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Comparative effect of polymer coating materials on physical properties of NPK fertilizer pellet

Gatot Trimulyadi Rekso*

Research and Technology Center for Application of Isotope and Radiation-BRIN, Jl. Lebak Bulus Raya No. 49, Jakarta 12440, Indonesia

Abstract. Slow-release fertilizer is one method to reduce the rate of loss of fertilizer from the soil due to leaching by rainwater or irrigation water. One of the agents that can be used for slow-release fertilizers is polymeric materials coated on NPK fertilizers. The NPK fertilizer coating polymer material used was a mixture of starch, acrylamide, PVA, and chitosan that was formulated and irradiated at a dose of 20 kGy. The purpose of this study was to obtain the best comparison between coating materials and NPK fertilizers made with a pelletizer machine. NPK fertilizer is mashed and mixed with polymer coating material with a weight ratio of NPK coating material/fertilizer; 1/9, 2/8, and 3/7. The results obtained showed the largest pellet yield capacity using a ratio of coating material and NPK fertilizer with a weight ratio of 1/9 of 4.28 g/minute and the greatest durability value at a ratio of 3/7 with a value of 87.1%. NPK released in NPK fertilizer coated with a polymer coating and fertilizer in a ratio of 1/9, 2/8, and 3/7 resulted in the release of NPK with not too big a difference. In the analysis of the functional group by FTIR between non-irradiated formulation and irradiated 20 kGy, there was no addition or change of molecular structure in the functional group. whereas thermal analysis with DSC displayed endotherm at temperature 50^0C to 120^0C and exotherm at temperature 250^0C until 320^0C for analysis of TGA degradation of the formulation is divided into 2 phases, in the first phase degradation begins at a temperature of 50^0C to 150^0C losing weight of 5% and in the second phase of degradation at 250^0C to 500^0C losing weighs 47%

1. Introduction

One of the efforts to increase the effectiveness and efficiency of fertilization is to modify it into a slow-release fertilizer (SRF) with supporting and environmentally friendly basic ingredients [1]. The main problem with the use of chemical fertilizers such as urea or NPK on agricultural land is their low efficiency due to their high solubility and loss due to the water-soluble, evaporation, and denitrification process of the fertilizer itself. Therefore, a formulation for the manufacture of coating materials with natural polymers based on natural polymers will be carried out which has three functions (multi-function) namely as a slow-release, plant growth inducer, and as a water-absorbent. Slow-release fertilizer is a fertilizer with a mechanism for releasing nutrients periodically following the pattern of nutrient absorption by plants. Several mechanisms that can be applied in the production of SRF are the mechanism of coating fertilizers with semi-permeable membranes and the mechanism of fusion of fertilizer nutrients in a matrix. The main principle of the two mechanisms is to create a barrier in the form of molecular interactions so that the nutrients in the fertilizer granules are not easily released into the environment. Controlled-release fertilizer (CRF) is one method to reduce the rate of loss of fertilizer from the soil due to leaching by rainwater or irrigation water and maintain water or mineral supplies for a long time until dry land recovery [2]. One of the agents that can be used for CRF is natural polymer materials. By using a polymer material that functions as a hydrogel, the release of water and nutrients can be slowed or even controlled so that plants can absorb more nutrients and water without wasting. Thus, hydrogel- controlled release fertilizer can increase the efficiency of nutrient application, and increase plant growth while reducing the impact on the ecological environment [3].

The research that will be carried out is to obtain the optimum ratio of coating material and urea fertilizer in the form of pellets. Parameters include the ratio of coating material and fertilizer weight and tool rotation speed. Characterization includes bulk density, durability, water absorption, and hardness.

2. Material

The materials used are starch, polyvinyl alcohol, acrylamide, potassium dihydrogen phosphate, sodium hydroxide (NaOH), sulfuric acid, nitric acid, ammonium vanadate, and ammonium molybdate. While the solvent is aquadest. Then for testing the slow release of phosphate, NPK (10:55:10) phosphate fertilizer was used.

2.1 Preparation of copolymer coating material-starch-PVA-AAm-oligo-chitosan [4]

First, the starch is added to the acrylamide solution little by little while stirring. Then the mixture of these

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* Corresponding author: gatot2811@yahoo.com

solutions was added to a solution of polyvinyl alcohol (PVA), acrylamide, and chitosan, stirred, and heated at 90oC for 1 hour. The composition of the coating material is as follows: 5% starch, 50% PVA (10%), 40% acrylamide (3%), and 5% chitosan (2%).

2.2 Irradiation

The resulting polymer mixture was irradiated by gamma rays of 60Co in the air at room temperature to allow the desired polymerization to occur. In this irradiation process, the sample is irradiated with an irradiation dose of 20 kGy.

2.3 Characterization of the starch-acrylamide-oligochitosan copolymer

The copolymer of starch-polyvinyl alcohol- acrylamide obtained was analyzed for functional groups using Fourier Transform InfraRed (FTIR) at wave numbers from 4000 to 400 cm-1 using KBr powder. In addition, the thermal stability of the copolymers was also analyzed using a Themo Gravimetric Analysis (TGA) instrument, and to ensure the surface morphology of the formed copolymers, the copolymers were analyzed using a Scanning Electron Microscope (SEM) with a magnification of 100 times and 500 times.

2.4 Process of making pellet

The process of making pellets is the formation of a mixture in the form of pellets. The first time the NPK was ground and mixed with the copolymer material at the ratio of NPK coatings/fertilizers = 1/9, 2/8, and 3/7 until smooth. The tool used is a pelletizer machine with a maximum working capacity of 50 kg/hour and a working enginespeed of 60 rpm.

2.5 Evaluation properties of pellets

2.5.1. The yield capacity of the pellet material

The yield capacity of the pellet material is done by dividing the weight of the pellet that is printed against the time it takes to print the pellet.
$KH = BC/T$. Where : KH = Yield capacity (g/min), BC = Printed weight (g), T = Time (minutes)

2.5.2. Durability test

Durability test is used to determine the physical qualityof pellets, namely knowing the percentage of the numberof pellets that are still intact after going through physicaltreatment with mechanical devices. The steps in this test are to prepare 500 grams of coated NPK fertilizer samples. Then put the weighed sample into a vibrating machine tool (shaker) and turn it on for 10 minutes. After 10 minutes, then the machine was turned off and the samples were weighed which were still intact/not broken. The durability value is calculated by the equation:

% Durability = Mo/Mi x 100%

where: Mo=mass of an intact sample (g), Mi=mass of the sample before the test (g)

2.5.3. Determination of Slow Release

Determination of Slow Release of Phosphate-NPK Fertilizer [5].

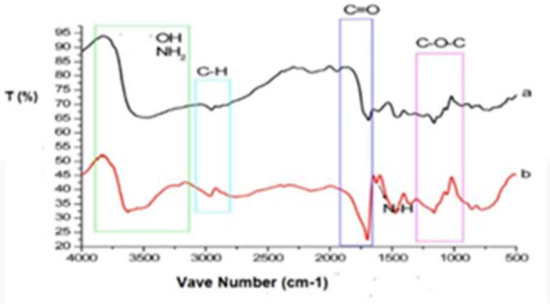
The polymer that has been weighed as much as 0.1 g and is contacted with a fertilizer solution is measured forits slow-release properties in water. Every certain period, 10 mL of soaking water is pipetted and then 10 mL of distilled water is added back into the immersion container. To see the slow-release properties of the polymer, the immersion was carried out for a period of 10, 20, 30, 40, 50, 60, 120, 180, 240, 300, and 360 minutes. The immersion water was measured for its phosphate content using the molybdate-vanadate method on a UV-VIS spectrophotometer. Then the results of the measurement of phosphate levels in the water are compared with the immersion time.

3. Results and Discussion

3.1. Characterization of polymer NPK fertilizer coating materials with FTIR

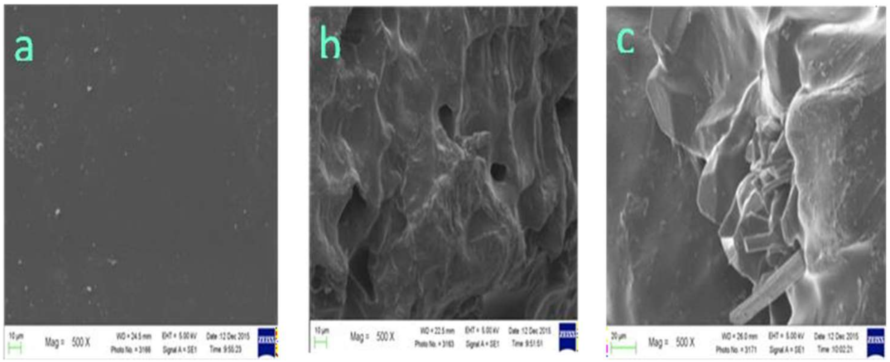
Figure 1. Shows the difference in FTIR spectra between copolymers before and after radiation on starch-PVA-acrylamide-chitosan samples.

Fig. 1. IR Spectra Coating material formula at a) 0 kGy and



b) at 20 kGy

The presence of narrowed spectra from 3400 - 3654 cm^{-1} is thought to be due to the reduction of the free -OH functional group due to copolymerization. In this case, it shows the existence of hydrogen bonds that occur between N-H derived from acrylamide and –OH derived from starch and also PVA with each other. In addition, it can also show -OH stretching of the intra and intermolecular hydrogen bonds between starch and PVA or also of free -NH on acrylamide and free -OH on PVA and starch [4]. Then there was a shift in the wave number from 1611 cm^{-1} to 1626 cm^{-1} and an increase in the intensity at wave number 1626. cm-1. The shift that occurs may occur due to the presence of inter and intra-molecular between PVA and acrylamide through intermolecular hydrogen bonds [6]. With the increasing number of these interactions, it will be seen that the spectra are getting stronger and sharper [7]. At the wave number of 1699 cm-1, it is seen that the shift and peak



shape are getting stronger and sharper when compared to the wave number of 1688.75 cm^{-1}. The shift and sharper peak shape are thought to be due to the stretching of C=O bonds from starch that appears other than acrylamide in the copolymer. At wave numbers, 1699 cm-1, 1626 cm^{-1}, and 1354 cm^{-1} indicated the presence of C=O stretching, N-H bending, and C-N stretching, respectively, and indicated the –CONH2 group [4]. In the spectrum at wave numbers around 900 cm-1 and 1050 cm^{-1}, there is a reduction between before radiation and after radiation. This is presumably because at C-O-C and C-OH copolymerization occurs with monomers or polymers in the mixture.

3.2. Thermal properties

Characterization using TGA was carried out on 3% starch and acrylamide samples. This was done to see the thermal stability of the polymer synthesis material and the effect of adding acrylamide on polymer synthesis.

In Figure 2. the sample has three stages of decomposition which are indicated by the appearance of three peaks on the thermogram.

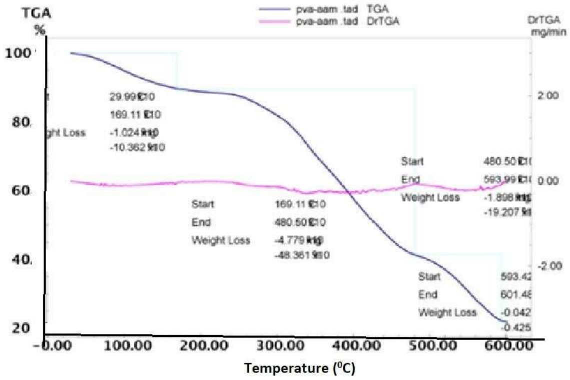


Fig. 2. Thermogram copolymer of starch and 5% acrylamide monomer

In the first stage, decomposition begins to occur up to a temperature of 176.78 ºC. At this stage, it is suspected that there will be the decomposition of water in the copolymer and the homopolymer that may have been from the functional groups in the polyvinyl alcohol-acrylamide copolymer. In the last stage, decomposition begins to occur up to a temperature of 575.20 ºC. Decomposition which occurs at this last stage is thought formed during the synthesis of the copolymer [7,8]. In the second stage, decomposition begins to occur up to atemperature of 487.72 ºC. At this stage, it is suspected that decomposition occurs to come from the remains of components that have not been decomposed at a lower temperature so that in the end it produces residual ash of 0.81%.

3.3. SEM

Characterization using SEM was carried out on control samples of starch and acrylamide before irradiation (a) and samples irradiated at a dose of 20 kGy (b) with a magnification of 500 X (c). From the picture above, 5% starch-acrylamide irradiated at 20 kGy formed pores surface for slowrelease.

3.4. Pellet material yield capacity

To determine the capacity of the pellet material is calculated by the weight of the pellet produced in a certain time unit. In this study, it was carried out for 5 minutes,after 5 minutes the pellet material produced was weighed in grams so that pellet production was obtainedwithin 5 minutes.

The weight of the pellet material with variations of coating material (polymer) and NPK fertilizer for 5 minutes is shown in Figure 4.

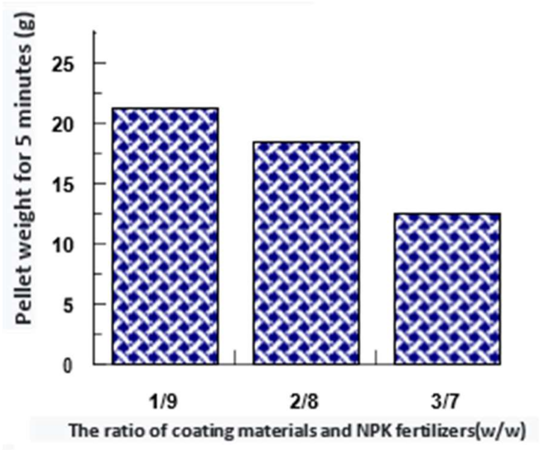


Fig. 4. The effect of variations in the ratio of the coating material (polymer) and NPK on the weight of the pellet material for 5 minutes

Figure 4 shows that the ratio of coating material and NPK fertilizer of 1/9 produces pellet material which is at most 21.4 g and the ratio of coating material on NPK fertilizer increases, namely at a ratio of 2/8, 18.6 g, and 3/7 are produced of 12.62 g. The cause of the decrease in the number of pellets produced is that the mixture of fertilizer with more coating materials becomes softer and sticky so that when it is made in the pelletizer machine there will be blockages in the discharge holes and sticking to the equipment [8].

Figure 5 shows that the ratio of coating material and NPK fertilizer of 1/9 produces pellet material which is at most 21.4 g and the ratio of coating material on NPK fertilizer increases, namely at a ratio of 2/8, 18.6 g, and 3/ 7 are produced. of 12.62 g. The cause of the decrease in the number of pellets produced is that the mixture of fertilizer with more coating materials becomes softer results in a higher yield capacity compared to a larger ratio (2/8 and 3/7). This is because, with the increase in the amount of coating material added to the fertilizer mixture, the pelleted fertilizer produced at a certain time and sticky so that when it is made in the pelletizer machine there will be blockages in the discharge holes and sticking to the equipment.

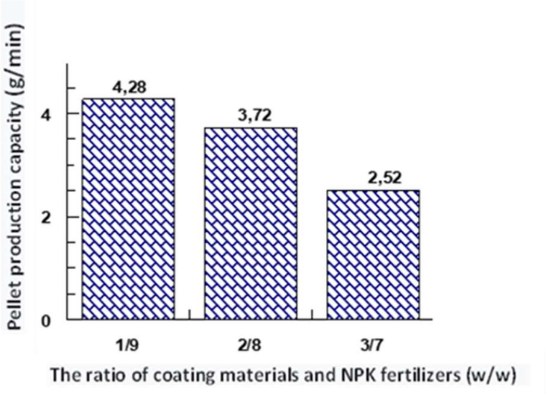


Fig. 5. Effect of coating material (polymer) ratio on pellet yield capacity (g/min).

A lower ratio of coating material and fertilizer is lower. This is because the dough is softer and stickier in the cavity of the pelletizer and clogs the outlet of the pelletizer so that the production capacity decreases [1].

3.5. Durability Test

Pellet durability is the resistance of pellet particles which is formulated as a percentage of the amount of whole pellet fertilizer after going through physical treatment in the test equipment. Durability is related to various processes in the use of pellets, such as the transportation process (transportation), as well as the distribution of the resulting pellets, therefore it is important to measure the durability of pellets [9]. The effect of coating material composition (polymer) and NPK on durability (%) is shown in Figure 6.

Good pellets are pellets that have a good durability so that in the process of handling and transporting pellets, they are not physically damaged, remain compact, sturdy, and not easily brittle. Dozier (2001) states that the minimum pellet durability specification standard is 80% [10]. Pellet durability is influenced by the chemical composition of the material, namely the coating polymer material and the composition of the polymer material and NPK fertilizer and durability can also be affected by the particle size of the pellet.

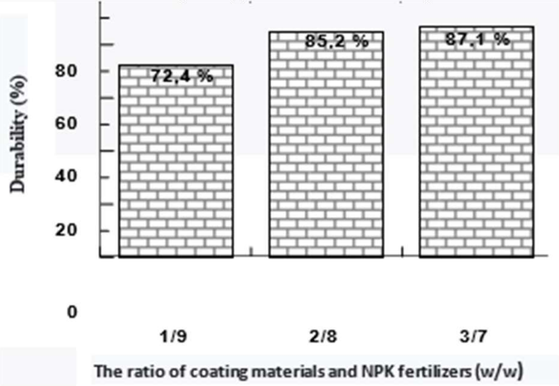


Fig. 6. Effect of coating material composition (polymer) on fertilizer on durability (%).

From the research conducted, the durability value on pellets at the ratio of coating material and NPK 1/9 was obtained at 72.4%, a comparison of 2/8 was obtained by 85.2%, and a ratio of 3/7 was obtained by 87.1%. The more coating materials added to the NPK fertilizer the more durability value increases. This is because the greater the coating material (polymer) given the bond between the fertilizers, the greater the coating material functions as an adhesive [11].

The results are shown in Figure 6. Composition of coating materials and NPK fertilizers with a ratio of 2/8 and 3/7. Durability values are above 80%, meeting the durability value standards for pellets. This shows that the pellets produced are not easily destroyed during handling and transportation.

3.6. Slow-Release properties of NPK coated with a polymer coating material

The test of slow-release properties on NPK coatedwith polymer with variations in the ratio of coating material and NPK is shown in Figure 7 which was carried out using the absorption-desorption method. The amount of phosphate absorbed and released in the copolymer was measured chemically using the molybdate-vanadate method [8].

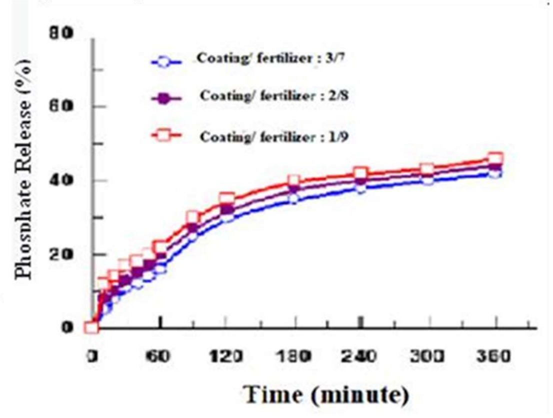


Fig. 7. Slow-release properties of NPK fertilizer coated with a polymer coating material

The results of the analysis are shown in Figure 7. The results show that the released NPK in NPK fertilizer coated with a polymeric coating and fertilizer with a ratio of 1/9, 2/8, and 3/7 resulted in the release of NPK with not too large a difference. At a ratio of 1/9, the slow-release time is slightly greater than that of fertilizers with a composition of coating material and NPK with a ratio of 2/8 and 1/9. This result is because more coating material will bind more NPK fertilizer [8]. After all, the coating material contains starch which functions as an adhesive and closes the NPK pores.

4. Conclusion

Based on the results of the research that has been carried out, it can be concluded: A copolymer between starch-PVA and acrylamide has been obtained which can be used as a coating material for NPK fertilizer and made into pellets. The largest pellet yield capacity uses a ratio of coating material and NPK fertilizer with a ratio of 1/9 of 4 .28 g/minute and the greatest durability value is at a ratio of 3/7 with a value of 87.1%. NPK released in NPK fertilizer coated with polymeric coating and fertilizer in a ratio of 1/9, 2/8, and 3/7 resulted in the release of NPK with not too big a difference.

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