added at room temperature for 24 hours. Then the liquid that was not absorbed was removed from the test tube and left with the tube upside down until no more liquid dripped. The hydrogel was then weighed as a mass after swelling. The procedure was repeated for solutions with a pH of 9 and 12.

The ratio of superabsorbent polymer swelling is calculated using the following equation:

$$\text{Ratio swelling} = \frac{W_2 - W_1}{W_1} \times 100\% \quad (3)$$

where: W<sub>1</sub> – weight of superabsorbent polymer in dry state;  
 W<sub>2</sub> – weight of superabsorbent polymer in condition swelling.

This analysis was carried out to identify functional groups in superabsorbent polymer products by spectroscopic methods i.e. Fourier Transform InfraRed (FTIR). The FTIR spectrum of the superabsorbent product that has been formed is then compared with the FTIR spectrum of bagasse cellulose and the FTIR spectrum of PVA before polymerization occurs. This analysis was carried out to observe the structural morphological changes on the surface of the superabsorbent product before the morphology of PVA was modified by the morphology of bagasse cellulose.

## RESULTS AND DISCUSSION

This study used PVA polymer as the main chain (backbone), bagasse cellulose as the daughter chain, and formalin as the crosslinker (crosslink agent) with KPS as an initiator triggering the formation of free radicals. The hydrogel products made in this study used a variation of the number of initiators of 0.4; 0.6; 0.8 and 1 gram as well as crosslink agent in the amount of 0; 0.4; 0.8 and 1.2 ml. The formation of hydrogel products was carried out using the method chemical crosslinking through the help of the initiator as a chemical reagent with the cast-drying method through a drying process at room temperature without using additional chemical reagents. This method produces hydrogels in the form of transparent thin films. Hydrogel that has dried needs to be stored in a desiccator to protect the hydrogel from the influence of humidity.

Bagasse cellulose was chosen as a material for modifying the characteristics of superabsorbent products because it contains cellulose and hemicellulose. Cellulose material has high potential as a hydrogel forming material composed of cellulose microfibrils and water with an interconnected porous network structure (Zhao et al., 2021). The content of the components of the bagasse compound used in this study has been treated through delignification to reduce lignin levels which can inhibit absorption and damage

**Table 1.** Sugarcane bagasse compound composition

Compound	Much (%)
Cellulose	76.42
Hemicellulose	8.88
Extractive substances	6.65
Lignin	8.05

the characteristics of superabsorbents. On the bases of the analysis with the Chesson method, in identifying the content in bagasse, the following data is obtained.

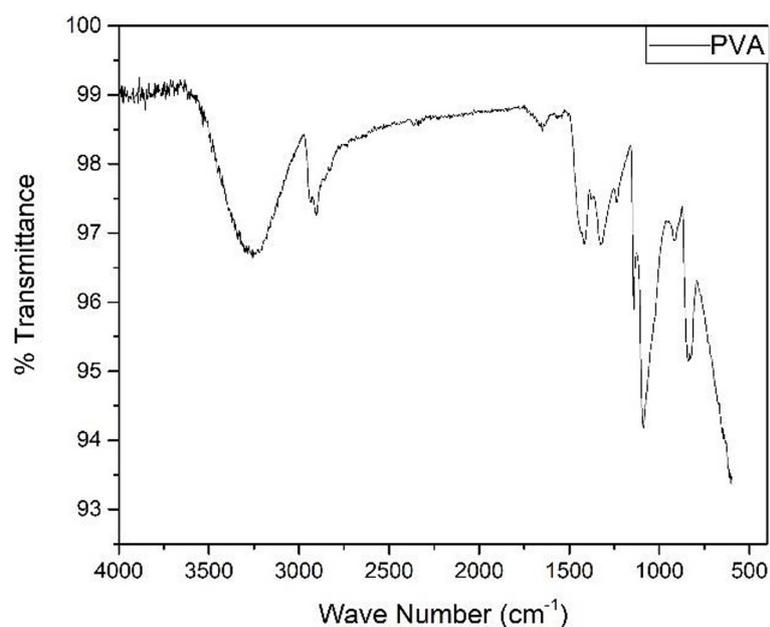
On the basis of Table 1, the cellulose content of bagasse reaches 76.42%. The data show that bagasse has excellent potential as a polymer modification material. Bagasse cellulose has fibrous based soft-gel characteristics so it has an advantage with a three-dimensional molecular macro network and the ability to bind and hold water very well in its structure (Li et al., 2021).

#### FTIR characterization of PVA, bagasse cellulose and superabsorbent

This step aimed to determine the functional groups contained in each material and to identify that the superabsorbent product has successfully polymerized with the formation of new functional groups in the main polymer chain. The results of the FTIR test to determine the functional groups of each raw material and superabsorbent product formed can be seen in Figure 1–4.

On the basis of the results of the FTIR spectrophotometry in Figure 1, it can be seen that the functional group waves was contained in the PVA structure as the main chain (backbone). Pada PVA, stretching band alkil C-H was detected at 2901.47  $\text{cm}^{-1}$ , whereas hydrogen-bonded band (-OH stretching) was detected at a wave of 3253.12  $\text{cm}^{-1}$ . PVA hydrolysis occurs at 1650.99  $\text{cm}^{-1}$  which is the vibration of the C=O group. According to Zubair et al. (2018) the range of C-O stretching ranges from 1150–1100  $\text{cm}^{-1}$ , on FTIR PVA the peak of the C-O stretching vibration occurred at 1143.30  $\text{cm}^{-1}$ . There are typical functional groups that appear on the waves absorption peak 3253.12  $\text{cm}^{-1}$  and 1143.30; 1088.10  $\text{cm}^{-1}$  in the form of an alcohol functional group (-OH) with strong hydrogen bonds so that the material is hydrophilic.

The bagasse cellulose produced before being used as a polymer main chain modification material is carried out in the functional group identification stage which is performed at wave numbers of 400–4000  $\text{cm}^{-1}$ . On the basis of the analysis results of bagasse content of the Chesson method, bagasse has main components in the form of cellulose, hemicellulose, extractive substances and lignin. These components are composed of alkanes, esters, aromatics and alcohols (Aditama et al., 2017). On the basis of the reading of the FTIR wave graph in Figure 2, the *single bones* area at the number of 1500–4000  $\text{cm}^{-1}$  are the main functional groups of cellulose, namely the O-H and C-H groups.

**Figure 1.** Polyvinyl alcohol FTIR spectrophotometry

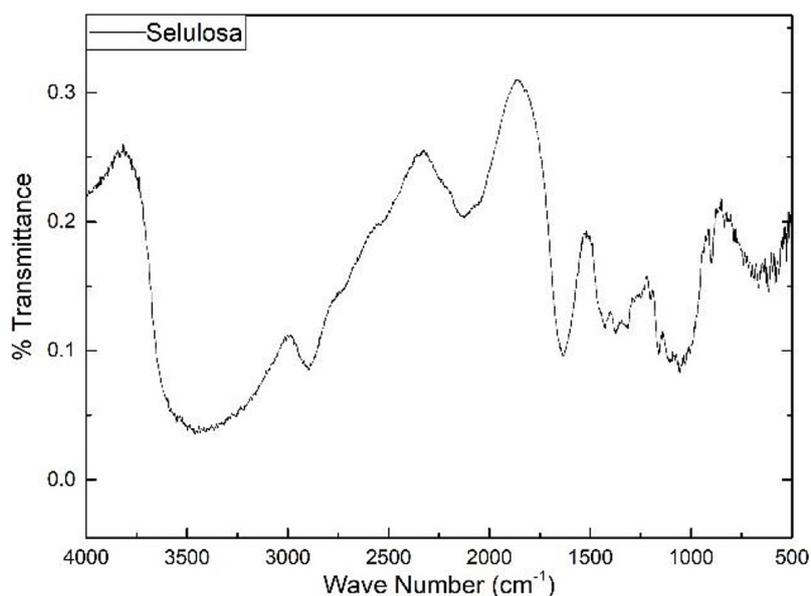


Figure 2. FTIR spectrophotometry of cellulose from sugarcane bagasse

The results of reading the FTIR spectrum graph for cellulose which is the dominant functional group in the bond is the -OH group. The height of the wave indicates that the process of alkalization at cellulose isolation can increase -OH levels in the bonds of cellulose functional groups (Aditama et al., 2017). The -OH group is indicated by the presence absorption *peak* in the area of 3461.03  $\text{cm}^{-1}$ , showing the presence of cellulose compounds which were not lost due to heating with an alkaline solution. Cellulose is a polysaccharide consisting of glucose units linked by bonds  $\beta$ 1,4-glycosidic (Zubbair et al., 2018). In the area wave number 1054.53  $\text{cm}^{-1}$ ,

$\beta$ -glycosidic absorption on the aromatic structure of cellulose was indicated. The alkalization process aims to remove the lignin content in the process bleaching by breaking the cyclic bonds in the lignin structure indicated by absorption *peak* in the area of 1372.09  $\text{cm}^{-1}$ . Absorption peak area 616.92  $\text{cm}^{-1}$  showed that there was residual absorption of extractive substances in the form of  $\text{ClO}^-$  from compounds bleaching in the lignin delignification process.

On the basis of on the results of the FTIR spectrophotometry in Figure 3, which shows the combination of functional groups between the main chains (backbone) of PVA by identifying

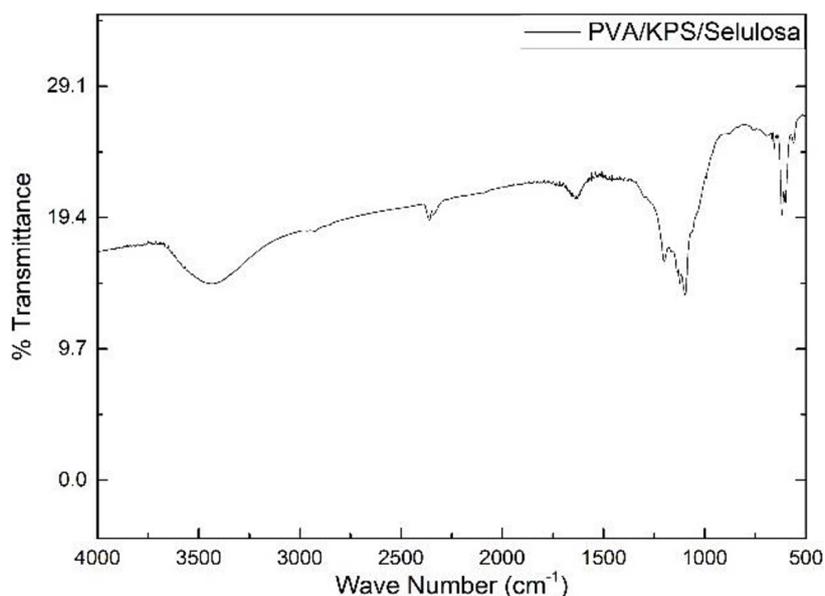


Figure 3. FTIR spectrophotometry of PVA/KPS/cellulose

the alcohol group (C-OH) in the region absorption *peak*  $1096.57\text{ cm}^{-1}$  and the hydroxyl group (-OH) of the daughter chain, namely cellulose absorption *peak*  $3436.39\text{ cm}^{-1}$ . In this sample, free radical attack occurs by the KPS initiator, in the main chain in the form of PVA. The free radicals that have been formed will attract the hydroxyl groups in the cellulose aromatic bonds that occur in the area absorption *peak* wave  $1123.65 - 1200.55\text{ cm}^{-1}$ . This results in the formation of a new group, namely C-O-C. The initiator will create an active site from the main chain so that reactions can occur with other monomers. When the initiator solution is heated, free radicals will form, which will initiate the polymerization process, this heat *capacity* affects the effectiveness of the initiator itself.

The results of the reading of the spectrum indicate the formation of a new functional group, namely C-O-C, which occurs in the aromatic structure of cellulose due to the attack of free radicals formed on the PVA main chain as a result of the role of KPS as an initiator. The functional group bonding that occurs in this case is not maximized as indicated by the identification of the alcohol group (C-OH) waves from PVA and absorption *peak* which is classified as low at  $1096.57\text{ cm}^{-1}$ . This could be due to the absence of a cross-linking process (crosslink) because KPS only acts as a trigger for the formation of initial free radicals in the polymerization process.

Referring to Figures 1–3, there is a change in transmittance which shows a decrease in

absorption *peak* functional group -OH. On FTIR the pure PVA sample waveform shows transmittance at a value of  $\pm 96\%$  then after bonding with cellulose through free radicals from the value initiator transmittance decreases to  $\pm 14.5\%$ . Transmittance decrease indicates that the amount of -OH is absorbed during the reaction process. The more drops transmittance indicates that more and more -OH groups from PVA and cellulose are released so that after reactions occur through free radicals the -OH concentration increases as indicated by a decrease in transmittance. There was an increase in the aromatic CH functional group transmittance from a value of  $\pm 0.1\%$  in the FTIR of cellulose to  $\pm 13\%$  after a reaction via free radicals from KPS. Transmittance increase indicates that the concentration of aromatic CH- decreases so that another aromatic CH will be formed from the cellulose bonds that increase after binding to the main chain of PVA.

On the basis of the results of the FTIR spectrophotometry in Figure 4, it can be seen that the bonding between the PVA polymer chains and bagasse cellulose is better than the results of the FTIR spectrophotometer waves on the PVA/KPS/cellulose samples. This difference occurs due to the role of formaldehyde as a crosslinker *agent* in forming cross-links between the two polymers. Indicated by the closer shift between the hydroxyl functional groups of cellulose absorption *peak*  $3436.39\text{ cm}^{-1}$  to  $3440.06\text{ cm}^{-1}$  and the alcohol functional group of PVA on absorption *peak*  $1096.57\text{ cm}^{-1}$  to  $1124.37\text{ cm}^{-1}$ . The bond that

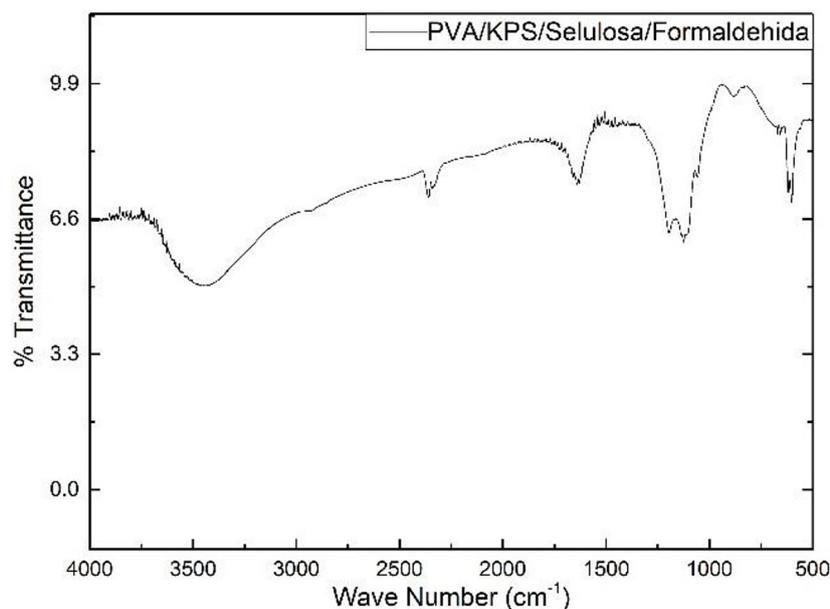


Figure 4. FTIR Spectrophotometry of PVA/KPS/cellulose/formaldehyde

occurs also produces a new functional group in the form of C=O which comes from the form-aldehyde functional group IR absorption *peak* 1529.86 cm<sup>-1</sup>. The formation of functional groups of compounds crosslinker indicates that polymeric cross links are formed (Abidin et al., 2018).

The results of the FTIR spectrophotometric readings differed from those of the FTIR spectrophotometric readings in Figure 3. A change in the intensity and position of the peaks indicated that there was a molecular interaction between the PVA functional groups and bagasse cellulose that appeared during the reaction due to the cross linker (Chalid et al., 2020). Crosslinker are expected to have a high solubility to the solvent and have a decomposition temperature equal to or lower than the boiling point of the solvent. The higher the solubility to the solvent, the more effective cross-linker will work in the cross-linking reaction between the main chain and the daughter chain.

### Effect of initiator and concentration crosslink agent on absorption capacity

The characteristics and success rate of the polymerization of a superabsorbent product can be

viewed from the ability to absorb water from the weight of the material itself. The main purpose of joining two different types of polymers or copolymerization is to improve one of the properties between the polymers. One of the properties that are the focus of this research is the ability to absorb water or absorption capacity. The characteristics of cellulose, which is brittle in a dry state and insoluble in water, will be modified and differ from the characteristic properties of PVA. The optimum variable conditions in the formulation of superabsorbent product formation in this study were viewed from the amount of initiator and crosslink agent used. The effect of variations in initiator and crosslink agent concentrations on the absorption capacity of superabsorbent products can be seen in Figures 5-6.

On the basis of the research results referred to in Figure 5, the effect of adding the amount of initiator in the form of KPS on the absorption capacity of superabsorbent products was explained. Increasing the number of initiators in polymerization will speed up the process of forming new polymer chains due to the increasing number of free radicals that are formed. The faster the main chain and daughter chains bind due to the

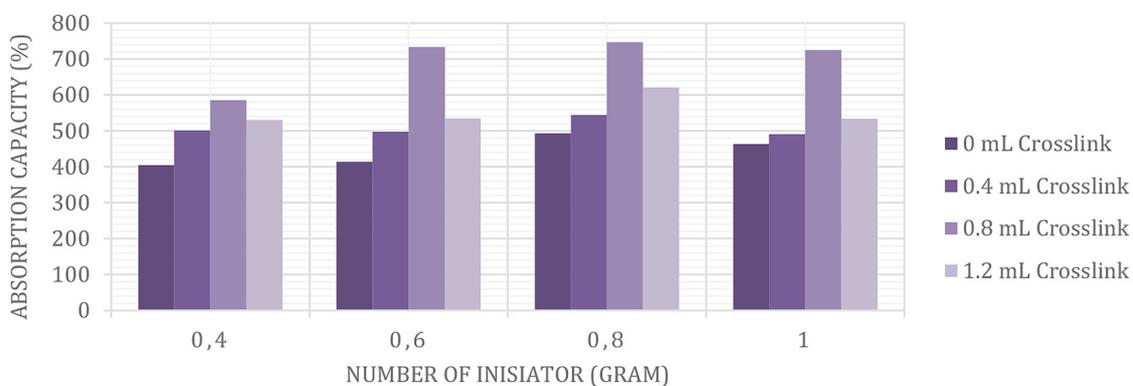


Figure 5. Effect of number of initiators on absorption capacity

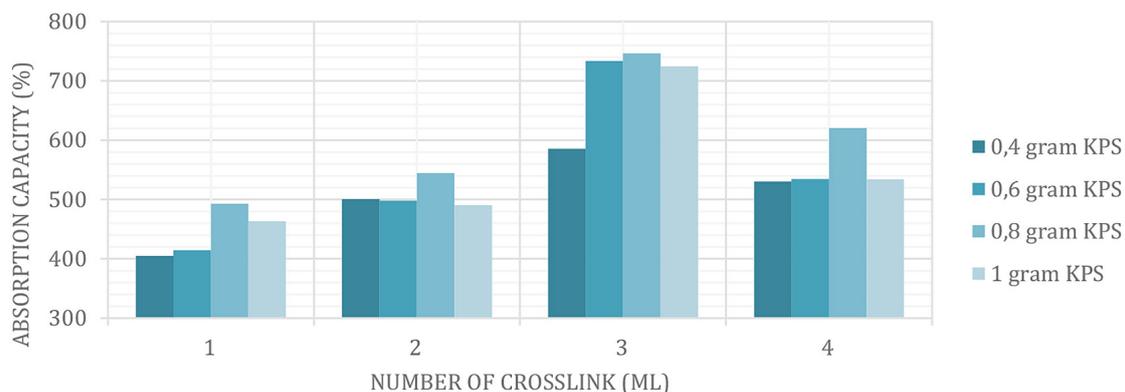


Figure 6. Effect of number of crosslinks on absorption capacity

presence of free radicals, the better the polymerization process will be. One of the parameters for the formation of good polymerization is the high level of absorption capacity that can be absorbed by the superabsorbent product that is formed. The initiator is an important part that will produce free radicals the activity of which can make the polymerization process take place (Kumar et al., 2021).

On the basis of the research results referred to Figure 6, the effect of increasing the number of crosslink formaldehyde on the absorption capacity of the superabsorbent was explained. Crosslink addition is also significant to the addition of initiator. The greater agent crosslinking between the two polymers, the stronger the bond and the characteristic properties grafting is, thereby increasing the adsorption capacity. Crosslink also plays a role in determining elasticity, increasing chemical resistance, viscosity, water absorption, and hardness (Zhu et al., 2021).

On the basis of the experimental data referred to in Figures 5 and 6, the optimum point with the highest absorption capacity of 746.4912% was obtained in the sample with 0.8 g of initiator and 0.8 mL crosslink. The greater number of initiators and crosslink *agent* will accelerate and strengthen the material bond that is formed to reach the optimum point. If the addition of the number of initiators and crosslink *agent* continues to be carried out until it passes the optimum point, the characteristics and properties of the polymer material will deteriorate again. This is because there is an accumulation of free radicals and agent cross fasteners on surface *polymer* which can be seen in the results of the SEM micrograph, Figure 6 part (b). Free radical buildup and crosslink *agent* is the factor that causes a decrease in the level of absorption capacity in the sample variations of 1 gram of initiator and 1.2 mL crosslink.

The minimum absorption rate occurs in the samples with variations in the amount of initiator 0.4 grams and crosslink 0 mL. Such samples with small capacity values are subject to the polymerization process and the need for free radicals agent less binder to be able to bind and combine both the main chain (PVA) and the link chain (cellulose bagasse). On the basis of these data, the use of initiators and crosslink greatly affects the characteristics of the absorption properties of the formed superabsorbent product. The greater the number of concentrations added, the better the absorption properties of the product, in accordance with the ratio of the number of main chain raw materials

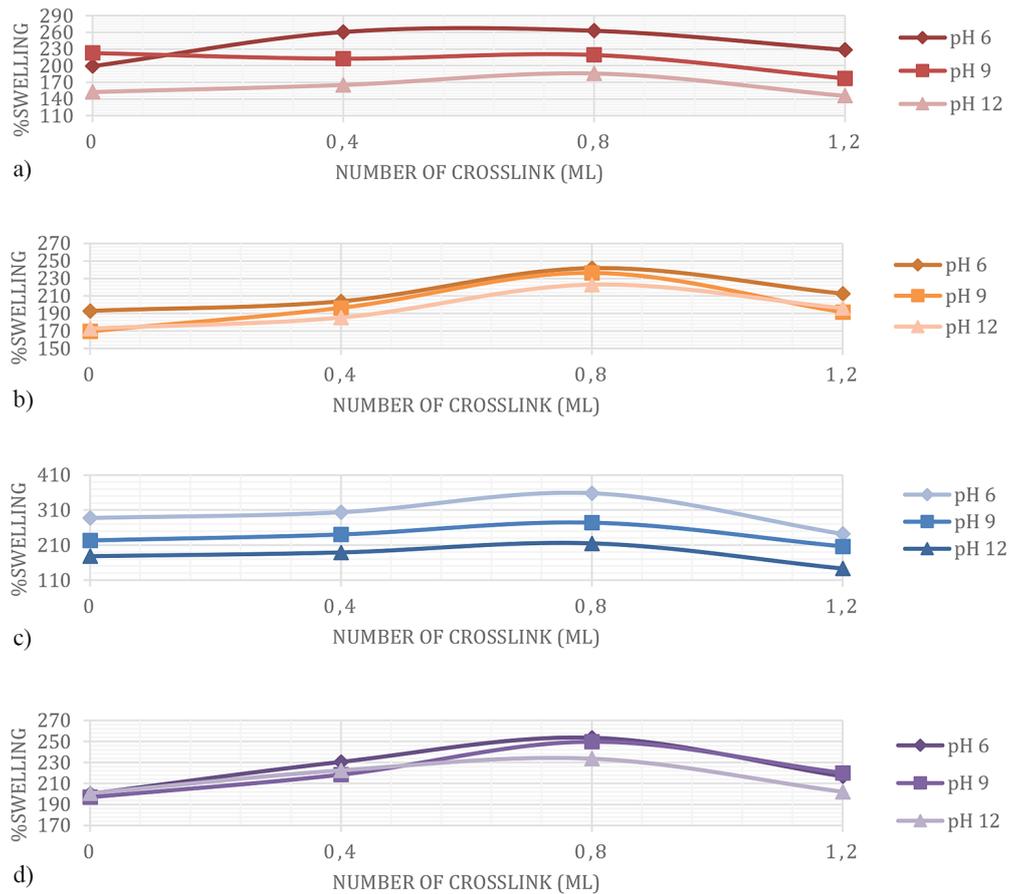
and polymer children. The high level of absorption capacity resulting from this study is due to the characteristics of PVA as the main chain. PVA has very selective properties against water. This property is due to the fact that PVA has many –OH groups, so that it can bond well with water molecules through hydrogen bonds. The hydroxyl group on the polymer chain is the main cause of PVA being polar. The PVA structure can also form anionic and cationic ions due to the large number of hydroxyl (-OH) and acetate (-OCOCH) groups is free in the PVA polymer chains formed during the adsorption process (Areal et al., 2018).

### Initiator and crosslink effect swelling

The next characteristic which is the focus of discussion in this study is ratio swelling. The superabsorbent product that is formed is analyzed for the absorption rate of the liquid with a certain pH to find out how suitable it is in an acidic or alkaline environment. In this study, testing was carried out ratio swelling using a solution buffer *acetate* by mixing acetic acid ( $\text{CH}_3\text{COOH}$ ) into its salt solution ( $\text{CH}_3\text{COONa}$ ) with pH 6, 9 and 12.

On the basis of the research results referring to Figure 7, the effect of adding initiators and crosslink agent against value swelling in a pH solution was explained. According to the data analysis performed, the optimum point is obtained with a value swelling the highest was in sample C with an initiator variation of 0.8 grams and crosslink 0.8 mL. The highest Mark Swelling was obtained under acidic conditions, namely pH 6 with a value reaching 358.30% or the weight of the material being 3.58 w/w from the initial material weight of 0.10 g. The higher the atmosphere the pH of the solution produces a value swelling which is becoming smaller. This can indicate that the superabsorbent product is difficult to dissolve under alkaline conditions. Under the variation sample conditions, crosslink 1.2 mL decreased the value of swelling caused by the accumulation of free radicals and crosslink agent on the polymer surface, which can be seen in the results of the SEM micrograph (Fig. 8).

Super absorbent products with the highest value swelling were found in a solution of pH 6. This product prefers to swell at pH 6 due to the influence of the pH of the solution crosslink agent. Formaldehyde as a crosslinking agent (crosslinker) can achieve ether exchange reactions with hydroxyl groups on polymers under acidic conditions. Formaldehyde will also undergo a reaction crosslinker



**Figure 7.** The relationship between initiator and crosslink effects swelling. Sample with an initiator amount of: (a) 0.4 gram, (b) 0.6 gram, (c) 0.8 gram, (d) 1 gram

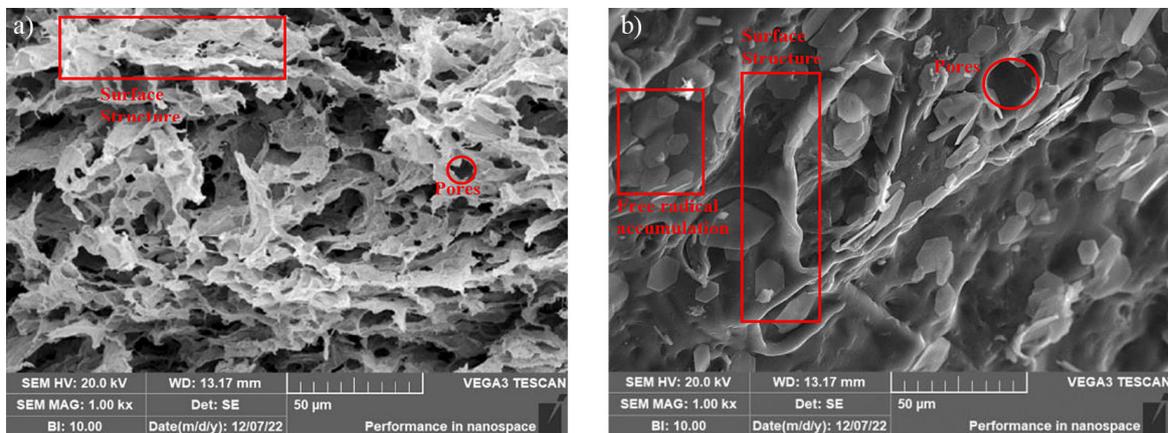
complex so as to increase chemical resistance, hardness and other properties (Zhu et al., 2021).

### Characterization of superabsorbent surface morphology

This analysis was carried out to determine differences in surface morphology of PVA raw

materials before and after the formation of superabsorbent products which are the cause of changes in the characteristics of brittleness, absorption capacity and ratio swelling in pH solution. The results of the SEM analysis can be seen in Figures 8.

On the basis of the results of Figure 8, the differences in the morphological structure of the pure PVA surface before and after being carried out



**Figure 8.** (a) SEM micrograph 1000× of PVA hydrogel; (b) SEM micrograph 1000× of superabsorbent KPS variation: formaldehyde (1 g : 1.2 ml)

grafting with cellulose chains and the formation of superabsorbent products were explained. According to the research conducted by Cascone et al. (2004) referring to Figure 8a the surface structure of pure PVA hydrogel is shown. The structure of pure PVA identified based on the micrograph shows a surface structure with small, non-uniform pores and the surface looks brittle and rough. The large number of pores on the surface is caused by the large number of -OH groups which are the main functional group of PVA, so that it is hydrophilic. Figure 8b shows the surface structure of the superabsorbent hydrogel with varying amounts of 1 g of KPS and 1.2 ml of formaldehyde. The identified superabsorbent structure has larger pores than pure PVA hydrogel, the surface looks elastic and strong but there are piles of polymerized materials.

On the basis of the changes in the morphological structure that occurred, it can be identified that polymerization grafting between the characteristics of PVA and bagasse cellulose by method chemical *crosslink* succeed. This success was marked by an increase in the pore diameter from  $\pm 4.10$  nm for pure PVA to  $\pm 11.75$  nm when superabsorbent was formed. The increase in pore diameter was due to the improvement in the characteristics of PVA from the characteristic properties of cellulose which is composed of cellulose microfibrils and water with an interconnected porous network structure so that the absorption capacity increases (Zhao et al., 2021).

On the basis of the results of the micrograph in Figure 8b explains that the material formed has more porous properties with larger diameters than before superabsorbent was formed. The surface is solid, strong and elastic compared to before the formation of superabsorbent the structural properties of which are still fragile. The change in surface structure proves that the grafting process and interfacial interactions of the two materials occur well (Chalid et al., 2020).

This new characteristic is the main factor for the polymeric material that is formed to act as a superabsorbent with an absorption capacity and high swelling ratio. There is a buildup of material. There is a buildup of material. The accumulation of this material is the amount of free radicals the capacity of which is excessively released by KPS with the number of daughter chains from cellulose which cannot accept all the free radicals formed. The remaining free radicals that do not attack the daughter chains of the cellulose accumulate and cause accumulation on the superabsorbent

surface so that the absorption ability of the material decreases. The amount of *Crosslink agent* in the form of excessive formaldehyde also hinders the absorption of pores which is characterized by the inhomogeneous pore diameter formed from cross-linking between PVA and bagasse cellulose. The excessive amount of *Crosslink agent* will reduce the space between the polymer chains and the structure will become rigid thereby reducing the water absorption capacity that can be accommodated (Sand and Vyas, 2020).

## CONCLUSIONS

The formation of new functional groups during polymerization is formed by the emergence of new functional groups identified from absorption peak namely the alcohol group of PVA (C-O), the hydroxyl group of bagasse cellulose (-OH), the aromatic structural group of cellulose which is attacked by free radicals from KPS (C-O-C), the aldehyde group of crosslink agent (C=O). Increasing the number of initiators and crosslink agents will accelerate and strengthen the material bonds formed in the polymerization, so as to increase the absorption capacity. The highest absorption capacity reached 746.4912% in the sample with 0.8 gram of initiator and 0.8 mL of crosslinks. The higher the atmosphere the pH of the solution produces a value swelling which is becoming smaller. This can indicate that the superabsorbent product is difficult to dissolve under alkaline conditions. Mark Swelling the highest was obtained under acidic conditions, namely pH 6 with a value reaching 358.30% or the weight of the material being 3.58 w/w of the initial material weight.

The surface morphology of the superabsorbent product explains that the material formed has more and more porous properties with a larger diameter from  $\pm 4.10$  nm to  $\pm 11.75$  nm after the superabsorbent is formed. The surface is solid, strong and elastic compared to before the formation of superabsorbent the structural properties of which are still fragile. The change in surface structure proves that the grafting process and interfacial interactions of the two materials are going well.

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