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Effect of Yeast Content as Pores Forming Agent on Porous Alumina Ceramic

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ABSTRACT

This research is carried out to determine the effect of yeast content on the physical, mechanical and macrostructure properties of porous alumina ceramic material. The porous ceramic material was fabricated through the mixing of alumina, calcium oxide and zeolite as the main materials. Meanwhile, the ethylene glycol act as the binder. Besides that, yeast was used as pores forming agent and the value is varied from 0 wt.% up to 20 wt.% from the total weight of ceramic materials. After that, the slurry was cast into mold and allowed it to dry under the room temperature before being sintered at the temperature of 1400 °C for two hours. Linear shrinkage, apparent porosity, macrostructural analysis, pores size measurement and mechanical tests were carried out to determine the effect of yeast content on the porous ceramic. The results showed that the linear shrinkage, average apparent porosity and pore size increased with the increased weight percentage of yeast content from 1.63% to 6.66%, 35.46% to 46.54% and 49.814 μm to 194.297 μm, respectively. The increasing of porosity and pore size give an effect to the mechanical strength of sintered porous ceramic by decreasing it from 17.47 MPa to 10.66 MPa, which were inversely proportional to porosity and pore size. Thus, this shows that yeast as pores forming agent have huge potential in fabrication of porous ceramic material products.

Keywords: *Porous ceramic material, yeast, pores forming agent, pore and porosity*

1. INTRODUCTION

Porous ceramic materials are widely used in various industries such as filtration application for Diesel Particulate Filters [1-2], water treatment and catalysis [3], construction materials for autoclaved aerated concrete and gypsum board [2], biomaterials application for bone substitute [4], sorbent for capturing and separating gas [5-7] and so on. Applications of porous ceramic are dependable on their characteristics and permeability. Normally, porous ceramic should have low density and thus, due to the distribution of pores in ceramic body, this could leads to high permeability.

In porous ceramic material, there are two groups of pores. The first group is open-celled structure or reticulate, where here, the structure is normally consisting of interconnected voids surrounded of a web of ceramic. The second group is also known as closed-cell structure or foam. Here, the voids are closed and they are no linkages within the continuous ceramic matrix. Ceramic materials with closed pores are useless in practical applications such as adsorption and catalyst, but useful in thermal insulation and lightweight structural applications. However, materials with open pores are vital in area separation, catalysis and filtration [8].

According to IUPAC (International Union of Pure and Applied Chemistry), the pores also can be divided into three types depending on the pore sizes. There are micropores, mesopores and

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macropores. Microspores have pores size smaller than 2 nm in diameter (<2 nm), mesopores have pores size between 2 up to 50 nm (2-50 nm) and macropores have pores size larger than 50 nm (>50 nm) [4,9]. These various sizes of pores can be controlled by choosing appropriate processing routes or techniques in producing specific porous ceramics toward their final properties and applications. Alumina is one of the main materials used in forming porous ceramic. In general, alumina has been used as a main material because it has excellent properties of mechanical, thermal and also inert to all chemical materials [10]. Meanwhile, zeolite is mainly composed of crystalline aluminumsilicates; it is also have pores channel with have high surface areas and capable to separate gases or as catalytic transformations of small molecules [5,11].

Many processing routes have been proposed and applied during alumina-zeolite porous ceramic preparation such as partial sintering process, sol-gel method, freeze casting method, polymeric sponge method and pores forming agent method [12]. Among of these methods, the pores forming is normally used in porous ceramic materials fabrication through controlled porosity and pore size instead of using polymer sponge as template method, which has limit in their mechanical properties due to the microstructural defects on the pore channel in the struts of the ceramic material. As compared to pores forming agent method, it will burn out to form voids or pores after had been sintered at elevated temperature in the body of porous ceramic body [13-15, 24-26].

In selecting pores former material during fabrication of porous ceramic, it very important consideration, because thus will affect to morphology of the voids. Nowadays, they are two types of pores forming agent can be used. They are synthetic organic template and natural organic. Synthetic organic template such as nylon and poly(ether-co-ocetene) [6], compared to natural organic template such as wax, starch, yeast and dextrin are cheap, non-toxic and environmentally friendly [13,16]. Besides that, synthetic organic template which is 1-150 μm [6], compared to natural organic template could produce open cell size about 100-700 μm.

Therefore, in this research, yeast (as natural organic material) was utilized as pores forming agent to determine the effect of yeast content on the physical, mechanical properties and macrostructure of porous alumina ceramic. This is due to its availability and cheaper price with a correspondingly well-defined size distribution compared to synthetic polymer particles [17].

2. MATERIAL AND METHODS

2.1 Raw materials

All main materials have been used in this research are alumina (purchased from CV Agung Menara Abadi (Indonesia)), zeolite (purchased from D&W Corporation, Indonesia), calcium oxide (purchased from HmbG chemicals) and the pore-forming agent, yeast (supplied by AB Mauri Malaysia Sdn. Bhd.). Meanwhile, the distilled water and ethylene glycol will act as the solvent and binder in the mixture. Table 1 shows the physical and chemical property of raw materials used in this research.

Table 1 Properties of the main materials

Properties	Materials			
	Alumina	Zeolite	CaO	Yeast
Particle size (μm)	2.88	13.19	5.11	(0.2-1) x10^3
Melting point, t_m (°C)	2072	1260	2572	N/A

2.2 Sample preparation

Alumina powder (56 wt.%) as the main materials, zeolite (33 wt.%) as carbon dioxide capture and calcium oxide (11 wt.%) as reduction of sintering temperature were mixed homogenously with yeast (varying from 0 up to 20 wt.%) as pores forming agent. During mixing process, the polyethylene glycol and distilled water have been added in the mixture. Table 2 shows the composition of raw materials. After that, the mixture has been stirred using the magnetic stirrer for 30 minutes until the mixtures were mixed homogeneously. Eventually, the mixture has been cast into mold (made from plaster of paris) and let dried in the normal temperature. During the first phase of sintering process, samples were hold for one hour at the temperature of 110 °C, to make sure that the samples were dried properly. For the second phase, samples were hold for two hours at the temperature of 350 °C in order to remove water in crystal oxide form. After that, the third phase was complex thermal treatment to decompose the organic mixtures and then sintering process at the temperature of 1400 °C with sintering rate of 10 °C/min for 2 hours by using KSL-1700X-A4 high temperature muffle furnaces.

Table 2 Composition of raw materials with different percentage of yeast content

Yeast content	Composition of raw materials (100%)			Polyethylene glycol
(0 -20%) total weight of raw materials	Alumina (%)	Zeolites(%)	Calcium oxide(%)	(10/100) from the total weight of raw materials and yeast content
0	56	33	11	10
10	56	33	11	10
15	56	33	11	10
20	56	33	11	10

2.3 Characterization

The linear shrinkage of sintered porous ceramic can be obtained by using Equation (1):

$$Shrinkage = \frac{l_g - l_s}{l_g} \times 100\% \tag{1}$$

where, l_g is length of sample before sintering (mm) and l_s is length of sample after sintering (mm). The length of the samples was measured using digital Vernier caliper. The porosity of the porous ceramic was determined based on the Archimedes' principle by using water as the immersion liquid. The microstructures of sintered samples have been observed and measured the pores sizes by using Scanning Electron Microscope (SEM). Meanwhile, the compressive strength was measured used the Universal Strength Test Machine Instron 5585 with the speed rate of 0.5 mm/min. Three samples had been used in determining the average of linear shrinkage, porosity and mechanical properties of the samples.

3. RESULTS AND DISCUSSION

3.1 Linear shrinkage

The result of average linear shrinkage of different weight percentage of yeast content (0, 10, 15 and 20 wt.%) is shown in Figure 1. Based on this graph, the average linear shrinkage is increased with the increment of weight percentage of yeast content. The shrinkages of sintered samples changed from 1.63% with the absence of yeast up to 6.66 %, when the 20 wt.% of yeast was added into the mixture. The increment in average linear shrinkage is attributed to the porosity and the pores size of the samples [18]. This result is in line with finding from Ali et. al. [18] where the linear shrinkage of alumina ceramic increases with the increasing amount of pore-forming agent used.

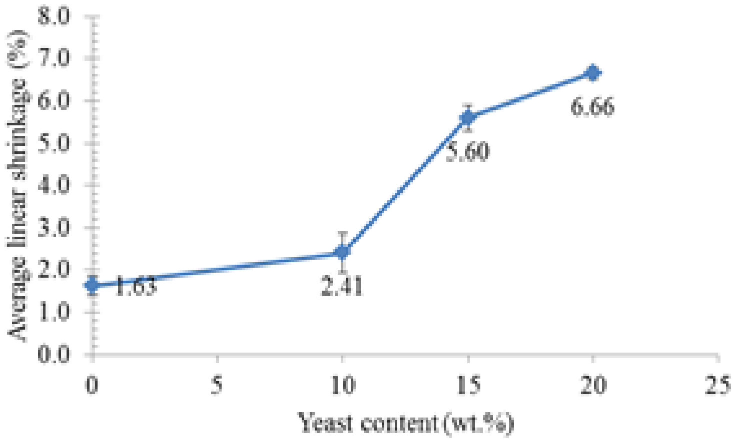

Figure 1 Average linear shrinkage against weight percentage of yeast content

3.2 Apparent porosity

Figure 2 shows the graph of apparent porosity against different weight percentage of yeast content. As shown in Figure 2, the apparent porosity has increased with the increment of 0 to 20 wt.% yeast content in the ceramic material. Thus, given the maximum of apparent porosity at 46.54%, the maximum apparent porosity can be achieved at yeast content of 20%. Obvious increment can be seen between the absence of yeast and 10 wt.% of yeast content from 35.46 to 45.00% and continues to be increased slightly (very small increment) after 10 wt.% of yeast content. According to Rahman and Guan [19], open porosity alumina foam is proportional with the increased of total porosity [22,23].

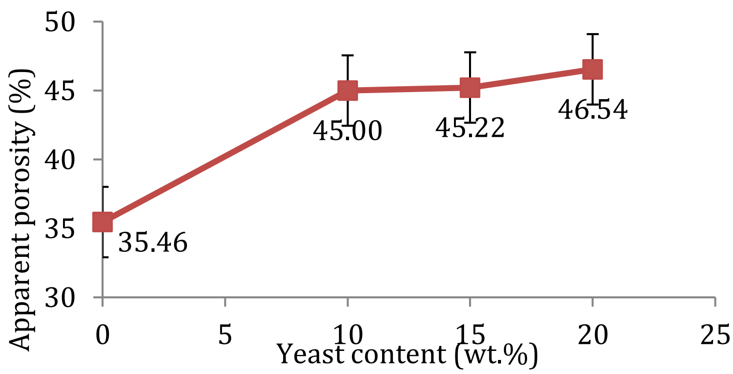

Figure 2 Apparent porosity of different weight percentage of yeast content

3.3 Macrostructure and pores size analysis

Figure 3 shows the macrostructure of 0, 10, 15 and 20 wt.% of yeast content under magnification of 75x and 750x. Based on this figure, it is clearly seen that 20 wt.% of yeast content gave the highest pores size compared to 0, 10 and 15 wt.% of yeast in the ceramic. The absence of yeast as the pore-former in the porous ceramic resulted to the irregular and smaller size of pores in the samples. When the yeast was added, the size of pores grew bigger and oval-like compared to the absence of pore former. Meanwhile, the shape and the structure of the pores is the same group with open-celled structure which have open pores and struts. This finding is similar to the research have done by Rahman and Guan [19] who also used yeast as pores forming agent in their preparation of porous mullite-corundum ceramic. From their result, the absence of yeast gave irregular pores arrangement in mullite-corundum ceramics compared to regular oval like pores when the yeast was added [11,20,21].

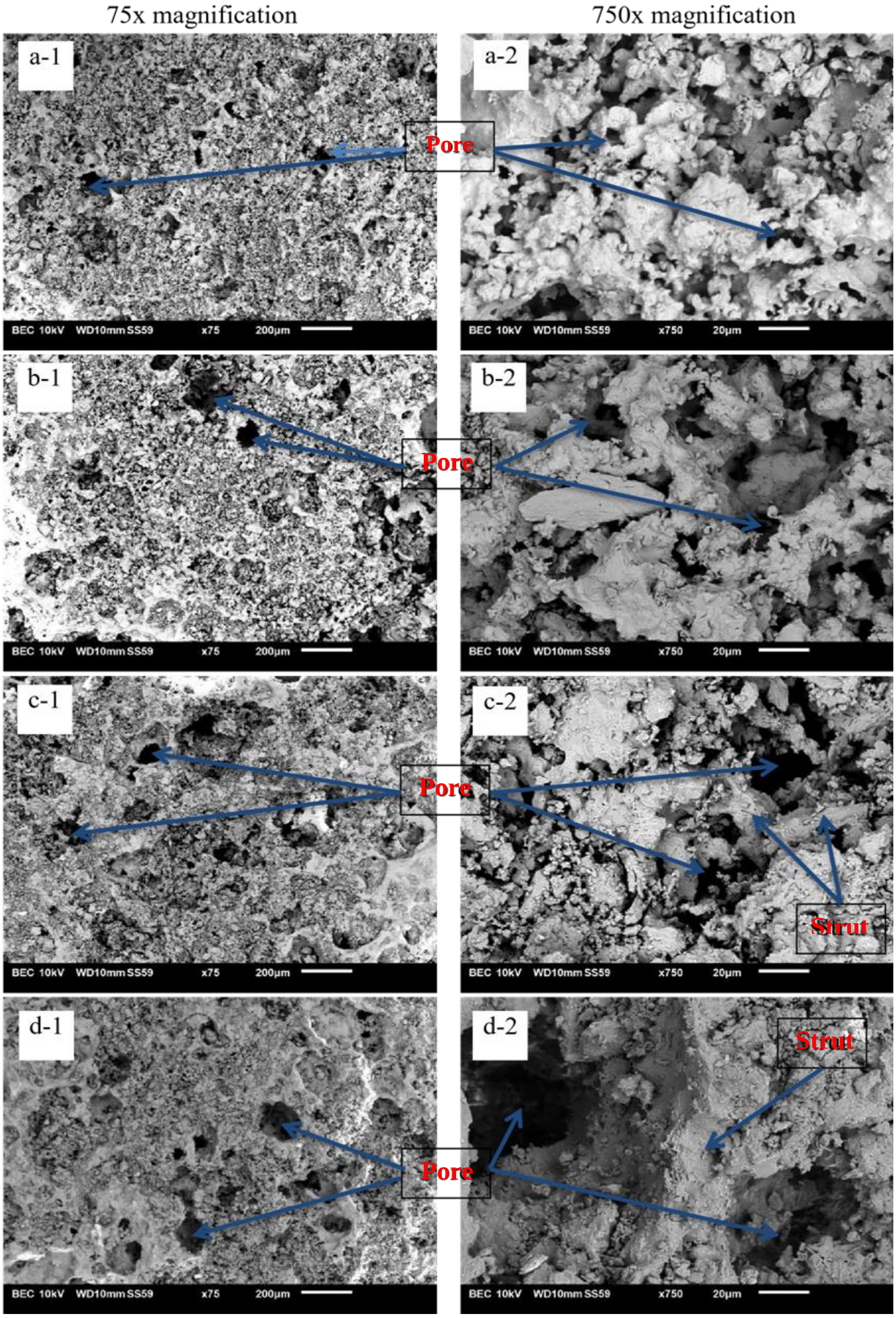

Figure 3 Macrostructure of sintered porous ceramic: (a) 0 wt.%, (b) 10 wt.%, (c) 15 wt.% and (d) 20 wt.% at 75x and 750x magnification by using scanning electron microscope (SEM)

Besides that, the average pores size increased with the increment amount of yeast in the porous ceramic which were up to 194.297 μm for 20 wt.% as shown in Figure 4. It was increased clearly between 0 and 10 wt.% of yeast content from 49.814 μm to 131.945 μm and continues to increase constantly about 30 μm after 10 wt.% of yeast content which were 166.108 μm (15 wt.%) and 194.297 μm (20 wt.%). The type of pores for this ceramic materials is macropores which have pores size larger than 50 nm (>50 nm).

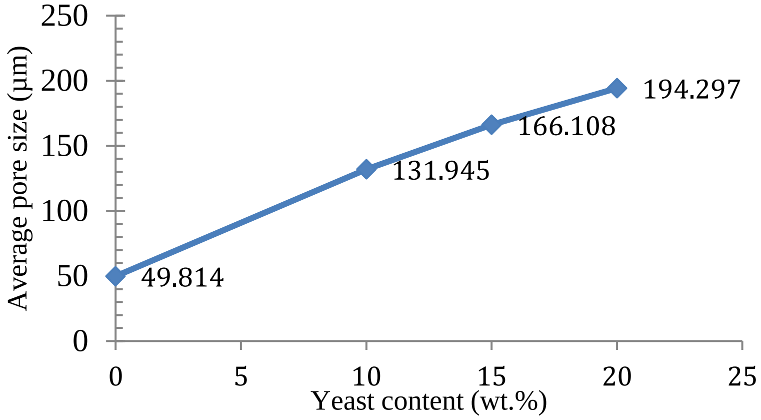

Figure 4 Average pore size against weight percentage of yeast content

3.4 Compressive strength and apparent porosity

Figure 5 shows the effect of different weight percentage of yeast content on apparent porosity and compressive strength of porous ceramic. The result shows that, the average compressive strength of 0 wt.% of yeast in the sintered ceramic is significantly higher which is 17.47 MPa, followed by 10 wt.% yeast (14.50 MPa), 15 wt.% yeast (10.80 MPa) and 20 wt.% yeast (10.66 MPa). In other words, the compressive strength is inversely proportional with the increasing amount of yeast in the porous ceramic material.

However, this contradicts when the amount of yeast content with the increment from 0 up to 20 wt.% where the apparent porosity increased gradually. These results are aligned with findings from Meille et al. [2] who stated that the mechanical strength of the material degrade with the increasing amount of porosity [2,2]. Moreover, the mechanical strength of porous ceramic also depends on their size and microstructure of the pores and struts [20,23,24,25]. If the thickness of the struts is lower and pore size is higher, the mechanical strength of ceramic body will be lower. This is due to the higher porosity of the ceramic body [26,27].

Furthermore, this finding shows the better result than the finding done by Rahman and Guan [19] whose applied yeast in the fabrication alumina-zeolite foam. From the result of their research, the mechanical strength for 50 vol.% of alumina showed 0.47 MPa, with 40% apparent porosity by using 30% yeast. Meanwhile, in this research, yeast is used as pores agent formation and with present of zeolites in their structure as carbon dioxide adsorption. With the increment of average apparent porosity and pores size, the volume of carbon dioxide can also be increased. It was found that 20 wt.% of yeast content suitable to be applied in producing these ceramic materials as carbon dioxide filter.

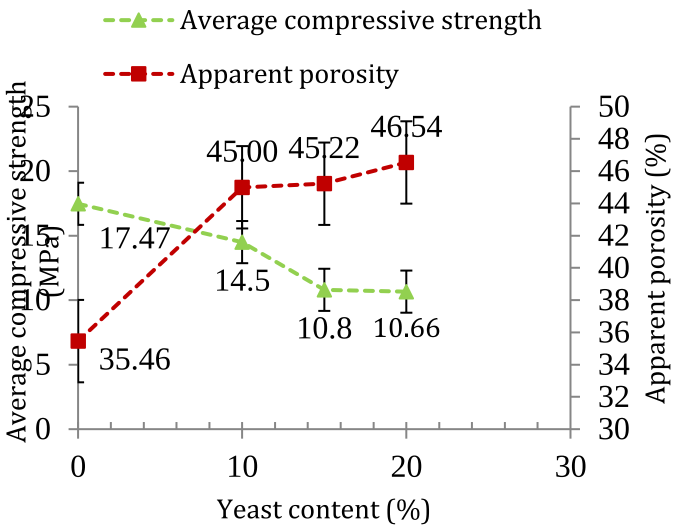

Figure 5 Relationship between average compressive strength and apparent porosity as functions of yeast content

4. CONCLUSION

As a conclusion, macroporous ceramic material was successfully produced by using yeast as pores forming agent. Yeast was used by varying the weight percentage of its content in the ceramic materials with alumina, zeolite and calcium oxide used as the main raw materials. From the finding of this research, it can be concluded that:

- The average linear shrinkage increased with the increment of weight percentage of yeast content from 1.63% to 6.66%.
- The average apparent porosity and pore size also increased with the increased weight percentage of yeast content from 35.46% to 46.54% and 49.814μm to 194.297μm, respectively.
- The increase of porosity and pore size affect the mechanical strength of sintered porous ceramic product. The mechanical strength of 0 to 20 wt.% of yeast content in porous ceramic were decreased from 17.47MPa to 10.66 MPa which were inversely proportional to porosity and pore size.

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