



Preliminary Characterization of Corn Cob Ash as an Alternative Material for Ceramic Hollow Fiber Membrane (CHF/M/CCA)

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ABSTRACT

Currently, exchanging trends in the expensive usage of ceramic materials such as alumina, zirconia etc. into economical ceramic raw sources have been extensively studied over the last decade for various technological applications. Despite the fact that this ceramic compound or elements offer a great performance and stability, especially at high temperature, the basic commercial price and higher sintering temperature of this compound which is a little bit higher have hindered the used of these materials. Thus interest in fabricating of bio-ceramic membrane using corn cob ash (CCA), an agricultural by product not only offered the development of new low cost materials but also able to enhance better properties and performance. The suitability of corn cob ash as an alternative material for ceramic hollow fiber membrane fabrication (CHF/M/CCA) as a main substrate was investigated via combined phase inversion and sintering technique based on several controlled operating parameters. The effects of selected bore fluid (5, 10, 15 and 20 mL/min) and different sintering temperature (800 °C, 900 °C, 1000 °C, 1100 °C) towards membrane structure and properties were observed and studied. Interestingly, characterization analysis of the SEM morphology showed that the potential of the main constituents of corn cob ash which highly consisted of silica, alumina and calcium oxide are able to improve the properties of CHF/M/CCA by lowering sintering temperature (1000 °C) as compared to the standard CHF/M bodies which normally has sintering temperature higher than 1200 °C. Thus, the use of corn cob ash not only able to enhance ceramic properties but also able to reduce sintering temperature. Reduction in energy consumption with slightly reduced sintering temperature also will offer a better sustainable process through recycling abundant waste materials as well as emphasis on the green resources. With that respect, the bio-material of corn cob ash is capable to replace the commercial ceramic membrane materials for membrane applications by considering the availability of this agro waste product as the main crops in most countries in the world.

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1. INTRODUCTION

Application of ceramic membranes nowadays, has been increasing and circumvent the polymeric membranes as their better resistance over chemical attack, thermal stability and long life span. In 1966, Finnigan and Skudder [1] pioneering ceramic membrane for application of beer and recovery of extract through microfiltration process. In addition, ceramic membrane

microfiltration has been widely studied for the application of membrane support for various applications such as gas separation, photocatalytic activities [2], hybrid membrane for combine separation-adsorption application [3], membrane contactor [4] and membrane distillation [5]. For example, Huang et al. applied a coating method to prepare superhydrophobic layers on ceramic membrane from alumina for membrane distillation application [6]. Also, previous work reported on preparation of tubular porous ceramic membrane from alumina through a phase inversion

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casting as membrane support for gas separation application [7]. However, ceramic membrane from alumina shows some drawbacks, especially in term of the cost production due to the expensive high-purity alumina [8]. Furthermore, higher sintering temperature up to 1500 °C is required by ceramic membrane from alumina, thus, making ceramic membrane extremely expensive [9].

Due to this, preparation of low cost ceramic membrane from clays and ashes from agricultural waste have attracted more attention as these natural materials highly consisted potential minerals that can be extracted at lower sintering temperature. Traditionally, a low cost ceramic membrane prepared from clay and starch as the main raw material and pore agent, and recently has been further investigated by Lorente-Ayza et al. [10]. In 2016, Hubadillah et al. [11] have prepared low cost ceramic membrane from kaolin clay through phase inversion and sintering technique by investigating the effect of kaolin content and particle size. Unfortunately, it should be mentioned that the world generated millions of tons of agricultural waste every day, i.e rice husk, corn cob, palm oil, sugar cane etc. These ashes if disposed of to open field causing traffic hazard besides the potential of health hazard leading to bronchi and lung disease [12, 13]. These abundant of unused agrowaste was burned in a boiler to produce or generate an energy. A recent work by Hubadillah et al. [11] on preparation of novel green ceramic membrane derived from rice husk ash which is highly consisted of silica have reported to be membrane adsorbent-separator for efficient heavy metal removal [3]. For instance, rice husk ash was reported to be used in porcelain body by incorporating 25% as a substitute of quartz [14]. Also in other application, activated carbon derived from an agricultural sugarcane bagasse waste was applied for adsorbing lead ions from wastewater [15].

Herein, we report on the potential of green corn cob ash as an alternative material for ceramic hollow fibre membrane (CHFM/CCA) prepared via phase inversion and sintering technique. Corn cobs also considered as a major agricultural waste from corn production [16]. It contains about 35 % hemicellulose, 45 % cellulose and 20% lignin. When turned into corn cob ash (CCA), it contains >60 % silica by mass with minor amounts of metallic elements. From literatures, CCA has been widely used as pozzolan in blended cement [17, 18]. Considering this, CCA pozzolanicity was proven can meet the demands requirement on the strength activities [17, 19]. CCA also have been used as a supplementary replacement material that able to improve compressive strength and workability of cementitious sample [20, 21]. Besides the above advantages, the effects of bore fluid flow rate and sintering temperature towards ceramic membrane with corn cob ash structure and properties were also investigated.

2. EXPERIMENTAL

2.1. Materials Briefly, the corn cob waste was first burned in a kiln furnace (Germany) at 700 °C for 8 hours at a heating rate of 10 °C/min to get a CCA powder, which then was ball milled and sieved to get uniform size of 25 µm. Arlacel P135 (Polyethyleneglycol 30 Dipolyhydroxystearate, CRODA) is used as dispersant (1 wt-%), N-methylpyrrolidone (NMP, QRċ™) solution as solvent, Polyethersulfone (PESf) (Radel A300, Ameco Performance, USA) as a polymer binder were used in dope suspension preparation.

2.2. Ceramic Hollow Fiber Membrane based Corn Cob Ash (CHFM/CCA) Fabrication

Prior to ceramic suspension preparation, 1 wt-% of Arlacel P135 was added to 51.5 wt% of NMP and gently stirred, then followed by the addition of CCA powder (42.5 wt%) into the mixture and milled for 48 hour at 15 Hz. 5 wt-% of PESf was then added to the mixture and continuously milled for 48 hour. The prepared suspension was degassed for 10 min and instantly transferred into stainless steel syringes. The CCA suspension was extruded through the spinneret (outer diameter: 2.8 mm and inner diameter: 1.2 mm) at a constant flow rate of 10 mL/min, as tap water was used as an internal coagulant bath with varying bore fluid at 5, 10, 15 and 20 mL/min by a syringe pump (PHD 2000, Harvard Apparatus). After the overnight immersion, the precursor fibers were rinsed off and cut into 20 cm length and dried at ambient temperature for 2–3 day, followed by the sintering process at a heating rate of 2 °C/min up to 600 °C, at which the temperature was kept constant for 2 hour to remove the polymer binder. The temperature was then increased to 800 °C, 900 °C, 1000°C and 1100 °C at a rate of 5 °C/min, and was held for 3 hours. Finally, the temperature was brought down to room temperature at a rate of 5 °C/min.

2.3. Characterizations The thermal gravimetric analysis (TGA) and derivative thermo-gravimetric (DTG) of raw corn cob (RCC) was studied using a Thermal Gravimetric Analyzer (TGA, Model Linseis, Germany) performed in the temperature range of 24 °C–1000 °C at a heating rate of 10 °C /min. Fourier transform infrared spectroscopy (FTIR) of CCA powder was performed using Spectrum One FTIR Spectrometer (PerkinElmer), in the wavelength range of 600 to 4000 cm⁻¹. Scanning electron microscope (Hitachi SU1510) and atomic force microscope (AFM, PARK XE-100) were used to observe the structural and topography morphology of the CHFM/CCA membrane. The rheological behavior of membrane suspension was analyzed using NDJ-9S Digital Rotary Viscometer. The mechanical strength of CHFM/CCA membrane was

examined by a three-point bending test via an Instron Model 5544 tensile tester provided with a load cell of 1kN and calculated using following Equation (1). CHFMs/CCAs were fixed on the sample holder at a 43mm distance.

$$\sigma_F = \frac{8FLD_o}{\pi(D_o^4 - D_i^4)} \quad (1)$$

where F is the measured load at which fractures occur (N), L is effective membrane length (m), and D_o and D_i are the outer and inner diameter (m) respectively.

3. RESULTS AND DISCUSSION

3.1. Characterizations of Waste Raw Corn Cob (RCC) and Corn Cob Ash (CCA)

Commonly, waste raw corn cobs are lignocellulosic material which composed of cellulose, hemicellulose and lignin [22] that can be decomposed by heating process. Owing to that, the thermal decomposition behavior of waste corn cobs was studied by thermal gravimetric analysis (TGA), as shown in Figure 1 (a). TGA graph indicates that there are three stages of corn cob weight loss took place, as the initial decomposition occurs with optimum moisture removal at about 102.9 °C by 10.94 % mass loss, with derivative weight loss of 0.054 mg/°C. Indeed, it should be noted that an increase in moisture content will increase the biodegradation rate of organic materials as more energy are needed for the vaporization of the moisture during the heating process.

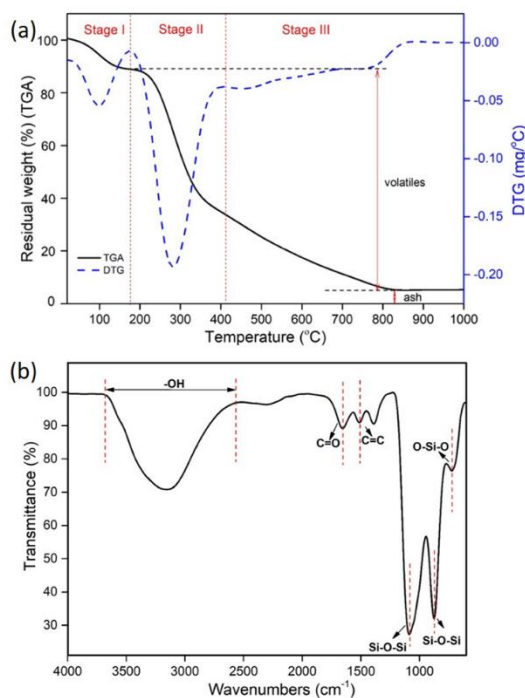


Figure 1. (a) TGA-DTG of RCC and (b) FTIR peak of CCA

As for the second stage, hemicellulose started to decompose at 180 °C to 400 °C by 53.98 % of mass loss, with derivative weight loss of 0.19 mg/°C at 285.9 °C. It was observed that at lower temperature, hemicellulose is easier degraded to volatiles such as carbon monoxide (CO), carbon dioxide (CO₂), and some hydrocarbon, as it be made up from an amorphous carbon structure of linear polymer structure with short side chains [17]. A weight loss occurred at 400 °C to 826.85 °C is noticeable as the degradation cellulose by 29.89 % of mass loss. Boonyisa et al. [23] reported that cellulose is mainly consists of semicrystalline arrangement chains which usually identified as a strong structure. Whereas for lignin, it was gradually decomposed at 170 to 826.85 °C as it is more thermally stable eventhough undergoing a pretreatment apartness to cellulose and hemicelluloses, also known as heavier volatiles component [24]. Previously in a work by Wanitwattanarumlug et al. [25], reported that lignin was the most rigid to decompose due to the complex structure of phenolic polymer covering the polysaccharides of the cell walls that produced durable and strong composite material.

Figure 1 (b) shows FTIR bands of produced CCA powder. The broad band around 3185 cm⁻¹ is belongs to O-H bond stretching vibration from the silanol group (Si-OH) substantial from the water molecules absorption on the silica. Whereas, peak at 1517 cm⁻¹ is referred to the carbonyl groups stretching (hemicellulose and lignin) and 1604 cm⁻¹ is referred to the C-O stretching vibration in cellulose, residual hemicellulose and lignin. In addition, peak at 1091 cm⁻¹ is owing to the asymmetric stretching vibration of the siloxane bonds (Si-O-Si), whereas peak at 879 cm⁻¹ is assigned to the network Si-O-Si symmetric bond stretching vibration. Whereas, the band at 729 cm⁻¹ is associated with network O-Si-O bending vibration modes [17, 26].

3.2. Membrane Suspension Viscosity

Basically, the rheology of polymer and particle suspensions plays an important role in controlling the formation of membrane end structure. As for ceramic membrane fabrication process, ceramic powders (distribution, particle shape and particle size) are the most significant component in the spinning suspension to predesign the membrane morphology and facilitate the spinning and dry-phase inversion process in obtaining the hollow fiber configuration. [27]. Prior to the spinning process, the rheological behaviour of produced CHFMs/CCA suspension was studied via viscometer within the range of 1 and 100 s⁻¹ at room temperature. This viscosity behavior is important to establish spinnability with an appropriate flow ability of the ceramic suspension in producing continuous spun membrane during the spinning of CHFMs/CCA membrane to circumvent

breaking up into droplets. Theoretically, a finger-like formation occurred due to less viscous fluid (non-solvent) comes into contact with highly viscous fluid of ceramic suspension [28].

As illustrated in Figure 2, the viscosity decreases as the shear rate is increased which indicates that the non-Newtonian or the pseudo-plastic flow behavior. It is also similarly has been reported by Kingsbury [28], the finger like structure was formed by determined at a shear rate of 30 s^{-1} as their critical viscosity is 12.1 cP using the alumina suspension, which established as the threshold value for the formation of finger-like void in the membrane morphology. Nevertheless, the obtained critical viscosity of CHF/CCA suspension is 6804.4 cP which beyond above from 12.1 cP that has hindered the viscous fingering mechanism and slightly small finger-like structure was occupied within the CHF/CCA body as supported in the SEM morphology in Figure 3.

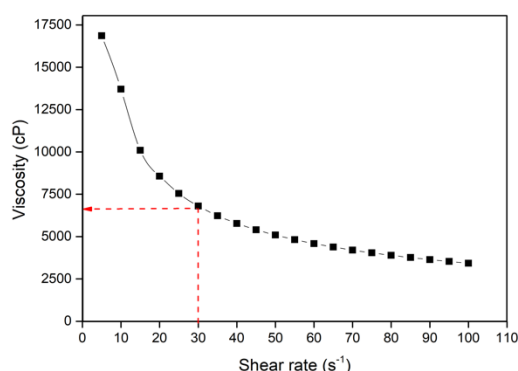


Figure 2. Rheological behaviour of dope suspension containing CCA/NMP/Arlacel P135/PESf

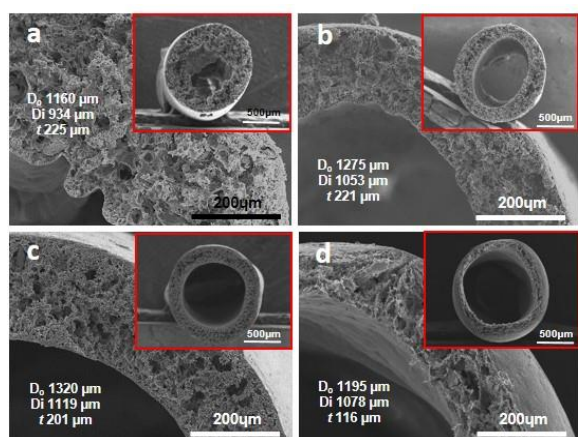


Figure 3. CHF/CCA precursor membrane with different bore fluid flow rate; a) 5 mL/min, b) 10 mL/min, c) 15 mL/min and d) 20 mL/min. Scale bar, $200\mu\text{m}$ ($200\times$ magnification) and insets are the corresponding low magnified images $500\mu\text{m}$ ($70\times$ magnification)

3. 3. Bore Fluid Flow Rate Control Towards CHF/CCA Morphology

It has been suggested that the internal coagulant flow rate has correlation towards the membrane morphology of finger like and sponge like voids, also the formation and elimination of isolated and encapsulated voids [28]. Therefore, the spinnability of the ceramic particle suspension should be observed at an applicable bore fluid flow rate. In order to achieved that, extruded fiber membrane with different bore fluid flow rate, i.e. 5, 10, 15 and 20 mL/min have been conducted as depicted in Figure 3.

At this CHF/CCA suspension viscosity revealed the small finger-like void formation at the inner contour, due to less viscous fluid (non-solvent) comes into contact with highly viscous fluid of ceramic suspension [28]. Despite inducing the sponge-like formation of all fibers at different bore fluid flow rate (i.e. 5, 10, 15 and 20 mL/min). Also, it is identified that the distortion of inner contour was remarked for the fiber formed at a low bore fluid flow rate of 5 mL/min and 10 mL/min CHF/CCA fiber, which are initiated by the shrinkage of the nascent fiber that resulted from the inward radial force due to the solidification rate and hydrodynamic forces.

In the cases of low bore fluid flow rate (5 and 10 mL/min), it was unable to sustain a sufficient hydrodynamic force against the ceramic suspension during spinning and affect the inner bore shape formation. According to by Kingsbury and Li, insufficient demixing at low flow rate lead to the polymer incomplete solidification of near the fiber inner surface that unable to sustain inward radial forces which produced an incomplete fiber inner contour [28]. On the contrary, a more rigid lumen skin was formed due to sufficient demixing and complete solidification of polymer near the inner surface as increasing bore fluid flow rate to 15 and 20 mL/min which resulted in a fully circular contour as depicted in Figures 3c and 3d, but it is only distinguished by the fiber thickness (t) and fiber dimensional diameter (outer diameter, D_o and inner diameter, D_i) as the membrane D_o decreased from $1320 \mu\text{m}$ to $1160.00 \mu\text{m}$. From the observation, increasing of bore fluid flow rate has an effect on the fiber dimensional thickness as it is also increased. Interestingly, it is noticed that during the suspension preparation, ash starch gelatinization promotes viscous suspension eventhough at the use of lower solid particle loading which has caused the inflexibility of membrane suspension spinnability. Thus, it has limited the use of corn cob ash in membrane fabrication and suggested to be modified and treated. Figure 4 illustrates the SEM images of CHF/CCA with different bore fluid flow rate after sintered at $1000 \text{ }^\circ\text{C}$. From the observation of morphology and dimensional changed as compared to the green fiber body, the sintered fibers were

significantly shrunk and obtained radial shrinkage due to the particle diffusion of the loose particle in precursor membrane structure (as shown in Figure 3). The sintered membrane was attributed to a very smaller size of fiber due to the excessive shrinkage which occurred after the water and binder removal, starch decompose and also the diffusion mechanism during the sintering process and yet the membrane was unable to sustain the membrane shape. Thus, due to this limitation in preparing the sintered membrane to be fixed in the testing apparatus, the membrane performance; contact angle and water permeability were unable to be conducted and reported. As for concern, starch removal of corn cob ash has been conducted to analyze the membrane performance and morphology and will be reported in the afterward finding paper.

3. 4. Sintering temperature Control Towards Membrane Morphology Structure and Membrane Strength

Sintering temperature have a significant effect on the densification of the porous CHF/CCA microstructure. To assess the sintering behavior of newly developed membrane, CHF/CCA fiber with 15 mL/min of bore fluid flow rate had undergone the sintering process at different sintering temperature; i.e. 800 °C, 900 °C, 1000 °C and 1100 °C as represented in Figure 5. It was reported that an increase in larger particle sizes inhibit open porosity formation [29]. As the sintering temperature increased, the densification of sponge-like structure has led to the decrease in porosity. The gradual growth of sintering neck contributes to the enhanced mechanical strength. As CHF/CCA sintered at relatively low temperature of 900 °C, the neck formation between the contacting grains of dried CHF/CCA membrane was observed during the sintering process.

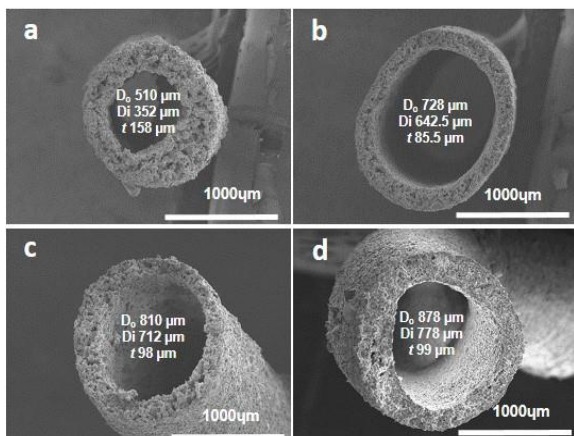


Figure 4. Cross sectional morphology of CHF/CCA membrane sintered body (at 100x magnification) with different bore fluid flow rate; a) 5 mL/min, b) 10 mL/min, c) 15 mL/min and d) 20 mL/min

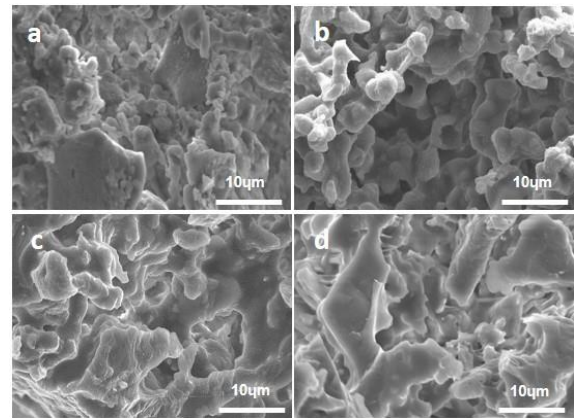


Figure 5. Cross sectional morphology of CHF/CCA sintered body (3000x magnification) at different sintering temperature; a) 800 °C, b) 900 °C, c) 1000 °C and d) 1100 °C

When the CHF/CCA was sintered at temperature above 800 °C, the grain boundary diffusion occupied and induced the neck formation, followed by the grain growth formation. Further densification by increasing sintering temperature promotes the continuous pores shrinkage and induced the pores elimination as shown in Figures 5c and 5d. Besides, the irregular form granules and the shape angles of corn cob ash particle is melting away as the sintering temperature increased up to 1100 °C. Over sintered up to 1200 °C has led to the CHF/CCA melting condition, which indicate that this newly developed material can be practically used at a low sintering temperature without sacrificing the mechanical strength.

In this study, CHF-metakaolin membrane that sintered at 1000 °C is represent as a standard sample and displayed in Figure 6. At this sintered body, it is observed that CHF-metakaolin membrane structure is still in loose powder form and the consolidation of ceramic particles was not fully take place within the matrix body. Indeed, this membrane need a higher sintering temperature for consolidating ceramic particles and permits the necks growth to form a continuous solid particles network. As for the CHF/CCA membrane induces a better stacked or closed particles uniform structure even though sintered at lower temperature (1000 °C).

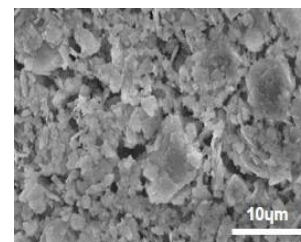


Figure 6. Morphology of CHF-metakaolin membrane sintered at 1000 °C

Therefore, CHFMs-metakaolin is not practically to be used for membrane applications due to brittle property and structure as compared to the CHFMs/CCA membrane that proven permits a bonding structure at lower temperature as shown in Figure 5c, showing the growth and necking particles indicate the diffusion mechanism has occurred that lead to the consolidation membrane structure.

Eventually, the mechanism of compacted loose particles of green body can be forming by the thermal consolidation during the sintering process. Therefore, sintering stage in membrane formation is undertaken to develop its strength by consolidating the ceramic component structure [30]. Figure 7 illustrates the mechanical strength of the prepared CHFMs/CCAs at different sintering temperature (800 °C, 900 °C, 1000 °C and 1100 °C).

The result showed the significant mechanical strength was increased from 9.87 MPa to 24.91 MPa with membrane sintered at 800 °C and 900 °C. This increased strength is due to the existence of diffusion mechanism involves in the membrane body that sintered at 900 °C as compared to the loose particles of membrane which sintered at 800 °C (as shown in Figures 5a and 5b). As for membrane sintered at 1000 °C and 1100°C, the strength is increased as given by 29.44 MPa and 31.35 MPa. It is noted that, further increasing sintering temperature of 1000 °C up to 1100°C promotes the diffusion between each particle during the consolidation in the firing stage leads to the stack of particles binding together. Hence, the strength of the sintered body is increased due to the bonding and growth of necks between the particles. Unfortunately, the loose particles behavior of metakaolin-membrane has hindered the strength testing for this standard controlled membrane sample.

3. 5. Surface Morphological and AFM Topography Properties of Ceramic Hollow Fiber Membrane (CHFMs/CCA)

Figures 8 (a-d) and 8 (A-D) displays the SEM morphology and AFM image of the outer surface of prepared CHFMs/CCA membrane. As shown in the sintered membrane surface topograph, the membrane that sintered at 1000 °C has the smoothest surface ($Ra=0.129\mu\text{m}$), whereas CHFMs/CCA membrane sintered at 800 °C has roughest surface ($Ra=0.992\mu\text{m}$).

Indeed, membrane surface with sintering temperature at 800 °C and 900 °C are slightly rougher that show higher existence of darker region that represent the valleys and slope, which able to describe the appearance of the bigger surface porosity on the membrane. Thus, smaller value on the membrane surface roughness that sintered at slightly higher temperature, 1000 °C indicates a better particle packing density and reduction of porosity formation.

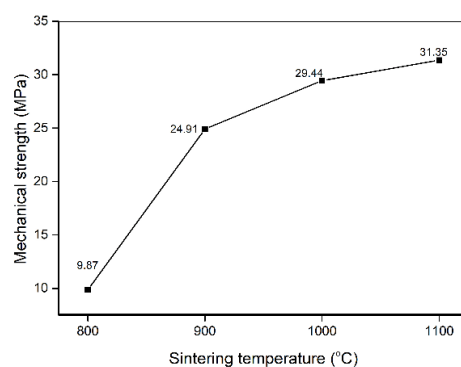


Figure 7. Mechanical strength of CHFMs/CCA membrane prepared at different sintering temperature (800 °C, 900 °C, 1000 °C and 1100 °C)

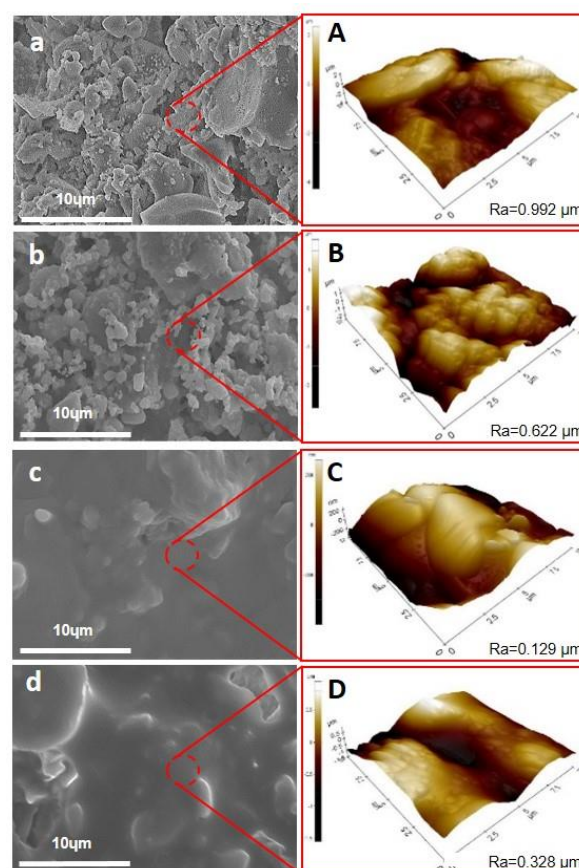


Figure 8. Surface morphology and AFM membrane surface roughness of CHFMs/CCA, sintered at (a-A) 800 °C, (b-B) 900 °C, (c-C) 1000 °C and (d-D) 1100 °C

This can relate to the surface diffusion mechanism that can be occurred faster and better indirectly induces better mechanical strength. Moreover, it was noticed that the interconnected pore formation of the membrane surface happened at sintering temperature of 900 °C and above. Also, membrane surface porosities are

significantly reduced when increasing sintering temperature and an obvious change in the surface morphology take place at about 1000 °C and becomes almost fully dense as displayed in Figure 8c.

4. CONCLUSION

A newly developed of corn cob ash (CCA) as an alternative material for ceramic hollow fiber membrane was successfully reported. Interestingly, from the preliminary characterization study, CCA has a great potential to practically used as raw main substrate with low sintering temperature (1000 °C) which indirectly able to reduce energy consumption. From the findings, due to remaining ash starch that cannot easily eliminated is able to create gelatinization into membrane suspension which put some membrane fabrication constraints in facilitating the spinnability of suspension. Thus, CCA treatment needs to be attempted and will be reported in the next further detail investigation that will be carried out to ensure the applicability and suitability of this proposed materials towards membrane applications. Thus, by utilising corn cob ash as the low cost ceramic material, it could successfully overcome the issue of significantly higher production cost of ceramic membrane. Knowing that, this corn cob waste has transformed into valuable and useful material, especially in membrane applications.

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Preliminary Characterization of Corn Cob Ash as an Alternative Material for Ceramic Hollow Fiber Membrane (CHFMC/CCA)

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اخیراً، روند استفاده از مواد سرامیکی گران قیمت مانند آلومینا، زیرکونیا و غیره که در دهه گذشته برای کاربرد های مختلف فن آوری مورد مطالعه قرار می گرفته است، به منابع خام سرامیکی مقرون به صرفه تغییر یافته است. با وجود این که این ترکیب سرامیکی یا عناصر عملکرد خوب و ثابتی را به ویژه در دمای بالا ارائه میدهند، قیمت پایه تجاری و درجه حرارت بالای پخت این ترکیبات که کمی بالاتر است، مانع استفاده از این مواد شده است. بنابراین علاقه به ساخت غشای بیومتری سرامیکی با استفاده از ضایعات کشاورزی خاکسترچوب ذرت، نه تنها توسعه مواد جدید کم هزینه را ارائه می دهد، بلکه قادر به بهبود خواص و عملکرد آنها نیز می باشد. مناسب بودن خاکستر ذرت به عنوان یک ماده جایگزین برای تولید غشای فیبر توخالی سرامیکی (CHFMC / CCA) به عنوان یک بستر اصلی، از طریق روشهای مختلف پخت و فازی معکوس بر اساس چند پارامتر عملیات کنترل شده مورد بررسی قرار گرفته است. اثرات فلوید بور انتخاب شده (۵،۱۰،۱۵ و ۲۰ میلی لیتر در دقیقه) و دمای پخت متفاوت (۸۰۰، ۹۰۰، ۱۱۰۰ درجه سانتیگراد) به ساختار و خواص غشا مشاهده و مطالعه شده است. جالب توجه است که، تجزیه و تحلیل مورفولوژی SEM نشان میدهد که پتانسیل اجزای اصلی خاکستر ذرت که از سیلیس، آلومینا و اکسید کلسیم تشکیل شده است قادر به بهبود خواص سرامیکی بهتر بلکه قادر به کاهش درجه حرارت پخت ۱۰۰۰ درجه سانتیگراد در مقایسه با استاندارد CHFMC که به طور معمول دارای دمای پخت بالاتر از ۱۲۰۰ درجه سانتیگراد است. بنابراین، استفاده از خاکستر ذرت نه تنها قادر به بهبود خواص سرامیکی بهتر بلکه قادر به کاهش درجه حرارت پخت است. کاهش مصرف انرژی با کاهش دمای پخت و نیز پایداری بهتر فرآیند را از طریق بازیافت مواد زائد و تأکید بر منابع سبز ارائه می دهد. با توجه به دسترسی این ضایعات زراعی کشاورزی به عنوان محصولات اصلی در اکثر کشورهای جهان، مواد زیستی خاکستر ذرت قادر به جایگزینی مواد غشایی سرامیکی تجاری برای کاربردهای غشایی هستند.

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