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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Investigation on Characteristics of Natural Starch Based Coating as Potential Urea-Fertilizer Coating

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Abstract

The conventional fertilizer application oftentimes inefficient due to rapid release and leaching, which in turn caused pollution to the environment. The technique to control or slowing down the release of nutrients of the fertilizer in a controlled manner known as slow-release fertilizer (SRF). In sustainable agriculture, the utilization of natural starch as coating materials give alternative of the use of non-green materials. The abundance of natural starches may be serve as potential sources for sustainable fertilizer coatings. This study aims to investigate the properties of the urea fertilizer coated with several natural starch materials and to identify the most potent natural starch coating agents. The research was conducted as follows: 1) formulation of fertilizer coatings sourced from 7 natural starches (porang, gadong, sago, taro, sorghum, glutinous rice, and mung bean starches) and one synthetic materials (carboxymethoxyl cellulose, CMC); 2) granulation of urea fertilizer with coatings produced from the formulation, 3) manufacture of fertilizer coating from 7 natural starches. The SRF fertilizers were then tested for drip resistance and nutrient release. Formulation of fertilizer coatings was 2% w/v of natural starch with polyethylene glycol (PEG) and gum arabic. Granulation with coatings resulted in 73% of the granule produced met the desired size criteria (2.5-5 mm in size). Drip resistance test showed that CMC showed the highest durability, followed by gayong starch and sorghum starch, consecutively. Comparison of nitrogen nutrient release of urea-SRF on distilled water and 2% citric acid showed higher urea-SRF solubility in 2% citric acid. Natural starches—particularly gadong, glutinous rice, sorghum, sago, and porang—have shown potential as natural coating materials. However, since the observed parameters were limited to water hatches and nitrogen release, further research is needed to optimize the use of these starches as slow-release fertilizer (SRF) coatings across a broader range of parameters.

Keywords: Natural starch, Slow-release fertilizer, Coating, Drip resistance, Nutrient release, Urea

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1. Introduction

Growth and nutritional quality, including nutrient quantity are factors important for plant growth and development. Currently, nutrients application in the form of fertilizer still inefficient, which shows implications for nutrient loss and environmental pollution. Yearly estimation of fertilizer needed, including urea are approximately $2.5x10^6$ tons, and estimated to improve crop yields up to 56-58% and grain yields 31-32%. However, 40-60% of the fertilizer cannot be absorbed by plants (Chen et al., 2021). According to Karakuş et al. (2022), nitrogen is the most lost nutrient in agricultural soils. The loss of N nutrient from the soil can be caused by leaching (NO_3 and NO_2), evaporation (NH_3) and denitrification (N_2O and N_2) (Demirkiran, 2017). Leaching is a serious environmental issue as it can cause pollution, groundwater contamination and trigger eutrophication in the aquatic environment. On the one hand, nitrogen is the main macro nutrient that is needed by plants for their growth (Noviana et al., 2023). Thus, efforts are needed to overcome this problem and to increase fertilizer absorbance efficiency by plants.

To increase the efficiency of fertiliser absorption by plants, one technique that can be used is to control the release of fertilizer in the form of slow-release fertiliser (SRF) formulations. Slow-release fertilizer has a distinctive characteristic that the rate of release of nutrients is more controlled (Purnomo and Saputra, 2021). According to (Trenkel, 2010) the use of slow-release fertilisers can reduce nutrient losses by 20-30% compared to conventional fertiliser applications. The SRF method is considered more efficient because nutrients are released and available slowly into the soil, thereby reducing environmental pollution (Firmanda et al., 2022).

The solubility of SRF can be controlled by fertilizer coating technique which is a technique of coating fertilizer granules with various materials that can reduce their solubility rate. Generally, synthetic polymers are used as coating materials. However, they can not degrade easily in soil and can accumulate as plastic residue up to 50 kg $year^{-1}ha^{-1}$ (Fertahi et al., 2021; Lawrencia et al., 2021). On the other hand, natural materials are considered to be an alternative of sustainable coating materials as they are readily available, easily obtained and biodegradable. Reports on several natural coating materials and their modifications have been previously investigated, such as mixture of pectin, chitosan and sugarcane vinasse (Cerri et al., 2020), alginate (Fan et al., 2019), cassava starch (Tanan et al., 2021; Versino et al., 2019).

Starch as natural polysaccharide polymer are biodegradable, easily-available and eco-friendly, which regard as potential candidates for fertilizer coating materials (Naz and Sulaiman, 2017; Salimi et al., 2023). Moreover, starch-based hydrogel is known to significantly improve the soil's water-holding capacity owing to its hydrophilicity, network structure and the ability to form strong hydrogen bonds with water molecules (Fertahi et al., 2021). The use of natural starch as a wrapping material for SRF is possible because the lignin layer slows the release of urea and remains intact after submerging in water, indicating a high potential as a biopolymer for SRF fertiliser. Based on its plant source, starch can be obtained from sago starch, corn, cassava, and glutinous starch. Until now, starch types such as cassava starch, corn starch and sago starch have been used as materials to make slow-release urea fertilizer coatings (Chen et al, 2008; Sarwono et al, 2013; Suci and Astar, 2022). There are still numbers of potential starch to be use as coating agents. With the various types of starch available, it is necessary to select starch that has good ability as a slow-release fertilizer coating. Therefore, this study aims to compare the properties of urea fertilizer coated with several types of starch from natural materials and obtain the source and type of starch that has the potential as a slow-release fertilizer so that nutrients are expected to be absorbed efficiently by plants and not pollute the environment.

2. Materials and Methods

2.1. Natural starches coating formulation

The coating formulation sourced of several natural starches (*Table 1*). Coating solution formulation was made by mixing 2% (w/v) starch and 1 g polyethylene glycol (PEG) and gum Arabic. The mixture was then added with distilled water up to 30 mL and stirred until homogeneous at room temperature. The solution was then heated until all the starch was dissolved and color turned. The heating process was carried out to make the PEG solution as well as the starch thicken. In addition, the process of colouring the SRF fertiliser is done to distinguish the type of coating. Afterwards, the solution is then ready to use.

Table 1. Treatment code and composition of coating materials in the study

Treatment Code	Composition per 30 ml solution (w/v)
D1	2% porang starch
D2	2% gadong starch
D3	2% sago starch
D4	2% taro starch
D5	2% sorghum starch
D6	2% glutinous rice starch
D7	2% mung bean starch
D8	2% carboxymethyl cellulose

The coating process were carried out on a laboratory-scale pan granulator machine and sprayer. The coating solution was put in a sprayer and sprayed on the surface of the urea fertilizer granules on the rotating granulator pan (30 mL) per 100 g of urea fertilizer. After spraying the coating, the fertilizer was at 50°C for 1 hour. Urea fertilizer that has been coated is then called urea-SRF.

2.2. Drip Resistance

The resistance to water droplet impact was tested by dripping distilled water on the fertilizer using a burette at a height of 20 cm until the fertilizer dissolved, and the time needed (in minutes) were then recorded

2.3. Nitrogen Nutrient Release

Nitrogen nutrient release test was conducted to measure the ability of 8 types of urea-SRF coating to control the release of nitrogen nutrient to the surrounding soil. The test was carried out in a shaker (type of equipment) using distilled water and 2% citric acid at shaking periods of 0, 15, 30, 45 and 60 minutes. The resulted released nitrogen nutrient was then measured using percolation test according to (Himmah et al., 2018). In shorts, a tube containing soil material of experimental site and urea-SRF coating formulation from various types of combinations and material ratios, which were conducted in triplicate. The resulting percolate was then analyzed for the soluble materials.

2.3. Statistical Analysis

The experimental was conducted using Randomised Complete Block Design with 4 replications. Research data were analyzed using SPSS software version 25. One way ANOVA (analysis of variance) was performed on the data to compare the effect of different treatments. The least significant difference (LSD) test was applied to the determine the significant difference. A p value of < 0.05 was considered statistically significant.

3. Results and Discussion

3.1. Fertilizer Characteristics

Granule Size of Granulated Fertilizer

The coating solution produced from the blending process has a paste-like shape, coarse texture, and high moisture content. The paste was then used to coat urea fertilizer using a pan granulator that was adjusted to parameters such as rotation speed, inclination angle and fertilizer moisture. The aim is to obtain fertilizer granules that meet the desired criteria based on the Indonesian national standard for urea fertiliser granule size between 1-2.25 mm. *Figure 1* shows the percentage of fertilizer granule sizes resulted from granulation process. As much as 73% urea-SRF sized 2.5-5 mm in size and this granule size was chosen as the finished fertilizer size as this size refers to urea-SRF commonly sold in the market which have been coated.

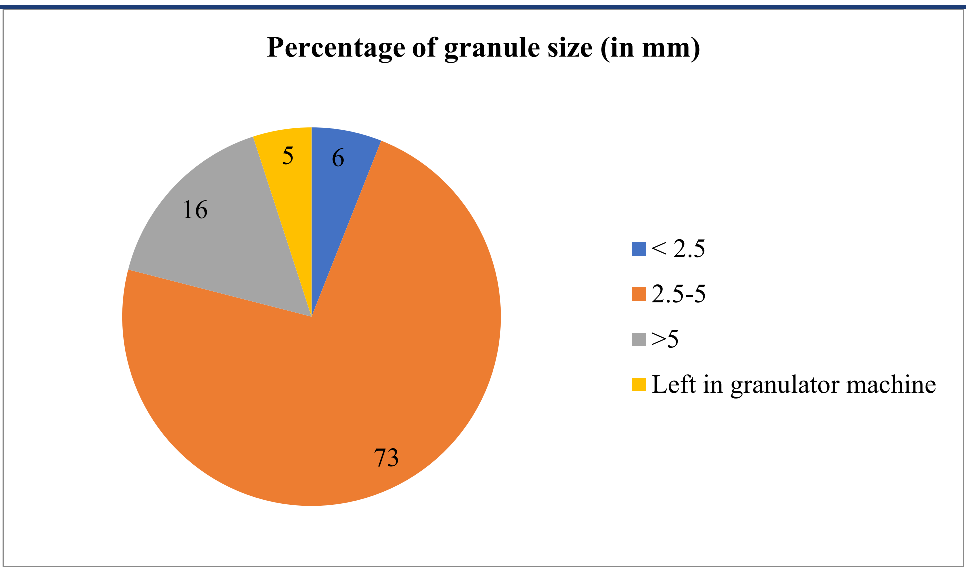

Figure 1: Size distribution of granulated urea-SRF from granulation process

3.2 Physical characteristics

Figure 2 shows the qualitative physical characteristics of the coated (SRF) fertilizer. SRF fertilizer is in the form of bright, light-coloured granules. The coating layer makes the SRF fertilizer appear shinier than its original colour. Coated SRF fertilizer has advantages in terms of quality and durability.

Figure 2 Physical appearances of urea-SRF formulation using various natural starches (D1 (Porang starch), D2 (Gadong starch), D3 (Sago starch), D4 (Taro starch), D5 (Sorghum starch), D6 (Glutinous rice starch), D7 (Mung bean starch), D8 (carboxymethyl cellulose (CMC)

Ningtias (2017) previously reported that commercial granulated urea fertilizer did not have a coating layer, so the surface was plain and smooth. However, in *Figure 2*, coated urea-SRF has a rough and diverse surface. This is in line with the study of Lestari et al. (2020), which stated that urea-microcapsules were formed with rough and aggregated surface. Moreover, (Muslim et al., 2015) stated that the sago starch layer on the outside acts as a mass transfer inhibitor of urea, so as to reduce the rate of diffusion of water into the core as well as to reduce the diffusion of nitrogen out of the urea core.

3.3 Nutrient release in urea-SRF

Drip resistance

The durability of the fertilizer is measured by the number of water droplets required to make the fertilizer break. Urea-SRF fertilizers coated with natural and synthetic materials showed different resistance to water droplets (*Figure 3*). The one-way ANOVA results showed that the type of coating material significantly affected the durability of the fertilizer. Of the seven natural materials used, glutinous rice starch (D6) and mung bean starch (D7) had the lowest durability, needed only 35 water droplets to break; which were then followed by taro Starch (D4) with 43 droplets. These three materials fall into the category of weak coating materials. Meanwhile, porang starch (D1) and sago starch (D3) have better durability, at 60 and 64 droplets to break, consecutively. Finally, sorghum starch (D5) and ganyong starch (D2) were the strongest natural coating materials, lasting up to 72 and 74 drips, respectively. On the other hand, the synthetic material CMC (D8) had the highest durability of all the coating materials, at 100 drips. The order of drip durability is decrease as follows: D8>D2>D5>D3>D1>D4>D6=D7. Thus, it can be concluded that the coating materials affect the drip resistance of urea-SRF fertilizers.

Addition of ingredients such as gums are common in formulation of SRF, since the starch alone tend to have high solubility in water. In this study, the use of gum arabic was meant to increase the stability of the formulation. The use of other types of gum such carragenan, gellan, xanthan gives various results on stability of cassava starch film, as well as the solubility of the cassava starch matrices (Kim et al., 2015).

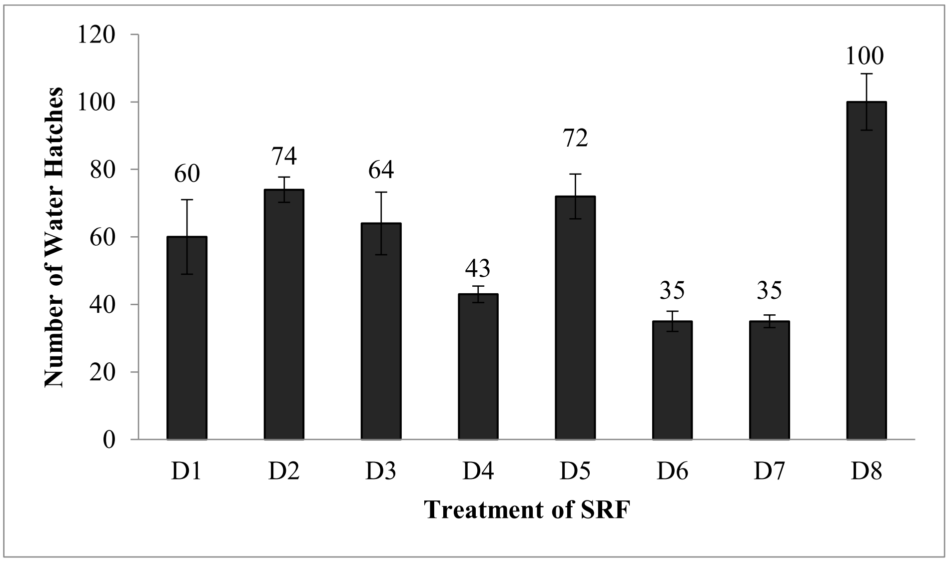

Figure 3. Resistance of SRF fertilizer to water droplets until the SRF fertilizer particles break. (D1 (Porang starch), D2 (Gadong starch), D3 (Sago starch), D4 (Taro starch), D5 (Sorghum starch), D6 (Glutinous rice starch), D7 (Mung bean starch), D8 (carboxymethyl cellulose (CMC)

Nitrogen nutrient release test with distilled water and 2% citric acid

Nitrogen nutrient release in this study were analyzed from the amount of nutrient leached in the form of percolate. The more nutrients leached from the percolate, the more nutrients released from fertilizer. Periods of shaking at 0, 15, 30, 45 and 60 minutes showed that urea-SRF nitrogen nutrient release had begun to occur, and 2% citric acid showed higher nitrogen release compared to distilled water. *Table 2* shows that nitrogen dissolved in urea-SRF fertilizer at 15, 30, and 60 minutes is increase with periods of shaking. D6 nitrogen solubility is higher (0.21%) compared to other treatments at 15 minutes of shaking, then at 30 minutes of shaking increased to 0.34%; the same value as D8. Similarly, nutrient release at 60 minutes shaking had the same trend as nutrient release at 30 minutes shaking. On the other hand, the lowest levels of N dissolved were observed gadong starch at 0.03%

and 0.15% at 0 and 15 minutes periods of shaking; sago starch at 0.24%, 0.24% and 0.30% at 30, 45 and 60 minutes shaking periods, respectively.

Table 2. Nitrogen nutrient release of urea-SRF in distilled water and 2% citric acid at various shaking periods. Different letters (a, b) indicate a significant difference within the column (One Way ANOVA, LSD test, $p < 0.05$)

Coating Treatment	Percentage of Nitrogen Nutrient Release of Urea -SRF									
	Distilled water					2% Citric acid				
	Shaking duration (minutes)					Shaking duration (minutes)				
	0	15	30	45	60	0	15	30	45	60
D1	0.03	0.16	0.25	0.28[a]	0.31	**0.13**	**0.24**	**0.28**	**0.30**	**0.34**
D2	0.03	0.15	0.27	0.27[a]	0.30	0.13	0.24	0.30	0.31	0.32
D3	0.03	0.15	0.24	0.24[a]	0.30	0.13	0.24	0.28	0.30	0.32
D4	0.03	0.18	0.26	0.29[a]	0.31	0.13	0.23	0.29	0.32	0.33
D5	0.03	0.21	0.33	0.32[a]	0.33	**0.13**	**0.25**	**0.34**	**0.37**	**0.34**
D6	**0.03**	**0.21**	**0.34**	**0.34[b]**	0.35	**0.14**	**0.24**	**0.35**	**0.38**	**0.35**
D7	0.04	0.19	0.28	0.31[a]	0.32	**0.14**	**0.25**	**0.33**	**0.34**	**0.34**
D8	**0.04**	**0.21**	**0.34**	**0.33[a]**	0.34	**0.14**	**0.29**	**0.35**	**0.35**	**0.35**
LSD 5%	**n.s**	**ns**	**n.s**	**0.09**	**ns**	**n.s**	**n.s**	**n.s**	**n.s**	**ns**

D1= porang starch, D2= gadong starch; D3= sago starch; D4= taro starch; D5=sorghum starch; D6=glutinous rice starch; D7= mung bean starch; D8= CMC (carboxymethyl cellulose); n.s= not significant

Furthermore, in shaking using 2% citric acid, there are no significant difference observed in all treatments (shaking duration of 0, 15, 30, 45, and 60 minutes) (*Table 2*). At 0 minutes of shaking, three types of coating showed the highest release of N nutrients eventhough there were no significant differences observed between other coating treatments. D6, D8 and D7 nitrogen nutrient release were as much as 0.14%, 0.14% and 0.14%, respectively, while D5, D1 and D4 were slightly lower at 0.13%, 013% and 0.13%, consecutively. The result is in correspondence with (Himmah et al., 2018), which pointed out the order of nitrogen nutrient release in the order of CMC>glutinous rice starch and sago starch. CMC is highly advantageous in reduction of water consumption and at the same time, improving soil's fertility. However, high production cost is one of its main drawback (Olad et al., 2018). Thus, several natural starches used as coating materials here showed promising initial result. On the other hand, the lowest release was recorded on D3 and D2 which were 0.13% and 0.13%, respectively. Furthermore, at 15 minutes shaking, the highest release of N nutrient in D8 was 0.29%, albeit not significantly different from other coating treatments, and the lowest was in D4 at 0.23%. Different results were found at 45 minutes shaking, where the highest release of nutrients was in the D6 treatment of 0.38%, significantly different from other coating treatments, and the lowest was in D3 of 0.30%.

Comparison between the results of shaking SRF fertilizer that has been coated with H_2O shaker material shows a clear difference with SRF fertilizer using 2% citric acid shaker. This is due to the fact that natural materials tend to have higher solubility in weak acids than in H_2O solution. This dissolution mechanism indicates that the use of SRF with natural material coating is more suitable for soils in Indonesia, which are generally acidic soils. The mixture of porang flour and chitosan is a blending biopolymer to improve physical properties due to the hydrogen bonding of starch in amylose and amylopectin. Compared to uncoated urea, which is subsequently converted to ammonium and goes through nitrification to form nitrate, coating on urea minimizes nitrogen loss by volatization. In terms of general benefits, SRF fertilizer results in savings in fertilizer quantity and labour in application frequency as only one application is required for the growing season. It also inhibits nutrient loss, seed toxicity, reduces emission hazards and improves soil quality.

4. Conclusions

Characteristics of natural starch as coatings materials for urea-SRF are greatly differ in relation with the properties of each of natural starch. The coating material used affected the drip resistance of the urea-SRF fertiliser. The drip resistance was sequentially obtained at D8>D2>D5>D3>D1>D4>D6=D7. Gadong, sorghum, sago and porang starches are potentials to be developed as coating materials in terms of dripping resistance. While glutinous rice starch, mung bean starch and sorghum starch showed comparable nitrogen nutrient release comparable to that of CMC. Further research is needed for better formulation of the natural starch to improve the quality as coating materials, including combination treatment of potential natural ingredients in this study, to facilitate the provision of ingredients on a wide scale.

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Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

We declare that there is no conflict of interest between us as the article authors.

Authorship Contribution Statement

Concept: Halus Satriawan; Design: Halus Satriawan, Eka Rahmi; Data Collection or Processing: Mariana.; Statistical Analyses: Halus Satriawan.; Literature Search: Halus Satriawan, Ernawita; Writing, Review and Editing: Halus Satriawan, Ernawita.

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