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Original Research Article

An environmental protection through organic dissipation into admirable activated carbon employed in day-to-day utilization

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ABSTRACT

An environmentally friendly method that eases the burden of biowaste disposal is turning into activated carbon. This work delivers the preparation of activated carbon from organic wastes like lemon peels. Lemon peel activated carbon (LPAC) have been prepared by physical activation method. Dried lemon peels were carbonized at 300°C for One and a half hours, two hours, and two hours thirty minutes, and activated at 350°C for about twenty minutes. The three different nano particles of LPAC are examined under XRD to confirm the nature and presence of carbon. FTIR analysis determines the functional group and Scanning electron microscope detects the surface of the nano powders, EDX identifies the material's elemental composition. Raman spectroscopy confirms the molecular structure of activated carbon, and hydrophobic nature is shown by optical imaging. At room temperature, the samples' dielectric characteristics were investigated. The results show that the LPAC's dielectric characteristics were improved in the audio frequency range after it was carbonized for two hours and thirty minutes at 300°C. The findings show that activated carbon made from organic wastes is highly useful for a variety of applications including waste water treatment, energy storage, and water filtration that leads to Environment protection and remediation.

1. Introduction

Lemon peel activated carbon is a unique and promising form of activated carbon derived from lemon peels, which are abundant by-products of the citrus fruit industry. With the increasing global concern over environmental pollution and the urgent need for sustainable solutions, lemon peel activated carbon has gained significant attention as a potential eco-friendly alternative to traditional activated carbon derived from non-renewable sources. This biochar exhibits excellent adsorption properties, making it suitable for various applications, including wastewater treatment, air purification, energy storage devices and soil remediation [1–4]. This explores the production process of lemon peel activated carbon, and its diverse applications, highlighting its potential as an environmentally friendly and cost-effective solution [5–8]. Throughout this discussion, reference is made to several studies and scientific articles to support the information presented.

The production of lemon peel activated carbon involves a series of steps, starting with the collection and drying of lemon peels. Lemon peels are typically considered waste material in the citrus fruit, resulting in vast amounts of agricultural waste. However, their high cellulose and lignin content make them a valuable resource for the production of activated carbon [9]. After drying, the lemon peels are subjected to a pyrolysis process, which involves heating the material to convert it into biochar. This thermal decomposition process breaks down the complex organic compounds present in the peels and transforms them into a highly porous carbon structure.

The physicochemical properties of lemon peel activated carbon play a crucial role in its adsorption capabilities [10]. Because of enormous surface area with fully developed pores, the biochar has a high capacity for adsorption. The activated carbon's surface area determines the amount of adsorbent material available for interaction with the target pollutants. Lemon peel activated carbon has been reported to exhibit a specific surface area ranging 744 m²/g [11], providing surface area for adsorption. Moreover, the pore structure influences the accessibility and diffusion of the adsorbate molecules within the carbon matrix. The versatile pore size distribution improves the adsorption capacity of the material, which makes it effective at capturing a wide range of pollutants. Thanks to the adsorption capacity of activated carbon in lemon peel, many environmental applications can be achieved [12]. Lemon peel activated carbon presents a promising and environmentally friendly alternative to traditional activated carbon derived from non-renewable sources [10]. Its production process utilizes abundant agricultural waste and transforms it into a highly adsorbent material with excellent physicochemical properties [13].

The diverse applications of lemon peel activated carbon in wastewater treatment, air purification, and soil remediation showcase its potential as a versatile solution for addressing environmental pollution [1]. By harnessing the adsorption capabilities of this biochar, it's contributed to a more sustainable future [14].

2. Materials and methods

Activated carbon, known for its excellent adsorption properties, is usually made from charcoal. Activated carbon is produced through the pyrolysis of organic molecules. In this instance, lemon peel scraps are utilized for this purpose. The process requires tap water, deionized water (DI water), a muffle furnace, and a mortar and pestle. These materials are crucial for transforming lemon peel scraps into activated carbon, which is widely used for purification and filtration purposes. LPAC is turned on using a pyrolysis process activation method. Lemon peels were collected from a nearby fruit store, washed in distilled water, and allowed to sun dry for seven days. The carbonized and activated dried peels were heated in a muffle furnace. The optimization process took place at 300°C for varying duration of time (300°C for one hour thirty minutes, two hours, and two hour thirty minutes).

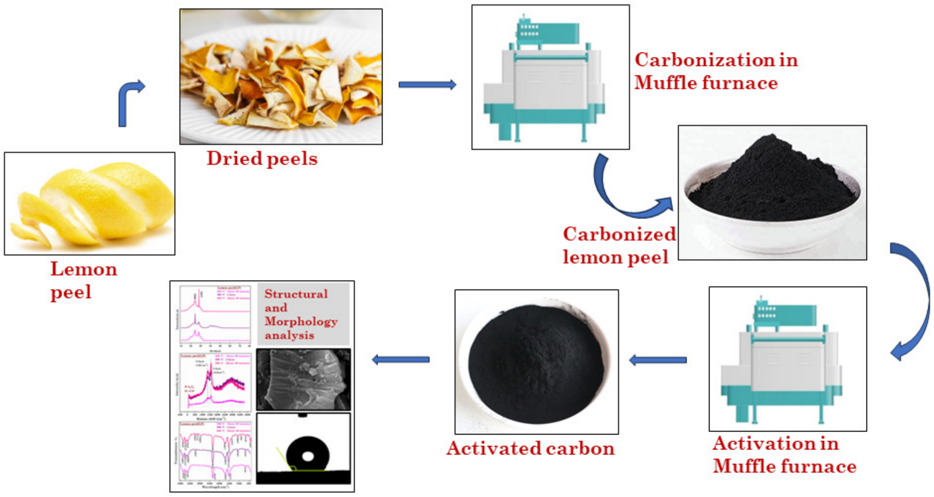

Figure 1: Synthesis of Lemon peel activated carbon

2.1 *Characterization techniques*

Phase confirmation is verified using an X-ray diffractometer (XPERT-PRO with CuK radiation). The pattern of diffracted x-rays is specific to a certain structure and may be used as a fingerprint to identify the sample type. FTIR (SHIMADZU FTIR-8400S) was used to locate functional groups. Information on topographical characteristics, morphology, phase distribution, compositional variations, structure, and orientation is provided by FE-SEM VEGA3, TESCAN (Czech Republic. The elemental composition is shown using EDX BURKER Nano, GmbH, D-12489(Germany). The strength and existence of the D band and the G band are confirmed by Raman analysis (WiTec alpha 300, Germany) [15]. Measurement of contact angle explains wettability (Holmarc's Contact Angle Meter, Model No. HO-ED-M-01). Dielectric studies (BI-870 Dielectric Constant Meter) are used to measure the dielectric constant of the material.

3. Results and discussion

The experimental results on the structural, morphological, functional group, elemental composition, and nature of the activated lemon peels are presented in this paper. For comparison, the LPAC's results at various time samples are shown.

3.1 *XRD analysis*

Figure 2 displays the X-ray diffraction data of all the Lemon peel activated carbon. For phase identification, all the data were examined in relation to a reference activated carbon phase with an ISSN of 2214-7853. The 24.11, 28.25 diffraction peak was found. The peak that lines up with the lattice planes (002) and (420) [15–17]. The graphitic carbon structure of LPAC is seen in the image below. At 300°C for two hours and thirty minutes, the crystalline character has been improved and an amorphous nature has also evolved. Additionally, the nanoparticle size was measured, and the expected grain size was estimated using the Debye-Scherrer formula [18–20].

$$D = \frac{K\lambda}{\beta \mathrm{Cos}\theta} \quad (1)$$

The computed grain size is 35.67 nm.

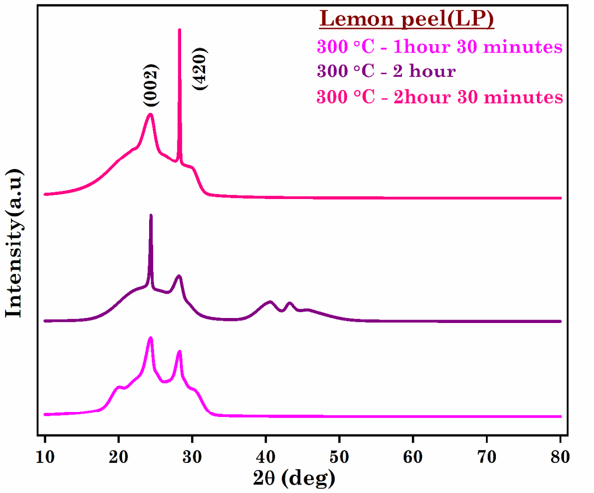

Figure 2: XRD of LPAC at 300°C for one hour thirty minutes, 2 hours, and two hour thirty minutes.

3.2 FTIR evaluation

Functional groups are seen in the activated carbon from lemon peel by FTIR analysis. Figure 3 depicts the bond stretching and bending vibrations, which covers from 400 cm^{-1} – 4000 cm^{-1} range.

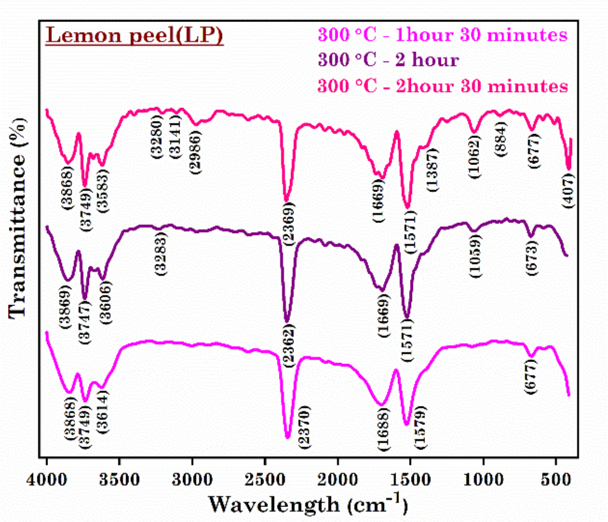

Figure 3: FTIR of LPAC at 300°C for one hour thirty minutes, two hours, and two hour thirty minutes

Peaks of the C-H group could be found at 677 cm^{-1} and 1062 cm^{1}, and there are C=C stretches in the aromatic ring bond that range at 1387 cm^{-1} [1, 10]. The existence of a carboxylic group, designated as a C=O stretching vibration, was revealed by the bending ranges at 1571 cm^{-1}. C-O group is responsible for the peak ranges at 1669 cm^{-1} [9]. C-H stretching is shown by stretches within a range about 2369 cm^{-1} [21], whereas C-H bending is indicated by bends around 2986 cm^{-1} [8]. The spectra at 3141 cm^{-1} and 3583 cm^{-1} represents the function group O-H. The band that appears at 3280 cm^{-1} [1] denotes a functional group with the chemical name hydroxyl. The carboxylic group found in the O-H band is represented by two distinct bands around 3868 cm^{-1} [16] as well as 3479 cm^{-1} [17]. The information demonstrates that when lemon peels are synthesized at 300°C for two hours and thirty minutes, more bonding groups are formed.

3.3 Morphological studies

The morphological features of the LPAC are studied using the FE-SEM. Ultra-high-resolution low voltage picturing and distinctive low vacuum capabilities are features of the SEM equipment. The SEM image and EDX of lemon peel-activated carbon is displayed in Figure 4. It is a sign that the pores on the LPAC's surface are all consistently open [22]. When lemon peels are carbonized at 300°C for 2 hour 30 minutes, the surface of activated carbon is also highly porous and uneven in texture [8]. It is evident that comparing the other activated carbons that are activated at 300°C for 1 hour 30 minutes, 2 hours, LPAC has a significant number of open pores after being heated to 300°C for 2 hours and 30 minutes. Additionally, it is obvious that the LPAC treated at 300°C for two hour 30 minutes has more pores than other treating times. The basic composition of the activated carbon developed from lemon peel is confirmed by EDX. The EDX results for three different types of activated carbon, which have a pair of peaks that represent carbon and oxygen.

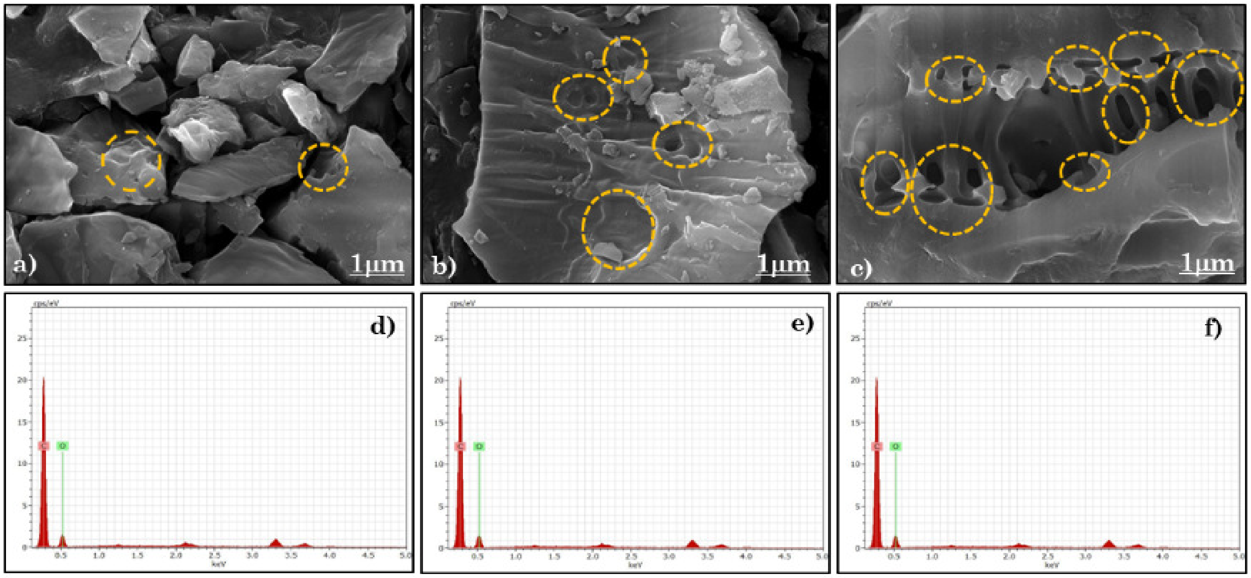

Figure 4: $^{a, b, c}$ FE-SEM of LPAC at 300°C for one hour thirty minutes, two hours, and two hour thirty minutes; $^{d, e, f}$ EDX of LPAC at 300°C for one hour thirty minutes, two hours, and two hour thirty minutes.

3.4 Raman spectroscopy investigation

The amount of carbon that has been graphitized was determined with the help of Raman spectroscopy. The G-band and the D-band, which stand for disordered carbon, are two distinct bands that were observed within the Raman spectral range of carbon, that depict graphitic nature [18]. Additionally, to gauge the level of disorder in carbon, one uses a ratio of I_D/I_G intensity spikes [11, 23]. The Raman spectrum for LPAC

300°C is presented in Figure 5, and contains both the D and G bands, which are located at 1380 cm^{-1} and 1559 cm^{-1}, respectively. The ratio for I_D/I_G was identified as being 0.89. The value of lemon peel activated carbons that are carbonized at various times are shown in Table 1. Although the pore structure and intensity both increase during the course of two hours and thirty minutes, as seen by the table's ID/IG intensity ratio.

3.5 Contact angle

Contact angle measurement is used to determine the surface wettability of LPAC [24]. LPAC's were used for the test. Three different LPAC's are discovered to have hydrophobic properties is shown in Figure 6. LPAC synthesized at 300°C for 2 hours and 30 minutes has an angle of 93°, demonstrating that the partially hydrophobic nature is occurred. The angles of the other two LPACs are125° and 112°.

Table 1: D band and G band of LPAC at various times

LPAC treatment for 300°C	D band (cm^{-1})	G band (cm^{-1})	R= I_D/I_G
1 hour 30 minutes	1334	1597	0.83
2 hours	1340	1598	0.84
2 hours 30 minutes	1380	1559	0.89

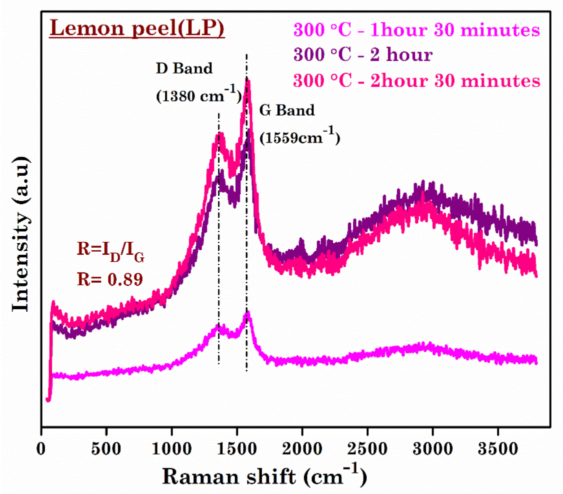

Figure 5: Raman spectra of LPAC at 300°C for one hour thirty minutes, two hours, and two hour thirty minutes

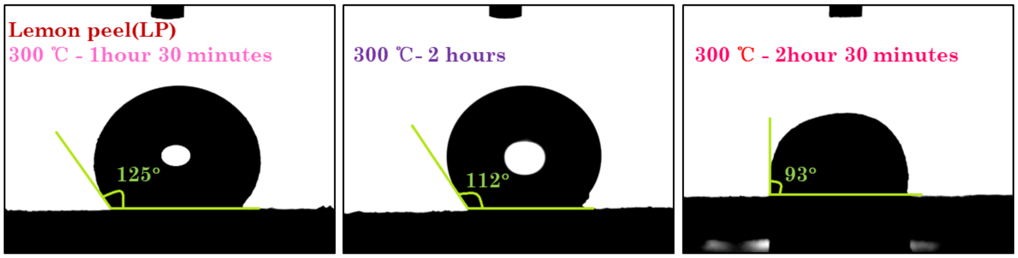

Figure 6: Contact angle of LPAC at 300°C for one hour thirty minutes, two hours, and two hour thirty minutes

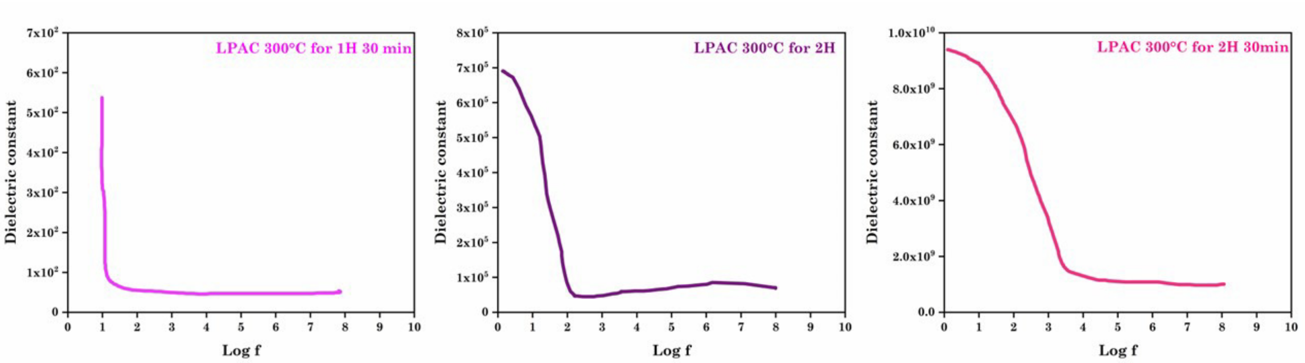

Figure 7: Dielectric analysis of LPAC at 300°C for one hour thirty minutes, two hours, and two hour thirty minutes

3.6 Dielectric studies

Nanostructured materials demonstrate better dielectric characteristics when compared to traditional bulk materials. In this study, the dielectric properties were explored over a frequency range of 1 Hz to 5 MHz using the two-probe method at room temperature. The dielectric constant was calculated utilizing a specific equation [25, 26].

$$\varepsilon_r = \frac{C \times d}{\varepsilon_0 \times A} \tag{2}$$

The area (A), thickness (d), and parallel capacitance (C) of the sample are related by the formula, where ε_0 represents the absolute permittivity of free space (8.859×10^{-12} Fm^{-1}). The graph in Figure 7 illustrates the dielectric constant curve for LPAC carbonized under 300°C for varying durations: one hour thirty minutes, two hours, and two hours thirty minutes, respectively. At lower frequencies, the dielectric constant exhibits a significant increase due to the contribution of four polarizations. As the frequency increases, the dielectric constant gradually decreases. Based on the dielectric measurements, LPAC carbonized under 300°C for two hours thirty minutes demonstrates a higher dielectric constant compared to LPAC carbonized under 300°C for one hour thirty minutes and two hours, as clearly depicted in Figure 6. For LPAC carbonized under 300°C for one hour thirty minutes and two hours, the dielectric constant saturates at 1Hz and 2 Hz. However, for LPAC carbonized under 300°C for two hours thirty minutes, the dielectric constant saturates at 3.5 Hz, indicating that a higher carbonization temperature leads to increased sustainability of the dielectric constant.

4. Conclusions

Lemon peel scraps were gathered and synthesized under various circumstances. The physical method for dealing with lemon peel waste is carbonization, followed by activation. At 300 °C for two hours and thirty minutes, lemon peel activated carbon (LPAC) confirms the graphitic carbon structure. For LPAC treated at 300°C for two and a half hours, FTIR analysis reveals an increase in functional groups; bending and stretching are slightly less for the other two timings. Morphological analysis reveals a highly porous structure at 300°C for two and a half hours, which explains the high surface area and adsorption capacity. The existence of graphitized carbon is explained by the Raman spectrum, which reveals that D and G bands were present at 1380 cm^{-1} and 1559 cm^{-1} at 300 °C for two hours and thirty minutes. and a relatively high ratio of D band to G band that leads to increase in intensity. And has high dielectric constant. LPAC's partially hydrophobic nature has been successfully attained, but the measured angle reveals that it has average contact angle and is partially wettable after being activated at 300°C for two hours and thirty minutes. LPAC plays an important role in various applications like waste water treatment, electrode in energy storage devices and purify air and water.

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