Asian Journal of Natural Sciences (AJNS)
Vol. 3, No.1, 2024: 49-58

Morphology and Mechanical Properties of Porous Ceramics with Corn Leaf Ash Addition

Ridwan Yusuf Lubis[1], Mulkan Iskandar Nasution[2], Hariyati Lubis[3]
[1,2]State Islamic University of North Sumatra
[3]Amir Hamzah University
Corresponding Author: Ridwan Yusuf Lubis ridwanyusuflubis@uinsu.ac.id

ARTICLE INFO

Keywords: Ceramic, Al2O3, Additives, Corn Leaf

Received : 10, Decmber
Revised : 15, January
Accepted: 20, February

ABSTRACT

Porous ceramics with alumina (Al2O3) material with the addition of corn leaf ash additives heated by a furnace at 600 0C. Alumina powder is mixed with additives with variations of 100%: 0%, 90% : 10%, 80% : 20% and 70%: 30%. The sample was molded using the dry pressing method and then tested for SEM, density, porosity and compressive strength. The resulting porous ceramic characterization results are: density of 1.20 - 1.79 g/cm3, porosity of 29.75 - 61.03%, water absorption of 16.60 - 50.80%, hardness of 41.41 - 187.58 MPa, compressive strength of 3.51 - 84.49 MPa. The more the composition of corn leaf ash, the higher the porosity while the compressive strength has decreased.

DOI: https://doi.org/10.55927/ajns.v3i1.11810
E-ISSN: 2986-2787
https://journal.formosapublisher.org/index.php/ajns

INTRODUCTION

Ceramics are widely used and various fields due to their stability and good mechanical properties and resistance to high temperatures (Zhang et al., 2022). Recently, ceramics have attracted much attention due to their characteristics of light weight, specific surface area, good mechanical properties, and good bearing capacity (Wei et al., 2022). At present, ceramics have been widely used in various engineering fields, such as anti-impact structures, shielding, heat retention, catalyst carriers, and medical bone implants (Papetti et al., 2018).

Porous ceramics are a type of ceramic material that has small cavities on its surface and inside that can cause fluid to flow through the material. Ceramics can be used in various applications such as filter membranes, electronic device insulators, and others. Ceramics have corrosion-resistant properties, low thermal conductivity and good heat capacity, but have weaknesses in mechanical strength due to ionic bonds in the constituent particles (Nasution et al., 2024; Rahma et al., 2023; Retno et al., 2023).

As a product of industrial production, ceramics are much sought after and are growing rapidly in modern times. The rapid development of technology and science has brought many influences and changes to all aspects of human life. With the existence of technology and knowledge about ceramics, it can be understood the structure and quality of the chemical composition and mixture of other materials that show the properties of ceramics to be more perfect. The technology that has developed allows the production of ceramic products that meet the various needs of the mechanical, electronic and filter industries (Sitohang, 2014).

Al2O3 structural ceramics are known as high-performance ceramic materials in the mechanical industry due to their high strength, high hardness, and excellent thermal resistance (Shi et al., 2020). The microstructure, or grain size of ceramic particles has a great influence on their mechanical and electrical properties. In terms of mechanical properties, microstructure refinement is crucial to optimize its mechanical capabilities (Feng et al., 2008). Porous ceramics are commonly used for filters because they have small pores that are easily passed through by liquids.

Porous ceramics have better resistance to corrosion, high temperature changes, and contamination with other materials, so they can be used as media filters, including wastewater, exhaust gas, disposal of liquid metals (e.g. tin) and others.The addition of additional materials can affect its ability to absorb (Ayu Dwi Retno et al., 2023). Clays are also known as ceramics, made from a mixture of materials from various phases used to make inorganic solid materials. Clays have several advantages over metals, including a smaller density than most metals.Due to clay's content of hydrated aluminum silica (Al_2O_3, SiO_2, H_2O), which is used to catalyze the ceramic forming process and has malleable plasticity, ceramics are preferred over metals (Siagian & Hutabalian, 2012).

LITERATURE REVIEW

Temperatures in Indonesia are quite high due to the fact that Indonesia is one of the countries located on the equator. Hot temperatures can be higher due to the increasing level of building and construction in Indonesia and the lack of land to plant trees. The use of materials in buildings is something that needs to be considered to make the room temperature cool, one of which is the use of materials such as absorbent walls. Construction materials that can be used as absorbent walls are ceramics (Anisah, 2019).

The term ceramics comes from the Greek keramos which means a form of clay that has undergone a combustion process. Dictionaries and encyclopedias in the 1950s defined ceramics as a result of art and technology to produce goods from burnt clay, such as pottery, tile, porcelain and so on. But nowadays ceramics are not only derived from clay. Generally, ceramic materials are widely available in the earth's crust, for example SiO2, Al2O3, CaO, MgO, Na2O, and many others. Ceramics have good properties such as strong, hard, stable at high temperatures, and non-corrosive so they are suitable for use as building construction materials. Today, along with the development of ceramic technology, ceramics can not only be made traditionally using clay but can be made and shaped in various ways tailored to their use. Various types of ceramics including cement, building bricks, firebricks and glass have been used for a long time as building construction materials (Astuti, 1997).

The properties of these ceramic materials are highly dependent on their chemical bonds. Covalent bonds give properties can lead to the strength of the crystal and its structure is more complicated than metal or ionic bonds. Covalent bonds are so strong that the crystals are strong and have a high boiling point and good insulating properties. The strength and bonding of ceramics lead to the high melting point, brittleness, corrosion resistance, low thermal conductivity, and high compressive strength of the material. Ceramics can generally be represented by the chemical formula of the compound: Ma Xc, Ma Nb Xc where M and N can represent metallic elements and X represents non-metallic elements that can form stable compounds with metals. The X is usually represented by O (oxygen), but may also be Cl, C, N, and S. The most common ceramics include SiO_2, Al_2O_3, CaO, Na_2O, TiC, UO_2, PbS, and Mg SiO_3 (Siagian & Hutabalian, 2012)..

Clay contains hydrated aluminum silica (Al_2O_3, SiO_2,H_2O) used to facilitate the creation of shapes in ceramics, has plasticity that can be formed easily, has the ability to bind non-plastic raw materials, can also be mixed with other materials such as quartz (part of silica) in order to reduce cracking during drying, reduce shrinkage during firing and improve quality, and is a skeleton during firing (Siagian & Hutabalian, 2012).

Corn leaves include agricultural waste which has the potential to be used in other uses because this waste has not been widely utilized and is often wasted. Corn leaves can be used as an additional material for making ceramics because they contain carbon compounds, namely silica, lignin and cellulose (Fagbemigun, 2014). Corn leaves serve as a partial substitute for cement using the utilization of corn leaf properties (physical and chemical) which have a relatively large silica composition and have good smoothness properties Corn leaves are organic leaves that are easily found in Indonesia, because corn is a food crop product produced by the Indonesian agricultural industry. Corn production continues to increase every year. The Ministry of Agriculture of the Republic of Indonesia provides a report on national corn production which increased by 3.91% in 2018 to 30 million tons compared to 28.9 million tons in 2017 (Pinem, 2020).

Tobing's research, (2009) on the effect of rice husk ash additives and sintering temperature on the characteristics of porous ceramics with natural zeolite base material Pahae using sintering techniques on combustion starting from 900 ^{0}C to 1100 ^{0}C with the addition of 30% additives obtained the highest porosity of 34.58% for sintering temperature 900 ^{0}C, 22.22% for sintering temperature 1000 ^{0}C and 12.33% for sintering temperature 1100 ^{0}C. The results of this study indicate that the higher the sintering temperature, the smaller the porosity. While for the same sintering temperature, the more the addition of rice husk ash composition, the greater the porosity value .

Sihite (2008) found that with the addition of additives the volume shrinkage, density, hardness and compressive strength tend to decrease while the mass and porosity tend to increase. Furthermore, in Sembiring's research (1995) rice husk is unique in terms of combustion with sintering techniques at temperatures of 7500C to 10500C. This occurs in the nature of density, porosity, hardness. At a temperature of 9500C, there is an increase in density and hardness while the porosity decreases.

The addition of corn leaf ash additives from combustion can increase the pore area of ceramics (Ayu Amalia rahma et al., 2023). In this study, porous ceramics have been made from clay mixed with corn leaf additives to improve their mechanical properties. The problem of developing porous ceramics that have large pores but are not brittle is the main objective of this research.

METHODOLOGY

The method used in the manufacture of porous ceramics using 99% alumina (Al2O3) powder material with the addition of corn leaf additives is the dry pressing technique.Corn leaf ash additives are heated at 600 0C then the ash is sieved using a 100 mesh sieve.A total of 30 grams of alumina with a size of 100 mesh was mixed with corn leaf additives with variations of 100%: 0%, 90% : 10%, 80% : 20% and 70%: 30%. then heated at 900 0C then held for 2 hours. The alumina powder and additive mixture was compressed with a pressure of 4 tons for 10 minutes in a 3 x 3 cm mold. The molded ceramics were dried for 3 days in the sun and then fired at 900 0C A (100%: 0%), B (90% : 10%), C (80% : 20%) and D (70%: 30%) for 24 hours.The porous ceramic samples were characterized for their morpholgy and mechanical properties.

RESEARCH RESULT

Ceramic is a corrosion-resistant, hard and relatively strong material that has a low density with a high melting point. Ceramics have the disadvantage of brittleness and tend to break suddenly with relatively small plastic deformation values. The brittleness factor is caused by the rapid formation and spread of cracks.

Amorphous materials do not have the usual grain size and plane in crystals, this makes ceramics susceptible to surface cracks. Compressive strength has an important role in the manufacture of ceramics in structures such as buildings. The compressive strength of ceramics is generally relatively greater than their tensile strength. To improve the quality of this property, ceramics are only used under pressure.

Thermal properties in ceramics are thermal conductivity, coefficient of thermal expansion, and heat capacity. Heat capacity is the ability of a material to absorb heat in the environment. The heat that has been absorbed is stored in solids stored in the form of vibrations of constituent ions in solids. In general, ceramics have strong bonds and lightness of atoms. Thus, vibrations in large-frequency atoms and not too disturb the crystal lattice.

Ceramics have a high melting point in some forms, which makes ceramics able to withstand deformation at high temperatures ceramics and can withstand high pressure. However, sudden and high temperature changes can make ceramics weak. Shrinkage and expansion due to temperature differences can damage ceramics.

This research produces clay-based porous ceramics with corn leaf additives by varying the composition of clay and corn leaf ash (100%: 0%), B (90% : 10%), C (80% : 20%) and D (70%: 30%). The mixture of clay and corn leaf ash is made into block-shaped porous ceramics using dry pressing technique with a sintering temperature of 900 ^{0}C for 2 hours. The characterizations carried out on the samples include density, porosity, and SEM (Scanning Electron Microscope).

a. Density

Density testing is done to determine the density of the material in determining the quality of porous ceramics by calculating from the equation 2.1. :

$$\rho = \frac{m_k}{V_t} \quad 2.1$$

Description :

ρ : Density (Kg/m^3)
m_k : Mass (Kg)
V_t : Volume sample (m^3)

Table 1. Density Measurement Results

Sample	Density (g/cm^3)	Average Density (g/cm^3)
A	1,81 1,78 1,77	1,79
B	1,59 1,53 1,48	1,54

C	1,22 1,28 1,32	1,27
D	1,19 1,21 1,20	1,20

b. Prosity

The purpose of porosity testing in order to determine the percentage of pore volume in porous ceramics to the volume of porous ceramics by calculating using the equation 2.2. :

$$\% \text{ Porosity} = \frac{(m_b - m_k)}{\rho_{air} \times V_t} \times 100\% \qquad 2.2.$$

Description :

m_b : Wet mass of sample (Kg)
m_k : Dry mass of sample (Kg)
ρ_{air} : Density of water (Kg/m^3)
V_t : Total volume of sample (m^3)

Tabel 2. Porosity Measurement Results

Sample	Porosity (%)	Average Porosity (%)
A	30,57 29,12 29,57	29,75
B	38,95 38,79 38,19	38,64
C	47,11 50,53 51,04	49,56
D	60,35 63,37 59,38	61,03

c. SEM

Morphological characteristics on the surface of porous ceramics using block-shaped samples in accordance with the sample mold used. The samples were characterized with magnification according to the required magnification.

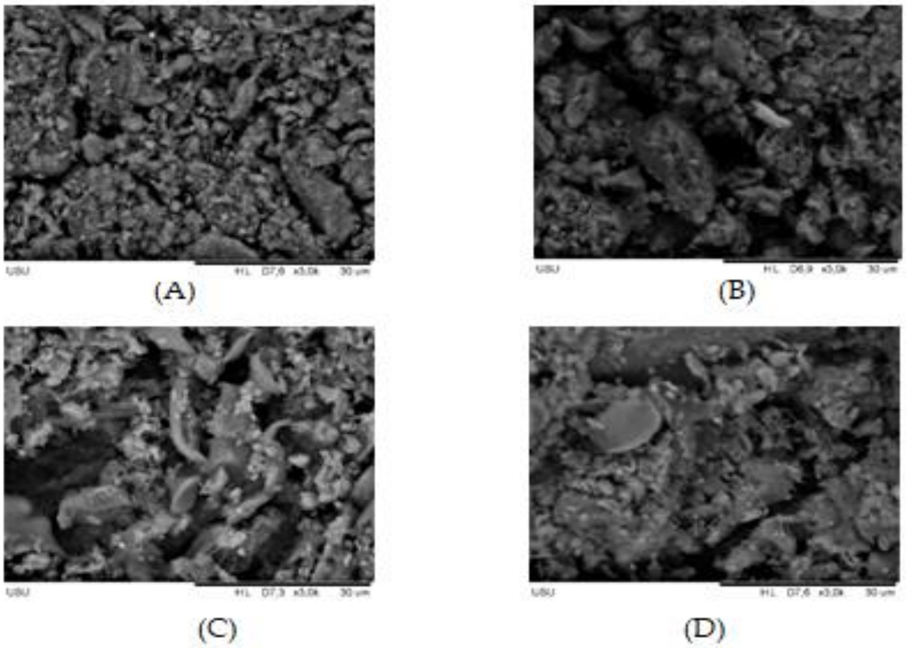

Figure 1. SEM Testing Results

DISCUSSION

Ceramics are compounds of carbon, oxygen, nitrogen and light metallic and semi-metallic materials. Because of this, ceramics are less dense. Some lightweight ceramics can be as hard as heavy metals. The strongest compounds are diamond and boron nitride.

Ceramics have a distinctive property, namely their chemical stability. The chemical properties that ceramics contain on the surface are positively utilized. Silica gel, activated carbon, zeolite and others that have such a large surface area and are used as adsorbent materials.

Ceramics have several advantages over metals. These are stiffness, hardness, corrosion resistance and wear resistance. Ceramics have a smaller density than most metals. This makes ceramics preferable as a substitute for metals if their use considers their weight. Ceramics are also good electrical insulators at normal temperatures and can survive well at high temperatures.

The weaknesses that ceramics also have are brittleness and relatively small tensile strength (easy to break). Ceramics have low thermal conductivity, but tend to have high thermal expansion. As a result, ceramics often experience *thermal shock*, which is a sudden change in local temperature that causes cracking. If metal or plastic is stressed it will bend or deform, but ceramics cannot absorb stress by bending or deforming but ceramics will become broken (Oxtoby, 2003).

From Table 3.1, the density values in the printed samples, namely samples A, B, C and D are 1.79 g/cm^3, 1.54 g/cm^3, 1.27 g/cm^3 and 1.20 g/cm^3. The decrease in density value for each composition variation of clay-based porous ceramics with corn leaf ash additives, and this decrease in density value begins with the 10% corn leaf ash mixing variation with a value of 1.54 g/cm^3, 20% with a value of 1.27 g/cm^3 and 30% with a value of 1.20 g/cm^3. The decrease in density value shows that the more the composition of corn leaf ash, the smaller the density value and inversely proportional to the volume value of porous ceramics (Ridayanti & Asifa Asri., 2017).

The maximum value of density obtained is 1.79 g/cm^3 in samples with 100% clay composition and 0% corn leaf ash and the smallest value obtained is 1.20 g/cm^3 in samples with 70% clay composition and 30% corn leaf ash. In Anisah's research (2019) where the effect of adding ash as much as 0 g, 10 g, 20 g, 30 g, 40 g and 50 g the density value produced decreased, namely 1.68 g/cm^3; 1.44 g/cm^3; 1.39 g/cm^3; 1.33 g/cm^3; 0.99 g/cm^3 and 0.95 g/cm^3.

Table 3.2 shows the porosity values in samples A, B, C and D are 29.75%, 38.64%, 49.56% and 61.03%. The increase in each composition variation for the porosity value of clay-based porous ceramics with corn leaf additives explains that the more the composition of corn leaf ash, the more pore marks are produced on the ceramic. Many pore marks are produced as a result of corn leaf ash which has silica content melting in the process of firing porous ceramics using a sintering temperature of 900 ^{0}C in a holding time of 2 hours.

The maximum porosity value is 61.03% in samples with 70% clay composition and 30% corn leaf ash and the minimum porosity value is 29.75% in samples with 100% clay composition and 0% corn leaf ash. In research proven by Anisah et al., (2019) where the effect of adding ash as much as 0 g, 10 g, 20 g, 30 g, 40 g and 50 g will increase the porosity value produced, which is 28.89%; 29.72%; 35.63%; 44.20%; 61.36% and 66.20% (Nisa Gulo et al., 2020).

Figures 3.1 show the results of SEM observation at 3000 times magnification so that it can be seen between samples with their respective composition variations. Starting from the sample with 10% corn leaf ash composition variation, it shows the formation of pores on the sample. This proves that the number of pores is proportional to the porosity test which shows that the porosity value of the sample with 0% corn leaf ash composition variation is smaller than the porosity value with 10%, 20% and 30% corn leaf ash composition variations. There is an increase in pore area characterized by the stretching of the distance between the sample particles which can be seen in the SEM test results.

CONCLUSIONS AND RECOMMENDATIONS

The characteristics of clay-based porous ceramics with corn leaf additives were obtained and showed that density had values of 1.79 g/cm3, 1.54 g/cm3, 1.27 g/cm3 and 1.20 g/cm3 (decreased), porosity had values of 29.75%, 38.64%, 49.56% and 61.03% (increased), SEM characterization has shown the pore diameter size and has values of 10.516 μm, 15.665 μm, 21.678 μm and 23.137 μm (increased). The addition of corn leaf ash additives can improve the quality of porous ceramics, especially in the field of porosity.

ADVANCED RESEARCH

This study has limitations in heating temperatures that cannot be higher. suggestions for future researchers, using tools that can heat samples above 1000 ^{0}C. Further research can do different additives so as to produce porous ceramics that have higher compressive strength.

ACKNOWLEDGEMENTS

Thanks to all those who have helped in carrying out this research. this research can be completed on time in accordance with the planned target..

REFERENCES

Anisah, Fitri. 2019. Pembuatan Keramik Berpori Berbasis *Clay* dengan aditif Karbon Aktif Cangkang Kemiri. Medan : Universitas Sumatera Utara.

Astuti, A. (1997), Pengetahuan Keramik, Gajah Mada University Press, Yogyakarta.

Ayu Amalia rahma, Ety Jumiati, & Ridwan Yusuf Lubis. (2023). Analisis Pengaruh Penambahan Daun Jagung Pada Keramik Berpori Berbahan Dasar Tanah Lempung. *Komunikasi Fisika Indonesia*, *20*(3), 9–15.

Ayu Dwi Retno, Ety Jumiati, & Ridwan Yusuf Lubis. (2023). Pengaruh Penambahan Aditif Daun Jagung (Zea Mays) Terhadap Sifat Fisis Dan Mekanik Keramik Alumina. *Komunikasi Fisika Indonesia*, *20*(3), 19–25.

Feng, Q., Li, T., Teng, H., Zhang, X., Zhang, Y., Liu, C., & Jin, J. (2008). Investigation on the corrosion and oxidation resistance of Ni–Al2O3 nano-composite coatings prepared by sediment co-deposition. *Surface and Coatings Technology*, *202*(17), 4137–4144. https://doi.org/https://doi.org/10.1016/j.surfcoat.2008.03.001

Nasution, A. S. S., Jumiati, E., & Husnah, M. (2024). Pengaruh Penyerapan Air Dan Porositas Pada Keramik Berpori Berbahan Clay Dan Puntung RokoK. *Jurnal Energi Baru Dan Terbarukan*, *5*(1), 14–19. https://doi.org/10.14710/jebt.2024.20664

Nisa Gulo, K., Sudati, & Mulyadi. (2020). Efek Penambahan Aditif SiO2 terhadap Suhu Sintering, Sifat Fisis, Struktur Kristal dan Mikrostruktur pada Keramik Al2O3. *Journal of Technical Engineering :PISTON*, *4*(1).

Oxtoby, David W. 2003. Prinsip-Prinsip Kimia Modern. Jakarta : Erlangga.

Papetti, V., Dimopoulos Eggenschwiler, P., Della Torre, A., Lucci, F., Ortona, A., & Montenegro, G. (2018). Additive Manufactured open cell polyhedral structures as substrates for automotive catalysts. *International Journal of Heat and Mass Transfer*, *126*, 1035–1047. https://doi.org/https://doi.org/10.1016/j.ijheatmasstransfer.2018.06.061

Rahma, A. A., Jumiati, E., & Lubis, R. Y. (2023). Komunikasi Fisika Indonesia Analisis Pengaruh Penambahan Daun Jagung Pada Keramik Berpori Berbahan Dasar Tanah Lempung. *Komunikasi Fisika Indonesia*, *20*(3), 267–274. https://doi.org/10.31258/jkfi.20.3.267-274

Retno, A. D., Jumiati, E., & Lubis, R. Y. (2023). Komunikasi Fisika Indonesia Pengaruh Penambahan Aditif Daun Jagung (Zea Mays l.) Terhadap Sifat Fisis Dan Mekanik Keramik Alumina. *Komunikasi Fisika Indonesia*, *20*(3), 275–278. https://doi.org/10.31258/jkfi.20.3.275-278

Ridayanti, Dien., & Asifa Asri. (2017). Analisis Porositas Dan Susut Bakar Keramik Berpori Berbasis Clay Dan Serat Tandan Kosong Kelapa Sawit. . *SSN 2337-8204, 51-54*, *5*(2), 51–54.

Shi, S., Cho, S., Goto, T., & Sekino, T. (2020). The effects of sintering temperature on mechanical and electrical properties of Al2O3/Ti composites. *Materials Today Communications*, *25*. https://doi.org/10.1016/j.mtcomm.2020.101522

Siagian, H., & Hutabalian, D. M. (2012). Studi Pembuatan Keramik Berpori Berbasis Clay Dan Kaolin Alam Dengan Aditif Abu Sekam Padi. *Jurnal Saintika*, *12*(1), 14–23.

Sihite, D.R. (2008), Pembuatan dan Karakterisasi Bahan Keramik Berpori Dengan Aditif Sekam Padi Yang Digunakan Sebagai Filter Gas Buang, Pascasarjana USU, Medan.

Tobing, N. (2009), Preparasi Dan Karakterisasi Keramik Clay Dengan Silika Sekam Padi Menggunakan Teknik Sintering, Jurusan Fisika FMIPA Unimed, Medan.

Wei, Z., Liu, S., Liu, D., Wu, J., Xia, H., Wang, B., & Shi, Z. (2022). Fabrication and properties of symmetrical W/Si3N4/W functionally graded materials by spark plasma sintering. *Journal of Alloys and Compounds*, *896*, 163077. https://doi.org/https://doi.org/10.1016/j.jallcom.2021.163077

Zhang, X., Zhang, K., Zhang, B., Li, Y., & He, R. (2022). Mechanical properties of additively-manufactured cellular ceramic structures: A comprehensive study. *Journal of Advanced Ceramics*, *11*(12), 1918–1931. https://doi.org/10.1007/s40145-022-0656-5