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Producing Precipitated Calcium Carbonate (PCC) from CO_2 Emissions during OFMSW Bio-Drying through Carbonation: A Preliminary Study

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ABSTRACT

Capturing CO_2 emissions during the bio-drying process of organic fraction municipal solid waste (OFMSW) presents an alternative approach to reducing CO_2 emissions in municipal solid waste (MSW) management. Absorption using an aqueous solution of $Ca(OH)_2$ is a viable CO_2 capture technology that produces precipitated calcium carbonate (PCC), a value-added product. The objectives of this study are to assess the impact of bio-drying aeration flow rate and absorption time in the $Ca(OH)_2$ solution on CO_2 absorption efficiency, the conversion of $Ca(OH)_2$, and the mass of the PCC product. The absorption process was performed in a semi-continuous bubble reactor with 15 L of 0.019 M $Ca(OH)_2$ aqueous solution. At bio-drying aeration flow rates of 5.1, 4.6, and 3.9 L/min/kg of waste, with CO_2 concentrations ranging from 1286 to 4395 ppm and temperatures between 23 to 30°C over a bio-drying period of 96 hours, it was observed that higher flow rates resulted in lower conversion rates of $Ca(OH)_2$ and reduced CO_2 absorption efficiency. The highest recorded conversion rates for $Ca(OH)_2$ and CO_2 absorption were 97.3% and 16.4%, respectively, yielding a PCC product of 4.8 g/kg of waste at an aeration flow rate of 3.9 L/min/kg waste and an absorption duration of 48 hours. FTIR and SEM analysis confirmed the presence of both calcite and aragonite crystal forms in the PCC product, as well as hydrated $CaCO_3$.

Keywords: bio-drying, CO_2, flow rate, OFMSW, PCC.

1. INTRODUCTION

The issue of global climate change affects nearly every nation today. Carbon dioxide (CO_2) is a key material contributing to the greenhouse effect. Carbon capture and storage (CCS) is a promising and effective approach for reducing CO_2 emissions into the atmosphere. The Intergovernmental Panel on Climate Change (IPCC) has indicated that CCS could cut CO_2 emissions by 15% to 55% by the year 2100 [1]. CCS can serve as a solution alongside the advancement of widely adopted renewable and sustainable energy technologies. One renewable energy source is organic fraction municipal solid waste (OFMSW), which can be dried and utilized as Refuse Derived Fuel (RDF). Bio-drying has become an appealing technology option for the drying of organic waste in recent years. Bio-drying, which can be combined with mechanical biological treatment (MBT), is recognized as a practical and effective method for drying solid waste to produce energy [2–4]. This process not only decreases the volume and mass of waste but also lowers transportation costs and reduces the area required for final disposal sites (referred to as *Tempat Pembuangan Akhir*, or TPA, in Indonesia). The outputs of OFMSW bio-drying can be converted into solid fuel (RDF), compost, and biogas. The primary principle of bio-drying is to decrease water content by utilizing internal heat energy from the bioconversion of organic waste [5,6]. During the bio-drying process, the decomposition of biodegradable materials primarily yields heat or energy, water (H_2O), and carbon dioxide (CO_2) [7]. The equation for the bioconversion of

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organic material can be expressed as Equation 1.

$$\text{Organic waste} + O_2 \rightarrow CO_2 + H_2O + \text{Heat} \quad (1)$$

CO_2 emissions contribute significantly to the greenhouse effect and global warming. Research conducted by Zaman et. al. [8] measured CO_2 emissions from municipal solid waste (MSW) bio-drying, revealing rates of 2.75-0.27 g CO_2 per kg of waste at aeration rates of 0-6 L/min. Most CO_2 emissions were observed during peak temperatures on days 2 to 3 of the bio-drying process. Additionally, a study by Contreras-Cisneros et. al. [9] on the bio-drying of orange peels found that CO_2 formation occurred between the third and tenth days, with concentrations ranging from 5% to 10% (v/v). It is essential to minimize these CO_2 emissions to reduce greenhouse gas output, and they could potentially be converted into a commercial PCC product. These products are applicable in the pharmaceutical, construction, paper filler, and polymer filler industries [10]. PCC tends to be more costly than ground calcium carbonate (GCC) because of its superior purity [11]. Carbon dioxide (CO_2) capture and storage (CCS) technology is a practical and effective approach for mitigating CO_2 emissions into the atmosphere. Of the various CO_2 capture technologies available, absorption is almost the only one currently in commercial use.

One of the absorption techniques for CO_2 capture is the carbonation process using an aqueous $Ca(OH)_2$ solution [12]. Currently, there are no studies on the production of PCC from CO_2 generated by the bio-drying of OFMSW. This process is advantageous as $Ca(OH)_2$ serves as an effective solvent for CO_2 absorption. Additional benefits include its low cost, availability, environmental safety, and the ability to recirculate water to produce a $Ca(OH)_2$ aqueous solution. Thus, utilizing CO_2 from OFMSW bio-drying emissions as a raw material for PCC manufacturing is seen as a profitable strategy for reducing CO_2 emissions. For example, with emission rates of 0.27 to 2.75 g of CO_2 per kg of waste, Malang city in East Java, Indonesia, which produces 750 tons of waste daily, would yield CO_2 emissions from 202.5 kg to 2062.5 kg. Therefore, producing PCC from these CO_2 emissions on an industrial scale is both potentially feasible and technically viable for adding value. The reaction between these materials results in the formation of an insoluble PCC carbonate salt. The overall reaction equation for CO_2 capture using a $Ca(OH)_2$ solution is presented in Equation 2 [13].

$$Ca(OH)_2\ (s) + CO_2\ (g) \rightarrow Ca(CO)_3\ (s) + H_2O \quad (2)$$

The aeration flow rate in the bio-drying process significantly influences the concentration and flow rate of CO_2 emissions produced. Furthermore, the CO_2 flow rate affects the conversion efficiency of the carbonation reaction, impacting PCC production and its morphology. Therefore, this study aims to evaluate the effect of aeration flow rate on the efficiency of CO_2 absorption, $Ca(OH)_2$ conversion, and the mass of PCC formed. In this research, PCC was produced from CO_2 emissions during OFMSW bio-drying through carbonation in an absorber reactor. CO_2 gas generated from bio-drying is bubbled into the $Ca(OH)_2$ aqueous solution, resulting in the formation of precipitated $CaCO_3$. The effects of aeration flow rate over 96 hours of bio-drying on $Ca(OH)_2$ conversion and CO_2 absorption efficiency are calculated. Additionally, the dynamics of CO_2 concentration emissions during bio-drying, along with FTIR and SEM analyses of the PCC product, are reported.

2. RESEARCH METHODS

The OFMSW components and characteristics consist of a mixture of vegetable waste, fruit peels, and food waste, with a moisture content of 60-68% and a density of 274 kg/m^3, sourced from the Tlogomas Temporary Waste Shelter in Malang City. Technical CaO was purchased from a building materials store, while demineralized water was prepared in the Chemical Engineering laboratory at Polytechnic Negeri Malang, where it was filtered using a reverse osmosis system.

In this research, the schematic flow diagram for PCC production from CO_2 emissions during OFMSW bio-drying through carbonation in the absorber reactor is shown in Figure 1. The volumes of the bio-drying and absorber reactors are 160.3 L (505 mm diameter, 800 mm height) and 95.2 L (435 mm diameter, 640 mm height), respectively. Both reactors were constructed from non-insulated polyethylene plastic. In the bio-drying reactor, a perforated plate (stainless steel, Ø2 mm) was installed 100 mm from the bottom to distribute aeration air. Air flow variations of 5.1, 4.6, and 3.9 L/min/kg were achieved using a blower whose impeller cover can be adjusted to regulate air flow. The blower was connected to the reactor through a PVC pipe (100 mm long, Ø25 mm) installed 30 mm below the perforated plate. Additionally, a hole was created in the reactor wall, 250 mm from the bottom, to accommodate a thermometer (a compost thermometer with a 20-inch stainless steel probe). A valve was fitted at the bottom of the tank to allow for leachate drainage. The exhaust gases from the bio-drying reactor were channelled through a PVC pipe (L: 1500 mm, Ø25 mm) attached to the reactor cover, which included a water trap to collect moisture carried by the gas. At a distance of 500 mm from the reactor, a CO_2/temp./RH data logger (HT-2000, China) was installed, with specifications of 0-9999 ppm CO_2, an accuracy of ±50 ppm ± 5% reading, a temperature range of -10 to 70°C with an accuracy of ±0.6°C, and humidity measurements ranging from 0.1 to 99.9%. During the experiment, no liquid condensate was observed in the water trap. The exhaust gas carried moisture primarily in vapor form due to the relatively high measured relative humidity (91–93%) and an average gas temperature of approximately 24°C, which limited condensation inside the pipeline. Therefore, the potential dissolution of CO_2 in condensate was considered negligible, and no significant effect on the accuracy of CO_2 measurements at the absorber outlet was expected.

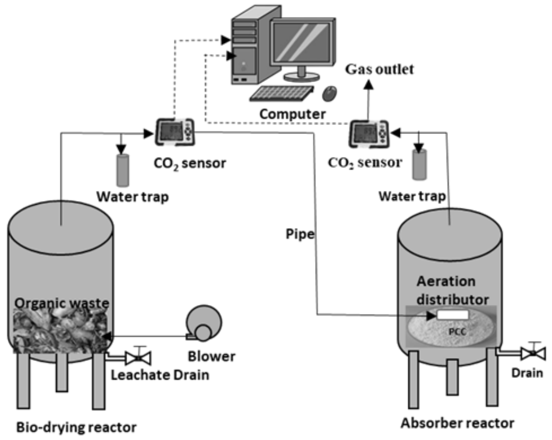

Figure 1. Experimental setup.

The bio-drying reactor was connected to an absorber reactor, which featured a perforated PVC pipe (L: 10 mm, Ø2 mm) installed 70 mm above the base to facilitate gas bubbling. The absorber reactor was positioned 1250 mm away and connected to the bio-drying exhaust gas pipe. Similar to the bio-drying reactor, a CO_2/temp./RH data logger and water trap were also installed at the end of the pipe. A total of 5 kg of unchopped OFMSW was introduced into the bio-drying reactor, and air was injected using a blower. The aeration flow rate for each kilogram of OFMSW was varied, allowing the air to flow into an absorber tank containing 15 L of 0.019 M $Ca(OH)_2$ aqueous solution. This solution was prepared by mixing 800 g of CaO with 20 L of demineralized water, followed by stirring, filtering, and taking 15 L of the resulting $Ca(OH)_2$ solution for the absorber reactor. The mass of OFMSW during the bio-drying process was continuously monitored using a digital scale placed beneath the composter, and the water content was calculated based on the mass difference between the initial and final OFMSW after the bio-drying process. The temperature within the bio-drying reactor was monitored using a compost thermometer, while the exhaust gas was bubbled into the absorbed through a perforated pipe.

The height of the $Ca(OH)_2$ solution in the absorber reactor was maintained at 100 mm, with the perforated pipe submerged to a depth of 30 mm. During the bubbling process, a reaction occurred between CO_2 (g) and $Ca(OH)_2$ (s), producing $CaCO_3$ (s) and H_2O (l), as described in Equation 2. The process was conducted semi-continuously, with the $Ca(OH)_2$ solution added in batches while the gas mixture was supplied continuously. The aeration flow rate was adjusted by modifying the blower impeller cover opening. This flow rate was calculated based on the superficial velocity of the air from the blower, measured using an anemometer (Germany). The concentration of CO_2 in the exhaust gas entering and leaving the absorber reactor was monitored in real-time using a CO_2/temp./RH data logger. CO_2 concentration was recorded continuously, and averaged values were reported at selected time intervals (0, 24, 48, 72, and 96 hours). A total of 10 data points from 2000 measurements are reported for each variation in bio-drying time, with each data point representing the average value of every 200 measurements.

The absorption process started simultaneously with the bio-drying process. The bio-drying and absorption processes were conducted for a total of 96 hours, until the reaction in the absorber reactor ceased. The end of the reaction was determined through pH measurements (Metrohm 632, Switzerland) and concentration analysis of the $Ca(OH)_2$ solution using the acidimetry method. pH and $Ca(OH)_2$ concentrations were measured and analyzed at 0, 24, 48, 72, and 96 hours during the absorption process. Each measurement involved a 50 mL sample, with each analysis performed twice. Calculations were conducted to determine the efficiency of CO_2 absorption and the conversion of $Ca(OH)_2$.

The CO_2 absorption efficiency was calculated by taking the difference in CO_2 concentration between the exiting bio-drying and absorption reactors and dividing it by the CO_2 concentration leaving the bio-drying reactor, expressed as a percentage. Conversion was determined by dividing the number of moles of reacted $Ca(OH)_2$ by the initial moles of $Ca(OH)_2$, also expressed as a percentage. The PCC product was obtained by filtering the slurry from the absorption reactor after 96 hours of the absorption process and then drying it. The mass and morphology of the PCC product were assessed through weighing and analysis using FTIR and SEM.

3. RESULTS AND DISCUSSION

3.1. Effect of Bio-Drying Aeration Flow Rate on CO_2 Concentration

CO_2 emission concentrations during the bio-drying process are affected by the aeration flow rate. As shown in Figure 2, CO_2 concentration data were recorded from the exit gas of the bio-drying reactor at flow rates of 5.1, 4.6, and 3.9 L/min/kg over a 96-hour period. Continuous inline monitoring of CO_2 concentration aimed to assess the influence of the bio-drying aeration flow rate. The concentrations across the three flow rates increased until reaching a peak at 64.8 hours of bio-drying, followed by a decrease. After 64.8 hours, OFMSW water content fell to 36.8%, approaching the minimum requirement for microbial activity of 30%, which led to reduced CO_2 levels resulting from the bioconversion reaction. It was observed that higher flow rates corresponded to lower CO_2 concentrations, as elevated aeration flow can lower bio-drying temperatures, subsequently impacting the activity of bio-converting microbes [14].

The highest CO_2 concentration recorded was at an aeration flow rate of 3.9 L/min/kg, reaching 0.44% (v/v). Comparative data from research conducted by Zaman et. al. [8] shows that CO_2 emissions from MSW processing without bio-drying can reach 80,000 ppm, which is 16 times higher than the 5,000 ppm emitted during the bio-drying process. This indicates that the aeration process in bio-drying effectively reduces CO_2 concentrations. The findings of this study are consistent with a 96-hour bio-drying study conducted by the author, where the highest and lowest CO_2 concentrations were observed at flow rates of 3.9 and 5.1 L/min/kg, respectively.

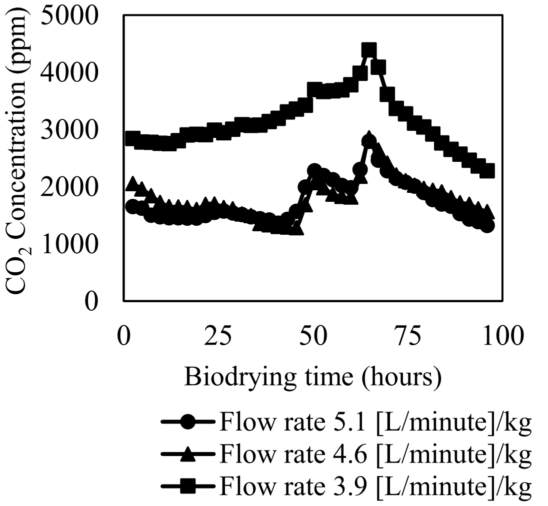

Figure 2. Effect of aeration flowrate on CO_2 concentration of bio-drying.

The higher CO_2 concentration observed at lower aeration flow rates can be explained by several bio-drying mechanisms. Lower airflow reduces the dilution effect caused by incoming air, allowing CO_2 produced from microbial respiration to accumulate in the reactor exhaust gas. In addition, decreased gas flow increases the retention time of gases within the reactor, thereby contributing to an elevated reactor temperature desired for the activity of biodegrading muds. However, in case of over aeration the reactor temperature may decrease as result of convective heat loss and dry condition can be shifted from biological drying to physical drying causing reduction in microbial respiration and CO_2 generation [2–4,14]. This suggests that increasing the aeration flow rate correlates with reduced CO_2 concentrations.

3.2. Effect of Bio-Drying Aeration Flow Rate on Absorbed CO_2

To investigate the influence of bio-drying aeration flow rate on CO_2 absorption, the gas emitted from the bio-drying reactor was channeled into a $Ca(OH)_2$ aqueous solution in the absorber reactor (Figure 3). CO_2 concentrations were recorded from both the bio-drying exhaust gas and the output from the absorber reactor. The CO_2 absorption efficiency was calculated by taking the difference in concentrations and dividing it by the concentration in the bio-drying exhaust gas, expressed as a percentage. The percentage of CO_2 absorbed at varying aeration flow rates of 5.1, 4.6, and 3.9 L/min/kg was calculated.

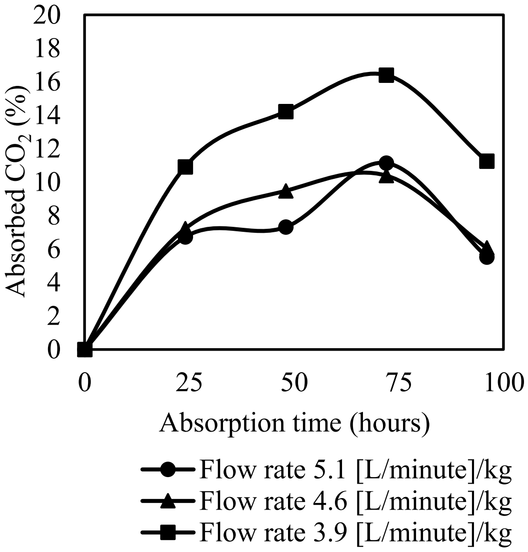

Figure 3. Effect of bio-drying aeration flowrate on absorbed CO_2.

Figure 3 illustrates the dynamics of CO_2 absorption by the $Ca(OH)_2$ aqueous solution during 96 hours of bio-drying. As the aeration flow rate decreases, the percentage of CO_2 absorbed increases. The gas flow rate influences the detention time of the gas components and affects the mixing regime of the solution [15]. A lower aeration flow rate results in a longer detention time and greater CO_2 absorption. In this study, the detention times for the three aeration flow rate variations were 10.4, 11.2, and 13.4 seconds, with the highest CO_2 absorption occurring at 72 hours, reaching rates of 11.15%, 10.4%, and 16.4%, respectively.

As the aeration flow rate decreases, the amount of CO_2 absorbed per liter of 0.019 M $Ca(OH)_2$ solution increases. This study recorded a CO_2 absorption capacity of 0.77 g CO_2 per liter of $Ca(OH)_2$ solution, which rose by 5.25% when the flow rate was decreased from 5.1 to 3.9 L/min/kg. Nonetheless, this absorption capacity is lower than the 3.05 g

CO_2 per gram of $Ca(OH)_2$ per liter reported by other researchers [12]. Their findings are based on a CO_2 concentration of 30%, substantially higher than the maximum concentration of 0.44% measured in this study.

3.3. Effect of Bio-Drying Aeration Flow Rate on $Ca(OH)_2$ Conversion

$Ca(OH)_2$ conversion was calculated based on concentration analysis data obtained at various bio-drying aeration flow rates. Measurements were conducted every 24 hours throughout the 96-hour bio-drying process using the acidimetric method. Samples of the $Ca(OH)_2$ aqueous solution were taken from the absorber reactor and analyzed twice for accuracy. The conversion percentage was determined by comparing the difference between the initial and measured concentrations of $Ca(OH)_2$ to the initial concentration. As shown in Figure 4, $Ca(OH)_2$ conversion varied during the 96 hours of bio-drying at aeration flow rates of 5.1, 4.6, and 3.9 L/min/kg. Higher flow rates resulted in lower conversion rates, with the maximum conversion achieved at an aeration flow rate of 3.9 L/min/kg after 48 hours of absorption.

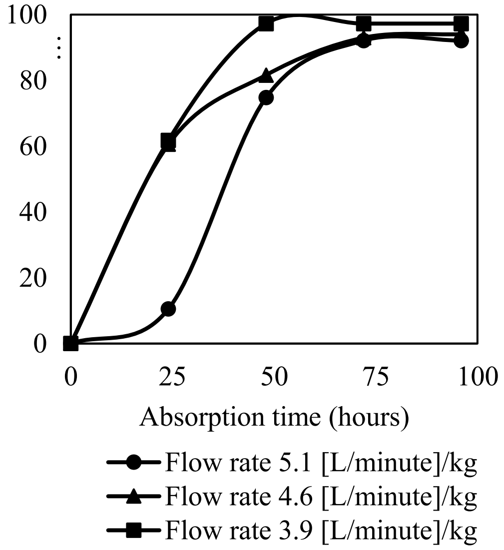

Figure 4. Effect of bio-drying aeration flowrate on $Ca(OH)_2$ conversion.

According to the results of Mufrodi et. al. [16], increasing the CO_2 flow rate can significantly enhance the reduction of $Ca(OH)_2$. At a fixed CO_2 concentration, a higher flow rate allows for a greater mass of CO_2 to react with $Ca(OH)_2$ in a given timeframe, thus speeding up the reduction. In this study, it was found that higher aeration flow rates during OFMSW bio-drying led to lower CO_2 concentrations and a decreased mass flow rate of CO_2 reacting with $Ca(OH)_2$. At the flow rate of 3.9 L/min/kg, $Ca(OH)_2$ reduction occurred most rapidly, achieving a conversion of 97.3% after 48 hours of absorption. After this time, the reaction was considered complete, with all $Ca(OH)_2$ fully reacted to form $CaCO_3$, corroborated by a measured pH of 8.1.

3.4. $CaCO_3$ Characterization

The total mass of $CaCO_3$ obtained during the 96-hour absorption process averaged 24.06 g across the three aeration flow rates, which is less than the theoretical 28.5 g calculated by reaction in Equation 2. This shortfall is primarily due to water evaporation from the aerated air during the absorption, leading to a decrease in the volume of the $Ca(OH)_2$ solution. Consequently, the shortened detention time resulted in a lower conversion rate of $Ca(OH)_2$.

Analysis of the IR spectra shows that the produced PCC contains a combination of hydrated and anhydrous $CaCO_3$ (Figure 5 and Table 1). The peak at 3432.65 cm^{-1}, corresponding to H_2O stretching, indicates the presence of hydrated $CaCO_3$. Peaks at 2511.32, 1795.73, and 1082.07 cm^{-1} point to $CaCO_3 \cdot 6H_2O$, while the presence of $CaCO_3 \cdot H_2O$ is suggested by peaks at 2131.34 and 871.82 cm^{-1}. The anhydrous $CaCO_3$ in this study predominantly shows calcite crystal formation, with characteristic peaks at 2976.16, 2872.01, 2511.32, and 1161.15 cm^{-1}. Aragonite crystal presence is indicated by peaks at 1454.33 and 1392.61 cm^{-1}. SEM analysis in Figure 6 reveals that the anhydrous $CaCO_3$ mainly consists of calcite crystals alongside aragonite, with the morphology showing elongated rectangular shapes indicative of aragonite and cubic forms representing calcite [17].

Table 1. Interpretation of the IR spectrum of the PCC Product.

Wavenumber (cm^{-1})		**Form**
Result Study	**References** [18]	
3423.65	3434	H_2O
2976.16	2980	calcite
2872.01	2872	calcite
2511.32	2515	calcite/$CaCO_3.6H_2O$
2131.34	2135	$CaCO_3.H_2O$
1795.73	1797	$CaCO_3.6H_2O$
1454.33	1477	aragonite
1392.61	1384	aragonite
1161.15	1162	calcite
1082.07	1082	$CaCO_3.6H_2O$
871.82	873	$CaCO_3.H_2O$
713.66	713	calcite/ aragonite

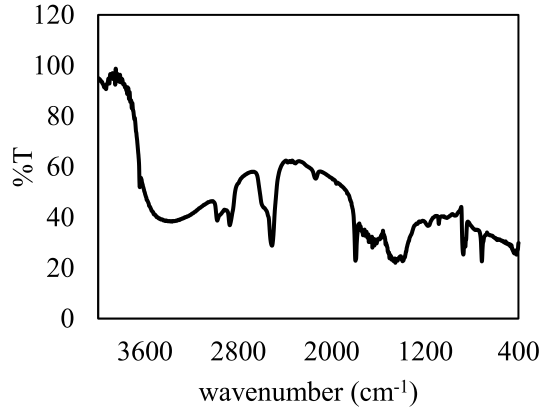

Figure 5. IR Spectrum of the PCC Product.

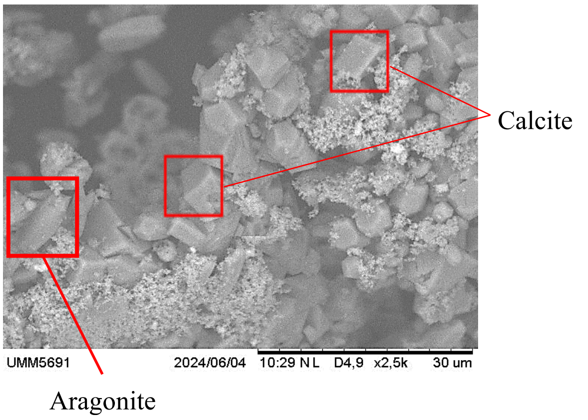

Figure 6. The morphology of PCC at 2500x magnification.

4. CONCLUSION

This paper presents a study on the production of precipitated calcium carbonate (PCC) from CO_2 emissions during the bio-drying of the organic fraction of municipal solid waste (OFMSW) through a carbonation reaction with a $Ca(OH)_2$ solution. The experiment was conducted by absorbing CO_2 at a concentration of 0.44% (v/v) in a 0.019 M $Ca(OH)_2$ solution. Results showed that the aeration airflow rate affects the efficiency of CO_2 absorption, $Ca(OH)_2$ conversion, and the mass of the PCC product. At flow rates of 5.1, 4.6, and 3.9 L/min per kg of waste during 96 hours of bio-drying, it was observed that higher flow rates led to lower CO_2 absorption efficiency and $Ca(OH)_2$ conversion. At an aeration flow rate of 3.9 L/min/kg during a 48-hour absorption period, the highest observed conversion rates for $Ca(OH)_2$, CO_2 absorption efficiency, and PCC mass were 97.3%, 16.4%, and 4.8 g PCC per kg of OFMSW, respectively. FTIR and SEM analyses indicated that the PCC product includes calcite and aragonite crystal forms, along with hydrated $CaCO_3$.The process effectively improved the utilization of the OFMSW bio-drying method as a waste management option through the production of PCC, a value-added product. However, regarding process performance, the reaction time is too long to attain a 97.3% conversion, due to the rapid detention time of 10.4-13.4 seconds at an aeration pressure of 0.294 kPa (30 mm water) in the absorption reactor.

Increasing the aeration bubbling pressure in the $Ca(OH)_2$ aqueous solution may provide a way to extend the detention time. Therefore, further research is necessary to enhance process performance by examining the effects of pressure on both detention time and $Ca(OH)_2$ conversion.

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REFERENCES

1. IPCC, Carbon Dioxide Capture and Storage, New York, 2005.
2. F. Tambone, B. Scaglia, S. Scotti, F. Adani, Effects of biodrying process on municipal solid waste properties, Bioresource Technology 102 (2011) 7443–7450.
3. A.P. Tom, R. Pawels, A. Haridas, Biodrying process: A sustainable technology for treatment of municipal solid waste with high moisture content, Waste Management 49 (2016) 64–72.
4. A. Bhatsada, S. Patumsawad, T. Itsarathorn, S. Towprayoon, C. Chiemchaisri, A. Phongphiphat, K. Wangyao, Improvement of energy recovery potential of wet-refuse-derived fuel through bio-drying process, Journal of Material Cycles and Waste Management 25 (2023) 637–649.
5. R. Alkarimiah, F. Suja’, Effects of technical factors towards achieving the thermophilic temperature stage in composting process and the benefits of closed rector system compared to conventional method – A mini review, Applied Ecology and Environmental Research 17 (2019) 9979–9996.
6. M. Bilgin, Ş. Tulun, Biodrying for municipal solid waste: volume and weight reduction, Environmental Technology 36 (2015) 1691–1697.
7. N.A. Ab Jalil, H. Basri, N.E.A. Basri, M.F.M. AbuShammala, The Potential of Biodrying as Pre-treatment for Municipal Solid Waste in Malaysia, Journal of Advanced Review on Scientific Research 7 (2015) 1–13.
8. B. Zaman, W. Oktiawan, M. Hadiwidodo, E. Sutrisno, P. Purwono, Calorific and greenhouse gas emission in municipal solid waste treatment using biodrying, Global Journal of Environmental Science and Management 7 (2021) 33–46.
9. R.M. Contreras-Cisneros, C. Orozco-álvarez, A.B. Piña-Guzmán, L.C. Ballesteros-Vásquez, L. Molina-Escobar, S.S. Alcántara-García, F. Robles-Martínez, The Relationship of Moisture and Temperature to the Concentration of O_2 and CO_2 during Biodrying in Semi-Static Piles, Processes 9 (2021) 520.
10. T. Thriveni, U.N. Il, J.W. Ahn, Aragonite Precipitated Calcium Carbonate: A New Versatile Functional Filler for Light Weight Plastic, Proceedings of the 8th Pacific Rim International Congress on Advanced Materials and Processing (2013) 243–253.
11. S. Madhania, Y. Ihsana, M.Z. Rizaldy, A. Afdiwibowo, K. Kusdianto, S. Winardi, Preparation of precipitated calcium carbonate from carbon mineralization of raw biogas with $Ca(OH)_2$ solution using bubble column contactor, AIP Conference Proceedings 2219 (2020) 030004.
12. S.-J. Han, M. Yoo, D.-W. Kim, J.-H. Wee, Carbon Dioxide Capture Using Calcium Hydroxide Aqueous Solution as the Absorbent, Energy and Fuels 25 (2011) 3825–3834.
13. N. Erdogan, H.A. Eken, Precipitated Calcium carbonate production, synthesis and properties, Physicochemical Problems of Mineral Processing 53 (2017) 57–68.
14. P. Payomthip, S. Towprayoon, C. Chiemchaisri, S. Patumsawad, K.

Wangyao, Optimization of Aeration for Accelerating Municipal Solid Waste Biodrying, International Journal of Renewable Energy Development 11 (2022) 878–888.

15. A. Gul, U. Tezcan Un, Effect of Temperature and Gas Flow Rate on CO_2 Capture, European Journal of Sustainable Development Research 6 (2022) em0181.
16. Z. Mufrodi, L.M. Shitophyta, H. Sulistyo, R. Rochmadi, M. Aziz, Reaction of Carbon Dioxide Gas Absorption with Suspension of Calcium Hydroxide in Slurry Reactor, Emerging Science Journal 7 (2023) 328–338.
17. N.I. Azkiya, F. Prasetia, E.D. Putri, A. Rosiana, S. Wardhani, Synthesis of precipitated Calcium Carbonate (PCC) from Lime Rock Nature Methods Caustic Soda (Kajian Konsentrasi HNO_3), Jurnal Ilmu Dasar 17 (2017) 31–34.
18. G.C. Jones, B. Jackson, Infrared Transmission Spectra of Carbonate Minerals, Springer, United Kingdom, 2012.