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Processing of Black Board Chalk from Pachymelania Aurita and Lanister Variscus Shells

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Abstract

A mixture of marble dust and periwinkle shells (achymelania Aurita) and a mixture of marble dust and snail (LanisterVariscus) shells were used to replace the conventional calcium carbonate (CaCO3) used for the production of classroom chalk. The bulk density for the crushed periwinkle shells and crushed snail shells at a particle size of ≤63µm were 1.14g/ml and 1.12 g/ml respectively. From the results obtained from the complexometric titration, the percentage composition of calcium carbonate (CaCO3) content in crushed periwinkle shells and crushed snail shells were 85.06% wt. and 85.91% wt. respectively. The quality of chalk produced from the mixture of marble dust (MD) and crushed periwinkle shells (CPS) at at a ratio of 1:3 was high with a breaking strength of 56.4 kg/cm2. The result from the mixture of marble dust (MD) and crushed snail shells (CSS) at a ratio of 1:3 was also high with a breaking strength of 54.7 kg/cm^2. The results obtained show that the mixture of marble dust and crushed periwinkle shells at ratio of 1:3 and a mixture of marble dust and crushed snail shells at a ratio of 1:3 could replace the conventional calcium carbonate for classroom chalk production.

Key words: PachymelaniaAurita, LanisterVariscus, complexometric, marble dust, snail, periwinkle shells, marble dust

1.0 INTRODUCTION

1.1 Background of the study

Chalk is a form of limestone and is composed of the mineral-calcite (Geology Science, 2021). Chalk is a form of limestone comprised primarily of the mineral calcite (Geology Science, 2021). Chalks (dusty and dustless) are frequently composed primarily of limestone (CaCO3) or gypsum (a dehydrated form of CaSO4) (Maruthi et. al., 2015). Chalk was obtained through the quarrying of limestone, another type of carbon carbonate (CaCO3). This limestone mining has had a detrimental effect on the environment. Lamare and Sigh (2017) highlighted that this technique resulted in landscape alterations and degradation of agricultural land, denudation of forest, water depletion, contamination of water, soil, and air, depletion of natural flora and fauna, soil erosion, and instability of soil and rock masses.

According to Fabricius (2007), chalk is a material with a broad range of technical applications, including use as a raw material for cement, a means of managing soil acidity and neutralizing acid gasses created in power plants, a filler in paper and plastic, and a white pigment. Chalk has long been used in educational institutions as a conventional teaching aid. It is likely to continue to play an important role in global education, regardless of advances.

Marble is a metamorphic rock formed when pure limestone undergoes metamorphosis. Marble's color and look are determined by its purity: it is white if the limestone is entirely formed of calcite (100 percent $CaCO_3$). When marble stone is chopped, a huge amount of powder is created. As a result, the bulk of marble trash, which accounts for 20% of total marble quarried, has risen to millions of tons. This vast neglected pile of marble debris comprised of extremely tiny particles is one of the world's major environmental challenges today (Pooja and Bhole, 2014). Calcium carbonate occurs naturally in a variety of materials, including limestone, gypsum, chalk, and marble. Marble's mineral content is determined by the original composition of the rock mass, which frequently includes manganese, magnesium, and iron. Alumina and silica are two more elements that may be present in marble dust (Ganesh and Danish, 2019).

Periwinkle shell is a byproduct of the consumption of a small marine snail (periwinkle), which is housed in a v-shaped spiral shell and is found in numerous coastal settlements around Nigeria. It is also found in a number of coastal places throughout the world and is an extremely strong, hard, and brittle mineral. However, a substantial proportion of these shells are discarded as garbage, posing environmental difficulties in areas where further exploitation of the shells is not possible (Abdullahi and Sara, 2015).Periwinkle shells contained a high concentration of calcium carbonate ($CaCO_3$), indicating that they are a likely source of calcium carbonate ($CaCO_3$). The shell's high calcium carbonate ($CaCO_3$) concentration is probably responsible for the shell's majority of applications (Orji et. al., 2017).

Snail shells are byproducts of the consumption of a small greenish-blue marine snail that lives in a spiral shell and is widespread across the Deltaic area. These shells are characterized by their strength and hardness. They are found in the delta's waterways and mudflats. The residents of this area consume the edible portion as sea food and discard the shell as waste, but a significant amount of these shells are still discarded as waste, creating a problem in areas where they cannot find a use for them, and large deposits have accumulated in numerous locations over the years (Eme and Nwaobakata, 2019).

Snail shells dumped as bio-shell trash from restaurants, diners, or snail dealers pose a severe environmental concern with little or no economic value. They are typically abandoned in an indiscriminate manner following the eating of edible meat. Thus, effective use of snail shells can result in enormous economic wealth (Kolawole et. al., 2017). Snail shells were previously used as a natural supply of calcium carbonate (Zakaria et. al., 2016).

This research concentrated on addressing the desire for a trash-free environment – marble dust, periwinkle shells, and snail shells – on transforming waste to wealth, and on meeting the high demand for chalk for its numerous applications. Additionally, this work focused on determining the chemical composition of waste materials found in Akwa Ibom State - periwinkle shells and snail shells - and comparing the quality of chalk produced using a mixture of marble dust and periwinkle shells and marble dust and snail shells to that produced using conventional raw materials.

This investigation was limited to the periwinkle and snail shell species Pachymelamia aurita and Lanister variscus, respectively.

2.0 THE STUDY'S AIM AND OBJECTIVES

The aim of this study was to create classroom chalk using a combination of marble dust and periwinkle shells and marble dust and snail shells. This was accomplished by pursuing the following goals:

1. characterizing the calcium carbonate content of periwinkle and snail shells, and
2. manufacture and assessment of the quality of chalk produced from the mixture of marble dust and periwinkle shells and marble dust and snail shells to that produced from standard raw materials.

3.0 MATERIALS AND METHODS

3.1 Materials

The major materials that were needed for the production of the classroom chalk are as follows:

1. Periwinkle shells

2. Snail shells
3. Marble dust
4. Gypsum
5. Zinc oxide

The periwinkle (*Pachymelania aurita)* and snail shells (*Lanister variscus*) were obtained from awaste disposal site in Uyo. Marble dust and gypsum wereobtained from a chemical shop in Uyo. The zinc oxide was obtained from a chemical store to serve as binder and to reduce dust associated with chalk respectively.

3.1.1 Samples preparation

The periwinkle and snail shells were washed with water to remove dirt. The shells were dried in a Gallenkamp laboratory oven (OV-335) at a temperature of 75ºC for 15 minutes. Thereafter, the shells were withdrawn from the oven and crushed separately using a hammer mill (MKHM 5000C) and ground into fine powder with a grinding machine (GX 390). The crushed shells were sieved separately to homogenous particle size using a sieve of 63µm mesh size to get a particle size distribution of less than 63µm. The powdered samples were collected and stored separately in a labelled container for analysis (Orji et. al., 2017).

3.2 Methods

3.2.1 Determination of calcium carbonate ($CaCO_3$) content of crushed periwinkle and snail shells (complexometric titration)

Half gram of the crushed periwinkle and snail shells were poured separately into two (2) separate conical flasks and few drops of ethanol was added to it. The addition of ethanol acted as a wetting agent to help the hydrochloric acid (HCl) dissolve the calcium carbonate ($CaCO_3$). Ten millimetres (ml) of 1.0M hydrochloric acid was added slowly to the two (2) separate conical flasks with swirling of the flask to wet the sample. The solutions were heated until it began to boil but not to dryness and then allowed to cool. Three drops of phenolphthalein was added to the two (2) separate conical flask and 0.1M NaOH solution was poured into the two (2) separate burette and clamp on retort stand. Titration of the 0.1M NaOH with the HCl was done to the first persistent pink colour that faded close to end point. The remaining NaOH was added dropwise until the colour change remained for at least 30 seconds. The titration was carried out twice and an average was calculated. The percentage of calcium carbonate was calculated using Equation 3.1 (Orji et. al., 2017):

$$\%CaCO_3 = \frac{(molesCalciumcarbonate)\ X\left(100.09g\frac{Calciumcarbonate}{moles}Calciumcarbonate\right)}{Gramsofsample} \quad (3.1)$$

Where 100.09g $CaCO_3$ is the molecular mass of $CaCO_3$.

3.2.2 Determination of bulk density of crushed periwinkle shells (CPS) and crushed snail shells (CSS)

A mass of 30 grams of the crushed periwinkle and snail shells were measured separately using a laboratory weighing balance (Aj-2200) and then poured into 2 graduated cylinders. The graduated cylinders were tapped mechanically until there was no significant change in the volume of the sample in it. The volume that was occupied by the sample at the point when there was no significant change in the volume while tapping the cylinder was recorded. The mechanical tapping was achieved by raising the cylinder and allowing it to drop under its own mass (WHO, 2012). The test was carried out twice and an average was calculated. The bulk density was determined by using Equation 3.2 (WHO, 2012):

$$\text{Bulk Density (g/ml)} = \frac{Massofsample(g)}{Volumeofsample(ml)occupied} \quad (3.2)$$

3.2.3 Mould Preparation

Pawpaw straw was used instead of the conventional chalk mould to form the mould. The pawpaw straw was sliced open at both ends and a nylon was used to cover the other ends and firmly held by a rubber band. The pawpaw straw was dipped into a mixture of oil and kerosene at a ratio of 3:1 litre (Gemechu, 2014).Its purpose was for lubricating the chalk mould to prevent the paste from sticking to it. It also helped to remove all dust and made the mould free for ejection (Chomo et. al., 2018).

3.2.4 Classroom chalk production

Marble dust was mixed at different percentages (0%wt., 2%wt., 4%wt., 6%wt., and 8%wt.) with crushed periwinkle shells and crushed snail shells at different percentages (8%wt., 6%wt., 4%wt., 2%wt., and 0%wt.) with some quantities of gypsum (90%wt.). The percentage (2% by wt.) of the additives was kept constant and the total mixture amount was 10 grams. Ten millimetres of water was added at each trial for proper mixing. The mixture was carefully poured into the pawpaw mould and allowed to set for about 12 to 15 minutes to give the shape of the chalk and this was the first stage of drying the chalk. When the chalk was ready to be drawn out, a blade was used to open the side from the top to the bottom. The drawn chalks was collected into a tray and sun-dried for about 4 hours and then taken into the oven to oven dry at a temperature of 110^{o}C for 10 to 15 minutes. The chalks was then withdrawn from the oven and allowed to cool (Gemechu, 2014). The dried chalks were being stored up for further analysis.

3.3 Test for the quality of the classroom chalk produced

After the chalk has been made into sticks, one stick from each batch was selected for tests. The tests included its breaking strength, writing abilities, erasibilities, the moisture content and the rate at which the dust particles (if any) settles when writing with the chalk (Udoh, 2019).

3.3.1 Determination of breaking strength

The binding strength of the chalk was determined using the digital compression testing machine (Mishra, 2016). In this method, the chalk was placed vertically between clean lower platen and the upper platen of the machine. The pressure valve was closed. The zero knob was adjusted to make the digital display to read zero. The display unit was on peak mode to hold the maximum load reading. The load was applied at a specified pace rate, which could be attained by adjusting the slow fast knob. When the pace rate was at a higher side, the indicator displayed a red colour and when the rate was at a lower side, the indicator displayed a yellow colour. When the pace rate was exactly equal to the set rate, the indicator displayed a green colour. As soon as the chalk samples fails, the pressure valve was released slowly. The breaking strength in N/mm^2 or kg/cm^2 was noted. The test was carried out twice and an average was calculated.The breaking strength was calculated using Equation 3.3 (Mishra, 2016):

$$\text{Breaking Strength (kg/cm}^2\text{)} = \frac{Mass of chalk (kg)}{Area of contact (cm^2)} \quad (3.3)$$

3.3.2 Determination of the writing abilities, erasibilities, and the rate at which the dust particles (if any) settles when writing with the chalk

One stick of chalk from each batch was selected for testing. The sample was used to write with on a blackboard and the quality of the mark was studied and recorded. The marks of a good chalk on a chalkboard should be visible and clear. Erasability was also studied, the chalk mark was erased using a dry eraser, and the quality of erasure was examined. The rate at, which the dust particles (if any) settled when writing with the chalk was also been observed and recorded.The test was carried out twice and an average was calculated.(Udoh, 2019).

3.3.3 Determination of the moisture content of the chalk produced

One stick of the chalk was selected for moisture content test. The sample was weighed, and the weight was recorded. The sample was then transferred to an oven at 110^{O}C for 15 minutes and allowed to dry, and the dry weight was measured. This was done till a constant weight was achieved.The test was carried out twice and an average was calculated. The moisture content was calculated using Equation 3.4 (ASTM D2216-19):

$$\text{Moisture content} = \frac{(Wetweight - Dryweight)}{Wetweight} X\ 100 \qquad (3.4)$$

The different compositions that makes up each of the samples can be found in Table 3.1.

Table 3.1 Composition of samples

Sample	MD(%wt.)	CPS(%wt.)	CSS(%wt.)	ZnO(%wt.)	$CaCO_3$(%wt.)	Gypsum(%wt.)	H_2O(ml)
A	0	8	0	2	0	90	10
B	2	6	0	2	0	90	10
C	4	4	0	2	0	90	10
D	6	2	0	2	0	90	10
E	8	0	0	2	0	90	10
F	0	0	8	2	0	90	10
G	2	0	6	2	0	90	10
H	4	0	4	2	0	90	10
I	6	0	2	2	0	90	10
J	0	0	0	2	8	90	10
K	0	0	0	2	6	92	10
L	0	0	0	2	4	94	10
M	0	0	0	2	2	96	10

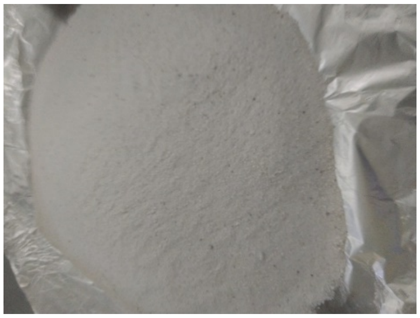
THE RAW RESULTS OBTAINED DURING THE EXPERIMENTS

FigureA1: Sample of washed periwinkle shells

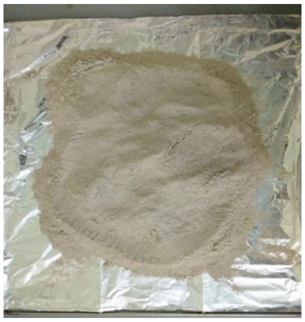
FigureA2: Sample of washed snail shells

FigureA3: Hammer mill for the crushing of the periwinkle and snail shells

FigureA4: Sample of crushed periwinkle shells



FigureA5: Sample of crushed snail shells



FigureA6: Sample of smooth Marble dust

Figure A7: Drying of periwinkle and snail shells in the oven

Figure A8: Sieving of crushed samples with an electric shaker

Figure A9: Sieving of crushed samples with an electric shaker (Snail shells)

FigureA10: Manual sieving of crushed

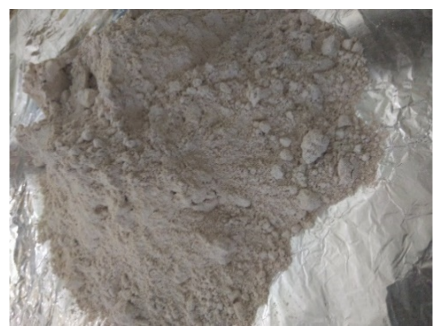


Figure A11: Sample of crushed periwinkle shells (63µm)

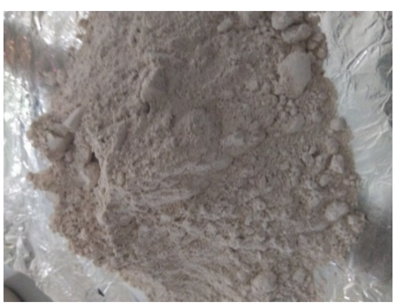


Figure A12: Sample of crushed snail shells (63µm)

Figure A13: Sample of sieved marble dust (63µm)

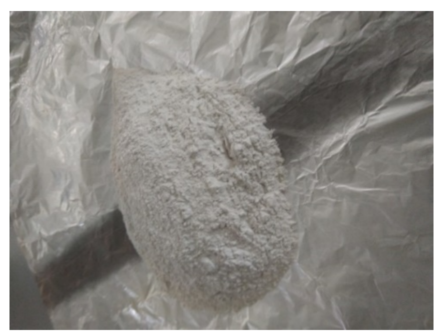


Figure A14: Sample of Zinc Oxide (63µm)

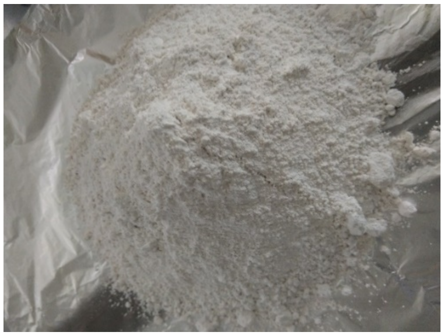


Figure A15: Sample of sieved $CaCO_3$ (63µm)

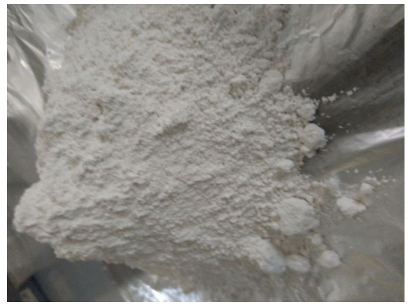


Figure A16: Sample of sieved gypsum (63µm)

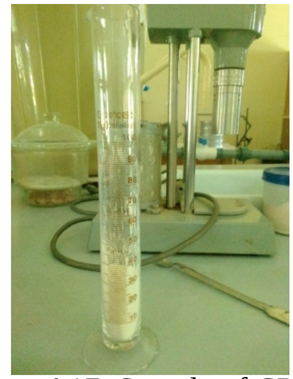


Figure A17: Sample of CPS in graduated cylinder for bulk density measurement

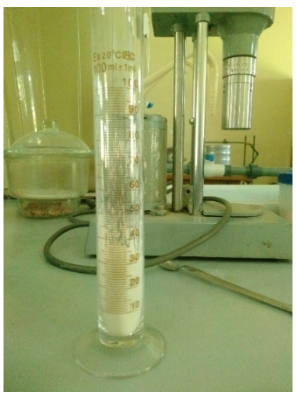


Figure A18: Sample of CSS in graduated cylinder for bulk density measurement

Figure A19: Diagram of diluted crushed samples (CPS & CSS) for titration

Figure A20: Diagram of end point of titrated samples (CPS & CSS)

Figure A21: Diagram of prepared pawpaw straws as moulds

Figure A22: Diagram of chalk setting

Figure A24: Classroom chalk gotten from the production process

4.0 RESULTS AND DISCUSSION

4.1 Physical properties of the sample obtained

The results of the physical properties of the samples obtained are given in Table 4.1 and 4.2.

Table 4.1 Calcium carbonate content of crushed periwinkle and snail shells

Sample	$CaCO_3$ % wt.
Crushed periwinkle shells (CPS)	85.06
Crushed snail shells (CSS)	85.91

Table 4.2 Bulk density of crushed periwinkle and snail shells

Sample	Bulk density (g/ml)
Crushed periwinkle shells (CPS)	1.14
Crushed snail shells (CSS)	1.12

4.2 Physical properties of the chalk obtained

The results of the physical property of the chalk obtained is given in Table 4.3

Table 4.3 Breaking strength of chalk produced from CPS and CSS

Sample	Breaking strength of chalk (kg/cm^2)
Chalk from marble dust and Crushed periwinkle shells (CPS)	56.4
Chalk from marble dust and Crushed snail shells (CSS)	54.7

4.3 Test analysis on the chalk obtained

The results the test analysis of on the chalk obtained are given in Table 4.4.

Table 4.4Test for writing abilities, erasibilities, rate at which dust particles settles when writing and moisture content

Sample	Settling time (sec.)	Writability	Erasibility	Average moisture content
A	10	Visible	Erasable	0.21
B	10	Visible	Erasable	0.20
C	20	Visible	Erasable	0.22
D	30	Visible	Erasable	0.22
E	30	Visible	Erasable	0.20
F	30	Visible	Erasable	0.20
G	20	Visible	Erasable	0.20
H	25	Visible	Erasable	0.21
I	30	Visible	Erasable	0.19
J	50	Visible	Erasable	0.23
K	40	Visible	Erasable	0.22
L	30	Visible	Erasable	0.21
M	10	Visible	Erasable	0.22

4.4 Discussion

Table 4.1 shows that the calcium carbonate content of CPS was 85.06%wt. while that of CSS was 85.91%wt. This shows that the calcium carbonate content of CSS is higher than that of CPS.

From Table 4.2, the bulk density of crushed periwinkle shells (CPS) of average particle size of ≤63µm was 1.14g/ml while that of the crushed snail shells (CSS) was 1.12g/ml. This shows that the bulk density of CPS is higher than that of CSS. The observed colour of CPS was Ash while that of the CSS was light brown.

From Table 4.3, the breaking strength of chalk produced from a mixture of marble dust and CPS at the ratio of 1:3 was 56.4kg/cm^2 while that from a mixture of marble dust and CSS at the ratio of 1:3 was 54.7kg/cm^2. This shows that the breaking strength of chalk from a mixture of marble dust and CPS was higher than that from a mixture of marble dust and CSS.

Table 4.4 shows the test for the writing abilities, erasibilities, rate at which dust particles settles when writing and the moisture content of each sample. All the chalk samples wrote well on a black chalkboard. All the chalk marks were erasable after writing. The moisture content of each chalk sample varied from each other.

Samples A, B, G and M settled faster when writing than other sample combinations.Visible means the writings on the board was clear enough to be seen while erasable means that the writings was easily erase.

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Calcium carbonate ($CaCO_3$) concentration in crushed periwinkle (*Pachymelania Aurita*) and snail (*Lanister Variscus*) shells as obtained from the complexometric titration were 85.06% wt. and 85.91% wt. respectively. The quality of classroom chalk obtained from the mixture of marble dust and crushed periwinkle shells in the ratio of 1:3 was high, in term of the rate at which the dust particles settles when writing with the chalk, while chalk obtained from the mixture of marble dust and crushed periwinkle shells in the ratio of 2:2 and 3:1 was lower. The quality of classroom chalk obtained from the mixture of marble dust and crushed snail shells in the ratio of 1:3 was high, in term of the rate at which the dust particles settles when writing with the chalk, while chalk obtained from the mixture of marble dust and crushed snail shells in the ratio of 2:2 and 3:1 was lower. In comparison to the conventional classroom chalk produced from limestone, the classroom chalk produced from a mixture of marble dust and crushed periwinkle shells in the ratio of 1:3 and marble dust and crushed snail shells in the ratio of 1:3 measured up to the conventional classroom chalk from limestone and may likely replace the limestone used in classroom chalk production.

5.2 Recommendation

Based on the results and conclusion shown in this study, it is recommended that a mixture of marble dust and crushed periwinkle or snail shell (ratio of 1:3) can be used to replace calcium carbonate in the production of classroom chalk. There is more energy requirement to mine limestone which is not cost effective compared to the periwinkle and snails shells which are merely obtained from disposal site. Utilizing these shells for the production of classroom chalk will reduce the quarrying of limestone which has negative impacts on the environment while minimising cost as well.

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