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The potential of plant-derived urease in calcite precipitation for soil improvement

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Introduction

The precipitate of calcite has been used to fill up the void of sand, restricting their movement, and hence, improving the stiffness and the strength of soil. Application of powdered urease enzyme as bio-catalysis mixing with urea and calcium carbonate to produce calcite precipitation has been confirmed. The unconfined compressive strength ranges from 400 kPa to 1.6 MPa, and the permeability is reduced by more than one order of magnitude [1)]. The price of powdered urease enzyme from jack bean is high. Thus, it required the other sources of urease enzyme which have lower economic value. Recently, research aiming at the establishment for grout material by using plant-derived urease have been developed. Plant-derived urease enzyme in watermelon seeds crude extract has efficacy to induce the precipitation of calcium phosphate compound, with the maximum UCS of 125.6 kPa after 28 days of curing [2)]. In this research examination of calcite precipitation from cabbage and soy pulp which is the leftover as food waste was investigated as the potential of plant-derived urease in calcite precipitation for soil improvement. The potential use of artificial bio-minerals has revolutionized various engineering applications; however, this novel area must be investigated thoroughly, to bring it as an environmentally safe, cost-effective method and to develop this technology from the laboratory to field scales.

Methods

Extraction of urease enzyme from cabbage and soy pulp was performed as follows: each sample was finely ground using a coffee mill, and 1.5g of the sample was soaked with 20mM buffer phosphate for 1 hour for occasional agitation of solution. The suspension was then centrifuged, stirred at 40g for 20 minutes and the clear or slightly cloudy solution without dregs was produced, and then filtered using filter paper (pore size 11μm) to remove the undissolved particles of crude extract. Precipitation of calcite was evaluated directly in transparent test tubes with concentration of 1 mol/L urea-$CaCl_2$, and prepared separately. Urea-$CaCl_2$ solution and the crude extract source of urease solution are mixed in total solution volume of 30 mL, the precipitation of $CaCO_3$ takes place after several days. After curing time (2 weeks), the solution is filtered with filter paper. Urea and $CaCl_2$, with claimed to purify levels greater than 95.0%, were obtained from the Kanto Chemicals Co. Inc. Expected reaction to obtain precipitated carbonates ions.

$$CO(NH_2)_2 + 2H_2O \rightarrow 2NH_4^+ + CO_3^{2-} \quad (1)$$

$$CaCl_2 \rightarrow Ca_2^{+} + 2Cl^{-} \quad (2)$$

$$Ca_2^{+} + CO_3^{2-} \rightarrow CaCO_3 \quad (3)$$

Mineralogical analysis using FTIR and XRD was used to determine the production rates of $CaCO_3$ using crude extract of cabbage and soy pulp and the evolution of crystal shape was obtained from SEM analysis.

Results

The addition of crude extract of cabbage and soy pulp as a replacement of urease enzyme produced the precipitation after mixing with urea and calcium chloride. Testing at microscale was conducted to analyze the formed mineral. The precipitates were tested by Fourier-Transformed Infra-Red spectroscopy (FT-IR) and X-Ray Diffraction (XRD) analysis to examine the polymorph of calcium carbonate.

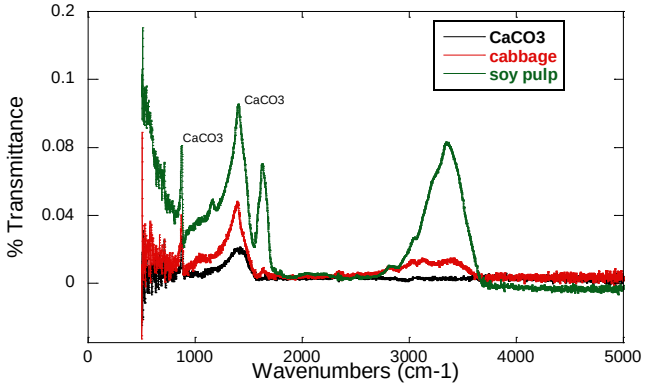

Figure 1: FT-IR spectra for precipitate formed of (a) CaCO3 powder from the factory (b) crude extract of cabbage (c) crude extract of soy pulp.

The occurrence of the major transmittance bands specific to calcium carbonate was observed. Fig. 1 shows FT-IR spectra for precipitate formed using a crude extract of cabbage and soy pulp as a urease enzyme. These spectra were compared to the standard spectrum of calcium carbonate from the factory. These results show that the crude extract from cabbage and soy pulp generated the $CaCO_3$ precipitation. The similar precipitation was assessed by XRD analysis to confirm the polymorph of crystals. The XRD patterns of the precipitates proved the presence of $CaCO_3$ (aragonite, calcite, and vaterite) coexisted. Furthermore, the XRD analysis confirmed that calcite is dominant polymorph in the calcium carbonate precipitation. The SEM analysis shows the crystal shape of calcium carbonate; calcite polymorph was clearly observed for all samples; the formation of rhombohedral appeared in that images. Intergrowth and steps may indicate some disturbances during the growth process of the crystal.

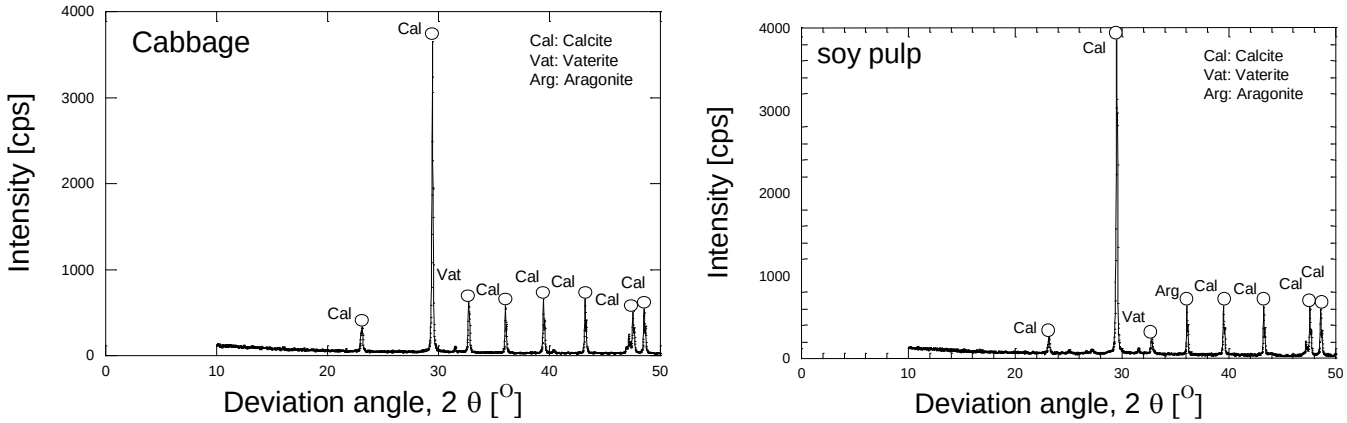

Figure 2: XRD spectra confirming the polymorph of crystals: (a) cabbage crude extract (b) soy pulp crude

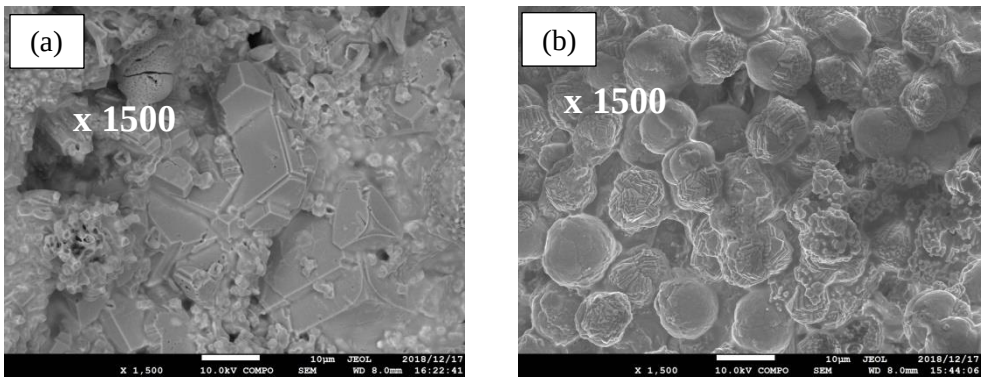

Figure 3: SEM images of calcium carbonate precipitated: (a) cabbage crude extract (b) soy pulp crude extract

Conclusions

This research examines the potential of plant-derived urease using a crude extract of cabbage and soy pulp without purification. The precipitation was obtained after mixing the sources of urease enzyme, urea, and calcium chloride. The mineralogical analysis using FT-IR and XRD test was conducted to confirm the calcium carbonate and the polymorph of calcium carbonate. The SEM test has confirmed the crystal shape as the effect of adding the crude extract of cabbage and soy pulp.

References

1) Yasuhara. H. et al., 2012. Experiment and prediction of physical properties of sand cemented by enzymatically-induced carbonate precipitation. Soils and foundations, 2012.
2) R.A.N. Dilruksi. et al., Sand cementation test using plant-derived urease and calcium phosphate compound, Material Transactions, 2015.