

## Use of Polymers as Coatings for Slow Release Fertilizers

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### **Abstract:**

**Background:** Slow-release fertilizers are used to reduce the release of active ingredients so as to minimize the level of dissolution of the active ingredients, then the addition of polymers is carried out. Fertilizers coated with biodegradable materials can not only increase the nutrients absorbed in the fertilizers but also avoid the deterioration of soil physical and chemical properties caused by nutrient loss.

**Materials and Methods:** The materials and methods used are based on official books and international journals for the last 10 years (2010-2020), the making of this article is looking for data through online media with the keyword polymer for slow-release fertilizer.

**Results:** From the discussion of the review articles that have been done, it was found that the use of several polysulfone polymers, Polyacrylate / Poly (silicone-co-acrylate), Chitosan, Polyhydroxybutyrate,  $\kappa$ -carrageen (CBH), polystyrene, and starch can be used for the manufacture of slow-release fertilizers. The resulting characterization can use UV-Vis spectrophotometry, FTIR, and SEM.

**Conclusion:** The use of polymers can be applied to slow-release fertilizers and can increase agricultural yield without wasting fertilizer use.

**Key Words:** polymer, biolend, slow release fertilizer,

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### I. Introduction

Slow or controlled-release fertilizer or commonly known as slow-release fertilizer is a fertilizer containing nutrients for slow release plants which are absorbed or used by plants immediately after application<sup>1</sup>. Slow-release fertilizers are produced from fertilizer compounds that are easily dissolved by coating. Fertilizers are coated with polymers or other materials which reduce the release of the active ingredients thereby minimizing the rate of dissolution of the active ingredients. Polymers are also used as film coatings to camouflage the unpleasant taste of a drug, increase drug stability and modify drug release characteristics<sup>2,3</sup>.

The coating is one of the methods to produce slow-release fertilizer (SRF)<sup>4</sup>. Non-biodegradable compounds can be mixed with biodegradable compounds so that they can be used as a coating for slow-release fertilizers. This mixing is referred to as bioblend<sup>5</sup>. Bioblend is a polymer mixture consisting of one type of biodegradable polymer and non-biodegradable polymer<sup>6,7</sup>.

Polymers are macromolecules formed by the chemical bonds of a large number of small molecules, or repeating units called monomers. The number of monomers in polymer molecules varies greatly and the presence of different monomers in the same polymer also varies. In many synthetic and natural polymers, the number of monomers (sometimes referred to as the degree of polymerization)<sup>8,9</sup>. Conventionally, slow release fertilizer coating polymers such as organic solvent-based polymers, thermosetting polymers formed of two or more components, and latex polymers in which the continuous phase is water. Polymers show decreased nutrient content in layered fertilizers. Environmentally friendly biodegradable materials have shown good results maintaining optimal controlled release rates, especially fertilizers coated with biodegradable polymers can not only increase the absorption of nutrients in the fertilizer but also avoid the degradation of soil physical and chemical properties caused by loss of nutrients. At the same time, soil quality can be maintained efficiently due to the breakdown of the lining<sup>10</sup>.

Biodegradability has become a key factor in technology fertilizers towards sustainable agriculture. Biodegradation is a natural process in which organic chemicals in the environment are converted into simpler compounds, mineralized and distributed through cyclic elements such as carbon, nitrogen, and sulfur cycled by the activity of microorganisms. The biodegradable polymer binder is a promising new candidate for use as a replacement for formaldehyde as an anti-caking and slow-releasing agent in the fertilizer industry<sup>5,11</sup>.

Biodegradable polymers are classified into two main groups, namely agropolymers obtained by the biomass of the fragmentation process (such as polysaccharides, proteins), and biopolyesters obtained by synthesis of biologically derived monomers (polylactic acid-PLA) or by extraction from micro-organisms (polyhydroxyalkanoate - PHA) or by synthesis from synthetic monomers (polycaprolactone, aromatic and aliphatic copolyester - PBA, PBSA<sup>11,12</sup>). Fertilizers coated with biodegradable materials can not only increase

the nutrients absorbed in the fertilizers but also avoid the deterioration of soil physical and chemical properties caused by nutrient loss. At the same time, soil quality can be maintained efficiently due to the breakdown of the lining<sup>10,13</sup>

## **II. Material and Methods**

The materials and methods used in the production of this article are based on official literature, both international journals and official books. Data search was conducted through online media related to polymer as a coating for slow release fertilizers. This literature is read, defined and analyzed to see whether the polymer is efficient as a coating for slow release fertilizers.

## **III. Results and Discussion**

### **Coating Preparation**

Bioblend polymer as an inner layer was used at a 4: 1 ratio. The mixture was dissolved in 50 ml chloroform and stirred using a magnetic stirrer at 380 rpm for 10 minutes<sup>18</sup>. The coating process is carried out using the pan coating method. A total of 25 g of NPK granules are placed into the coating pan. The first coating is poured into a container of a solution in a spray gun. NPK granules are sprayed with the coating solution into a coating pan rotated at a speed of 70 RPM, and a temperature of 60 to 70 °C. First the coated NPK granules obtained are oven-dried at 70 to 80 °C for 1 hour to ensure that the solvent evaporates completely. It was previously coated with the polymer coating the second solution. The treatment is similar to the previous coating process<sup>14</sup>.

### **Polysulfone (PSF 1700) as a coating for slow release fertilizers**

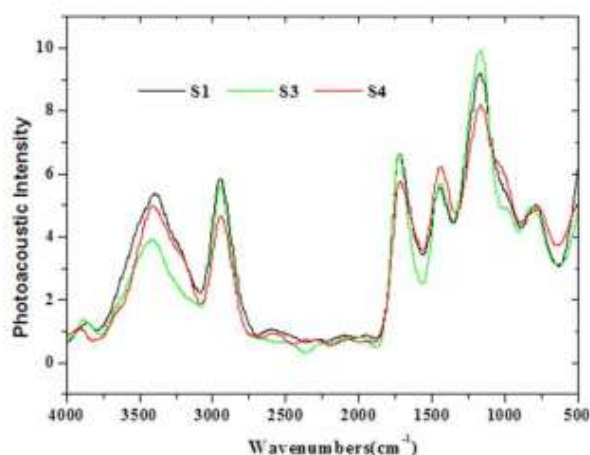
Polysulfone is used as a coating for dissolved NPK fertilizer in CRF formulations to obtain a porous coating to prepare slow release fertilizers. The dynamic test results are carried out to determine the release rate of the active components through single or multiple layered polymers. The release rate of the active component in water, the rate of release of nutrients as a function of time for each product obtained is checked at room temperature. The dynamic test was carried out for 5 hours. One gram of fertilizer is placed in a beaker containing 50 mL of water or five measuring cups. The mixture is mixed mechanically. Periodically, every hour, a sample of the solution is taken from the beaker, and the concentration of the material is determined. The static test was carried out for 10 days, in water media. The polymer coating is distributed in 10 beakers containing 50 mL of water each. The beaker is stored at room temperature. During the experiment, sample solutions were taken from the next container for measurement of the concentrations of N, P, and K every 24 hours<sup>15,16</sup>.

The release of nutrients in this experiment was observed from the number of nutrients that were released from the percolation test each week. The more nutrients that dissolve in the absorption means that more nutrients are released from the fertilizer. Control (K) is used to show the nutrients dissolved from the soil without the addition of fertilizer. Nitrogen from fertilizers was analyzed in the form of ammonium-N ( $\text{NH}_4^+ - \text{N}$ ) and nitrate-N ( $\text{NO}_3^- - \text{N}$ ) in percolation. The release pattern shows that ammonium-N continues to increase until it reaches a peak then gradually decreases its release. The reduction in  $\text{NH}_4^+ - \text{N}$  leaching can be caused by the loss of  $\text{NH}_3$  by volatilization or the transformation of  $\text{NH}_4^+ - \text{N}$  to  $\text{NO}_3^- - \text{N}$  by nitrification. There was a significant difference in the cumulative amount of ammonium-N dissolved between treatments<sup>17,18</sup>.

The fertilizer that has been coated with the outer layer is the effect of repeated spraying with a coating agent mixture. Compared to the initial prepared material, a decrease in the degree of phosphate release from the material obtained occurs as the thickness of the coating increases. The diffusion mechanism of release may be suggested as the reason for this correlation. As the thickness of the layer increases, the diffusion coefficient value decreases and the removal process becomes more inhibited<sup>19</sup>.

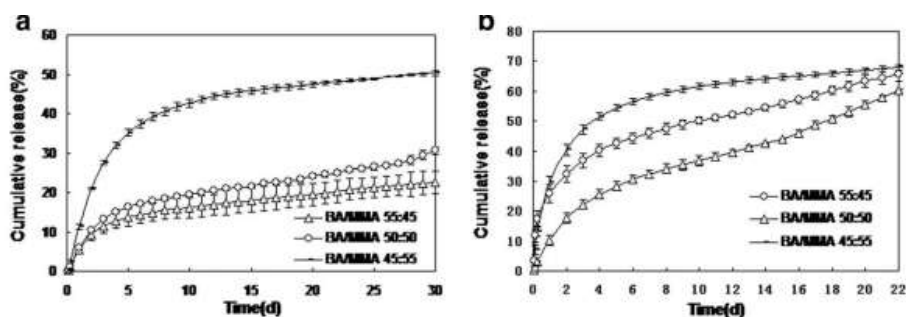
### **Polyacrylate / Poly (silicone-co-acrylate)**

The lowered layer strain can be explained by the lower T<sub>g</sub> (the glass-transition temperature) of the poly (silicon-co-acrylate) film prepared by superior polymerization. The tensile strength of the films formed from the miniemulsion polymerization presented a higher value compared to the films formed from superior polymerization and copolymerization. EG (ethylene glycol), apart from suppressing the hydrolysis and condensation of VTES (vinyltriethoxysilane), also has a plasticization function. This decreases intermolecular interactions; therefore, his strength was lowered. EG is not present in the manufacture of poly (silicon-co-acrylate) by miniemulsion, only in the manufacture of poly (siliconecrylate) with superior polymerization and copolymerization<sup>20</sup>.



**Figure 1.** FTIR spectra of CRF coated with S1, S3, S4. S1 and S3 denote polyacrylate with BA / MMA ratios of 55:45 and 45:55. S4 presents the poly (silicone-co-acrylate) emulsion with BA / MMA 55: 45<sup>20</sup>.

FTIR spectrometer (The spectrum is recorded at a wavelength of 500–4000 cm<sup>-1</sup>, and the mirror velocity is set to 0.63 cm / s. The FTIR-PAS spectrum of CRF coated with S1, S3, and S4 is shown in Figure 1. Absorption width at 3250–3550 cm<sup>-1</sup> (OH-strain vibration) shows a lower intensity in S3 than in S1; this is due to the higher monomer reactivity ratio MMA compared to BA.44 in the 990–1136 cm<sup>-1</sup> range wider than in S1 and S3 due to the asymmetric stretching of Si-O-Si and Si-OC, coupled with the high EG content in the poly (silicon-coacrylate) emulsion, all previous results provide evidence for the copolymerization of VTES to the polyacrylate chain<sup>20</sup>.

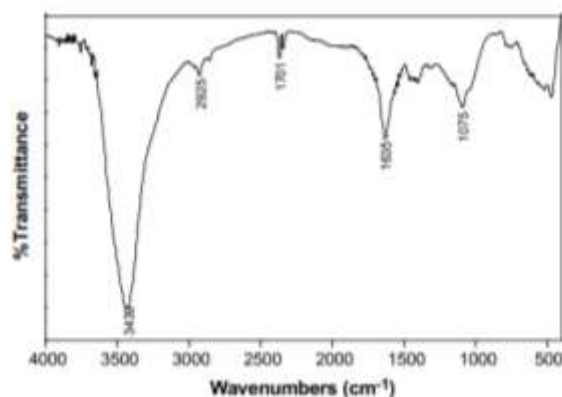


**Figure 2.** Effect of the BA / MMA ratio on the nutrient release of CRF coated with a). Polyacrylate (b). Poly (silicone-co-acrylate) emulsion<sup>20</sup>.

The nutrient release profile is important for evaluating whether the coating is suitable for CRF. The final nutrient release of CRF profiles is directly related to the physicochemical properties of the coating, namely, water resistance performance, glass transition temperature, and mechanical properties. The effect of the ratio of n-butyl acrylate (BA) / methyl methacrylate (MMA) has an effect on the physicochemical properties of the emulsion. Nutrient release from CRF is shown in Figure 2. Effect of BA / MMA ratio on the nutrient release profile of CRF coated with (a) polyacrylate and (b) poly (silicon-co-acrylate) emulsion. Nutrient release profile S1 is similar to S2, whereas nutrient profile S3 release rates accelerated sharply. S3 water resistance performance is improved; this is beneficial for slow nutrient release. However, the T<sub>g</sub> (19.58 °C) was much higher than the coatings suitable for CRF (5–15 °C). In addition, the rigidity of S3 is greatly increased, and its flexibility significantly decreases; this causes a brittle coating. The slowest nutrient release for BA / MMA ratio was 50:50 (S5), while the nutrient release ratio at 55:45 (S4) was medium and the ratio at 45:55 (S6) was the fastest and the cumulative nutrient release did not exceed 15% in 30 days at 25 °C<sup>20</sup>.

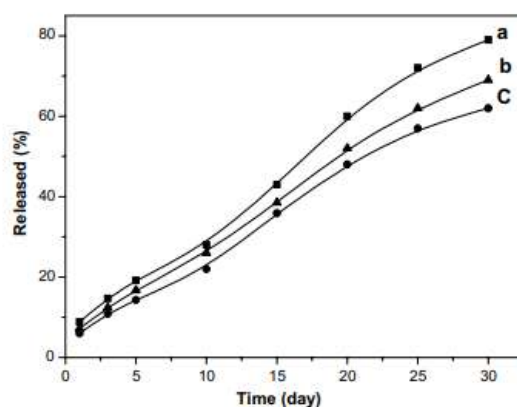
### Chitosan- Poly (Acrylic-Co-Acrylamide)

Chitosan is a highly deacetylated chitin derivative, one of the biodegradable natural polymers. NPK compound coated with chitosan fertilizer with controlled release and water retention (CFCW), with an inner layer of chitosan (CTS), and the outer layer is poly (acrylic-co-acrylamide) (P (AA-co-AM)) superabsorbent polymer. The chitosan in the first layer is biodegradable and the AA and AM copolymers of the outer coating material can also be degraded<sup>21</sup>.



**Figure 3.** The FTIR spectrum P (AA-co-AM)<sup>21</sup>

The outer coating material is CFCW, P (AA-co-AM) marked with a Fourier Transform Infrared (FTIR) spectrophotometer. The infrared spectrum of P (AA-co-AM) is shown in Figure 3. The observed peaks were at 3439 cm<sup>-1</sup>, corresponding to N - H acrylamide units, 2925 cm<sup>-1</sup>, corresponding to the CH strain of acrylate units, 1701 cm<sup>-1</sup>, corresponding to stretching C = O in acrylate units, 1635 cm<sup>-1</sup>, corresponding to the carbonyl portion of the acrylamide units, 1075 cm<sup>-1</sup>, corresponding to -CO- O - stretching acrylate units. These results prove that the outer layer is a superabsorbent P (AA-co-AM) polymer<sup>21</sup>.



**Figure 4.** release behavior of nitrogen (a), potassium (b), and phosphorus (c) in soil <sup>21</sup>.

One of the most important features of CFCW is its controlled release property. Figure 4 Slow release of N, P and K from CFCW in soil. It can be seen from Figure 4 that N, P, and K in CFCW released 14.7, 10.9 and 12.4% on day 3, 19.2, 14.3 and 16.7% on day 5, with the amount of nutrient release lower than 15% on day 3, and not more than 75% on day 30, this indicates that the slow-release character of the CFCW we prepared is following the standard of slow release fertilizer and also indicates that CFCW has excellent controlled release properties<sup>21</sup>.

The mechanism of releasing CFCW nutrients in the soil is (1) The outer layer of P (AA-coAM) slowly swells by water in the soil and turns into a hydrogel. The dynamic exchange between the water in the hydrogel and the water in the soil will develop (2) When the free water in the P layer (AA-co-AM) migrates to the middle layer, namely the CTS layer, the water will penetrate the inner layer slowly at the initial stage and compound fertilizer NPK dissolves in the core. At this stage, the diffusion will be limiting the rate of release of the step. (3) Under the influence of water, ions and microorganisms present in the soil, the middle CTS layer will slowly degrade and dissolve the NPK compound fertilizer. At this stage, the rate of degradation determines the rate of nutrient release. (4) NPK dissolved compound fertilizer diffuses out of the CTS layer and into the P layer (AA-co-AM), and then released into the soil through the dynamic exchange of free water<sup>21</sup>.

The outer layer is a super-absorbent P (AA-co-AM) polymer, which can absorb large amounts of water. The middle layer is CTS, which serves as a physical barrier for mass transfer, and reduces the rate of water diffusion to the core and diffusion of nutrients outside the core, giving CFCW good controlled release properties. Water soluble inner core NPK compound fertilizer granules. In short, the outer P layer (AA-co-AM) allows CFCW water retention properties, and the middle CTS layer activates the CFCW controlled release property. The results show that CFCW is a good slow release fertilizer with excellent water retention ability. Therefore, the CFCW will find good application in agriculture<sup>21</sup>.

### Polyhydroxybutyrate

Polyhydroxybutyrate (PHB) and Ethyl Cellulose (EC) were used to coat SRF in chloroform and acetone solutions by spraying. The fertilizer granules are sprayed with a manual pulverizer with a trigger (output between 0.6 and 0.9 mL/spray). To inhibit agglomerate formation, the granules are mixed manually. To produce fertilizer granules coated with PHB, 1.50 g of polymer were dissolved in 30 mL of chloroform. To produce a coating with PHB and EC, 0.75 g PHB and 0.75 g EC were dissolved in 30 mL chloroform. The solution was maintained under magnetic stirring at 380 rpm at 40 ° C for 10 minutes<sup>22</sup>.

### Release Profile of Urea in Distilled Water

Prepared by placing a known mass (0.25 g) of the product in 100 mL distilled water at 24 ° C. To keep the absorbance value within the calibrated spectrophotometer range. The release of fertilizers and some of its products in distilled water at 24 ° C. Under the conditions analyzed, > 50% by weight was released in 30 seconds, whereas complete dissolution was observed after 2 minutes of analysis. It can also be observed that only products made with CTAB in PHB solutions, either alone or in combination with SLS, are used to slow down the fertilizer release rate, when compared to other products. The results showed that the spray procedure was effective in producing a good polymer coating. In this case, half of the fertilizer in the PL-PHB / CTAB product was released in about 3 minutes, whereas 90% of the available fertilizers are dissolved after 1 hour<sup>18,22</sup>.

### Fourier Transform Infrared Spectroscopy.

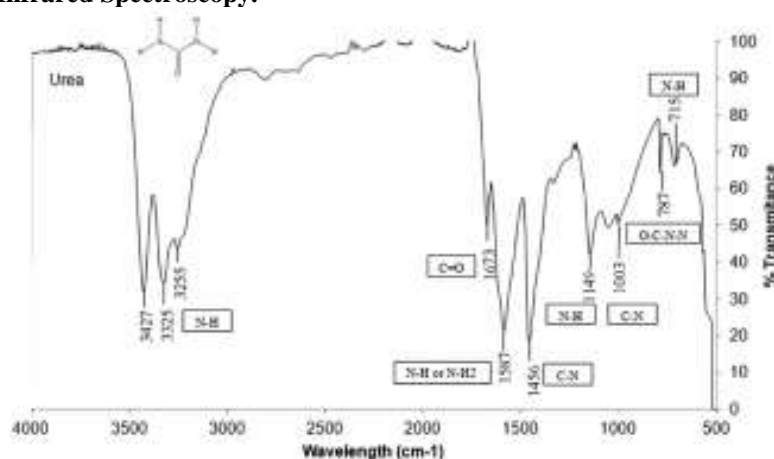


Figure 5. FTIR spectrum of urea coating PHB<sup>22</sup>.

Showing the FTIR spectrum of urea, the product is prepared by immersion in PHB solution. Pure urea stretching C - H (between 3000 and 2840  $\text{cm}^{-1}$ ), stretching C - O (between 1300 and 1000  $\text{cm}^{-1}$ ), indicating the presence of surfactant and / or PHB around the fertilizer. However, IM-PHB / CTAB displayed considerable variation in the band characteristic of N-H bonds, indicating the interaction between fertilizer and surfactant. The interaction between the coating and urea granules was evaluated in connection with the coating procedure. The product prepared by spraying with PHB showed a displacement of the associated band of the N - H bond, but with a stronger displacement observed in the material prepared by immersion. These observations indicate that the process has an influence on the physical interaction between urea and PHB, represented by the increasing number of layer attached to the grain (3.82 and 4.41%)<sup>18,22</sup>.

The results of Polyhydroxybutyrate (PHB) and Ethyl Cellulose (EC) used to coat the slow release fertilizers showed that the interaction between fertilizer granules and PHB was only enhanced by the addition of CA to the polymer solution, resulting in a more uniform film on the particles in natural urea. CTAB is the matching agent which provides the highest incorporation efficiency of PHB to urea, giving a slower release rate<sup>18,22</sup>.

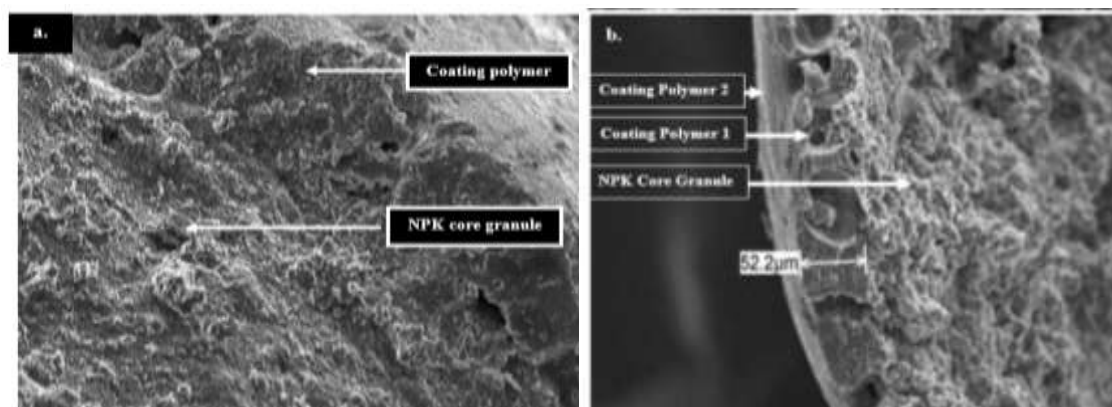
### Polystyrene/Polycaprolactone

The phosphate release characteristics of the NPK slow release samples in distilled water were evaluated at room temperature. The phosphate release profile generally occurs due to immersion and penetration of steam water into NPK granules which can dissolve a small portion of solid fertilizer. It happened because of coating the NPK fertilizer with coating. During a period of constant release rate, the concentration of the solution in the granules becomes saturated and eventually becomes constant. In this step the diffusion of nutrients from inside out of the granules through the polymer layer also becomes constant. During the reduced nutrient release step, all the nutrients are dissolved, the concentration gradient begins to decline and diffusion also decreases. This

means that the release of nutrients begins with an accelerated rate of nutrient release and ends with a decrease in the rate of nutrient release<sup>17,18</sup>.

### Scanning Electron Microscope (SEM) examination in a polystyrene / polycaprolactone mixture

Morphological and cross-sectional examinations using a Scanning Electron Microscope (SEM) of noncoating NPK granules and slow release NPK granules at a magnification of 300 dpi can be seen in Figures 6 a and b. Figure 6a Scanning electron micrograph of an uncoated NPK grain showing a grain core without a coating layer. Figure 4b. shows the morphology of the slowly released first-layer NPK granule. It can be observed that the boundary between the NPK grain core and the polymer layer. Figure 6b. shows the morphology of NPK double-layered double release granules. It shows the coating surface looks like a fine thin film. The outer polymer layer has water retention characteristics<sup>14,17</sup>.



**Figure 6.** SEM of slow release NPK granule at 300x magnification, (a). SEM of single coating slow release NPK granule; (b). SEM of double coating Slow release NPK granules<sup>17</sup>.

### FTIR examination of a polystyrene/polycaprolactone mixture

FTIR spectroscopy was used to study surface changes of polystyrene films. Structurally polystyrene consists of aliphatic chains with aromatic rings attached to every other carbon atom Fourier Transform Infrared Spectroscopy (FTIR). The functional groups, bond types, and components identified in the sample are determined by the FTIR Spectrophotometer Infrared spectrum of the sample recorded in the range frequency 400–4000  $\text{cm}^{-1}$ <sup>23</sup>.

The FTIR spectrum of NPK grains coated in polystyrene-polycaprolactone blend samples showed similarities to the spectrum of uncoated NPK grains. 1080  $\text{cm}^{-1}$  peaks are not coated with NPK granules and 1047  $\text{cm}^{-1}$  in coated NPK grains have flexible vibrations from the CO group. The peaks of 890  $\text{cm}^{-1}$  and 753  $\text{cm}^{-1}$  in uncoated NPK grains and coated NPK grains have CH bending vibrations. The peaks were 2940  $\text{cm}^{-1}$  and 2924  $\text{cm}^{-1}$  in the polycaprolactone and the coated NPK spectrum showed -CH<sub>2</sub> asymmetric strain vibration. The sizes 1721 and 1727  $\text{cm}^{-1}$  peaked in polycaprolactone and the NPK coated spectrum was C = O carbonyl strain vibration. The 754 and 753  $\text{cm}^{-1}$  peaks in polystyrene and the NPK layered spectrum were benzene strain vibrations. The peaks 2.919 and 2924  $\text{cm}^{-1}$  in NPK coated polystyrene polistirenspektrum are strain C-H<sup>24</sup>

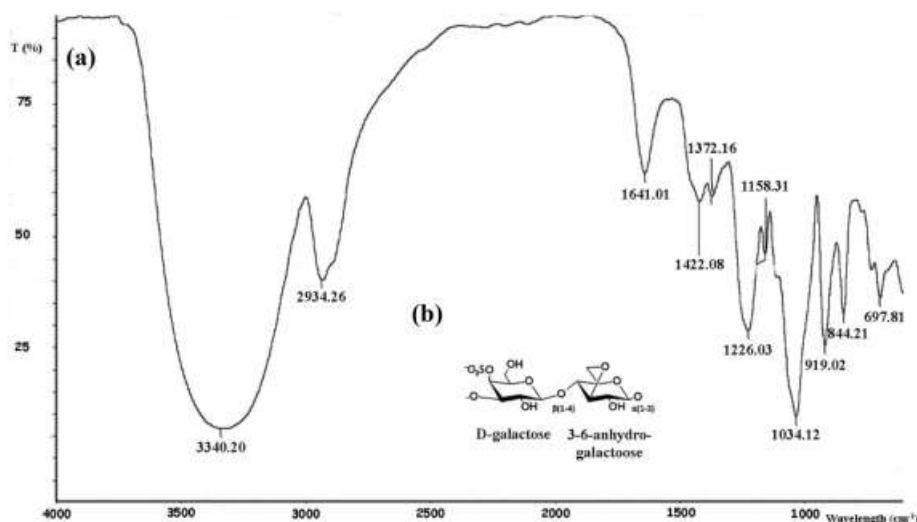
### $\kappa$ -carrageen (CBH)

Characterization of  $\kappa$ -carrageen (CBH) based hydrogels with a water retention capacity that reduces leaching of nutrients from fertilizers to the environment when used for coating. NPK fertilizer granules without negative effect on plant growth. To test the slow release behavior of the fertilizer layer and to determine adequate nutrient availability for the plants, the leaching rates of N - NH<sub>4</sub><sup>+</sup>, P - PO<sub>4</sub>-3, and K + were determined by soil column experiments, and plant growth indicators were measured through greenhouse experiments. Potato plants were selected to evaluate the effect of layered fertilizers<sup>25</sup>.

### FTIR $\kappa$ -carrageen (CBH) examination

The chemical structure of the CBH polymer was characterized by interpreting the infrared (IR) spectrum of the CBH polymer sample. IR was recorded using a Fourier transform infrared spectrometer (FTIR) (Thermo Scientific Nicolet iS10 with ATR module, verified with a 1.5 mm polystyrene standard traceable to the NIST standard) in the wavelength range from 4000–600  $\text{cm}^{-1}$  with a mean of 64 scans per sample. Each sample was vacuum sealed in a watertight polystyrene packaging and stored in a container with a silica gel dryer prior to the IR test. The IR spectrum of the CBH polymer showed some typical  $\kappa$ -carrageenan absorption. For example, the strain vibrations of the ester-sulfate bond were assigned the bands 1422 and 1226  $\text{cm}^{-1}$  as reported

for the pure carrageenan samples, and a sufficiently strong band around  $844\text{ cm}^{-1}$  indicates the presence of C - O - SO<sub>4</sub> on the C4 carbon of d-galactose-4-sulfate. Likewise, the presence of a strong band fixed by uptake to the C - O  $\kappa$ -carrageenan bonds at about  $912\text{ cm}^{-1}$  indicates that its chemical structure has 3,6-anhydro-d-galactose groups. The characteristic band of  $\kappa$ -carrageenan structure is also shown in  $1158\text{ cm}^{-1}$ , which has been displaced from  $1034\text{ cm}^{-1}$  due to hydrogel formation in the water. This band can be assigned to the C - O 3,6-anhydro-1-galactopyranose ring bond. On the other hand, the presence of a band at  $1226\text{ cm}^{-1}$  corresponds to the sulfate esters. This tape is stronger for dry solid carrageenan than for hydrated gels. The band at  $697\text{ cm}^{-1}$  in the spectrum is given to the skeletal bending of the galactose ring, especially in the anomeric region, that is, it has been previously reported between  $700$  and  $900\text{ cm}^{-1}$ . The signal at  $3340\text{ cm}^{-1}$  corresponds to the absorption of the OH- group, concluding that glycerol is physically bound and integrated with carrageenan as a hydrogel is formed<sup>25</sup>.



**Figure 7.** The IR spectra the CBH polymer (a) and  $\kappa$ -carrageenan structure (b) 25

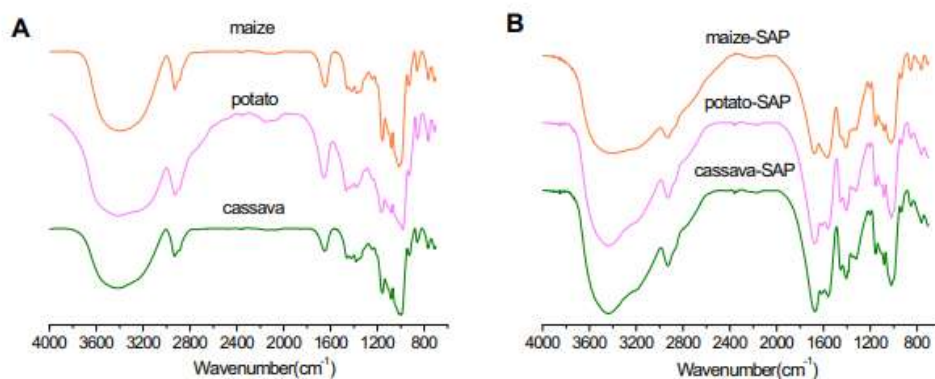
### Examination Scanning Electron Microscope (SEM) $\kappa$ -carrageenan (CBH)

SEM of CBH polymer shows a material with a homogeneous appearance with a pore and "gap" structure, a space with a predominantly water proportion retained in the polymer network. This structure is similar to the interconnected pores reported in previous studies for different hydrogels. SEM images of CBH polymers with fertilizers in them show crystals of different lengths according to the NPK nutrients homogeneously deposited on the hydrogel surface. A similar figure has been presented previously for a superabsorbent hydrogel containing fertilizer<sup>25</sup>.

### Starch

Slow-release nitrogen fertilizer by coating urea granules with ethyl cellulose (EC) as the first layer and starch SAP as the second layer. Using acrylamide (AM) and starch from three native plants (maize, potato and cassava), starch sap (i.e., starch-gpolyacrylamides) was synthesized via a double roll mixer with ceric ammonium nitrate (CAN) as the initiator and N, N'-methylenebisacrylamide (N-MBA) as a cross-linker. Then, a slow-release fertilizer (ie, coated with urea particles in first EC and starch-SAP second) was prepared, and the evaluation was tested on the soil<sup>26,27</sup>.

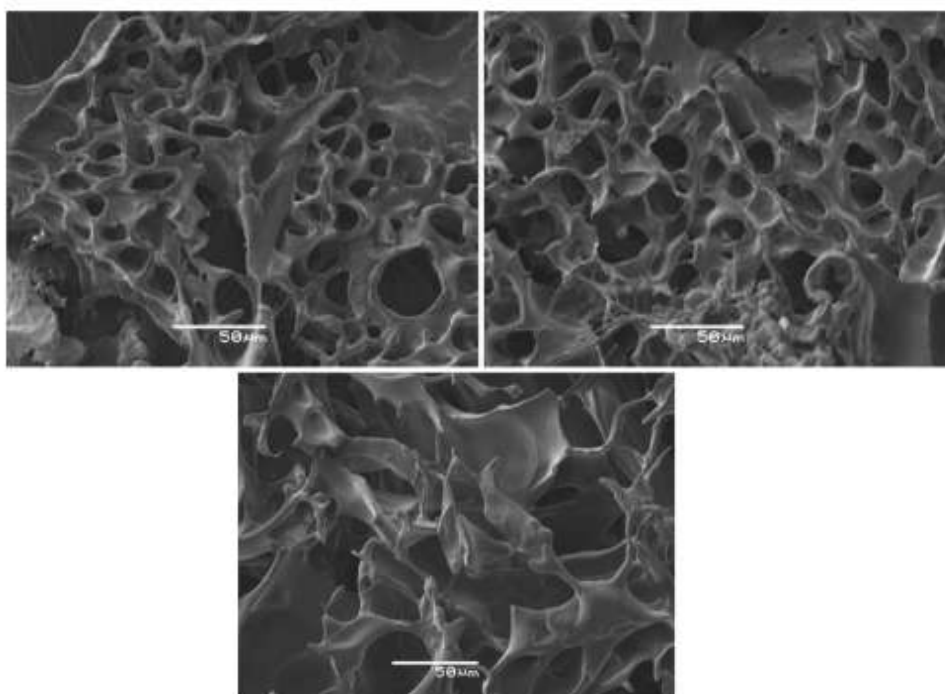
### Starch FTIR examination



**Figure 8.** FTIR spectra of native maize, potato and cassava starches, and their superabsorbent polymers (SAPs)

In Figure 8 the original starch shows a typical IR band, including the absorption strain  $O = H$  ( $3500\text{--}3200\text{ cm}^{-1}$ ), the  $C = H$  strain ( $3000\text{--}2800\text{ cm}^{-1}$ ), the triplet peak for the  $C = O = C$  stretch ( $1158$ ,  $1081$  and  $1015\text{ cm}^{-1}$ ), and peaks at ca.  $1642\text{ cm}^{-1}$  for water adsorbed in the amorphous region of starch. For starch-SAPs, bands at  $1658$ ,  $1600$  and  $1409\text{ cm}^{-1}$ , associated with stretch  $C = O$ ,  $N = H$  bending and stretching  $C = N$  respectively, were observed for the  $-\text{CONH}_2$  group. For starch-SAPs, bands at  $1658$ ,  $1600$  and  $1409\text{ cm}^{-1}$ , associated with the  $C = O$ ,  $N = H$  and  $C = N$  stretches, respectively, were observed for the  $-\text{CONH}_2$  group. Thus it can be concluded that the starch-SAP copolymer is evident in the slow release fertilizer<sup>26</sup>.

### Examination Scanning Electron Microscope (SEM) Starch



**Figure 9.** SEM image of maize, potato and cassava starch-based superabsorbent polymers (SAPs)<sup>26</sup>.

Figure 9 shows a SEM micrograph of the starch-SAP hydrogel. The hydrogel presents a homogeneous porous structure. In particular, because of the hydrophilicity of the  $-\text{COO}-$  group and the associated osmotic pressure, starch-SAP absorbs a lot of water. As the chain starch-SAP molecules (Glucan and PAM) are cross-linked by N-MBA a strong grid wall is formed, most of the water is retained in the grid which is similar to superporous pores which are connected to hydrogel, although some water molecules interact with the starch molecule chains. -SAP to form a gel. While cassava-sap exhibited a flake-like structure with a larger grid size (about  $50\text{ m}$ ) than the other two samples, there was no significant difference in grid size (especially  $10\text{--}25\text{ m}$ ) between maize and potato sap. Nevertheless, this is in contrast to the case for native starch hydrogels which



show a pore size of only ca. 2.5  $\mu\text{m}$  under SEM observations, because less water is retained and the physical bond without cross-linked starch molecule chains is not strong enough to form a perfect pore wall<sup>26</sup>.

Tested in wet soil for 24 hours, 95% of nutrients (nitrogen) were released from uncoated urea, whereas EC coated particles showed a marked reduction in the amount of nutrient release (about 60%) as hydrophobic EC resisted penetration of water molecules into urea core. Interestingly, compared to the product with EC self-coating, which was further coated with starch-SAP slowed the release of nutrients to some extent, and in particular, the potato SAP coated fertilizer showed excellent slow-releasing properties with a release rate of 40% at 24 hours and could be continuously released. nutrients for a long time (approx. 70% at 96 h at present), exhibiting slow release behavior for fertilizer granules in the soil. Based on this, We suggest that changes in the starch structure and absorption properties are essential for changing the nutrient releasing behavior of the slow release fertilizer. Picture. 7 shows a proposed schematic model for the relationship between starch-SAP characteristics and the slow release behavior of the fertilizer bilayer<sup>26</sup>.

The release of nutrients from fertilizers undergoes three main stages. The stages: (i) water is absorbed into the starch sap and penetrated through the EC layer; (ii) the nutrients in the urea nucleus can be gradually dissolved by water; (iii) nutrients delivered to the soil by penetrating through the EC layer and the starch-SAP hydrogel. Since the EC coating is the same for all coated samples and thus its contribution to slow release should not change, the fertilizer release behavior is mainly related to the characteristics of the starch-SAP coating. In the initial stage, the starch-SAP layer acts as a water-absorbing promoter. The lower the WAC and the higher the water absorption rate, which is induced by the larger grid size, will facilitate the first stage by making the water more rapidly enter the starch sap layer to achieve an absorbance balance. The fertilizer coated with corn sap and cassava-SAP coating also exhibits certain slow-releasing properties. In short, a slow release fertilizer with water retention capacity was successfully prepared using ethyl cellulose as the inner layer and starch sap as the outer layer. Fertilizer particles coated with potato SAP (with greater  $R_g$  and a smaller lattice diameter) show excellent slow-release behavior for nitrogen from the fertilizer core<sup>26,27</sup>.

### Coating Efficiency

Mtotal NPK granules (g) were dissolved in 100 mL of distilled water at room temperature  $\pm 24^\circ\text{C}$ . The polymer was crushed, dissolved in distilled water, and filtered using filter paper. The residue was washed with distilled water, dried at  $120^\circ\text{C}$  for approximately 4-6 hours and weighed<sup>14,17</sup>.

Several factors that can affect the quality of the film layer are the interaction between the core of the material and the coating solution, the drying process, especially the drying temperature, and the uniform distribution of the layers. Faster drying rate will affect coating and increase dust formation. This situation will reduce the percentage of coating efficiency. The percentage of coating efficiency on a single layer is smaller than that of a double layer. This is due to an increase in the number of polymer ratios used. The results of measuring the percentage of coating efficiency in the slow release NPK granules provide coating efficiency above 90%. It shows the most complete coating process when the polymer is sprayed onto the grain core<sup>17,18</sup>.

### IV. Conclusion

NPK fertilizer is applied as a slow-release fertilizer using several polymers (polysulfone, Polyacrylate / Poly (silicone-co-acrylate), Chitosan, Polyhydroxybutyrate,  $\kappa$ -carrageen (CBH), polystyrene and starch). The morphology of the polymer was tested with Scanning Electron Microscope (SEM), the boundary between the fertilizer grain core and the polymer layer can be observed. The functional groups will be tested with the peak point on FTIR spectrophotometry. So it can be stated that the use of polymers can be applied to slow release fertilizers and can increase agricultural yields without wasting fertilizer use.

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