Porous Ceramic As Basic Contraction Material Based Passive Cooling Clay Mixed With Charcoal Candlenut Shell
(Aleurites Moluccana)

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Abstract. It has been made of porous ceramics made of clay with a mixture of candlenut shell activated charcoal through conventional techniques of printing and presses the clay composition variation: activated charcoal shell candlenut 100: 0, 90:10, 80:20, 70:30, 60:40, 50: 50 grams. Clay and activated charcoal candlenut shells sifted with a particle size of 100 mesh. Clay and activated charcoal powder candlenut shells which have been mixed printed by the dry pressing method with the pressure of 5 tons was detained for 10 minutes. Then the beam-shaped sample was burned with a combustion temperature of 900°C and held for 3 hours. Each sample is characterized that include: physical properties (porosity, water absorption, and surface morphology), mechanical properties (hardness, compressive strength, and XRD) and thermal properties (DTA). The results showed that variations in the composition of clay: candlenut shell activated charcoal optimum at 50: 50-gram composition with 66.20% porosity; water absorption value of 69.42%; 298.19 Mpa hardness values; 6,75Mpa value of the compressive strength and optimum pore diameter 1.0785 μm with oxygen element content of 51.76%. The XRD results showed the addition of activated charcoal on a pecan shell does not form a porous ceramic crystallinity, and from the graph shows that the dominant crystal structure is monoclinic. DTA testing results 70°C and temperature endotherm temperature eksoterm450°C. The XRD results showed the addition of activated charcoal on a pecan shell does not form a porous ceramic crystallinity, and from the graph shows that the dominant crystal structure is monoclinic. DTA testing results in endothermic temperature 70°C and exotherm temperature 450°C.

1. Introduce
Global warming is closely related to the increase in temperature is very high, estimated the earth's temperature will rise in the form of duration and frequency in the next 10 years (IPCC, 2014) \cite{1}. With global warming will have an impact on food security, the pattern of human life in the world, especially in the crop sector and the room temperature used by humans. Some studies have estimated a substantial reduction and growth of human life due to high temperatures (Lobell et al., 2013; bassu et al., 2014; schaubberger et al., 2017) \cite{2}, \cite{3}, \cite{4}. In addition to global warming also lead to the greenhouse effect so that the temperature of the earth is more easily changed \cite{5}. Of greenhouse effect
is a large increase in atmospheric concentrations of carbon dioxide (CO$_2$), methane (CH$_4$) and nitrous oxide (N$_2$O), which is regarded as the dominant cause that lies behind the global warming [6]. Emissions of greenhouse gases will lead to sustainable further warming and encourage long-term changes in the climate system, more frequent heatwaves and extreme temperatures [7]. Therefore needed a solution to reduce global warming mainly to reduce the high temperatures that exist in the space of living beings. One that can be done by planting more plants that produce more oxygen. While at room temperature can be done by installing a wall of the house using a material that has larger pores of porous ceramics so that the high temperature in the air space can be dropped because it is absorbed by the surface of the pore walls and the better air circulation. Less than 90% of people spend indoors so necessary material close porous ceramic wall to produce clean air circulation [8], [9].

Clay is the main raw material for the manufacture of ceramics which undergo decomposition reactions, transformation, dehydroxylation on thermal treatment. Compared to other metal oxides clay is more durable and lower combustion temperature. 800°C clay firing temperature is up to 1200°C and can be adapted to the purpose of its application [10], [11]. Activated charcoal is a carbon material that has a large surface structure, widely used in various applications, including adsorption, catalyst support, separation and gas storage, recovery and dilution solvent color, supercapacitors, and as an electrode. Internal porosity and related properties such as surface area, pore-volume, pore size distribution, and the presence of functional groups on the surface of the pores have an important role in the adsorption capacity of activated charcoal. Activated charcoal can be produced from organic materials that contain the element carbon, one candle nut shell. The shell is the remainder of the candle nut farm processing can be used as raw material for activated charcoal has a porous structure that can absorb [12], [13]. In this study the use of activated charcoal candle nut shells as filler in the manufacture of porous ceramics with a matrix of clay. Activated charcoal candle nut shells used as forming pores in the porous ceramic because it will evaporate when the high-temperature combustion process. Characterization testing of the research is divided into two, namely the physical properties (porosity, water absorption, and SEM-EDX), mechanical properties (hardness, compressive strength, and XRD), and thermal (DTA).

2. Experimental Method

In this study used two materials as matrix material is clay and activated charcoal candle nut shells as filler in the manufacture of porous ceramics. The clay used comes from the highway TanjungMorawa, Deli Serdang, North Sumatra. Meanwhile, candle nut shells used are leftover candle nut production solution comes from the public housing industry pales, Simalingkar, North Sumatra. Clay in the form of chunks of dried, sieved and crushed to a powder. Candle nut shells inserted into the furnace drum subsequently burned with 600°C temperature for one hour, and candle nut shell that has become charcoal is cooled for 24 hours, then crushed to a powder.

Clay and charcoal powder hazelnut shells sieved with 100 mesh sieve. The chemicals used in this study is H$_2$SO$_4$ with pure concentrations of 96% (Merck), which serves as a solvent at the time of chemical activation on clay and charcoal candle nut shells. Besides, it also can use distilled water as a diluent during chemical activation solution mixing clay and charcoal candle nut shells.

2.1 Methodology

2.1.1 Activation of Clay and CarbonCandle Nut Shells. Clay and charcoal powder of 100 mesh activated candle nut shell with chemical activation and physical activation. Clay and activated charcoal used in the manufacture of a porous ceramic still contains impurities of organic and inorganic materials that cover the surface so that the required activation process to improve absorbs. Activation using H$_2$SO$_4$ solution concentration of 0.1 M. The activation process on clay also aims to open up the clay interlayer space and reduce shrinkage large. Then do the physical activation to use the drying oven at a temperature 105°C clay powder and candle nut shell charcoal with 110°C temperature for 2 hours.
2.1.2 Fabrication / Printing. The printing process of porous ceramics made from clay and the activated charcoal mixture of candlenut shells with variations of the composition of 100:0, 90:10, 80:20, 70:30, 60:40, 50:50 gram. Clay and activated charcoal powder candle nut shells sifted using BBS Laboratory Test Sieve size of 100 mesh. Clay powder and activated charcoal that has been activated candle nut shell physically blended using a mixer (CM Cosmos 1279). Mixing of clay and activated charcoal powder candle nut shells for 10 minutes with a little addition of distilled water. Clay and activated charcoal powder candle nut shells which have been mixed and then printed using Hydraulic Press (Maekawa Testing Machine Tokyo Japan Type MR-20-CT) with a pressure of 5 bar for 10 minutes. After printing is left for 1 week in the open air and the sample prepared burned.

2.1.3 Sintering. After printing of porous ceramics made of clay with a mixture of activated charcoal in the roasted hazelnut shells with 900℃ temperature in the furnace (Thermo Scientific D130) with a hold time of 3 hours.

2.2 Characterization

2.2.1 Porosity. Porosity testing purposes to determine many pores a material is calculated by finding the percentage (%) based on the absorption of the material to water and absorbed volume ratio of the total volume of the sample. In the formula can be written as follows:

\[
\text{Porosity(\%)} = \left(\frac{m_h-m_k}{\rho_{\text{air}} \times V_t}\right) \times 100\%
\]

(1)

2.2.2 Water absorption. Water absorption is an event in which the particles are trapped in the structure of the material and become part of the material. Water absorption is proportional to the porosity, the greater the porosity, the greater the value of water absorption. Water absorption test procedure refers to ASTM C-20-00-2005 [14]. To test the water absorption power is done by using Archimedes experiment with the formula:

\[
\text{Water Absorption(\%)} = \frac{m_h-m_k}{m_k} \times 100\%
\]

(2)

2.2.3 SEM-EDX. SEM (Scanning Electron Microscope) is a tool that can form an image surface. The structure of the surface of a specimen can be studied with an electron microscope beam because it is much easier to study the structure of these surfaces directly. SEM using the signal generated by electrons which are then reflected or so-called secondary light beam. The main principle is the SEM electron beam is directed at the point - the point of the specimen surface. SEM forming an image by firing a high-energy electron beam, usually with an energy of 1 to 20 keV, passing through the sample and then detect 'secondary electron' and 'backscattered electrons' being issued. 'Secondary electron' comes at 5-15 nm from the surface of the sample and provide topographical information and to less extent, on the variation of the elements in the sample. 'Backscattered electron' regardless of the sample are deeper and provide information primarily on the average atomic number of the sample.

2.2.4 Hardness Testing. Violence is a test for NDT (Non-Destructive Test) which in this test can be known as a hardness value on a material/test specimen. How the test is done by a method hardness Vickers (Vicker Tester Matsuzawa Seiki Co., Ltd. No. 71C) and has the equation:

\[
H_v = 1,8544 \frac{F}{d^2}
\]

(3)
2.2.5  Compressive Strength Testing. The compressive strength test is a comparison of the magnitude of the load force applied to the ceramic unit area using UTM (RTF 1350 Tensilon). For the measurement of compressive strength can be calculated by the following equation:

\[ P = \frac{F}{A} \]  

(4)

2.2.6  XRD. The use of XRD (X-Ray Diffraction) in this study aimed to analyze the crystal structure formed by a mixture of clay and activated charcoal shells of candlenut in the manufacture of porous ceramics and to see the effect of the addition of activated charcoal candlenut shell to the hardness value is generated on the composition addition activated charcoal candlenut shell.

2.2.7  DTA. Differential Thermal Analysis characterize a material based on the material response to temperature. Recorded temperature difference occurring during the process of heating and cooling. Then displayed in the form of enthalpy curve. DTA curves can capture the current transformation of the absorption or release of heat. DTA help understands the results of XRD, chemical analysis and microscopic. DTA curve is a curve of the temperature difference between the sample concerning the time.

2.3  Results and Discussion

2.3.1  Porosity test. Porosity testing purposes to determine many pores a material is calculated by finding the percentage (%) based on the absorption of the material to water and absorbed volume ratio of the total volume of the sample.

![Figure 1. Porosity Porous Ceramics with the Variations Composition](image)

Figure 1 shows that the value of porosity in each variation of a mixture of porous ceramic-based clay with a mixture of activated charcoal candlenut shell is burnt at a temperature sintering 900°C withholding time 3 hours have increased, the increase in porosity values begins on variations of a mixture of activated charcoal candlenut shell 10 grams 29.72% value, 20 grams = 35.63% = 44.20% 30 grams, 40 grams = 61.36%, and 50 grams = 66.20%, the increase in porosity is comparable to the increase in the addition of activated charcoal candlenut shell growing number of active charcoal addition the candlenut shell porosity value will also increase. This is because the Ca content of the melt when the combustion process at high temperature and leave scars pores and increase the levels of oxygen in it.

2.3.2  Water Absorption Test. Water absorption test aims to determine the percentage of porous ceramic ability to bind or absorb water. The water absorption was calculated using a dry mass ratio of the wet mass of porous ceramics and porous ceramics.
Figure 2. Water Absorption Porous Ceramics with the Variations Composition

Figure 2 shows the relationship between the value of water absorption and compositional variations that experience boosts the addition of activated charcoal every candlenut shells. The resulting water absorption value that is equal to 10 grams with a value of 20.57%; 20 grams of 24.45%; 30 grams of 33.21%; 40 grams of 61.94%, and the addition of 50 grams of 69.42%. The amount of water absorption is also due to the pore formed in the porous ceramic as a result of high-temperature combustion.

2.3.3 Hardness Test. Violence in porous ceramics obtained by using a Vickers Hardness Tokyo. The addition of activated charcoal candlenut shells intended to form pores in the porous ceramic. Results of hardness testing are shown in Table 1.

| Mix (g) | Active charcoal | $H_v$ (MPa) |
|--------|-----------------|-------------|
| Clay   | candlenut Shells|             |
| 100    | 0               | 2141.44     |
| 90     | 10              | 2036.89     |
| 80     | 20              | 1431.8      |
| 70     | 30              | 794.10      |
| 60     | 40              | 354.85      |
| 50     | 50              | 298.19      |

Figure 3. Violence Porous Ceramics with the Variations Composition

Figure 3 shows that the hardness value on every variation of a mixture of clay and ceramic based porous activated charcoal candlenut shells were burned at a temperature of 900°C sintering with 3 hour hold time has decreased in every variation of the mixture. The resulting hardness values that decline started in the addition of 10 grams of a mixture of active charcoal with a pecan shell hardness value
obtained 2036.89 MPa. The minimum hardness values contained in a mixture of 50 grams of activated charcoal candlenut shell with a value of 298.19 Mpa. The hardness value is inversely proportional to the value of the porosity and water absorption are experiencing raising.

2.3.4 SEM-EDX

2.3.4.1 SEM

![SEM results for Porous Ceramics with Clay Composition: Active Charcoal Candlenut Shells (a) 100: 0, (b) 50:50](image)

Figure 4. SEM results for Porous Ceramics with Clay Composition: Active Charcoal Candlenut Shells (a) 100: 0, (b) 50:50

Figure 4 shows a porous ceramic surface topography of the test results of SEM shows that the presence of pores formed by the addition of active charcoal with candlenut shells was not the same size. Contrasting colors in the image that shows the color of light gray and dark gray homogenate caused by lack of material during the mixing process. Results of an average diameter of pores in the sixth variation of the composition of the mixture is a mixture of 0.3394 μm to 100: 0 grams and 1.0785 μm to mix 50:50 gam. Pore diameter value after the addition of activated charcoal candlenut shell on porous ceramic has a value $d > 50$ nm and included into the macroporous ceramic [15].
2.3.4.2 EDX

![EDX spectrum](image)

(a)

![EDX spectrum](image)

(b)

**Figure 5.** Results of EDX Porous Ceramics with Clay Composition: Active Charcoal Candlenut Shells (a) 100:0, (b) 50:50

Figure 5 shows the elements contained in the porous ceramic after burning at temperatures 900°C with a hold time of 3 hours. Results showed that the addition of activated charcoal candlenut shell on each variation of the composition results in increased oxygen content of the porous ceramic, it can be seen that the element oxygen has a greater percentage than any other element. The element oxygen is the most widely obtained on porous ceramic composition gram 50:50 that is equal to 51.76%. The number of elements of oxygen may also cause the formation of pores in the porous ceramic thus increasing the value of its porosity.
2.3.4.3 Test XRD

![XRD graph](image)

**Figure 6.** XRD results in Porous Ceramics with 50:50 grams Composition Clay and Activated Charcoal Candlenut Shells

| No. | Post °2θ | d-Spacing [Å] | Crystal structure | h | K | l |
|-----|----------|---------------|-------------------|---|---|---|
| 1.  | 11.1405  | 7.93          | Monoclinic        | 1 | 1 | 0 |
| 2.  | 9.54     | 9.2639        | Triclinic         | 0 | 1 | 1 |
| 3.  | 10.62    | 8.3243        | Tetragonal        | 1 | 0 | 1 |
| 4.  | 13.6450  | 6.48674       | Orthorhombic      | 2 | 0 | 1 |
| 5.  | 14.77    | 5.9916        | Monoclinic        | 1 | 3 | 0 |
| 6.  | 20.48    | 4.3613        | Monoclinic        | 3 | 0 | -1|
| 7.  | 23.36    | 3.80498       | Monoclinic        | 1 | 0 | 5 |
| 8.  | 28.60    | 3.1188        | Triclinic         | 0 | 0 | 2 |
| 9.  | 32.52    | 2.7508        | Orthorhombic      | 1 | 4 | 4 |
| 10. | 38.34    | 2.3458        | Monoclinic        | 4 | 1 | 1 |
| 11. | 45.25    | 2.0023        | Cubic             | 1 | 0 | 1 |
| 12. | 49.72    | 1.8323        | Orthorhombic      | 1 | 0 | 7 |
| 13. | 68.36    | 1.3711        | Orthorhombic      | 4 | 5 | 0 |

From the test results of XRD analysis on the composition of the porous ceramic with 50:50 grams of clay and activated charcoal candlenut shells, the resulting diffraction pattern peak to show not clear that the composition of 50:50 is one material that has a structure that low crystallinity. The crystal structure of porous ceramics on XRD test results can be shown by the high and low intensity of the peak, the higher the peak intensity increases in the crystal structure of porous ceramics. XRD test results can be seen that the addition of activated charcoal candlenut shells does not have a low crystallinity structure, so the more the addition of activated charcoal in porous ceramic candlenut shell can reduce hardness.
2.3.5 Compressive Strength Testing. Testing the compressive strength of porous ceramics aims to determine the ability of a porous ceramic to withstand a given load using the UTM (RTF 1350 Tensilon).

![Compressive Strength Vs Composition](image1)

**Figure 7.** Compressive Strength Porous Ceramics with the Variations Composition

Figure 7 shows that the value of the pressure test on every variation of the porous ceramic mixture has decreased in every variation of the mixture. This decrease is caused by the content of calcium (Ca) contained in the sample with added activated charcoal burnt candlenut shells during high-temperature combustion and leave the pore, the more the addition of candlenut shell activated carbon will reduce the compressive strength. The maximum compressive strength value contained in the variation of the activated charcoal mixture of candlenut shells 0 grams with a value of 31.17 MPa whereas the minimum compressive strength value contained in the activated charcoal mixture of candlenut shells 50 grams with a value of 6.75 MPa.

2.3.6 DTA Test. Differential Thermal Analysis characterize a material based on the material response to temperature. Recorded temperature difference occurring during the process of heating and cooling. Then displayed in the form of enthalpy curve.

![DTA results in Porous Ceramics Clay and Activated Charcoal Candlenut Shells](image2)

**Figure 8.** DTA results in Porous Ceramics Clay and Activated Charcoal Candlenut Shells
Figure 8 shows the results of testing the thermal properties, it is observed that the temperature at the reference material is higher than the temperature of the sample then obtained a negative temperature or changes in endothermic and vice versa. When the same means there is no change, in this case, means the show with a straight line. The temperature of the sample endothermic exothermic temperature of 70°C and 450°C. These results indicate that the porous ceramic-based clay with activated charcoal additive candlenut shells can be applied to the walls and ventilation in building construction.

3 Conclusion

The addition of activated charcoal in porous ceramic candlenut shell can increase porosity, from 28.89% in the composition of 100: 0 grams, being 66.20% at 50: 50-gram composition, water absorption value of 17.18% being 69.42%, hardness values decreased, from 2141.44 Mpa into 298.19 Mpa, compressive strength values decreased, from 31.17Mpa into 6.75Mpa. SEM testing results show that the mixing of the clay and activated charcoal powder candlenut shells have not been distributed evenly, the addition of activated charcoal candlenut shells on the porous ceramic capable of increasing the pore diameter of 0.3394 μm (without the addition of activated charcoal candlenut shell) to 1.0785 μm (with the addition of candlenut shell activated charcoal at 50:50 composition gram). The test results showed the addition of activated charcoal EDX candlenut shell on a porous ceramic capable of increase percentage oxygen content of 30.92% to 51.76%. The XRD results showed the addition of activated carbon in porous ceramic candlenut shell can reduce the crystallinity, where a decline in the main peak intensity of the peak, which means a decrease in the crystallinity of the porous ceramic samples. As well as testing the thermal properties of porous ceramics using DTA sample endothermic temperature is 70°C and 450°C exothermic temperature.

4 References

[1] IPCC, 2014. Climate change 2014: synthesis report. Contribution of working groups I, II and The third to the fifth assessment report of the intergovernmental panel on climate change. In: Pachauri, RK, Meyer, LA (Eds.), Core Writing Team, pp. 145.
[2] Lobell, DB, Hammer, GL, McLean, G., Messina, CD, Roberts, MJ, Schlenker, W., 2013. The critical role of extreme heat for maize production in the United States. Nat. Clim. Change 3, 497-501More references
[3] Bassu, S., Brisson, N., Durand, JL, Boote, K., Lizaro, J., Jones, JW, Rosenzweig, C., Ruane, air conditioning, Adam, M. Baron, C., Basso, B., Bernath, C., Boogaard, H., Conijn, S., Corbels, M., Deryng, D., De Sanntis, G., Gayler, S., Grassini, P., Hatfield, J., Hoek, S., Izaarulade, C., Jongsschaap, R., Kemanian, AR, Kersebaum, KC, Kim, SH, Kumar, NS, Makowski, D., Müller, C., Nendel, C., Priesack, E., Pravia, MV, Sau, F., Scherbak, I., Teixeira, E., Timlin, D., Waha, K., 2014. How do various maize crop models vary in their responses to climate change factors? Glob. Chang. Biol. 20, 2301-2320.
[4] Schauberger, B., Archontoulis, S., Arnet, A., Balkovic, J., Ciais, P., Deryng, D. Elliott, J., Folberth, C., Khabarov, N., Müller, C., Pugh, TAM, Rolinski, S., Schaphoff, S., Schmid, E., Wang, X., Schlenker, W., Frieler, K., 2017. The consistent negative response of US crops to high temperatures in observations and crop models. Nat. Commun. 8, 13931
[5] Wheeler T, Von Braun J: Climate change impacts on global food security. Science 2013, 341: 508-513.
[6] Donatelli M, Magarey RD, Bregaglio S, Willocquet L, Whish JPM, Savary S: Modeling the impacts of pests and diseases on agricultural systems. Agric Syst, 2017, 155: 213-224.
[7] Miraglia M, Marvin HJP, Kletter GA, Battilani P, Brera C, E Coni, Cubadda F, Croci L, De Santis B, Dekkers S, et al.: Climate change and food safety: an emerging issue with special focus on Europe. Food Chem Toxicol 2009, 47: 1009-1021.
[8] Kulmala, M., 2015. Atmospheric chemistry: China's choking cocktail. Nature 526, 497
[9] Luengas, A., Barona, A., Hort, C., Gallastegui, G., Platel, V., Elias, A., 2015. A review of
indoor water treatment technologies. Rev. Environ. Sci. Biotechnol. 14, 499-522

[10] Mossaab, M., Abdelmjid, B., Abdelkrim, A., Abdelaziz, B., Youssef, EH, Mohamed, O., Younes, A. Saad, AY, Agnès, S. Hassan, H., 2019. Materials Chemistry and Physics. Volume 227, Pages 291-301

[11] Nigay, PM, Custard, T., Zhou, A., 2017. The impact of heat treatment on the microstructure of ceramic clay and its thermal and mechanical properties. Ceramics International, 43 (2), 1747-1754.

[12] Kumar, A., Jena, HM, 2016. Preparation and characterization of high surface area activated carbon from Fox nut (Euryale Ferox) shell by chemical activation with H3PO4. Results in Physics, 6, 651-658.

[13] Turmuzi, M., David, WR., Tasirin, S., Takriff, M., & Luke, S., 2004. Production of activated carbon from Candlenut shell by CO2 activation. Carbon, 42 (2), 453-455.

[14] ASTM C-20-00-2005. Testing of water absorption. ASTM International (ASTM).

[15] Borislav, DZ, Jir ij, C, Martin, S., Josef, J., 2007. Pore classification in the characterization of porous materials: A perspective. Department of Environmental Chemistry. The Institute of Chemical Technology Prague. Central European Journal of Chemistry 5 (2) 2007 385-395

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