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FABRICATION OF AEROGEL FROM KOMBUCHA BACTERIAL CELLULOSE: INVESTIGATION OF SOME PROPERTIES

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ABSTRACT

Aerogels with large surface area, are very light related to the filling of pores with air (99%). Due to these features scientific studies on aerogels have increased at great speed. Aerogels are obtained using many materials as inorganic substances like silica as well as cellulose as biodegradable organic polymers. Bacterial cellulose is eco-friendly material, and it can be produced in economic ways with simple processes.

The aim of this study is to investigate the importance of the bacterial cellulose obtained by Kombucha scabby in order to fabricate aerogels with some properties such as heat resistance and swelling features. Kombucha bacterial cellulose has been produced to obtain heat resistance property by simple diffusion method. The characteristic property of the obtained aerogels was investigated by SEM and TGA. The results of this work showed that, the resistance of the bacterial cellulose aerogels increases the degradation temperature. This study showed that Kombucha bacterial cellulose can economically be obtained by simple techniques and use in different fields of aerogels as eco-friendly raw materials.

Keywords: Aerogel, Kombucha scoby, Bacterial cellulose, Thermal properties.

INTRODUCTION

Nowadays, scientific studies focus on the production of environmentally non-hazardous, functional materials. Environmental protection requires limitation of synthetic plastics usage; therefore, scientists try to find out and develop alternative materials. Especially, ecologically non-hazardous materials are preferred instead of petroleum-based synthetic plastics in order to reduce the pollution and wastes. For this reason, the production of new kinds of materials with excellent properties and reusable performance is gaining importance for their wide application. Recently, the use of cellulosic materials in the fabrication of eco-friendly products is becoming more popular (Bandyopadhyay, and Brodnjak, 2018). Several structural bioplastics with various properties were introduced and the most popular ones are based on cellulosic derivatives. It is known that cellulose which is the most abundant natural polymer obtained from renewable sources such as plants is not degradable without appropriate enzymes (Gironi, and Piemonte, 2011). In addition to the sources of plants' cellulose can be produced by some species of bacteria, fungi, seaweed.

Bacterial Cellulose (BC) is a biopolymer with several advantages over vegetal cellulose, such as purity, permeability of liquid and gases, strong mechanical property, high porosity, absorption capacity of water. There are many research articles in the literature to produce bacterial cellulose (Portela, Leal, Almeida, and Sobra, 2019; Zhang et al., 2019; Luo et al., 2019). BC can be modified to acquire antibacterial response and it can be used for the drugs delivery systems (Portela et al., 2019). Zhang described a new strategy to produce bacterial cellulose by fermentation in the presence of Ca-alginate and they obtained a new material with different pore sizes (Zhang et al., 2019). Luo and co-workers produced flexible, highly conductive and strong bacterial cellulose from graphene nanosheets (Luo et al., 2019). Oui and Netravali reviewed various fabrication methods of bacterial cellulose based on nanocomposites and their novel applications (Qiu and Netravali, 2014). Volova et

al. in 2018, prepared a thin layer of bacterial cellulose which was then coated with Ag nanoparticles and antibiotics and they observed its bacterial growth capacity (Volova et al., 2018). Wang et al., prepared a review articles to discuss the production of Bacterial cellulose and they explained their properties and applications, (Wang, Tavakoli, and Tang, 2019). Wake and co-workers fabricated biodegradable polymer foams for tissue engineering applications (Wake, Gupta, and Mikos, 1996). Pure cellulose is obtained from fermented Kombucha tea after being washed under proper alkali conditions to remove nutriments and microbiological organisms (Dima et al., 2017).

In this work, Kombucha Bacterial cellulose (KBS) was produced from fermented Kombucha tea with acetic acid bacteria that lives with yeast on its leaves. Silica was added to the prepared cellulose to increase heat resistant property. The swelling behavior of the samples was investigated in distilled water.

MATERIAL AND METHODS

Preparation of Kombucha bacterial cellulose

Preparation of bacterial cellulose by using Kombucha tea black Tea leaves are first thoroughly washed to remove microbiological organisms and broken down into small pieces after washing process. It was then kept in hot water. The sugar (%10 w) was put in the hot solution and left to cool to room temperature. Acetic acid was added to the cooled tea by adjusting pH=6. Kombucha yeast and bacteria were added to the medium and cellulose was formed by waiting 7 days at 28°C. The raw cellulose was then washed to remove sugars and bacteria and to obtain pure cellulose. Fig. 1 shows the bacterial cellulose hydrogel, after washing process. After incubation process the thickness of the bacterial cellulose film reduced to 0.5cm. Following the washing treatment, all the samples were lyophilized. Labconco market free zone model lyophilizer was used in the lyophilization process during the experimental study.



Figure 1: Schematic representation of the Kombucha bacterial cellulose (KBS) preparation process

Preparation of silica-cellulose aerogels

Silica was added into the Kombucha bacterial cellulose (KBS) in order to increase its heat resistance. The mixture of Tetra Orthosilicate (TEOS)/Ethanol solution was prepared first with the ratio of 1/5 (v/v) and 50% percentage of distilled water was added. NH_3 was then added to the solution dropwise. After stirring, the solution became opaque and silicate particles were observed. Into this solution, KBS was added and the solution was kept at room temperature for 24 hours for bacterial aging then the solution was directly lyophilized.

RESULTS AND DISCUSSION

The swelling behavior of the prepared samples in distilled water was performed after lyophilization processes. Bacterial cellulose aerogel tends to swell quite well. The swelling percentages were calculated using the formula (1).

$$\text{Swelling \%} = \frac{W_{last} - W_{first}}{W_{first}} \times 100 \quad (1)$$

Where W_{last} is the weight of the aerogel after swelling and W_{first} is the weight of the dry aerogel.

The swelling results and the maximum swelling of the samples; KBS, KBS/PVA and PVA homopolymer can be observed in Figure 2.

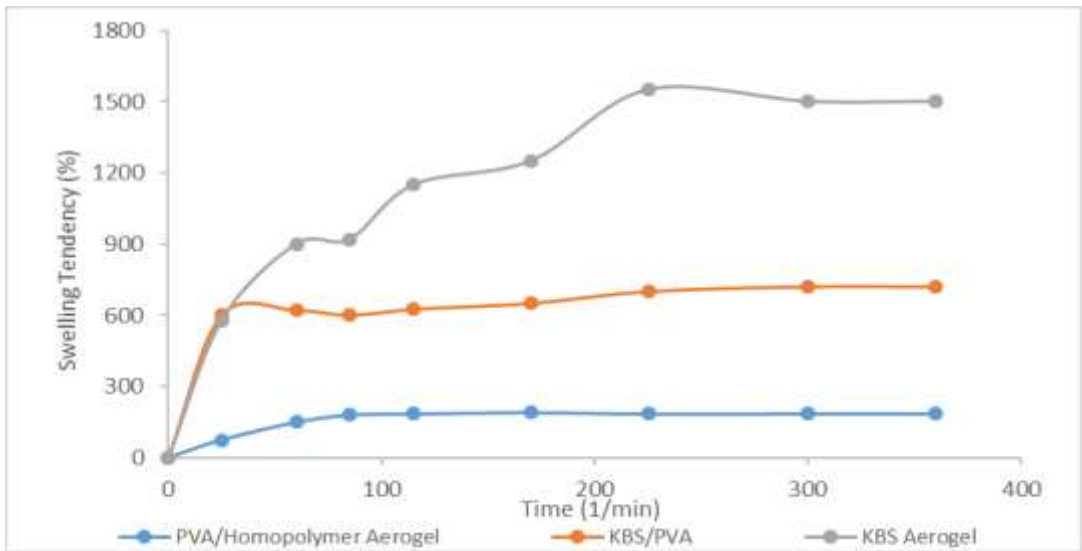


Figure 2: Swelling Tendency prepared of aerogels samples in distilled water at, 25°C

The maximum swelling percentage was obtained for KBS aerogel which is around 1550 % comparing with its original weight at initial state as seen in Fig. 2. Bacterial cellulose aerogel tends to swell quite well. KBS was added to sample based on PVA to increase its swelling behavior. From Fig.2 it can be seen that PVA-cellulose aerogel showed a better swelling property compared to PVA homopolymer.

Bacterial cellulose aerogel is a material with poor temperature resistance. Therefore, TEOS was added by sol-gel method to increase its thermal resistance. Thermal experiments showed that bacterial cellulose aerogel decompose at 400°C and at this temperature 27,7% of substance was left. After addition of TEOS the thermal decomposition temperature increased to 650 °C and 53% of the substances was left without decomposed.

SEM analysis also support the thermal resistance results. The Scanning Electron Microscope images of Kombucha bacterial cellulose prepared in this work are also shown in Figure 3(a). It is seen that silica particles are bound to bacterial cellulose fibers as seen in Fig 3(b).

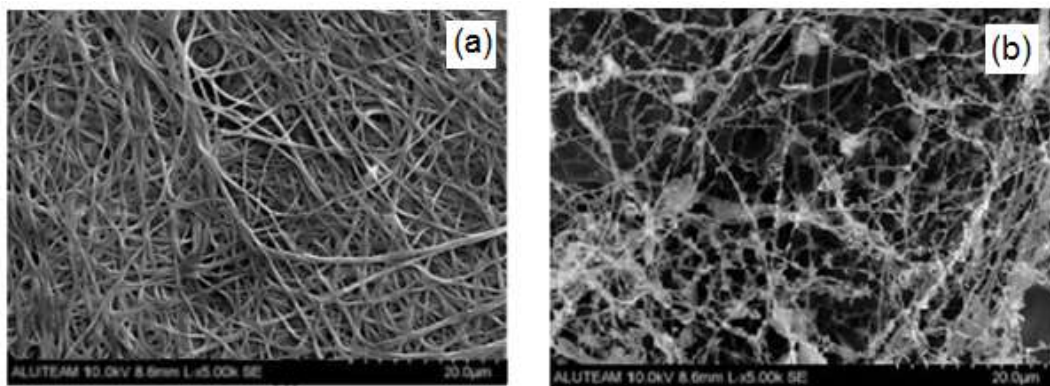


Figure 3: SEM micrographs (a) KBS Aerogel 5.0 X; (b) KBS/ Si Aerogel 5.0X

CONCLUSIONS

In the current study, Kombucha bacterial cellulose were prepared using an environmentally-friendly freeze-drying method. This method is alternatives to replace the bacterial cellulose traditionally prepared from environmental pollutants Petro-chemical products. The resultant aerogel composites were expected to show improved thermal and swelling properties. It was found that PVA-cellulose aerogel showed a better tendency to swell compared to PVA homo-polymer aerogel. It was found that the TEOS is highly effective on the improvement of thermal properties of Kombucha bacterial cellulose.

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