Precipitation Test of Soybean Crude Urease-Calcite Precipitation Method in Different Reagent Concentrations as a Soil Improvement Technique

Keywords: Soil improvement technique, reagent, calcite, soybean

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Introduction

The soybean crude urease-calcite precipitation method is one of the innovative soil improvement techniques [1]. This method uses soybean as a biocatalyst to hydrolyze urea into ammonium and carbonate ions [2]. The carbonate ions are precipitated as calcite in the presence of calcium ions [1]. Evaluation of soil strength improvement by UCS test was obtained at 65-870 kPa [3]. In previous research, soybean powder was extracted with a centrifugation technique to separate the undissolved soybean solution from the supernatant [3]. This technique takes a long time to proceed so it wasn't efficient in terms of time. Another technique that had been used to extract soybean solution efficiently was the filter technique [1]. However, the filter technique in the soybean extraction process results in high undissolved soybean or organic content [2]. The organic content may hamper the precipitation process [2]. Besides organic content, one parameter may also hinder the soybean crude urease-calcite precipitation method process [1]. Previous research reported the efficiency of the precipitated calcite was seen to decrease at a high level of reagent [1]. It was concluded the increase in reagent concentration may inhibit the activity of the urease enzyme and reduce the precipitation ratio of calcium carbonate, hence, reducing the hydrolyzing efficiency [1]. Therefore, a precipitation test must be conducted to evaluate calcite and soybean content in different reagent concentrations to consider the organic matter and reagent concentration may inhibit the precipitation process. The purpose of this research is to evaluate the precipitation test of soybean crude urease-calcite precipitation method in different reagent concentrations as a soil improvement technique. Precipitation tests were performed directly in transparent test tubes to evaluate the number of precipitated materials. Acid leaching on precipitation test was carried out to determine precipitated calcite and soybean content in transparent test tubes. The evaluation of calcite and soybean content in different reagent concentrations was explicitly investigated.

Methods

Dry soybean purchased from the local market were used in this research. The soybean was grilled using a grinder for 100 g/min to obtain a powder with particle sizes of 0.1-0.5 mm. The soybean powder was stored in a vacuum container and refrigerator at 4°C. A precipitation test was performed directly in a transparent test tube to evaluate the number of precipitated materials. The mixed solutions of reagents composed of urea ($CO(NH_2)_2$), calcium chloride ($CaCl_2$) with purity levels > 95% from Kanto Chemical Co. Inc., and soybean from Kouta Happy Food Market. In this research, the concentrations of reagent were varied out by 0.25, 0.50. 0.75, and 1.00 mol/L, and the concentrations of soybean powder were varied out by 5, 10, 20, and 30 g/L. First, the reagent and soybean powder separately were mixed with distilled water and stirred using a magnetic stirrer for 5 minutes. Next, the soybean solution was filtered using sieve No. 400 (0.038 μm). Then, the reagent and soybean solutions were mixed in a transparent tube with a total volume of 30 ml. Next, the transparent tube is cured for 7 days and a precipitated mass can be obtained. The precipitation test procedure is shown in Figure 1 [2].

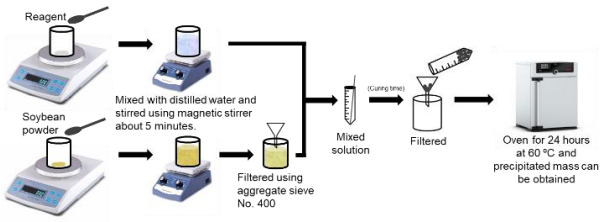

Fig. 1 Precipitation test procedure

Acid leaching on precipitation test was carried out to determine calcite and soybean content in transparent test tubes. Hydrochloric acid was used to dissolve calcite in a transparent tube and leave the soybean. After the precipitation test, transparent tubes were poured with 10% diluted hydrochloric acid several times until air bubbles no longer appeared. Filter paper (pore size of 11 μm) was used to minimize the loss of mass of soybean during the washing process. Then, the transparent tube and filter paper were oven

for 24 hours at 60°C and weight loss during acid leaching was assumed to be the weight of calcite [1].

Results and Discussion

The result of the precipitation test after a curing time of 7 days in Figure 2 shows an increase in precipitation ratio as long as the addition of soybean and reduction of reagent concentrations. Precipitation ratio higher than the theoretical value may cause by undissolved soybean. High soybean and low reagent concentration produce the highest precipitation ratio and low soybean and high reagent concentration produce the lowest precipitation ratio. Using 5 g/L soybean concentration, the gap of precipitation ratio in different reagent concentrations is high. However, as long as the addition of soybean concentrations, the gap of precipitation ratio in different reagent concentrations decreases.

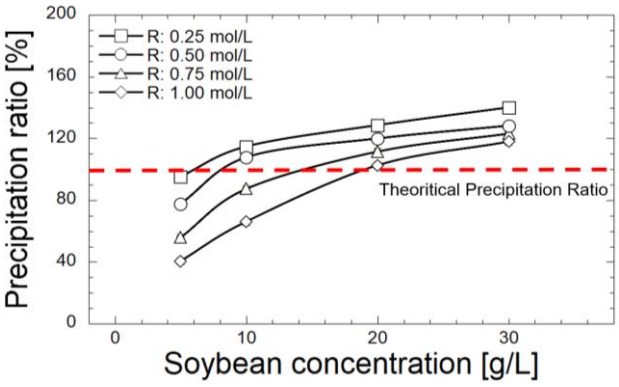

Fig. 2 Precipitation test result

Results of acid leaching on precipitation test in Figures 3 and 4 show an increase of precipitation mass as long as the addition of soybean and reagent concentrations. Increase of precipitation mass due to the increase of soybean and calcite mass. High soybean and reagent concentration produces the highest soybean and calcite mass and low soybean and reagent concentration produces the lowest soybean and calcite mass. Calcite content is the ratio between actual calcite mass and theoretical calcite mass [1]. The addition of soybean concentrations in all different reagent concentrations increases calcite content. However, the addition of reagent concentrations for the same soybean concentration results in decreases in calcite content. As shown in Figure 3, using 5 g/L soybean concentration, the calcite content in 0.25 mol/L reagent concentration is 71% and decreases to 22% in 1.00 mol/L reagent concentration while soybean mass increases by 66%. This result is the same using other soybean concentrations in different reagent concentrations. It's suspected the increase of reagent concentrations produces higher precipitation mass which includes higher soybean mass. Therefore, soybean mass or organic matter may hamper the precipitation process so the increase of reagent concentrations results in decreases in calcite content. The increase in reagent concentrations may also inhibit the activity of the urease enzyme and reduce the precipitation ratio of calcium carbonate [1]. This result shows organic matter and reagent concentration inhibit the precipitation process.

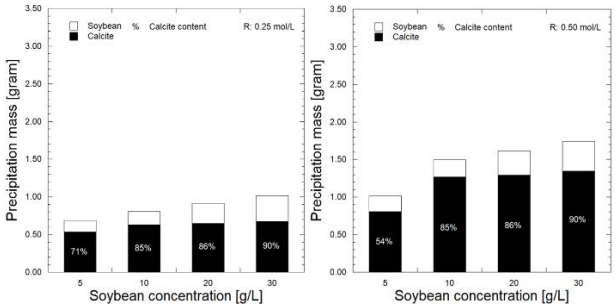

Fig. 3 Precipitation mass in reagent concentrations 0.25 and 0.50 mol/L

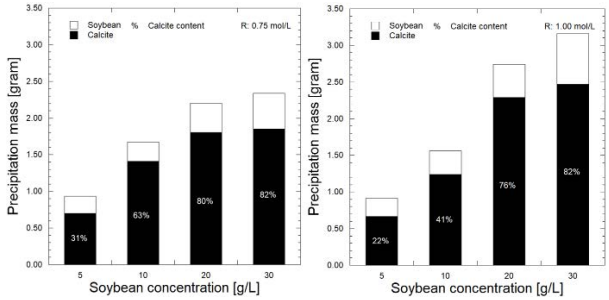

Fig. 4 Precipitation mass in reagent concentrations 0.75 and 1.00 mol/L

Conclusion

The results of this research show precipitation ratio and mass of soybean crude urease-calcite precipitation method are varies in different reagent concentrations. This result shows organic matter and reagent concentration inhibit the precipitation process.

References

[1] H. Putra, H. Yasuhara, Erizal, Sutoyo, and M. Fauzan, "Review of enzyme-induced calcite precipitation as a ground-improvement technique," *Infrastructures*, vol. 5, no. 5, pp. 1–14, 2020.

[2]H. Putra, Erizal, Sutoyo, M. Simatupang, and D. Yanto, "Improvement of organic soil shear strength through calcite precipitation method using soybeans as bio-catalyst," *Crystals*, vol. 11, no. 9, pp. 1–14, 2021.

[3] S. Lee and J. Kim, "An experimental study on enzymatic-induced carbonate precipitation using yellow soybeans for soil stabilization," *KSCE J. Civ. Eng.*, vol. 24, no. 7, pp. 1–12, 2020.