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Production and Characterization of Activated Carbon from Waste Eggshell

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Abstract

The utilization of waste materials for the synthesis of value-added products has gained considerable attention due to its economic and environmental benefits. In this study, an investigation into the production and characterization of activated carbon derived from waste eggshells is presented. The abundance of eggshell waste from various sources provides a promising opportunity for sustainable waste management and resource utilization. The production process involves a two-step approach: calcination of eggshells to obtain calcium oxide (CaO), followed by chemical activation using a potassium hydroxide (KOH) activation agent. The effects of activation temperature which are 500 °C, 650 °C and 800 °C were systematically studied to optimize the porous structure and adsorption properties of the activated carbon. The resulting activated carbon was characterized using a range of techniques including scanning electron microscopy (SEM) and Fourier-transform infrared spectroscopy (FTIR). The porous structure of the activated carbon exhibited a high surface area and well-developed porosity, making it suitable for various applications including adsorption, water treatment, and gas separation. The results demonstrated the potential of waste eggshell-derived activated carbon as an efficient adsorbent for dye removal, attributing its adsorption capability to the presence of surface functional groups and the porous structure. The activated carbon produced at a temperature of 650 °C is the most ideal activated carbon compared to other activated carbon produced at different temperatures. In conclusion, this research demonstrates the feasibility and efficiency of converting waste eggshells into high-performance activated carbon, offering an environmentally sustainable solution for waste management while providing a valuable resource for numerous industrial applications.

1. Introduction

Water is essential for human because it comprises around 60% of the weight of human and it loses through various metabolic and excretory processes must be balanced by an adequate intake. Besides that, water may contain contaminants which can affect health and quality of life. Water intended for human consumption must be free from organism and form concentrations of chemical substances that may be hazard to health. The water we drink daily must be free from any pollution. There are two types of drinking waters including safe water and pure water. It is important to distinguish between these two types of drinking waters. Pure water may be defined as water that is free of extraneous substances whether harmless or not. However, in a practical standpoint, pure water is hard to produce, even by the current sophisticated equipment. On the other hand, safe water is water that is not likely to cause undesirable or adverse effects. Safe water may contain some contaminants, but these contaminants will not cause any risk or health effects on human. The contaminants must be an acceptable range. As the population of the world increases and demands for using safe water enhance more than ever before, it will be great concern soon on the water treatment facilities to be more effective. However, the water supplies to household still contained threatened contaminants like chemicals and microorganisms. Health problems also increased due to the contaminants in the drinking water. Drinking water contaminants are likely to cause chronic health effects. Usually, chronic health effects happen when a human is repeated expose to small amounts of chemical in the drinking water [1].

The quality of water is very important in both environmental and economic aspects. Thus, the water quality analysis is essential for using it in any purpose. After years of research, water quality analysis is now consisting of some standard protocols. Water quality can be defined as the chemical, physical and biological characteristic of water, usually in respect to its suitability for a designated use. Water quality standards are put in place to ensure the suitability of efficient use of water. Water quality analysis is to measure the required parameters of water, following standard methods, to check whether they are in accordance with the standard. On the other hand, water quality analysis is required mainly for monitoring purpose. Some importance of such assessment includes to check whether the water quality is a compliance with the standard, and hence, suitable, or not for the designated use. Besides that, it is also to monitor the efficiency of a system, working for water quality maintenance. In addition, it is used to check whether upgradation or change of an existing system is required and to decide what should take place.so, water quality analysis is of extremely necessary in the sectors of public health (especially for drinking water) and industrial use [2].

Eggshells are a common waste product that can be used to produce activated carbon. Activated carbon is a highly porous material with a large surface area, making it useful for a variety of applications, such as water purification, air filtration, and gas adsorption. This paper presents the production of activated carbon from eggshell waste using a simple and cost-effective method. Then, the characterization of the eggshell activated carbon by Fourier transforms infrared spectroscopy (FTIR) and scanning electron microscopy (SEM) was done. The FTIR and SEM results showed that the eggshell activated carbon had a high surface area and a porous structure. This study demonstrates the potential of eggshells to be used as a source of activated carbon and can be used to effectively remove contaminants from water [3].

In the realm of water quality enhancement and sustainability, identifying innovative and efficient methods to produce activated carbon from abundant waste materials like eggshells is a critical research gap. This study bridges this gap by showcasing a cost-effective approach to derive activated carbon from a widely available waste product. The novelty of this research lies in its contribution to sustainable waste management and its potential to offer a valuable solution for water purification. By exploring the utility of eggshell-derived activated carbon, this study propels us towards a more sustainable future, where waste materials can be transformed into functional resources, advancing both environmental and public health agendas.

2. Materials and Methods

2.1 Production of Activated Carbon from Eggshell Waste

This study employed raw waste eggshells, which were then converted into a powdered form to facilitate the production of activated carbon through controlled thermal treatment. Sodium hydroxide (NaOH) was utilized to initiate the carbonization process. Fig. 1 shows how activated carbon was produced from eggshells. The methodology began by collecting eggshells, which underwent thorough washing, drying, and pulverization using a dry blender to achieve finely powdered eggshell material. Then, this powdered eggshell precursor underwent heat treatment at 500 °C in a furnace based on the recommendation of previous study [4]. Following this, the resulting eggshell powder was immersed in a 1 M NaOH solution and maintained at 500 °C for a duration of 24 hours. Further thermal treatments were conducted at 650 °C and 800 °C, involving additional burn-in processes with the powdered eggshell material. The resulting mixture was then filtered to separate the eggshell material, followed by a one-hour drying phase at 100 °C. To achieve additional carbonization, the product underwent an extra hour of treatment in a furnace set to 400 °C. Subsequently, the obtained activated carbon product carefully stored within an airtight container for subsequent analysis and applications.

Fig. 1 *Production of activated carbon from eggshell*

2.2 Characterization of Activated Carbon from Eggshell Waste

The sizes of pores in activated carbon from eggshell that help in absorption during filtration was investigated using scanning electron microscopy (SEM, HITACHI TM3000) [5]. The functional group was characterized using Fourier Transform Infrared (Perkin Elmer Spectrum Two FTIR Spectrometer) [6].

3. Results and Discussion

3.1 Scanning Electron Microscope

The scanning electron microscope (SEM) image of eggshell activated carbon shows that the surface is rough and irregular. The activation process creates a porous structure with cracks and fissures, which increases the surface area of the activated carbon. The surface of the activated carbon appears to be more textured and non-uniform. The SEM image also shows that the activated carbon has a porous network, with interconnected pores of various sizes. These pores are essential for the adsorption capabilities of the activated carbon. Fig. 2 shows the SEM images of 650 °C activated carbon. For further reading on SEM, readers could check the work done in [7].

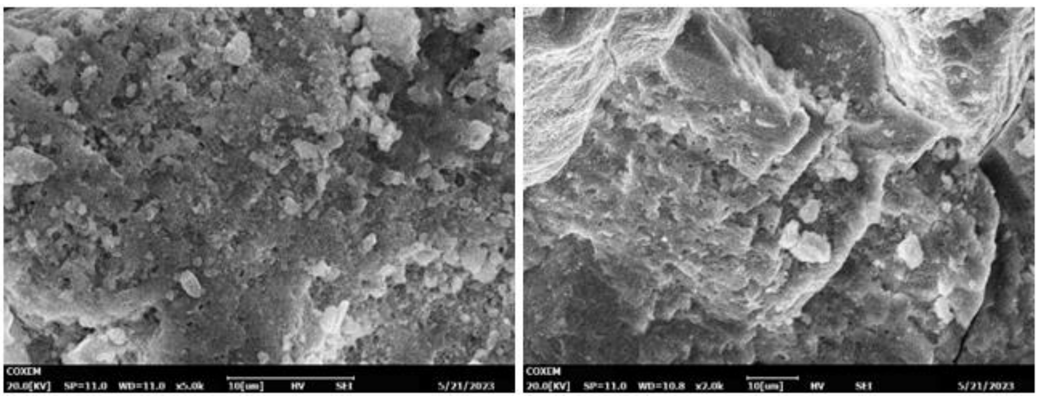

Fig. 2 *SEM images of 650 °C activated carbon*

3.2 Fourier Transform Infrared Spectroscopy

Utilizing Fourier transform infrared Spectroscopy (FTIR), the functional group and chemical components of eggshell-based activated carbon were identified. Fig. 3 depicts the FTIR spectrum of activated carbon. For activated carbon that has been heated to 650 °C in a furnace, the presence of the methoxy. Methoxy is a functional group consisting of an oxygen atom bonded to a carbon atom, commonly represented as -OCH3. It is found in a wide range of organic compounds, playing a role in their physical, chemical, and biological properties. The presence of a methoxy group can affect a compound's solubility, reactivity, and pharmacological activity. Methoxy stretching vibration indicates that the activated carbon contains methoxy groups, and this peak at approximately 3000 cm^{-1} is due to Methoxy stretching. The presence of the C-O stretching vibration indicates that activated carbon contains carbon-oxygen bonds; this peak at approximately 1150 cm^{-1} is a result of the stretching vibration [8].

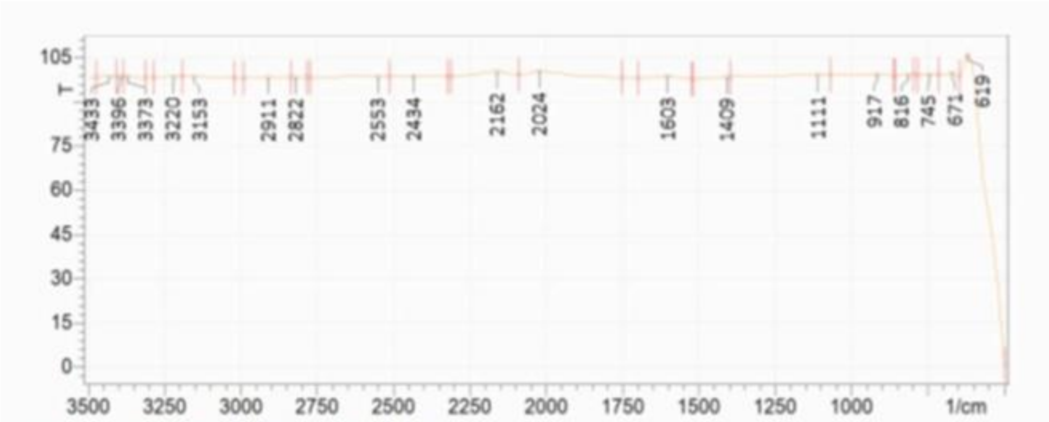

Fig 3. *FTIR peak of the 650 °C of activated carbon*

4. Conclusion

This study has successfully demonstrated the potential of utilizing waste eggshells for the production of activated carbon, contributing to the enhancement of water quality through efficient contaminant removal from river water. The investigation into different activation temperatures revealed distinct advantages and drawbacks associated with each variant of activated carbon in water treatment applications. Upon careful analysis of the results, the activated carbon produced at 650 °C emerged as the most optimal choice for water filtration purposes. Its superior performance can be attributed to its balanced adsorption capacity and structural characteristics. This finding underscores the significance of tailoring the activation process to achieve specific desired outcomes.

Looking forward, there are several avenues for further enhancement of this approach. One such recommendation involves exploring the potential for recycling the adsorbent material, which could contribute to long-term sustainability. Additionally, considering the practical application of the activated carbon on a larger scale, the implementation of a user-friendly handling solution, such as encapsulating the material in pouches, could simplify deployment, especially in extensive water treatment scenarios.

In summary, the successful utilization of waste eggshells for the synthesis of activated carbon offers a promising solution for improving water quality. The discernment of the most effective activation temperature and the consideration of practical deployment strategies open doors for broader adoption of this environmentally conscious approach, ultimately contributing to both resource utilization and water remediation efforts. Through these advancements, this research is not only enhancing water quality but also addressing environmental sustainability and striving for equitable access to safe drinking water, thereby benefiting communities and society at large.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Adam Iqmal Razman Shah, Lochena Devi Santharan, Muhammad Nazmi Alif Mohd Najib, Nilavarasi Muniswaran, Norhaliza Abu Bakar;* ***data collection:*** *Adam Iqmal Razman Shah, Lochena Devi Santharan, Muhammad Nazmi Alif Mohd Najib, Nilavarasi Muniswaran, Norhaliza Abu Bakar;* ***analysis and interpretation of results:*** *Adam Iqmal Razman Shah, Lochena Devi Santharan, Muhammad Nazmi Alif Mohd Najib, Nilavarasi Muniswaran, Norhaliza Abu Bakar;* ***draft manuscript preparation:*** *Adam Iqmal Razman Shah, Lochena Devi Santharan, Muhammad Nazmi Alif Mohd Najib,* *Nilavarasi Muniswaran, Norhaliza Abu Bakar. All authors reviewed the results and approved the final version of the manuscript.*

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