Nanoporous Carbon from Durian Peel via Hydrothermal-Carbonization and their Application in Ripening Delay of Durian

Thanat Sitthisantikul¹, Pee Poolsili¹, Jindabha Devakula², Anuchit Jarawanawat¹ and Apiluck Eiad-ua¹*
¹ College of Nanotechnology, King Mongkut’s Institute of Technology Ladkrabang, Bangkok, Thailand
² Mr.Fruity Company Limited, Khlong nung, Khlong luang, Pathum thani, Thailand

*Corresponding author’s E-mail: apiluck.ei@kmitl.ac.th

Abstract: This research was aimed to examine conditions on synthesis of nanoporous carbon materials from durian peel via the process of hydrothermal carbonization (HTC) as an application for delaying durian ripening process. The experiment was conducted by using durian peel as materials for producing nanoporous carbon via the process of hydrothermal at 160-200 °C for 8-24 hours. It also included the process of carbonization at 500-900 °C for 2 hours under nitrogen atmosphere for developing pore structure and removing contaminants to obtain the nanoporous carbon. The properties of nanoporous carbon were characterized by scanning electron microscope (SEM), Fourier transform infrared spectroscopy (FT-IR) and Raman spectrometer analysis. The results indicated that the process of hydrothermal at 200 °C for 12 hours and carbonization at 900 °C for 2 hours was suitable for delaying ripe durian. This is become of the carbon content, porous structure and amorphous structure increased with HTC temperature.

1. Introduction
Durian (Durio zibethinus) is one of the tropical fruits in Southeast Asia such as Indonesia, Malaysia and Thailand. This fruit has hard outer shell and distinctive smell [1]. Demands of durian consumption are significantly increasing. However, fast ripening process of durian during transportation becomes one of main problems that effect on the quality product when reaching the consumer. In addition, disposed of peel from durian consumption are causing of environmental pollution.

Synthesis of nanoporous carbon from durian peel, which contain many feature such as high surface area high porous volume [2], and resist to chemicals and heat in anaerobic condition [3-5]. It is one of effectively solution for reduce environmental pollution also obtain economic value from zero-cost waste and application as an ethylene adsorbent [6-7] for delaying durian ripening process. One of methods for effectively synthesize carbonaceous materials is hydrothermal carbonization (HTC) which is process of reaction that change biomass to carbon material by water molecule, heat and pressure. HTC process was explained with 4 reaction by the principle, hydrolysis, dehydration, polymerization and carbonization reaction, to destroy the bond such as lignin, hemicellulose and cellulose, which are the main component of biomass. Nanoporous carbon material prepared via HTC can achieve a higher yield of hydrothermal char, higher level of carbon and lower ash content [8-10].
This study was aimed to examine the synthesis of nanoporous carbon from durian peel via hydrothermal carbonization, including different hydrothermal and carbonization condition. The nanoporous carbon obtained was characterized in term of the porous structure, change of chemical composition and amorphous structure.

2. Material and method

2.1 Material
Durian peel powder was obtained from Mr.Fruity company limited, Khlong nung, Khlong luang, Pathum thani. Nitrogen with a purity of 99.95% was used as inert gas in the carbonization process.

2.2 Preparation of Nanoporous carbon.

![Diagram of Nanoporous Carbon Synthesis](image)

**Figure 1.** Schematic Diagram of Nanoporous carbon from durian peel via Hydrothermal-carbonization process.

The schematic diagram of nanoporous carbon from durian peel via HTC in Figure 1. Durian powder was dried and mashed from durian peel, 30 g of Durian peel powder was mixed with 60 ml of DI water and prepared by process of hydrothermal at 160-200 °C for 8-24 hours, afterward hydrothermal char was carbonized in furnace at 500 -900 °C for 2 hours under nitrogen atmospheric to obtain nanoporous carbon.

2.3 Nanoporous carbon characterization

Nanoporous carbon from durian peel via HTC were characterized for morphology, Chemical composition and amorphous structure by scanning electron microscope (SEM), Fourier transform infrared (FT-IR) and Raman spectrometer, respectively.

3. Result and discussion

3.1 Morphology of Carbon and Hydrothermal char
Figure a-e2 shows SEM images of durian peel through HTC process at different reaction temperature (500-900 oC) under nitrogen atmospheric for 2 hours and Figure f2 show SEM image of durian peel through hydrothermal process at 200 oC for 12 hours. The SEM analysis show that increasing reaction temperature of carbonization process was destroy chemical bond structure and developing pore structure. In figure e2, hydrothermal-carbonization at 900 oC for 2 hours under nitrogen atmospheric was the optimum condition for produces ethylene adsorbent.
Figure 2. SEM image (500x) of durian peel through Hydrothermal process at 200 °C for 12 hours and carbonization process at different temperature of (a) 500 °C (b) 600 °C (c) 700 °C (d) 800 °C (e) 900 °C for 2 hours under Nitrogen atmospheric for 2 hours and (f) Hydrothermal char at 200 °C for 12 hours.

3.2 Structure analysis and composition of porous carbon
The FT-IR spectra analysis show that in Figure a3 the peak at 3343 cm⁻¹ was assigned to hydroxyl group, carbonyl group, alcohol from cellulose or phenols from lignin. The peak at 2918 cm⁻¹ was represent the CH2 stretching (aliphatic). The peak at 1615 cm⁻¹ was assigned to vibration of aromatic ring C-C stretching, which found in lignin. The peak around 1152 and 1028 cm⁻¹ are indicated to the stretching of C-O from hemicellulose ester. The FTIR spectra of hydrothermal char from durian peel at 200°C for 12 hours are displayed in Figure b3 shows the decomposition of alkane content increased, hemicellulose, cellulose and lignin decreased. The FT-IR spectra analysis of hydrothermal-carbonization process with different reaction temperature (500-900 °C) under nitrogen atmospheric in Figure c-g3 show that OH, aliphatic C-H, aromatic C-C and C-O linkage are decreased when compared with hydrothermal char. The result indicated that decomposition of hemicellulose, cellulose, lignin and OH group are increase with increasing reaction temperature of carbonization process. The
process of hydrothermal at 200°C for 12 hours and carbonization process at 900°C for 2 hours under nitrogen atmosphere was the optimum condition for produce ethylene adsorbent.

Figure 3. FT-IR spectra of durian peel through hydrothermal process at 200°C for 12 hours and carbonization with different reaction time (a) Raw material (b) Hydrothermal char at 200°C for 12 hours (c) HTC 500°C (d) HTC 600°C (e) HTC 700°C (f) HTC 800°C (g) HTC 900°C for 2 hours under nitrogen atmospheric.

Table 1. Raman spectra data of durian peel through process of hydrothermal at 200°C for 12 hours and carbonization with different reaction temperature for 2 hours under nitrogen atmospheric

| Sample                  | ID   | IG   | D band (cm⁻¹) | G band (cm⁻¹) | ID/IG |
|-------------------------|------|------|---------------|---------------|-------|
| Hydrothermal (200°C, 12 h) | 144.23 | 186.43 | 1358         | 1570         | 0.77  |
| HTC 500°C               | 122.37 | 114.28 | 1342         | 1577         | 1.07  |
| HTC 600°C               | 123.62 | 115.41 | 1339         | 1577         | 1.07  |
| HTC 700°C               | 124.07 | 112.51 | 1338         | 1576         | 1.10  |
| HTC 800°C               | 115.14 | 102.51 | 1334         | 1577         | 1.12  |
| HTC 900°C               | 66.83  | 47.53  | 1347         | 1582         | 1.40  |

From Raman spectra analysis with different reaction temperature of hydrothermal-carbonization process under nitrogen atmospheric in figure 4 and table 1 indicated that The ratio of ID and ID/IG values for hydrothermal-carbonization for 500-900°C were calculated to be 1.07,1.07,1.10,1.12,1.40 respectively. The result indicated that The high ratio of ID and IG are more carbon defect. So that, The process of hydrothermal at 200°C for 12 hours and carbonization at 900°C for 2 hours with the D-Band (1347 cm⁻¹) and G-Band (1582 cm⁻¹) has more carbon defect than other condition. The destroy porous structure was increasing with reaction temperature of hydrothermal-carbonization process.

4. Conclusion
The process of hydrothermal at 200°C for 12 hours and carbonization at 900°C for 2 hours was suitable for producing ethylene adsorbent for delaying ripe durian. This is become of the carbon content, porous structure and amorphous structure increased with reaction temperature of HTC and carbonization process.

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