PUREBRED CHICKEN EGGSHELL WASTE AS A MATERIAL MANUFACTURE OF CALCIUM HYDROXIDE NANOPARTICLES

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Abstract

This research informs environmentally friendly, inexpensive, and easy-to-implement techniques in the manufacture of Calcium hydroxide ($Ca(OH)_2$) nanoparticles. For this purpose, purebred chicken eggshell waste is crushed using porcelain mortar and then calcined in two stages, namely at a temperature of 600 °C and 900 °C with a temperature of 5 °C / minute. Characterization of calcined results using XRD instrumentation, and identified the cfactal phase $Ca(OH)_2$ nanoparticles at angles of 2θ (°) 17.82, 28.54, 33.92. The acquisition of $Ca(OH)_2$ crystalline phase products using top-down techniques is 76.70% with a size of 11.23 nm. In addition to the main product, a crystal phase of CaO of 23.30% was also obtained which was identified at peaks of 2θ (°);32.04, 37.22, 53.78, and through calculations using the Debeye Scherrer equation obtained a particle size of 31.07 nm.

Keywords: Calcium hydroxide ($Ca(OH)_2$) nanoparticles, Calcination, Debeye Scherrer equation, Purebred chicken eggshell waste, Top-down techniques,

1. INTRODUCTION

Purebred chicken eggs are foods that are recommended to many people because they have a caloric value of 70 calories/chicken eggs and nutritional values that are needed by the body such as choline 140 mg, potassium 40 mg, calcium 25 mg, sodium 60 mg, protein 6 g, fat 5 g, then after consumption will generally leave the remaining eggshells that are rarely used to accumulate as waste that disturbs the environment and ends up in landfills (Awogbemi et al., 2020; Yankes Kemkes, 2022).

According to the report of De Angelis et al (2017), The problem of purebred chicken eggshell waste (PCEW) can be solved by processing and modifying it so that it can become a useful product. Scientific investigations have revealed that the eggshell of purebred chickens that have been considered waste in landfills can be recovered, reused, and regenerated to improve their usefulness, where PCEW weighs an average of about 5g–6g and crystals of calcium carbonate ($CaCO_3$), magnesium carbonate ($MgCO_3$), calcium phosphate ($Ca_3(PO_4)_2$), and some organic substances (Tanpure et al., 2022). Purebred chicken eggshell waste that has been processed and used in various fields including adsorbents, catalysts, fertilizers, antibacterials, calcium hydroxide, and others (X. Chen et al., 2019; Djayasinga et al., 2022; Nurlaili et al., 2017; Purwanti and Heruwati, 2020; Siriprom et al., 2014).

The high calcium carbonate content in PCEW is a potential material to be used as a variety of calcium hydroxide ($Ca(OH)_2$) products, where this product is widely needed in fields such as biodegradable wastewater, antibacterial, denture-making materials, electronic equipment, and others (Nguyen et al., 2019; Nishanthi and Ravindran, 2020; Wang et al., 2023; Yousefshahi et al., 2018).

Many studies have been conducted to process PCEW into useful products such as those conducted by Johnson Jeyakumar et al (2023), synthesizing nanohydroxyapatite for

bone graft applications in vitro, a heterogeneous catalyst used for the manufacture of biodiesel (Ali et al., 2021; Buasri et al., 2013; Tan et al., 2015), Improving the quality of compost (Costa et al., 2017; Lee et al., 2022), as an ingredient for the improvement of biogas products (Andrade Cruz et al., 2022), Antibacterial (Nath et al., 2021; Tao and Huang, 2022),

However, from previous studies, researchers still identified no manufacture of calcium hydroxide nanoparticles made from PCEW raw materials using a top-down technique with a two-stage calcination process, where the first stage of PCEW decomposition at 600 °C and the second stage at 900 °C. Therefore, the contribution of this research is to add information on the method of making $Ca(OH)_2$ nanoparticles made from PCEW raw materials.

The purpose of this study is to make $Ca(OH)_2$ nanoparticles made from PCEW raw materials, so this research has contributed to the handling of environmental waste. The selection of techniques and methods for making $Ca(OH)_2$ nanoparticles is based on the advantages obtained, namely the $Ca(OH)_2$ nanoparticle products obtained are nano-sized and relatively quiet lot, PCEW processing equipment is simple and easy to obtain, do not use other chemicals so that the costs required are relatively economical.

2. LITERATURE REVIEW

In general, nanoparticles are defined as particles that have a size from one to one hundred nanometers and have relatively different properties to the same material in a relatively larger size (Alok et al., 2013; Auffan et al., 2009; Christian et al., 2008). Many new nanoparticles have been created through emerging nanotechnology in the 21st century and have been used in fields such as pharmaceuticals, medicine, optics, energy, mechanics, and electronics in recent years (Kumar et al., 2023). Among the new materials include calcium hydroxide nanoparticles that are applied as antimicrobials (Perepelkin et al., 2023; Yeasmin et al., 2023), catalysis (T. Chen et al., 2023; Tong et al., 2023), drug delivery (Kurawattimath et al., 2023), solar cells (Schuster et al., 2015), semiconductor materials (Kubiak et al., 2023).

Nanoparticle manufacturing methods are grouped into two techniques: bottom-up and top-down (Torres et al., 2022). The bottom-up method has an important process, namely crystal growth. Many methods of making $Ca(OH)_2$ nanoparticles with this bottom-up technique include the ion exchange method (Yang et al., 2020), sol-gel (Sierra-Fernandez et al., 2019), and Precipitation (Zhang et al., 2023). Furthermore, Dinda et al (2020) applied top-down methods mechanically to the manufacture of $Ca(OH)_2$ nanoparticles.

The advantage of the bottom-up method in making nanoparticles is that the size distribution of nanoparticle products tends to be homogeneous with a size scale from very small to large, while the disadvantage of this method is that there are many obstacles when nanoparticles are produced in large quantities (Paramasivam et al., 2021). Nanoparticles made using the top-down method have the advantage of being able to be produced in relatively larger quantities, while this method has the disadvantage of being difficult to control the shape and size of nanoparticles (Baig et al., 2021).

3. METHOD

This research was conducted in August 2022, using raw materials for purebred chicken eggshell waste obtained from fried rice sellers in the Bandar Lampung city area, Indonesia. The instrumentation used includes mortar and porcelain samples, muffle furnace Lenton type UAF 16/10, and XRD-6000 Schimadzu. Figure 1 informs the manufacturing process of $Ca(OH)_2$ nanoparticles.

The manufacture of $Ca(OH)_2$ nanoparticles begins by collecting PCEW from goring rice traders, then PCEW is crushed using a mortar and a porcelain stampler, then after fine continued with the temperature calcination process of 600 °C with a temperature increase of 5 °C/minute, and after the temperature is reached, then this temperature is maintained for 10

hours, then the instrumentation is activated. A little later calcination continued like the first stage, but in this second stage, the temperature reached 900 °C.

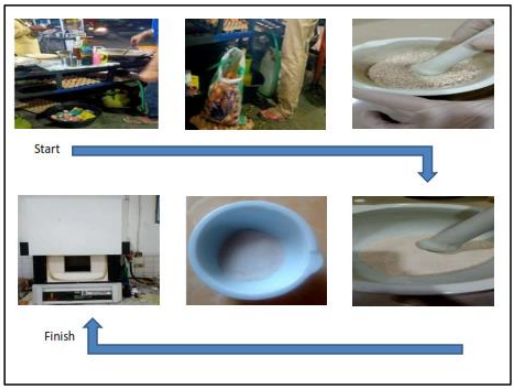


Figure 1. The Flow of Synthesis of $Ca(OH)_2$ Nanoparticle Powder.

4. RESULTS AND DISCUSSION

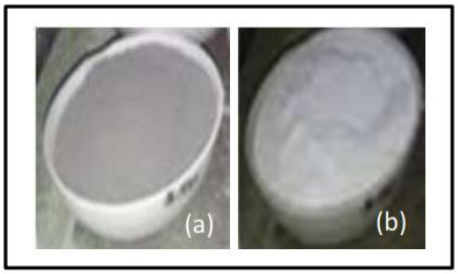


Figure 2. (a) Temperature Calcination Result at 600 °C, and (b) at 900 °C.

Figure 2 (a) is a calcined product of chicken eggshell powder, the taste appears gray, indicating that there is still a lot of carbon that has not been separated, and Figure 2 (b) is white, indicating that $Ca(OH)_2$ has been formed.

Furthermore, the calcination results in Figure 2 (b), analyzed crystal phase composition using XRD instrumentation, and then the data obtained from scanning using XRD instrumentation were characterized using Match software! Crystal Impact version 3.1.5 build 247 (Karlshrue, 2006; Putz, 2022). Diffractogram comparison of XRD PCEW powder before calcining and after calcination is shown in figures 3 and 4 below;

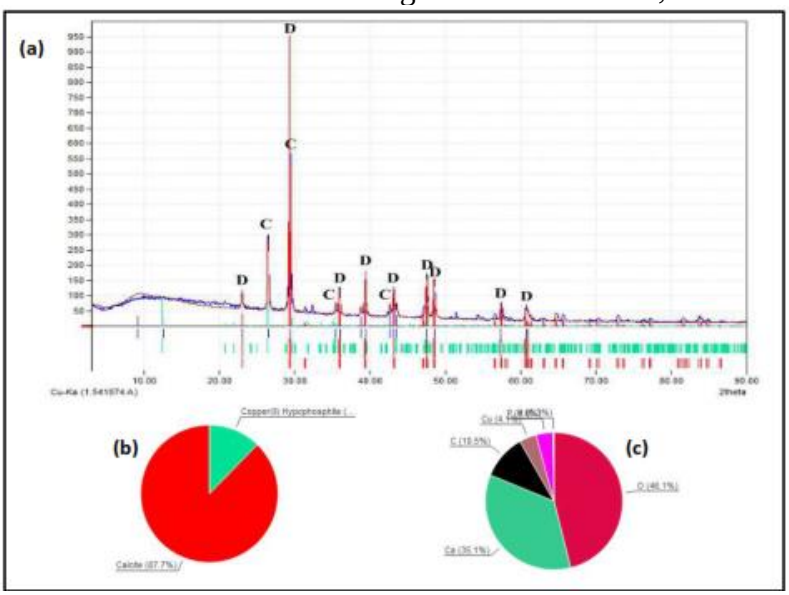


Figure 3. XRD PCEW diffractogram before calcination, where peak D is the crystal phase of calcite.

($CaCO_3$), C are the peaks of the crystalline phase of copper(II) hypophosphite ($CuH_4O_4P_2$)

The characterization information obtained from the results of the XRD PCEW diffractogram before and after calcination as shown in Figures 3 and 4, is presented in Table 1 below.

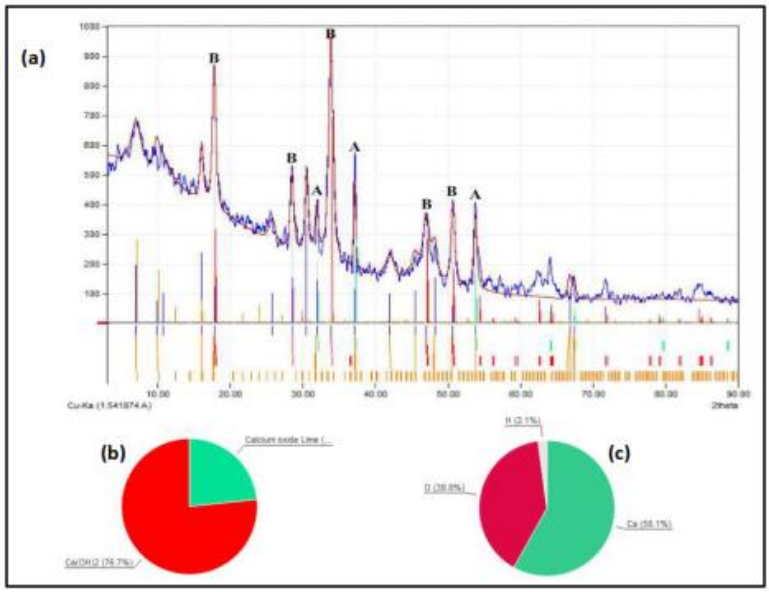


Figure 4. XRD PCEW diffractogram after calcination, where the peaks B are the crystal phase of calcium hydroxide ($Ca(OH)_2$) nanoparticles, A are the peaks of the crystalline phase of calcium oxide (CaO) nanoparticles.

Based on Figure 3 (b), the percentage of $CaCO_3$ content in non-calcined FCEW is 87.70%, $CuH_4O_4P_2$ is 12.30%, then in Figure 3 (c) is the percentage of the constituent atoms of each compound, where Ca atoms are 35.10%, C 10.50%, Cu 4.10%, P 4%, and O 45.10%.

Ca(OH)2 products of 76.70% and 23.30% were obtained from the calcination of 900 °C FCEW powder as shown in Figure 4 (b), further, each percentage of crystalline phase constituent atoms is informed in Figure 4 (c), where Ca atoms 58.10%, O 39.80%.

Table 1. Noncalcined FCEW Crystal Phase Peaks

Crystalline Phases of Non-Calcined Samples	Analysis Results 2 θ (°)			COD ID (Crystallography Open Data Base Identity)		Researchers
$CaCO_3$	23.22	29.49	39.61	COD-96-900-9669	CIF-9009668	(Sitepu et al., 2005)
$CuH_4O_4P_2$	26.52	29.25	35.50	COD-96-224-1204	CIF-2241203	(Naumov et al., 2002)

Significant peaks of the crystalline phase of calcite ($CaCO_3$) contained in noncalcined FCEW powder identified at 2θ (°); 23.22, 29.49, 39.61 are sufficient (Sitepu et al., 2005). In addition, FCEW powder has a crystalline phase of copper(II) hypophosphite identified at peaks 26.52, 29.25, and 35.50 (Naumov et al., 2002).

Table 2. PCEW Crystal Phase Peaks Calcining at 900 $°C$

Crystalline Phases of Calcined Samples at 900 °C	Analysis Results 2 θ (°)			COD ID		Researchers
$Ca(OH)_2$	17.82	28.54	33.92	COD-96-900-0114	CIF-0000117	(Nielsen et al., 2012)
CaO	32.04	37.22	53.78	COD-96-156-3197	CIF-1563199	(Oftedal, 1927)

$Ca(OH)_2$ products made from PCEW are known based on the appearance of characteristic peaks at an angle of 2θ (°); 17.82, 28.54, 33.92 which refer to previous studies

(Nielsen et al., 2012), In addition to these products, there are also CaO products, where the characteristics of significant peaks resemble those carried out by Oftedal (1927) where the crystal phase is identified at angle 2θ (°); 32.04, 37.22, 53.78.

The nanoparticle size of the $Ca(OH)_2$ and CaO products was calculated using the Debeye Scherrer equation (Tamura and Gilbert, 2013).

$$D = \frac{k\,\lambda}{\beta\,cos\theta} \quad \text{..... (1)}$$

Where D = crystal phase size (nm), k = shape constant valued at 0.9 – 1, λ = X-ray wavelength used = 1.542 nm, $\beta =$ Measurement result of half the maximum peak width height (in radians, $\alpha\,° \frac{\pi}{180°}\,x$ FWHM (Full Width Half Maximum), $\alpha\,° =$ Bragg angle). From these calculations, the crystal phase size of $Ca(OH)_2$ is 11.23 nm and CaO is 31.07 nm.

5. CONCLUSION

In this study, PCEW raw materials can be used to make calcium hydroxide ($Ca(OH)_2$) nanoparticles with top-down techniques. The results showed that $Ca(OH)_2$ had formed as much as 76.70% with a size of 11.23 nm. A series of two-stage calcining activities have been able to support the formation of $Ca(OH)_2$ nanoparticles through a thermal decomposition process.

Through the findings obtained in this study, the application of top-down techniques with a two-stage calcination process can be a consideration to be implemented. Further research that examines the application of $Ca(OH)_2$ nanoparticles made from PCEW raw materials can be carried out in various fields.

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