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(RESEARCH ARTICLE)

Processing of Ogbolokuta limestone through calcination technique for quicklime production

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Abstract

Report on processing of Ogbolokuta limestone through calcination technique for quicklime production is presented. The limestone was washed to remove impurities, dried, ground in to powder form and classified with the aid of the automatic vibrating sieves of 80μm, 90μm, 100μm, 300μm and 425μm. X-ray fluorescence spectroscopy was used to determine the chemical compositions of the limestone, while its mineralogical composition was determined by X-ray diffractometer. Scanning electron microscope was used to study the surface morphology of the sample. Sample size area was grossly estimated by Langmuir method, while density functional theory was used to obtain different pore structural morphology of the sample. Analyses of the results showed that CaO (65.7%) is the predominant chemical constituent, and calcite is the main mineral of the limestone. Quicklime was successfully produced from Ogbolokuta limestone through calcination process. Calcination of the limestone enhanced its surface morphology. The quicklime yield was temperature, particle size and time dependent.

Keywords: Ogbolokuta limestone; Calcination technique; Quicklime production

1. Introduction

Limestone is a mineral with enormous diversity of uses. The specific chemical properties of a particular limestone or dolomite deposit will dictate applications for which that material may be used. Limestone has numerous uses that range from agricultural applications to building materials to medicines [1]. It has been utilized for construction and agricultural purposes. An addition of finely ground limestone filler up to 18% gives a better strength for the same cement content and reduces the cost of concrete for the same target strength [2]. Many limestone products require rock with specific physical and chemical characteristics. Some limestones are sought for their use in producing lime, pharmaceuticals and in glass-making; whereas dolomites may be best suited for aggregate and construction uses. According to previous report [3], limestone is used for various industrial purposes. In general limestone is used for various purposes:

- It is used to manufacture quicklime (CaO).
- It is used to manufacture Slaked lime ($Ca(OH)_2$).
- It is used to manufacture cement and mortar.
- It is used in making glass.
- It is used for making filler, paint, pigments and tiles.
- It is applied as soil conditioner to neutralize acidic soils.
- It is used for treating water.

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Due to strategic importance of limestone, there are several research works on limestone processing. Kinetic of Jakura limestone calcination process was investigated using power rate law [4]. Effect of particle size of minerals that influenced the concentration of limestone was studied in terms of grade and recovery by flotation [5]. Geochemical of Tse-Kucha limestone of the middle Benue Trough was investigated [6]. Odukpani limestone deposit was studied using geophysical and laboratory techniques with the aim of generating information on its spread and quality [7].

From the review of previous related works, there is no adequate information on the effects of process variables for calcination of Ogbolokuta limestone for production of quicklime. Ogbologuta is a town in Benue State. Benue state geographic coordinates are longitude 7° 47' and 10° 0' East; Latitude 6° 25' and 8° 8' north; and shares boundaries with five other states namely: Nassarawa to the north, Taraba to the east, Cross-River to the south, Enugu to the south-west and Kogi to the west (www.benuestate.gov.ng). The State also shares a common boundary with the Republic of Cameroun on the south-east. When the limestone is properly harnessed and processed, it will promote economic growth of the area.

2. Material and methods

The limestone sample was washed to remove impurities such as clay and sand associated with the limestone crystals. They were gradually sun dried at ambient atmospheric condition. 3000g of the sample was crushed and ground in to powdered form. Then, they were classified with the aid of the automatic vibrating sieves of 80µm, 90µm, 100µm, 300µm and 425µm arranged vertically such in descending order of magnitude and the system set in vibration for 10 minutes.

2.1. Determination of Chemical Composition

X-ray Fluorescence spectroscopy (Supreme 8000, Oxford instrument) was used to determine the chemical compositions of the limestone. Method used by previous works [8, 9] was adopted in this study, with slight modification.

2.2. Determination of Mineralogical Composition

Mineralogical composition of the limestone sample was determined by X-ray Diffractometer (XRD). This study adopted a method used by previous works [8, 9], with slight modification. The XRD analysis was performed on finely ground sample of the limestone.

2.3. Determination of Surface Morphology of the Samples

Scanning electron microscope, (Phenom Pro X-ray, phenom world Emdhoven Netherlands) was used to study the surface morphology of the sample, in line with method used by [9].

2.4. Size Analyses of the Samples

Size analysis of the limestone was carried out in accordance with standard method [10, 11, 12, 13]. Sample size area was grossly estimated by Langmuir method, while density functional theory (DFT) was used to obtain different pore structural morphology of the sample. DFT accounted for the effects of microporosity and predicted the pore size.

2.5. Calcination of the limestone

Quicklime (CaO) was produced from the Ogbolokuta limestone by calcination process. Effects of temperature, particle size and time on quicklime yield were determined. 10g of the limestone sample (80µm particle size) was weighed into pre-weighed empty crucible plate. The pre-weighed crucible plate with the limestone was set into laboratory furnace and heated at various temperatures 800 ^{0}C - 1200 ^{0}C. The first sample was removed after 30 minutes of holding time, thereafter other samples removed at the time of 1, 2 , 3 and 4 hours. After heating the calcined sample, it was allowed to cool for 15 minutes. The calcined samples were transferred to desiccators to maintain their integrity. The weight of the quicklime produced was measured. The experiment was carried out at temperatures of 800, 900, 1000, 1100 and 1200 ^{0}C and particle sizes of 80µm, 90µm, 100µm, 300µm and 425µm. Quicklime yield was calculated using Equation (1).

$$\boldsymbol{Y} = \frac{\boldsymbol{W_2}}{\boldsymbol{W_1}} \text{x} \frac{100}{1} \quad (1)$$

where W_1 = Weight of limestone before calcination, W_2 = Weight of limestone after calcination, Y = percentage yield.

3. Results and discussion

3.1. Chemical Compositions of the Limestone

The chemical composition of Ogbolokuta limestone was obtained through the XRF analysis. As shown in Table 1, the limestone contains CaO (65.7%), MgO (25.4%), SiO_2 (6.6%), Al_2SO_3 (1.1%) and traces of Fe_2O_3, SO_3, TiO_2, Mn_2O_3, K_2O, Cl, P_2O_5, Cr_2O_3 and SrO. It showed that the limestone is rich in CaO.

Table 1 Chemical Compositions of the Ogbolokuta Limestone

Element	Concentration (wt%)
Na_2O	0.181
MgO	25.409
Al_2O_3	1.125
SiO	6.588
P_2O_5	0.087
SO_3	0.322
Cl	0.263
K_2O	0.094
CaO	65.664
TiO_2	0.012
Cr_2O_3	0.006
Mn_2O_3	0.006
Fe_2O_3	0.209
ZnO	0.000
SrO	0.035

3.2. Mineralogical Compositions of the Limestone

The mineralogical composition of Ogbolokuta limestone as determined by XRD is shown in Figures 1. It revealed that calcite is the major mineral of Ogbolokuta limestone, although there are traces of quartz in it.

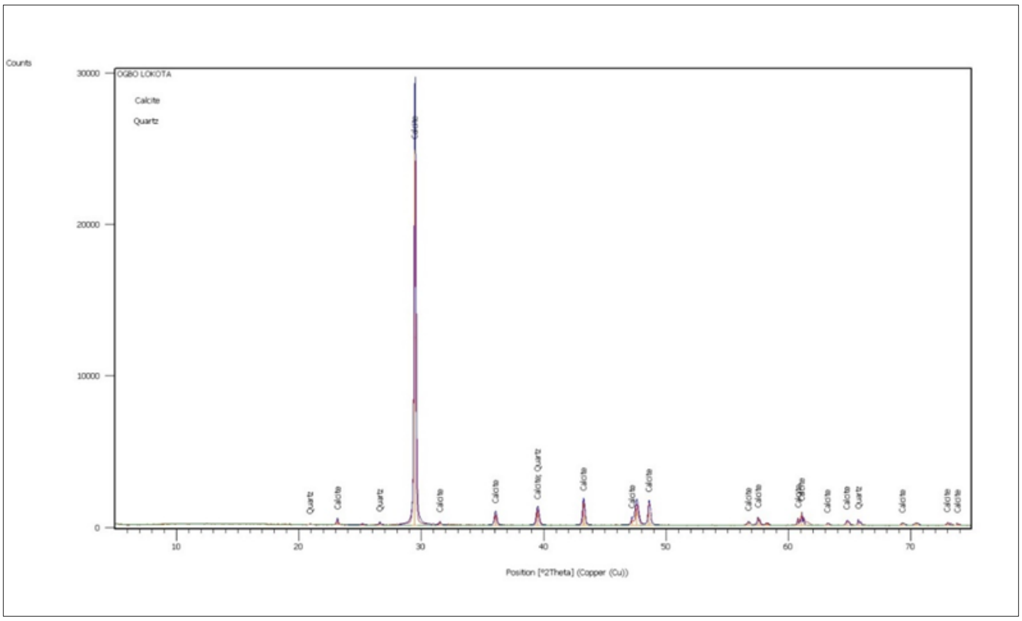

Figure 1 Mineralogical Compositions of Ogbolokuta Limestone

3.3. SEM Analysis of the Limestone

The scanning electron microscopic analysis of Ogbolokuta limestone is presented in Figure 2. The surface morphology of the limestone showed that the particles are packed together in powdered form with visible pores. Such pores allow passage of fluids, thereby enhancing its solubility in the soil. The presence of the pores is also an indication that there will be efficient removal of CO_2 during the calcination process [9, 14].

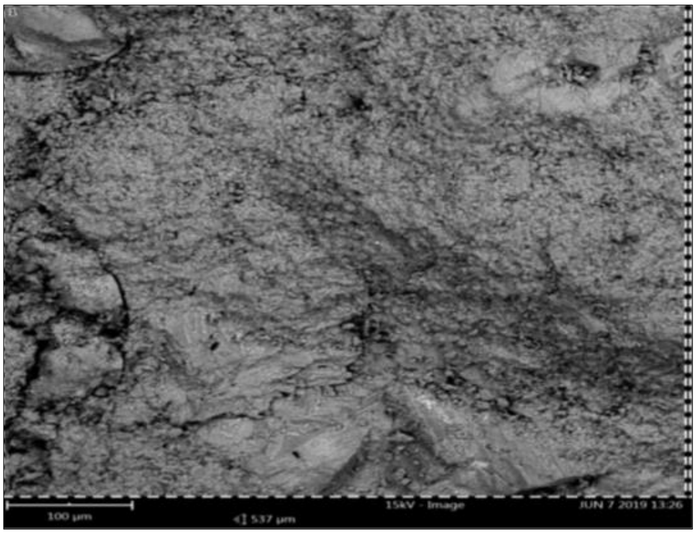

Figure 2 SEM Analysis of Ogbolokuta Limestone

3.4. Size Analysis of the Limestone

Size analyses (surface area, pore volume and pore size data) of the Ogbolokuta limestone sample are presented in Tables 2. It revealed $1.181X10^3 m^2/g$ as the Langmuir surface area of the limestone. Langmuir methods grossly estimated the surface area [10]. The density functional theory (DFT) cumulative surface areas of Ogbolokuta limestone is obtained as 7.144 x $10^1 m^2/g$. The parameters from the DFT method provide avenue for customization to different materials and pore morphologies [12]. DFT is adequate for the characterization of micro- and mesoporous materials of various origins. It reveals the surface roughness as additional structural property.

Table 2 Size Analysis of Ogbolokuta Limestone

Analysis	Surface Area Data
Langmuir surface area	1.181 $X10^3 m^2/g$
DFT cumulative surface area	7.144 $X10^1 m^2/g$
	Pore Volume Data
DFT method cumulative pore volume	8.587 $X10^2 cc/g$
	Pore Size Data
DFT pore Diameter (Mode)	2.647nm

3.5. Effects of the Process Variables on the Quicklime Yield of Ogbolokuta Limestone

Effects of temperature on Ogbolokuta quicklime yield are presented in Figures 3 – 7. For any particle size, the Figures showed a relationship between the yield and temperature at various times of the calcination. The quicklime yield decreased with increase in temperature, particle size and time. This observation is in agreement with previous findings [9].

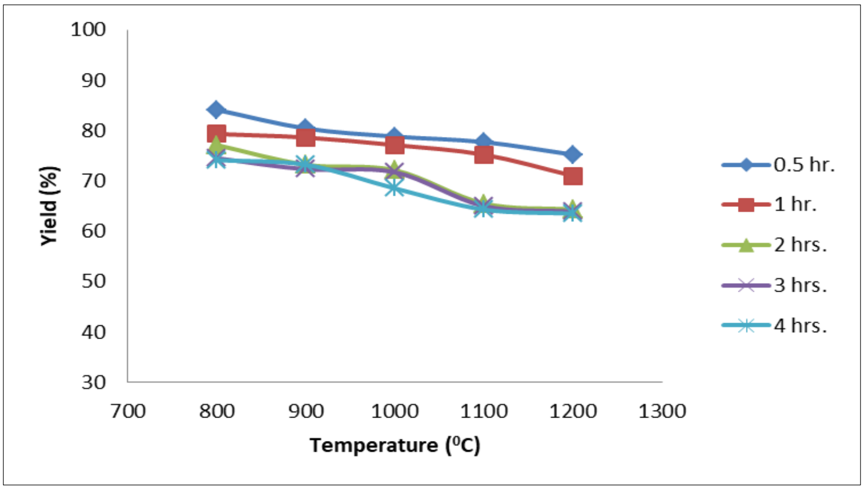

Figure 3 Effects of Temperature on the Calcination of 80 µm of Ogbolokuta Limestone

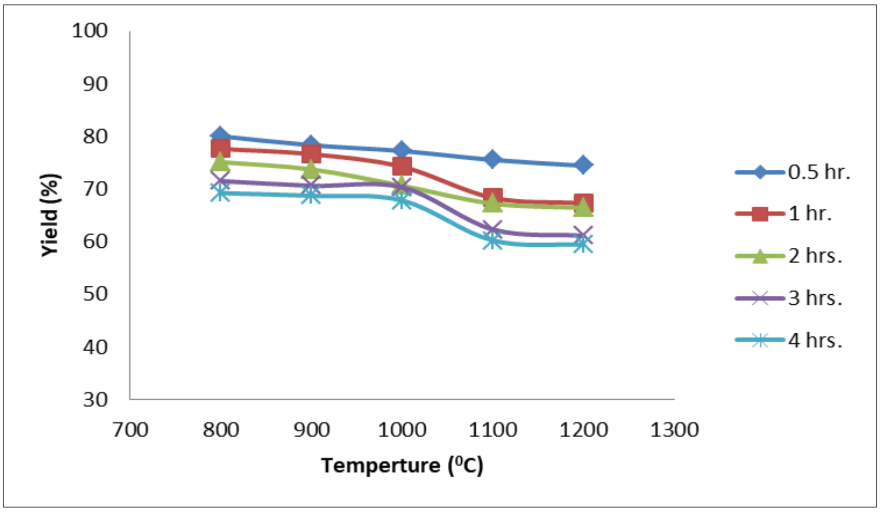

Figure 4 Effects of Temperature on the Calcination of 90 µm of Ogbolokuta Limestone

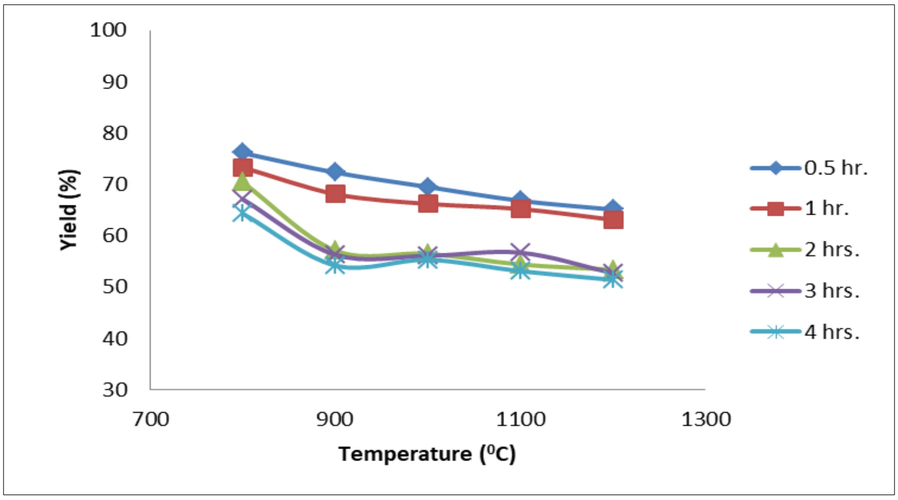

Figure 5 Effects of Temperature on the Calcination of 100 µm of Ogbolokuta Limestone

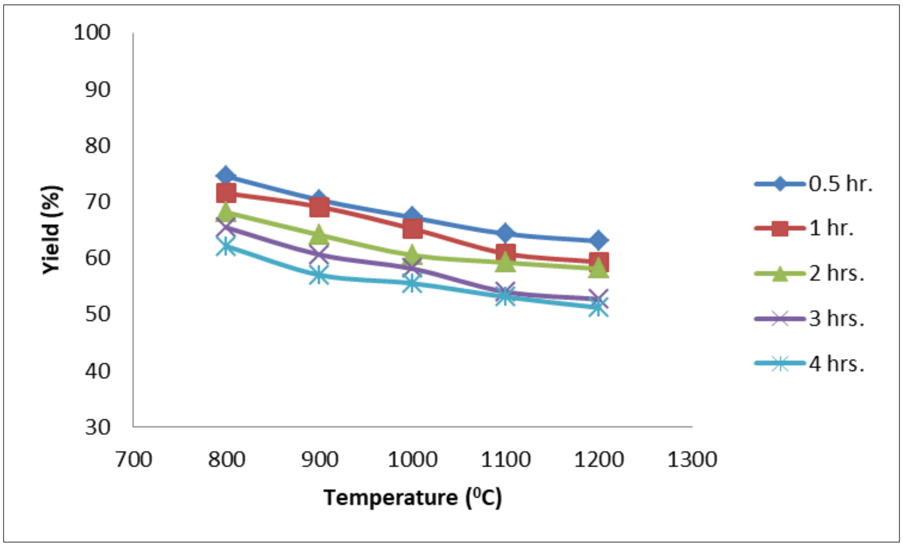

Figure 6 Effects of Temperature on the Calcination of 300 µm of Ogbolokuta Limestone

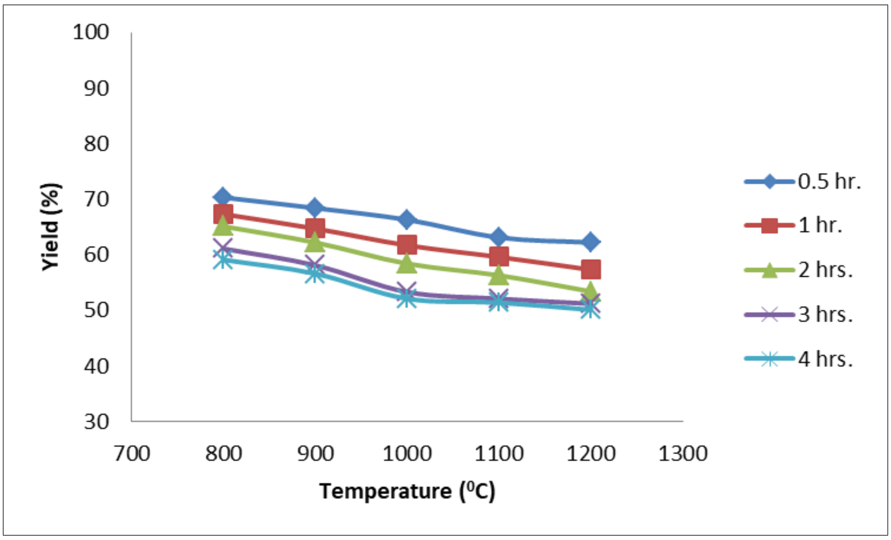

Figure 7 Effects of Temperature on the Calcination of 425 µm of Ogbolokuta Limestone

4. Conclusion

As obtained by the XRF analysis, CaO is the predominant constituent in respect of chemical composition of the limestone. The XRD analysis revealed calcite as the main mineral of the limestone. The surface morphology of the limestone revealed that the particles are packed together in powdered form with visible pores that will enhance its solubility capacity. Density Functional Theory (DFT) accounted for the effects of microporocity of sample, and it gave reliable surface area and pore volume measurements.

Quicklime was successfully produced through the calcination of Ogbolokuta limestone. The quicklime yield varied with temperature, particle size and time.

Compliance with ethical standards

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