FABRICATION OF WATER FILTER FROM RICE HUSK WASTE PRODUCT VIA COLD ISOSTATIC PRESSING (CIP) METHOD

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Abstract. Many researchers are interested in exploring the practical ways to expand the usage of RH waste. The objective of fabricating the silica water filter is to remove contaminants from the well water. The fabrication process involves burning Rice Husk (RH) waste at 550 °C, which produces black RH ash that contains a generous amount of amorphous silica. The silica water filter was fabricated with varying the compositions of silica rice husks which were 78 wt.%, 84 wt.%, and 88 wt.%. Porcelain and PVA has been added in the mixture and acting as a binder. The mixture of amorphous silica and binders have been used to fabricate the silica water filter by using Cold Isostatic Pressing (CIP) method. The CIP pressure used was 8 kPa and the mold used was rubber plastic. After compaction using the CIP method, the samples were sintered at a temperature of 1200 °C. The results obtained from the Scanning Electron Microscope (SEM) analysis provide visual insights into the pore structure of the sample under examination. Apparent porosity, and bulk density were recorded for each sample. The results obtained for the composition of 78 wt.%, 84 wt.% and 88 wt.% for the bulk density are 0.43861 g/cm^3,0.3729 g/cm^3 and 0.35143 g/cm^3, respectively. The result for apparent porosity for every composition of 78 wt.%, 84 wt.% and 88 wt.% are 54%, 60% and 68%, respectively. The results indicate that the 78 wt.% silica composition produces the best silica water filter. Overall, our findings demonstrate a promising approach for repurposing RH waste and producing a sustainable water filtration solution.

Keywords: Amorphous, sintering, porosity, density, pore

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Introduction

The trend towards waste reuse and cost reduction in industrial processes has led to the utilization of Rice Husk (RH) as a value-added resource. RH and black RH ash have been found to be suitable for various residential and industrial applications. In this study, we conducted a comprehensive investigation of the characteristics and industrial uses of RH in response to its increasing demand and significance. Our research findings indicate that rice husk (RH) holds great promise for future applications, potentially extending its utilization to new locations and expanding its range of uses. Overall, this paper provides valuable insights into the potential benefits and opportunities associated with the utilization of RH as a valuable resource.

Researchers are increasingly interested in studying the potential benefits of abundant Rice Husk (RH) and finding appropriate methods to increase its utilization while reducing waste generated by paddy agriculture. RH can be effectively transformed into fuel and fertilizer, offering numerous advantages. Unfortunately, RH is often undervalued by farmers due to its low market value, leading to the underutilization of this waste material. As a result, the waste generated by paddy crops remains abundant and largely unutilized. RH recycling aims to conserve limited resources by reusing materials or finding sustainable substitutes to study the fundamental of water filter.

The relative amount of silica was increased after burning out the RH at different times and temperatures. A 95% silica powder could be produced after heat-treating at 700 ºC for 6 hours [1]. During the combustion of rice husk (RH), the resulting ash contains both amorphous and crystalline forms of silica. The form of silica in RH ash is dependent on the temperature at which the burning process occurs. Amorphous silica is generated within the temperature range of 550 ºC to 880 ºC, while higher temperatures ranging from 780 ºC to 1300 ºC lead to the production of crystalline silica [2]. Proper disposal of RH ash is crucial as its indiscriminate dumping in open spaces can result in environmental and health hazards. Hence, it is essential to explore effective methods to maximize the utilization of RH ash. This ash exhibits a range of colors, predominantly white, but also including shades of grey and black [3]. Notably, RH ash is rich in amorphous silica, constituting a significant proportion (84%-95%) of its composition [4]. Then, it is a low-cost and renewable resource, RH is a proving adsorbent material for eliminating various pollutants. So, in this research the amorphous silica has been chosen to product water filter because of the low consumption of energy to produce the silica form RH.

Ceramic water filtration is the method of purifying water from contaminants or germs using a porous ceramic material [5]. Water filters have grown from a desire to improve poor tastes, then to successfully remove materials that may cause diseases, and ultimately to eliminate elements that influence appearance. Furthermore, cold isostatic pressure (CIP) is a manufacturing technique that applies uniform pressure from all directions to shape and consolidate powders or particulate materials. It is used in various industries to create precise, complex parts with enhanced density and improved properties. CIP is versatile, reducing porosity and maintaining the material's composition and structure The objective of this study is to fabricate a silica water filter using CIP and analyse the physical properties of silica once the water filter is created. Overall, it enables high-quality production with enhanced properties.

Materials and Methods

Materials

Raw Rice Husk (RH) sourced from Pasir Puteh, Kelantan, was used as the primary material. For every 1 kg of raw RH burned, 100 g of silica has been produced. The RH was subsequently transformed into powder form through a burning process at a temperature of 550 ºC in a box furnace. Porcelain and Polyvinyl alcohol (PVA) were supplied by Maju Saintifik Sdn. Bhd. This PVA works as a binder, which keep the porcelain particles together, structuring the filter, maintaining its strength, and enabling control over filtration efficiency by altering the binder-to-porcelain ratio. Table 1 shows the composition of water filter formulation.

Table 1: Compositions of rice husks in water filter formulation

Material	Preparation of RH-Silica slurry		
	78wt.%	**84wt.%**	**88 wt.%**
	Mass, m (g)		
RH-Silica	500	500	500
Porcelain	125	88.24	55.6
Binder	20	10	10

The fabrication of water filters involved milling the RH formulation for 30 minutes to break down the rice husk into smaller particles. The RH particles were then sieved through a 90-micrometer mesh size. This sieving procedure, lasting for 30 minutes, is crucial for achieving the correct particle size distribution. Subsequently, the screened rice husk underwent the CIP process, ultimately resulting in densely compacted water filter samples.

Preparation of Rice Husk Water Filter

Figure 1 illustrates the CIP machine used for producing silica water filter samples. The CIP machine was manufacturing by Maju Saintifik Sdn. Bhd. Then, varying the silica composition helps us assess its impact on sample properties such as porosity and filtration efficiency. In the CIP method, a rubber plastic mold was employed to apply pressure during the moulding process. The advantages of CIP lie in its ability to ensure uniform powder density for both simple and complex shapes through the application of isostatic pressure and minimal frictional forces [6].

After compacting and shaping the powders, the samples were sintered at 1200 °C in a box furnace. Sintering temperature and soaking time were identified as critical parameters with the potential to significantly influence the outcome. In this study, sintering was performed at 1200 °C for a duration of 120 minutes, with a controlled heating rate of 5 °C per minute, as shown in Figure 2. By carefully controlling these sintering parameters, the study aimed to achieve optimal material densification, phase transformation, and structural integrity necessary for the desired properties of the fabricated samples. The chosen sintering temperature and soaking time were based on previous experimental observations and theoretical considerations, aiming to strike a balance between achieving the desired material characteristics and avoiding excessive grain growth or thermal degradation.

Figure 1: Cold Isostatic Pressing (CIP) machine

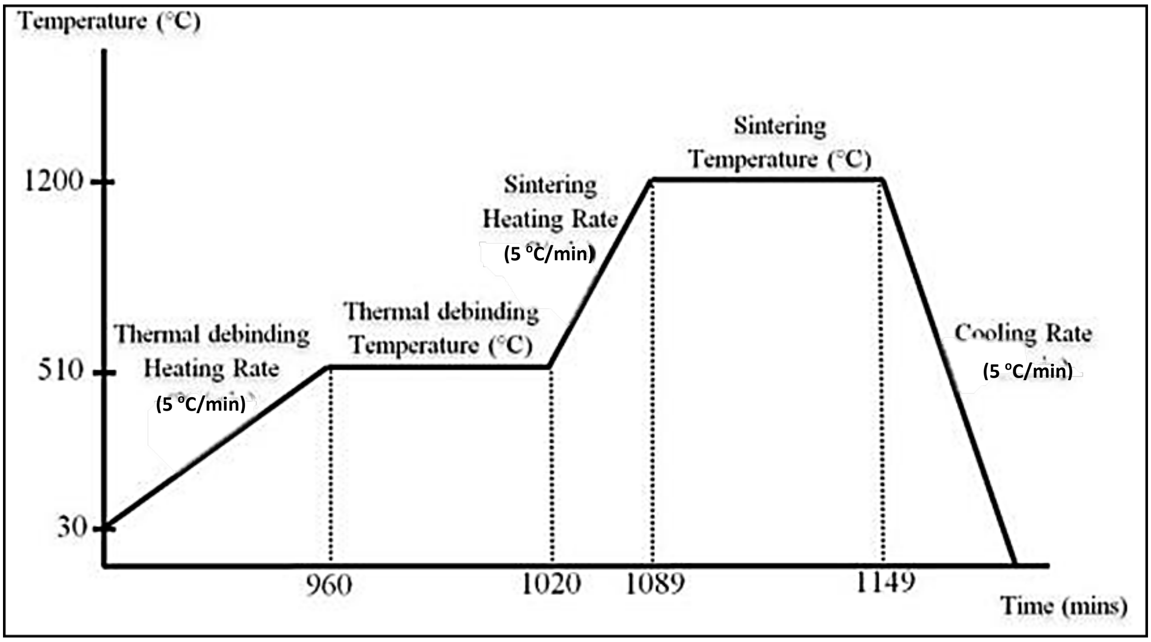

Figure 2: Sintering profile for sintering the silica water filter samples.

Characterizations

Physical testing was performed to determine the physical properties of silica water filter samples. Physical properties obtain from the testing provide evidence of localized density variation, type of porosity and volume drop off from the composition of the samples. The morphological examination of the RH was meticulously conducted using a state-of-the-art 2600SN Hitachi (Japan) Scanning Electron Microscope (SEM) that was equipped with a high-sensitivity Germanium detector and a durable Diamond window for optimal imaging quality and precision. Bulk density and apparent porosity test were conducted according to the ASTM C373-14 standard. The sample was carefully selected from a fractured sample to represent the desired material characteristics. The sample has been weighed and its volume determined using

Archimedes' principle. Bulk density is then calculated as the ratio of specimen weight to volume. For the Apparent Porosity test, the same specimen is saturated by immersion in water for a specified duration, and excess surface water is gently removed before weighing. Apparent porosity is calculated as the percentage difference between the weight of the saturated specimen and the weight of the dry specimen, offering valuable insights into the material's density and interconnected void space.

Results and Discussion

Figure 3 shows an overview of the microstructure of the sample at the magnification of 1000x. This analysis aimed to determine the pore and densification of particle that was produced at the sintering temperature of 1200 °C. The utilization of SEM in this analysis provided valuable insights into the structural properties of the silica water filter, contributing to the overall understanding of their suitability for the intended application [7].

The SEM micrograph in Figure 3 provides a visual representation of the appearance of the samples with silica compositions of 78 wt.%, 84 wt.%, and 88 wt.% from rice husks (RHs) when magnified 1000 times. The SEM analysis allowed for detailed observation of the sample surfaces and their structural characteristics. The micrograph reveals distinct features of the samples, differences in surface morphology, particle densification and pore arrangement.

For Figure 3(a) upon magnification 1000 times, the micrograph shows the variation in pore distribution, with the 78 wt.% silica composition exhibiting a greater number of pores distributed throughout the sample surface. The pores appear to be of varying sizes and shapes, suggesting a more porous and interconnected structure in this sample. Followed by Figure 3(b) the pores were eliminated, and more particles densification can be seen for 84 wt% of silica. The SEM micrograph in Figure 3(c) reveals that the particle size is significantly larger in the sample with a silica composition of 88 wt.% compared to the other compositions. The pore also eliminated more than other compositions. Moreover, the pore size decreased with the increasing of the silica RH composition. This observation suggests that the silica composition plays a crucial role in determining the porosity and pore density of the samples. The higher pore in the 78 wt.% silica composition could have implications for the material's properties, such as increased surface area, enhanced fluid permeability, or improved adsorption capacity. An increasing of sintering temperature also can reduce the porosity and glassy phase of ceramic. An elevation of composition of silica causing an increasing of the liquid phase presence which derives from fluxes that helps the process of merging and arrangement of particles. Thus, the size of porosity shrinking when large of granules were formed [8].

Figure 4 shows the graph of bulk density against the sintering temperature. Density was measured by Archimedes principle and the result provide were based on the different composition silica. Figure 4 reveals the result for different composition of silica which are 78 wt.%, 84 wt.% and 88 wt.%. The graph shows the value obtained for bulk density is increase as the composition of silica increase. The density of the silica water filter at different compositions were investigated, and it was observed that the composition of 88 wt.% had the highest bulk density compared to other compositions.

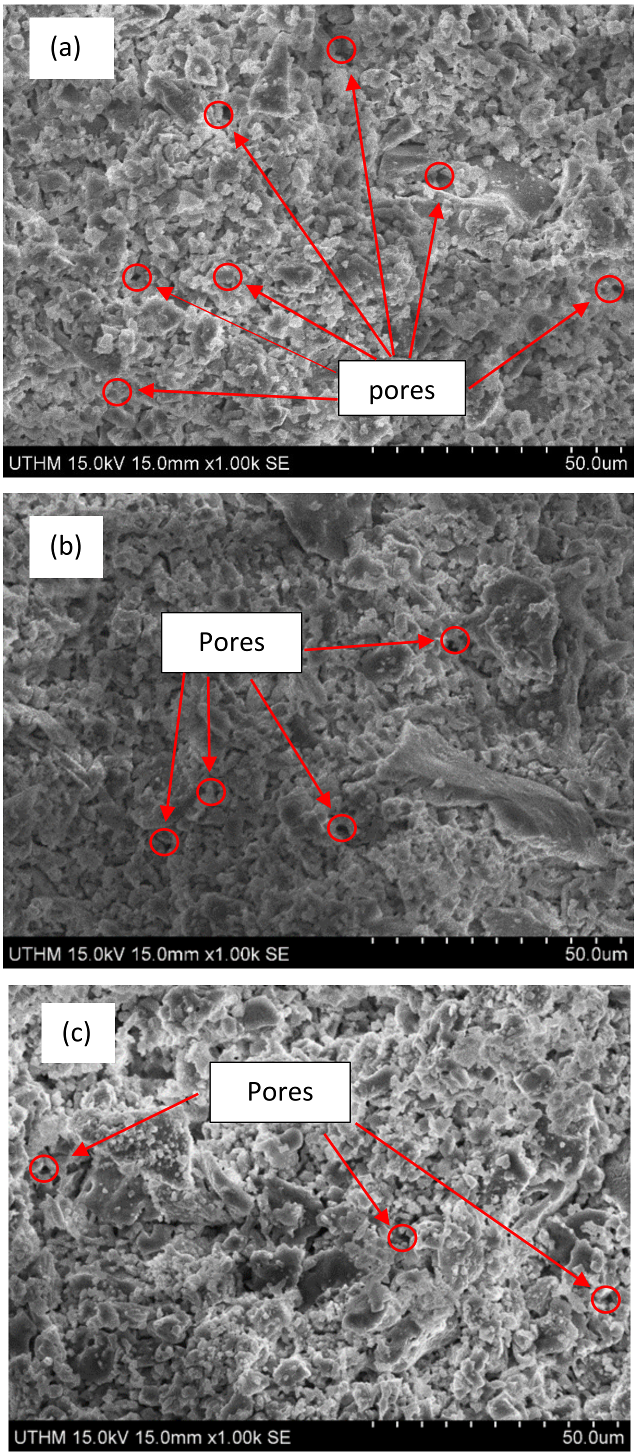

Figure 3: SEM micrographs of (a) 78 wt.% composition of silica, (b) 84 wt.% composition of silica and (c) 88 wt.% composition of silica

The bulk density values for the 78 wt.%, 84 wt.%, and 88 wt.% compositions were found to be 0.31 g/cm^3, 0.37 g/cm^3, and 0.44 g/cm^3, respectively. The results show an increasing trend in bulk density values for the 84 wt.% and 88 wt.% compositions when sintered at 1200 ^{o}C. The increment in bulk density values observed from the 78 wt.% to 84 wt.% and from the 84 wt.% to 88 wt.% compositions of silica were found to be 0.06% and 0.18%, respectively. This relationship between bulk density and silica composition could be related to the pore characteristics observed in the SEM micrograph as shown in Figure 3. From previous research the porosity affected the bulk density value, because of the increase in strength with sintering temperature is due to the sintering phenomena, where particle rearrangement, mass diffusion to pores and grain growth take place [9]. As the result, the bulk density increase, the porosity decreases.

In additional, the idea behind bulk density states that when density increases, internal porosity decreases, possibly resulting in the proppant becoming more compact [8]. From previous research the porosity affected the bulk density value, because of the increase in strength with sintering temperature is due to the sintering phenomena, where particle rearrangement, mass diffusion to pores and grain growth take place [7]. As the result, the bulk density increase, the porosity decreases. In additional, the idea behind bulk density states that when density increases, internal porosity decreases, possibly resulting in the proppant becoming more compact [10]. The higher number of pores has been seen in the sample with 78 wt.% silica composition, suggesting that the presence of more pores within the material could contribute to a lower overall density. As the silica composition increase from 78 wt.% to 84 wt.% and further to 88 wt.%, the increasement in bulk density values indicates a trend towards a denser material with lower pores and more particle densification. Generally, the investigation of bulk density values provides valuable insights into the physical characteristics of the silica water filter for different compositions, which can be useful in determining the filter's effectiveness in water filtration applications.

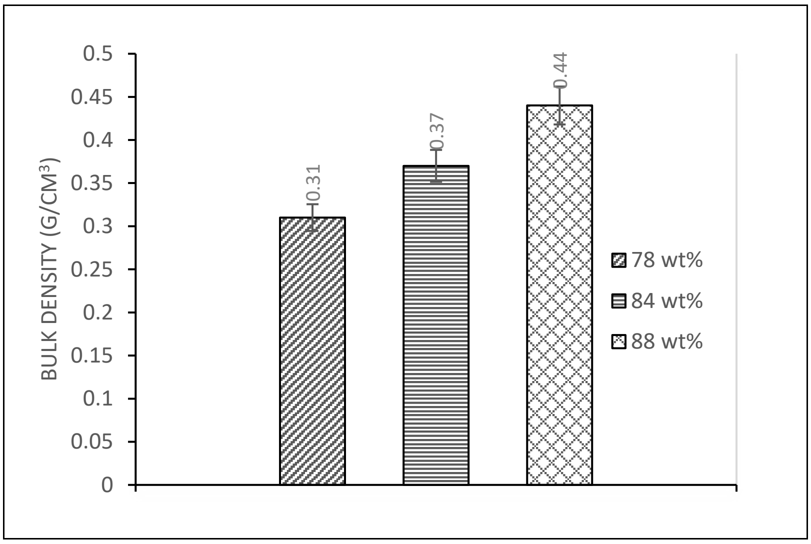

Figure 4: Results of bulk density for silica water filter at 1200 °C sintering temperature

Figure 5 shows the graph of apparent porosity against 1200 °C sintering temperature. Apparent porosity analysis was carried out for this study because the porosity would have a significant influence on the physical properties of silica water filter. The structure of the ceramic body would become more fragile if the value of the resulting porosity is large. By reffering to the Figure 5, the investigation of the apparent porosity values for the different compositions of silica water filter showed that the composition of 88 wt.% had the lowest apparent porosity value, which was 55%. On the other hand, the apparent porosity values for the 84 wt.% and 78 wt.% compositions were 60% and 68%, respectively. This indicates that there was a significant decrease in the apparent porosity value between the 84 wt.% and 88 wt.% compositions.

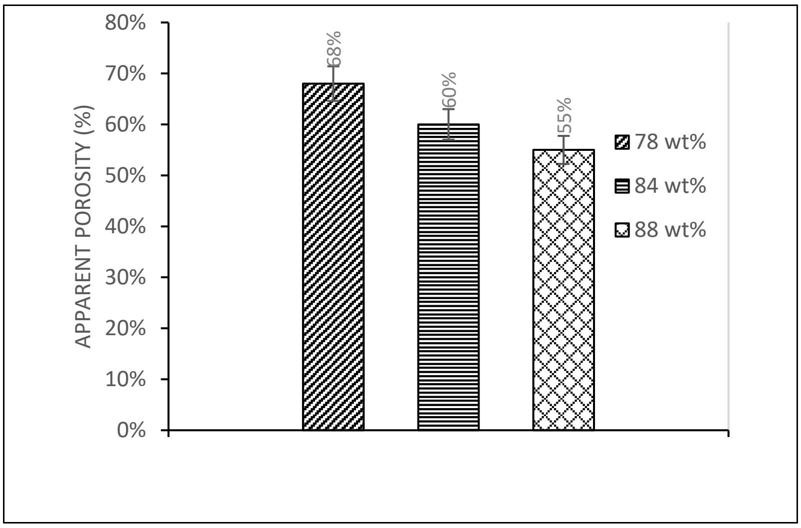

Figure 5: Results of apparent porosity for silica water filter at 1200 ˚C sintering temperature

However, the smallest decrement in the apparent porosity value was observed in the range of 84 wt.% to 78 wt.%, which was 5.91% only. This suggests that there was a relatively smaller decrease in the apparent porosity value between the 84 wt.% and 78 wt.% compositions compared to the 88 wt.% and 84 wt.% compositions. Overall, the investigation of the apparent porosity values provides valuable insights into the filter's effectiveness in water filtration applications for different compositions of the silica water filter. The composition of 78 wt.% with high apparent porosity value will be suitable for applications where high water flow rates are required, whereas the compositions of 84 wt.% and 88 wt.% was suitable for applications where a more compact and dense structure is desired. High porosity indicates that there are more pore in the silica filters, allowing water to travel through the filter components [11]. The high flow rate with 63.91% value of apparent porosity is good for reduce clogged of water filter with high turbidity which is easiest way to allow the water to flow through the element [11]. Form this research was shown that the sample with 78 wt% silica was suitable to produce water filter.

The graph trend produced was opposite with bulk density result .Previous research findings indicate that the incorporation of silica in the composition led to a decrease in density while simultaneously promoting an increase in porosity [12]. Composition of silica elevation would give lower apparent porosity value at 78 wt.% and increasing composition of silica will decrease apparent porosity. Additionally, analysis of the results showed that sample' apparent porosity tends to decline as sintering temperature increases. A decrease in apparent porosity caused by an increase in RH results in a reduction in unit weight and an improvement in the thermal insulating qualities [13].

Conclusions

In conclusion, the use of Rice Husk (RH) waste to fabricate silica water filters provides a sustainable solution to water filtration while repurposing a commonly disposed of waste material. The burning of RH waste at 550 °C produces RH ash, which contains crystalline silica that can be used to fabricate the silica water filter. The CIP method was used to create the filter in three compositions of 78 wt.%, 84 wt.%, and 88 wt.%, with the 78 wt.% silica composition producing the best results with an apparent porosity of 68% and bulk density was 0.31 g/cm^3. The results obtained demonstrate a promising approach to sustainable water filtration and provide a practical way to expand the usage of RH waste.

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Author Contributions

All authors contributed toward data analysis, drafting and critically revising the paper and agree to be accountable for all aspects of the work.

Disclosure of Conflict of Interest

The authors have no disclosures to declare.

Compliance with Ethical Standards

The work is compliant with ethical standards.

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