Efficiency of Shell Waste as a Source of Calcium Carbonate to Produce Calcium Oxide Through Calcination Process

ABSTRACT

Aims: The aim of this research is to examine the efficiency of batik shellfish shells as a source of calcium carbonate to produce calcium oxide compounds.
Study design: The type of research is Experimental.
Place and Duration of Study: Sample: Department of Physics Education, Kristen Indonesia University, Jakarta, between June 2023 and December 2023.
Methodology: There are two stages in the research process, namely the first stage is the preparation and sterilization of batik shellfish shells. The second stage is the calcination of batik shellfish shells to produce CaO Clean the batik shellfish shells using distilled water. Then crush them using a hammer until they become small fragments. Next, dry the small fragments of batik shellfish shells by air-drying them in a closed room. Then, the sample inside the container will undergo calcination process using a furnace/heating furnace with temperature variations of 800°C and 900°C for 8 hours.
Results: The results obtained show the formation of CaO compounds with the characteristic white color of CaO powder and small or fine particle size. The average efficiency of CaO compounds resulting from the calcination of batik shellfish shells at a temperature of 800°C is 61.85%. Meanwhile, the average efficiency of CaO compounds resulting from the calcination of batik shellfish shells at a temperature of 900°C is 55.64%.
Conclusion: The average efficiency of CaO compounds resulting from the calcination of batik shellfish shells at 800°C is greater than the average efficiency of CaO compounds obtained at a calcination temperature of 900°C. This is because the higher the temperature, the purer the CaO compounds produced will be.

Keywords: Calcination, shell, batik shellfish, CaO

1. INTRODUCTION

Indonesia is rich in abundant aquatic resources, one of which is shellfish. In Indonesian waters, there are thousands of species of shellfish, some of which have high economic value, such as green mussels, blood cockles, pearl oysters, razor clams, and oysters. Additionally, there is also batik shellfish which has recently gained popularity among the community. Indonesian society has not fully utilized the potential of the abundance of shellfish. Generally, people consume the meat and discard the shell of shellfish. Based on previous research, these unused shellfish shells can cause environmental problems, especially regarding cleanliness [1]. Various types of shellfish are often only used as food because of their high protein content, while their shells are used as ornaments or decorations [2]. Currently, shells are only utilized in handicrafts, such as decorations or as additives in animal feed [3].

The batik shellfish is a favorite among local communities because of its delicious meat. The taxonomy of the batik shellfish (Paphia undulate) is as follows: Phylum Mollusca, class Bivalvia, Order Veneroida, Genus Paphia, and Species Paphia undulate. This shellfish has an elongated elliptical shell, with a greenish-brown color and dark brown zigzag pattern decorations. The shell is somewhat thick and yellowish-brown, with a smooth and shiny surface [4].

Shellfish shells contain more calcium than shellfish meat [5], but they have not been fully utilized yet. Previous research has found that the main component of shellfish shells is calcium carbonate ($CaCO_3$) at around 96% [6]. Additionally, there is other research stating that the composition of shellfish shells is 98% calcium carbonate, 0.79% $MgCO_3$ compound, and 0.15% $SrCO_3$ compound.

Some methods used for calcium extraction from shellfish shells include carbonation [7], deproteinization [8], and calcination [9]. Among these three methods, the easiest and most effective in producing high-quality calcium is the calcination method (heating at high temperatures). If calcium carbonate from shellfish shells is heated to temperatures above 700 ºC, it will transform into calcium oxide (CaO) [10]. Besides high temperature, the heating time also affects the characteristics of the resulting CaO compound [11]. If the heating temperature of the shellfish shells is raised to 750 ºC to 800 ºC, the obtained CaO compound will have better characteristics compared to at 700 ºC. High temperature is necessary to heat the shellfish shells so that the water content, organic compounds, and carbon dioxide within the shellfish shells are removed, and the expected compound present is pure CaO.

From several previous studies, it has been found that the utilization of shellfish shell waste is still not optimal, especially as a source of calcium carbonate ($CaCO_3$) which can then produce solid CaO compounds through high-temperature heating processes, and with appropriate treatment, CaO derived from shellfish shell waste can be used for various purposes in daily life. The aim of this study is to examine the efficiency of batik shellfish shells as a source of calcium carbonate to produce calcium oxide compounds. It is hoped that the produced CaO can be used as an environmentally friendly material and can be widely applied in various fields.

2. EXPERIMENTAL DETAILS

There are two stages in the research process, namely the first stage is the preparation and sterilization of batik shellfish shells. The second stage is the calcination of batik shellfish shells to produce CaO. In the Sample Preparation and Sterilization stage, it begins with the collection of batik shellfish shells to be used. The batik shellfish shells used are household waste from the Kalimantan region. Prepare 0.5 kg of batik shellfish shells. Clean the batik shellfish shells using distilled water. Then crush them using a hammer until they become small fragments. Next, dry the small fragments of batik shellfish shells by air-drying them in a closed room. This is to prevent contamination of the samples by impurities if they were to be dried outdoors.

The drying process is carried out for 24 hours. If the sample is already dry, it can proceed to the next stage, namely the sample calcination. Batik shellfish shells prepared in the previous stage are weighed before being placed into a container/crucible. Then, the sample inside the container will undergo calcination process using a furnace/heating furnace with temperature variations of 800°C and 900°C for 8 hours. Afterward, the sample is cooled. Next, the resulting calcination in the form of CaO, batik shellfish shells are crushed using a mortar, placed into sample plastic bags, labeled with their names, and then weighed to determine their mass.

Figure 1. Steps of calcination of batik shellfish shells

Information:
1.Batik shellfish shell sample
2.Prepared sample
3.Sample weighed
4.Sample calcined
5.Sample crushed with a mortar
6.CaO powder

3. RESULTS AND DISCUSSION

The results of the calcination of batik shellfish shells using a furnace with temperature variations of 800°C and 900°C, each for 8 hours, are in the form of powder as shown in Figure 2. From the three repetitions conducted and observed, there is a significant difference in the color of the samples before and after calcination. The initial milk chocolate color of the sample turns white after calcination.

(a) (b)

Figure 2. Powder resulting from the 8-hour calcination of batik shellfish shells. (a) At a temperature of 800°C. (b) At a temperature of 900°C.

This is evident in both samples that were calcined at temperatures of 800°C and 900°C. This means that at both calcination temperatures of 800°C and 900°C, the batik shellfish shell samples have produced CaO compounds. This is consistent with previous research stating that shellfish shells heated at temperatures above 700°C will transform into CaO compounds [10]. Additionally, the change in color to white is an indicator of the transformation of the compound found in limestone, which was initially CaCO3 and has now changed to CaO[13].

The compound which was initially $CaCO_3$ then decomposes into CaO through calcination temperatures of 800°C and 900°C. This decomposition occurs due to a high-temperature combustion process, resulting in the release of carbon. Below is the reaction of the decomposition of $CaCO_3$ compound into CaO compound.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

When comparing the most effective calcination temperature in producing CaO compounds, it is found that 900°C is the optimal temperature. This is because the higher the calcination temperature, the purer the CaO compound obtained.

From Table 1, the average efficiency of CaO compound resulting from the calcination of batik shellfish shells at 800°C is 61.85%. Meanwhile, from Table 2, it can be observed that the average efficiency of CaO compound resulting from the calcination of batik shellfish shells at 900°C is 55.64%. Comparing the average efficiency of CaO compound resulting from calcination at 800°C and 900°C, it can be seen that the average efficiency of CaO compound obtained at a calcination temperature of 800°C is higher than that obtained at a calcination temperature of 900°C. This is because the higher the temperature, the purer the CaO compound produced.

Table 1. Efficiency of CaO compound from the calcination of batik shellfish shells at 800°C temperature.

Batik Shellfish	Mass	Efficiency

Shell Samples	Before Calcination ($CaCO_3$)	After Calcination (CaO)	
Container 1	21, 74 gram	13,98 gram	64,3 %
Container 2	24, 79 gram	11,99 gram	48,3 %
Container 3	27,05 gram	18,86 gram	69,7 %
Container 4	30,87 gram	20,09 gram	65,1 %
Average Efficiency			**61,85 %**

Table 2. Efficiency of CaO compound from the calcination of batik shellfish shells at 900°C temperature.

Batik Shellfish Shell Samples	Mass		Efficiency
	Before Calcination ($CaCO_3$)	After Calcination (CaO)	
Container 1	43,79 gram	24,33 gram	55,56 %
Container 2	47,09 gram	26,24 gram	55,72 %
Average Efficiency			**55,64 %**

When heating is conducted at a higher temperature, the water content, organic compounds, and carbon dioxide present in the shellfish shells are lost, and the expected compound to form is pure CaO. The difference in average efficiency values at 800°C and 900°C is not significantly different, only about ± 6%, so if it is not possible to raise the calcination temperature to 900°C, using a calcination temperature of 800°C can still be considered. However, at 800°C, there may still be some impurity compounds present. But if 900°C is feasible, the resulting CaO compound will be purer.

In Table 1, there is a significant difference in the efficiency values of the CaO compound produced between containers 1, 3, and 4 compared to container 2. Containers 1, 3, and 4 have average efficiency values above 60%, while for container 2, the average efficiency value of the CaO compound produced is 48%. This is because during the calcination process, container 2 broke inside the furnace, causing some of the batik shellfish shell samples to fall out of the container. The weighed sample is only the portion that remained inside container 2, resulting in a different efficiency value of the CaO compound produced compared to containers 1, 3, and 4. However, when calculating the average efficiency values of the CaO compound produced across containers 1 through 4, the obtained results are still above 60%.

4. CONCLUSION

The batik shellfish shells were successfully calcined into CaO at temperatures of 800°C and 900°C with a calcination time of 8 hours. The results obtained include the formation of CaO compounds with characteristic white CaO powder color and small or fine particle size. The average efficiency of the CaO compound resulting from the calcination of batik shellfish shells at 800°C is 61.85%. Meanwhile, the average efficiency of the CaO compound resulting from the calcination of batik shellfish shells at 900°C is 55.64%. The average efficiency of the CaO compound resulting from the calcination of batik shellfish shells at 800°C is higher than the average efficiency of the CaO compound obtained at a calcination temperature of 900°C. This is because the higher the temperature, the purer the CaO compound produced. When heating is conducted at a higher temperature, the water content, organic compounds, and carbon dioxide present in the shellfish shells are lost, and the expected compound to form is pure CaO.

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