Synthesis of Carbon from Tea Powder Waste for Development of Polymer Nanocomposites

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Abstract. Tea waste is inexpensive and is plenteously available around the world especially in south Asian countries. The filtered tea powder waste acts as a carbonaceous source which can be utilized for variety of applications. Calcination of tea powder at 300°C and 400°C resulted in carbon powder which is further characterized using Raman Spectroscopy and Scanning Electron Microscopy (SEM). The D and G bands of Raman spectroscopy revealed the presence of graphitic planes in the structure. The morphology of synthesized carbon suggested that synthesized carbon has porous structure. The porous structure of the carbon makes it widely applicable in water filtration applications. Furthermore, the synthesized carbon can be used as filler material for 3D printable filaments.

1. Introduction

Tea is one of the foremost extensively consumed beverages after water in the world, and is primarily derived from the leaves of Camellia sinensis [1]. India holds the second largest producer of tea in the world after China. According to the recent statistics, the consumption volume of tea in India was approximately 1.10 million tons during the financial year 2019. Generally, in India, milk and sugar are added to tea and is consumed. Owing to the immense increase in consumption of tea, huge number of tea stalls has been developed in urban as well as suburban areas. Consequently, massive amount of tea waste is obtained from the filtered tea which further resulted in the enormous increase in the waste deposition [2]. Thus deposited waste results in detrimental effects due to solemn environmental impact which became a pressing issue that needed immediate attention [3]. Ergo, researchers and scientists are focused on the management of generated tea waste and attempts are being made to re utilize the tea waste. Generally, lignin, hemicelluloses, and cellulose are a few of the valuable compounds of the infused tea residue which can be used to create useful products [4]. Numerous investigations have been made by a number of researchers about the resourceful usage methods of tea residue which includes extraction of active elements, serving as substrate, adsorbents for removing contaminants, toxic metals from aqueous solutions, for bio energy, and as reinforcing filler for construction and bio polymer composites [5]. Even though some attempts have been made to evaluate the tea waste(TW) in...
textile industry, agricultural applications and production of animal feed, the efficient utilization of the TW is limited [6].

In this modern era, in order to compensate the environmental effect, synthesis of activated carbon (AC) from agro, industrial and bio waste has become the research of interest. Till date, AC is produced from various sources of bio waste such as seeds, shells, husk, and peels. Thus obtained AC has been used for various applications such as development of electrodes, catalysts, and adsorbents [7]. Remarkably, the waste tea leaves and the biochar obtained from the tea waste have been widely used for adsorption due to its wide availability [8]. Furthermore, the physiochemical characteristics of the tea waste including large surface area and the adsorption kinetics makes it a potential inexpensive adsorbent which is utilized for elimination of emanations in waste water [8]. In addition to this, in the recent years, the carbonaceous materials such as such as carbon nanotubes, dots (CDs), fibers, fullerenes, and graphene have been favored eminently due to their remarkable applications in multifarious fields such as drug delivery, bioimaging and sensing [9]. The tea waste generated from the tea which contains milk and sugar can be considered as rich source of carbon which can be further utilized for wide variety of applications [9].

In this study carbon is synthesized from Tea waste Powder by calcinations process in an induction furnace. The tea powder waste was calcinated at 300°C and 400°C. This synthesized carbon is characterized by using Raman spectroscopy and Scanning Electron Microscopy.

2. Materials and Methods

2.1. Materials

Disposed tea powder waste (TPW) is collected from tea stalls located at Hayat Nagar, Hyderabad, India and is further cleaned by removing unwanted solid material like ginger and cardamom. The TPW is sundried to remove the moisture content.

2.2. Synthesis of carbon

Approximately 30g of sundried TPW is taken in a ceramic crucible and is placed in the induction furnace. The TPW is calcinated at 300°C and 400°C respectively for 2hrs in an induction furnace. After completion of calcination the samples were allowed to cool and are hand ground using mortar and pestle. The samples are then stored for further characterization.

2.3. Characterization of carbon particles

2.3.1. Raman Spectroscopy

Raman spectroscopy was carried out using Confocal Micro-Raman Spectrometer to study the graphitization degree of the carbon of TPW. The range of the spectrum was 60 - 4000cm-1 and the optical resolution is 1µm.

2.3.2. Scanning Electron Microscopy

The morphology of the synthesized carbon TPW was investigated using JEOL JSM-7610F field emission scanning electron microscope at 10 and 15KV. The samples were sputter coated with gold/palladium (Au/Pd) for 3min using a sputter coater.

3. Results and discussions

3.1. Raman spectroscopy

Raman spectroscopy is a non-destructive technique used to assess the presence and structure of carbon materials such as graphitization, defects, and layer of graphene formed. The most basic characteristic in finding out the characteristic of sp2 carbon are the D and G bands. The D band and G band indicates the graphitic and defect features[10] . Raman analysis was performed for carbon calcinated
at TPW 300°C and 400°C as shown in figure 1. The analysis revealed that the disordered D band peak for TPW 300°C is exhibited at 1332.63cm$^{-1}$ and G band is observed at 1559.86cm$^{-1}$, respectively. The carbon from TPW at 400°C shows D band and G band at 1352.99cm$^{-1}$ and 1581.66cm$^{-1}$, respectively. The D and G bands for both of the samples were around 1360 cm$^{-1}$ and 1585 cm$^{-1}$ which suggests the presence of graphitic planes in the structure [11]. The ID/IG ratios of carbon obtained at 300°C and 400°C were 1.08 and 1.24, respectively where ID and IG are the intensities of corresponding D and G bands. The ID/IG ratio increases with increase in the calcination temperature which suggests the decrease in the graphitic phase [12].

![Raman spectroscopy analysis for TPW calcinated at 300°C and 400°C](image)

**Figure 1** Raman spectroscopy analysis for TPW calcinated at 300°C and 400°C

3.2. *Surface morphology of carbon*

The microstructure of carbon obtained from TPW after calcination is shown figure 2. The carbon particles are observed to be agglomerated for both 300°C and 400°C. The images indicated that structure contains the porous zones. The irregular pore structure was obtained. The morphology suggests the presence of combination of sheet like structures and particles.

![Scanning Electron Microscopy for TPW calcinated at (a) 300°C and (b) 400°C](image)

**Figure 2** Scanning Electron Microscopy for TPW calcinated at (a) 300°C and (b) 400°C
4. Conclusion

The porous carbon has been successfully synthesized from the calcination of tea powder waste that is obtained from the local tea stalls. The synthesized carbon was analyzed at two different calcination temperatures 300°C and 400°C. The Raman spectroscopy suggests that with the increase in calcination temperature, the graphitization decreased. These results were complemented by the SEM results which showed more sheet like structures for the carbon obtained at 300°C. Furthermore, SEM results suggested that the obtained is porous and hence can be used in wide variety of applications. In the future, we intend to use this carbon as a filler to develop 3D printable filaments such that it enhances the thermal and mechanical properties.

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