Photocatalytic degradation of anthracene by biochar-based graphitic carbon nitride

S N Q Syed Abd Halim¹, N A M Nazri¹ and N A H M Nordin²

¹Section of Chemical Engineering Universiti Kuala Lumpur Kampus Malaysian Institute of Chemical and Bioengineering Technology (UniKL MICET), Lot 1988, Kawasan Perindustrian Bandar Vendor, Taboh Naning, 78000, Alor Gajah, Malacca, Malaysia
²Chemical Engineering Department, Universiti Teknologi Petronas, Seri Iskandar, 32610, Perak, Malaysia

Email: syarifah.halim19@s.unikl.edu.my

Abstract. Polycyclic aromatic hydrocarbons (PAHs) are persistent and toxic to living organisms, that can be classified as carcinogenic, mutagenic and teratogenic pollutants. In this study, a green photocatalyst of biochar-based graphitic carbon nitride (BC/g-C₃N₄-M) is derived from sugarcane bagasse (SB) and melamine were developed as a potential material for the degradation of PAHs. BC(SB)/g-C₃N₄-M prepared with varied ratios of melamine to SB and different synthesis temperature were characterized by FTIR, BET and UV-DRS. The efficiency of the catalyst for the degradation of anthracene were investigated further in terms of its efficiency at various pH mediums, catalyst dosage and anthracene initial concentration. Experimental results revealed that g-C₃N₄ showed better degradation efficiency to anthracene than BC(SB)/g-C₃N₄-M. Additionally, the best degradation efficiency of anthracene by g-C₃N₄ and BC/g-C₃N₄-M75% composites were found at pH 3 with 1.0 g/L dosage at 2 ppm and 1 ppm initial concentration, respectively. The catalysts were also discovered to be reusable for 5 cycles with a slight decrease in photocatalytic degradation. The use of agricultural biomass waste in this study could provide a promising approach to water and wastewater treatment.

Keywords: Biochar; graphitic carbon nitride; thermal polycondensation; photocatalytic degradation; melamine.

1. Introduction
Polycyclic aromatic hydrocarbons (PAHs) can be regarded as one of the priority pollutants in water system, affecting not only the living and growing environment of plants and animals, but also human health. This is due to a number of factors such as hydrophobicity, bioaccumulation tendency, acutely toxicity and persistence in the environment, all of which contribute to global pollution [1]. Natural and anthropogenic sources of PAHs in riverine environments and water systems include petroleum spills, industrial effluent, municipal waste water discharge, chemical refineries and volcanoes [1, 2]. In the past, several conventional process like physical techniques (i.e., coagulation, flocculation, activated carbon adsorption and photo degradation) [3, 4], chemical and biological method (i.e., chemical oxidation, aerobic and anaerobic treatment) [5], have been used for the removal of pollutants (i.e.,
dyes, antibiotics, pesticides and herbicides) from water system. However, the conventional used methods are associated with the formation of secondary waste, generation of toxic by-products (i.e., bromine, hydrogen peroxide) [6, 7] and also inefficient due to strict control of conditions, time consuming and also costly. Currently, heterogenous photocatalysis which is one of the advanced oxidation processes (AOP) has received growing interest in photodegradation of various toxic compounds because of its advantages such as non-toxic, mild reaction conditions [8], reduced or no formation of secondary pollution [4] using catalyst that can be regenerated after process.

Under UV light irradiation, semiconductor photocatalyst (i.e., TiO₂, CdS, ZnO, WO₃ and g-C₃N₄) [6, 9] can degrade a wide range of organic pollutants such as herbicides, dyes, pesticides, phenolic compounds, tetracycline, and others [4]. Recently, a metal free material, graphitic carbon nitride (g-C₃N₄), that consist of carbon and nitrogen compounds has been widely utilized as photocatalyst due its high oxidation efficiency, non-toxic nature, significant chemical and thermal resilience [10,11]. Unlike TiO₂, which can only be activated in UV regions (3.2 eV), g-C₃N₄ has a 2.7 eV band gap and a good visible light response up to 460 nm [12]. Furthermore, using inexpensive nitrogen rich precursors such as melamine, dicyanamide, urea and thiourea, g-C₃N₄ can be easily synthesized by thermal polycondensation [13]. However, the use of g-C₃N₄ is limited due to a number of disadvantages such as low electrical conductivity [14], a small specific surface area (<10 m².g⁻¹) due to the graphitic layered structure [15,16], low charge separation [17] and high recombination rate of photogenerated charge carriers [18], all of which reduced photocatalytic efficiency and hindering large scale applications.

To overcome this limitation, various modifications of g-C₃N₄ has been explored in order to enhance its photocatalytic efficiency for the remediate the environmental pollutants such as metal (i.e., Zn, Fe³⁺, Na, Ag) and non-metal doping (i.e., S, P, C, O), hybridization with carbon nanomaterials (i.e., carbon nanotubes, carbon nanospheres, graphene oxide) and coupling with other semiconductors. Introduction of biochar to g-C₃N₄ is also favourable to further improve the features of BC/g-C₃N₄, and consequently its performance for degradation of various pollutants as conductive carbon materials in the biochar can serve as an efficient electron-transfer channel and acceptors to allowing photogenerated electron-hole pairs to be separated more effectively [19,20]. Organic materials with a high carbon content, primarily biomass waste from agriculture, forestry and food processing can be used as feedstock materials for the production of biochar [21]. The main compositions of biomass known as insoluble fibre include cellulose, hemicellulose and lignin which highly indigestible by animals and has low biodegradability [22]. Biomass conversions into value-added carbon materials considered as an economically and environmentally viable solution rather than disposal in a landfill. To date, biomass waste has received significant attentions in photocatalytic treatment as it can be used as a carbon source of biochar for the preparation of g-C₃N₄ due to its distinctive properties, easily tunable functional groups, chemical stability and high conductivity [7]. Moreover, biochar has a remarkable adsorption capacity [21,22] and high surface area that can improve the photocatalytic degradation.

The objective of this study is to synthesize BC(SB)/g-C₃N₄-M by thermal polycondensation method with improves adsorption and photocatalytic performance with high surface area and high photoresponsiveness under visible light. The present study also discusses the roles of biochar in BC(SB)/g-C₃N₄-M for photocatalytic degradation derived from SB. This works evaluates the effect of important parameters to identify the optimum conditions for high efficiency photocatalytic degradation of anthracene.

2. Methodology

2.1. Materials and chemicals
Sugarcane bagasse wastes as biochar feedstock was examined in this study. Melamine (AR, 99.0%), absolute denatured ethanol (AR, 99.5%), buffer solution (pH 7 and pH 4), sodium hydroxide (NaOH) and hydrochloric acid (HCl) were purchased from DNS Saintifik Sdn Bhd (Malaysia). Anthracene
(AR, 97.0%) was purchased from Polyscientific Enterprise Sdn Bhd (Malaysia). All the chemicals were used exactly as they were received. Throughout the experiments, deionized water was used.

2.2. Preliminary thermal gravimetric analysis

The thermal analysis of g-C₃N₄ were performed by using Thermal Gravimetric Analysis thermal analyzer (TA instruments) under constant static air atmosphere ramping of 5 °C.min⁻¹ from 30 to 800 °C.

2.3. Synthesis of BC(SB)/g-C₃N₄-M

Waste biomass was washed, dried at 100 °C for 8 hours, crushed with a grinder (12,000 rpm), and sieved through a 30 mesh sieve (0.6 mm). Thermal polycondensation was used to produced BC(SB)/g-C₃N₄-M composites. In detail, melamine as a precursor was first ground in mortar with biomass at different melamine to biomass ratios indicated as BC(SB)/g-C₃N₄-MX (X = 25%, 50% and 75% of melamine). For 3 hours, samples were placed in a closed alumina crucible and heated in a muffle furnace at various synthesis temperatures (450 °C, 500 °C, 550 °C and 600 °C), at a constant rate of 5 °C.min⁻¹. Pure g-C₃N₄ is synthesized from melamine, and biochar is synthesized from SB under the same reaction conditions. The prepared samples were collected and kept in a desiccator at 25 °C.

2.4. Characterization and analysis

The average sample yield was calculated as the weight of thermal polycondensation product divided by the weight of the original materials. The surface area was determined by running N₂ sorption isotherms on an automated surface area using the Brunauer-Emmett-Teller (BET) methods (4 hour degassed). The UV-vis diffuse reflection spectra (UV-DRS) for dry-pressed disc samples were obtained using a Scan UV-vis spectrophotometer (Perkin Elmer Lambda 35) equipped with a 60 mm integrating sphere assembly and BaSO₄ as the reflectance sample. Tauc plot methods were used to calculate the optical band gap of the samples. Fourier-transform infrared (FTIR) spectroscopy (Thermo Scientific, US) was used with dried potassium bromide (KBr) in the 400 to 4500 cm⁻¹ range with a resolution of 4 cm⁻¹ and 8 accumulation modes.

2.5. Photocatalytic activity of anthracene

The photocatalytic activity of the catalyst was evaluated by anthracene degradation. The experiments were conducted in a batch mode of photocatalytic reactor. A magnetic stirrer was used to agitate the reaction mixture. The pH of the anthracene solution can be adjusted by adding of 0.1 M NaOH or 0.1 M HCl. The suspension was stirred in the dark until the anthracene concentration was horizontal to achieve adsorption equilibrium. The photocatalytic degradation experiments were carried out for 240 minutes while being illuminated by a 24 W LED light with a UV filter to maintain the main wavelength. With air circulation, the experimental temperature was kept at room temperature. At 1 hour intervals, 3 mL of suspension was syringed and filtered through a 0.45 µm microfilter. Anthracene concentration was determined using high performance liquid chromatography (HPLC)(Perkin Elmer) on an Ace C-18 column (150 mm x 4.6 mm) at a wavelength of 254 nm. Acetonitrile and deionized water (75%:25%) were used as the mobile phase, with a flowrate of 1.0 mL.min⁻¹ for 12 minutes. The catalyst’s reusability was determined by reusing it for 5 consecutive cycles in the same photocatalytic degradation process. After each cycle, the catalyst was filtered, ethanol washed, and oven dried before being reused. The effluent was disposed of as laboratory waste.

3. Result and discussion

3.1. Thermal gravimetric analysis

The thermal polycondensation of melamine had been recognized as a facile synthesis pathway to generate the g-C₃N₄ polymer [25]. Thermal gravimetric analysis (TGA) has been widely implemented to obtain information on the processes taking place for physical and chemical transformation from
melamine to g-\(\text{C}_3\text{N}_4\). In this set of experiments, air at constant flow rate of 20 mL.min\(^{-1}\) was used with constant heating rate of 5 °C.min\(^{-1}\) ramping from 30 to 800 °C. The thermal gravimetric analysis (TGA) in figure 1 showed that g-\(\text{C}_3\text{N}_4\) had small weight loss below 250 °C resulted by removal of bound moisture [26]. Above 250 °C, the significant weight loss possibly due to the rapid volatilization of moisture and deamination condensation of melamine to form melam [27]. When the temperature increased from 360 °C, further condensation process of melam to form melem, which has the tri-s-triazine structure unit. Then, the structure unit was condensed into based compounds such as melon and formation of polymeric N-bridge tri-s-triazine graphitic carbon nitride started by 540 °C. The g-\(\text{C}_3\text{N}_4\) decomposition process started from 360 to 630 °C with less than 10% residual content. The thermal analysis of melamine indicates two temperature regions to analyses in this research: (a) 360 to 540 °C and (b) 540 to 630 °C. The catalyst synthesized in muffle furnace via thermal polycondensation at different synthesis temperature within the range at 450 °C, 500 °C, 550 °C and 600 °C.

![Figure 1. TGA graph g-\(\text{C}_3\text{N}_4\).](image)

3.2. Characterization and analysis
The FTIR spectra of g-\(\text{C}_3\text{N}_4\) samples obtained at various thermal polycondensation synthesis temperatures are shown in figure 2. The stretching vibrational modes of N-H in primary (3510 to 3330 cm\(^{-1}\)), secondary (3330 to 3130 cm\(^{-1}\)) amides and their intermolecular hydrogen bonds are responsible for the broad band at around peak 3000 to 3700 cm\(^{-1}\). The intensity of these peaks decreases with the increase of synthesis temperatures indicating the reduction of N-H or amide groups. The series of peak in the region of 1270 to 1630 cm\(^{-1}\) are related to the typical stretching mode of aromatic C-N heterocycles [19]. With higher synthesis temperatures, the intensity of these peaks became more intense, implying that the degree of polycondensation increased. The breathing mode of tri-s-triazine structure unit was assigned to the peaks around 810 to 830 cm\(^{-1}\) [28]. A weak band observed at 2360 cm\(^{-1}\) are attributed to C-N, implying that some molecules were not entirely react during the thermal polycondensation process [29].
As shown in figure 3, the FTIR spectra of BC(SB), BC(SB)/g-C$_3$N$_4$-M composites and g-C$_3$N$_4$ that is derived at 600 °C synthesis thermal polycondensation temperature. The commonly functional groups on biochar can be observed from BC(SB) sample. The BC(SB) showed bands 3700 to 780 cm$^{-1}$, which assigned to the O-H stretching mode of hydroxyl groups due to the absorption of water molecules (3700 to 3400 cm$^{-1}$), aliphatic CH$_2$ and CH$_3$ groups (2970 cm$^{-1}$), N-H stretching vibration (2300 cm$^{-1}$), N-H groups in amide (1550 cm$^{-1}$), aliphatic C-H and C=C stretching vibration (1400 to 1480 cm$^{-1}$), C-N stretching and C-O aromatic ester (1290 to 1293 cm$^{-1}$) and aromatic C-H bending (780 to 880 cm$^{-1}$), respectively [30]. The BC(SB)/g-C$_3$N$_4$-M composites varied in the intensities when the weight percentage melamine to SB changes, however, the composites show no obvious g-C$_3$N$_4$ characteristic peaks, implying that the BC(SB)/g-C$_3$N$_4$-M structure more likely as BC(SB). In contrast to the BC/g-C$_3$N$_4$-M composites produced by Pi et al. [19], the g-C$_3$N$_4$ characteristic in FTIR peaks can be observed suggested that biochar comprised the composites without change the polymeric reaction of melamine.

Table 1 shows the average yield, surface area ($S_{BET}$), and bandgap ($E_g$) of the catalyst. The average catalyst yield was calculated by dividing the synthesized product by the original materials used in thermal polycondensation. The average yield produced decreases as the amount of SB in the samples.
increases. This is because there is a significant amount of residual plant material present, which increases the volatile matter volatilization and organic material loss at high temperature thermal polycondensation temperatures, resulting in a more porous structure [31].

The $S_{\text{BET}}$ for g-C$_3$N$_4$ was 14.6 m$^2$.g$^{-1}$, which was nearly 29 times less than the $S_{\text{BET}}$ for BC(SB), which was 425.1 m$^2$.g$^{-1}$. As shown in table 1, the different percentage melamine to SB ratios have a significant effect on the $S_{\text{BET}}$ of BC(SB)/g-C$_3$N$_4$-M composites. As the melamine ratios increase, the $S_{\text{BET}}$ decreases, resulting in g-C$_3$N$_4$ aggregation clogging the biochar porous structure [32]. The addition of biochar can act as an attachment, preventing g-C$_3$N$_4$ reunion and stacking, as well as exhibiting a more developed nanopore structure, which provides more reaction sites to improve adsorption and photocatalytic degradation [33]. Furthermore, while a high surface area of the catalyst may increase adsorption capacity, it may reduce the rate of photocatalytic degradation. The availability of active sites on the surface decreases as more pollutant molecules adsorb onto the catalyst, limiting active radical generation and thus the pollutants ability to be attacked [29, 34].

The Tauc plot method was used to calculate the indirect $E_g$. The g-C$_3$N$_4$ exhibits strong visible light absorptions at 480 nm, which can be attributed to a narrow bandgap with $E_g$ value of 2.60 eV, which is comparable to previous reported [35]. As for the BC(SB) and BC(SB)/g-C$_3$N$_4$-M composites, they have a significant shift towards shorter wavelengths at 340 nm and 400 nm, respectively, with a wide bandgap of 3.28 to 3.27 eV, which slightly higher than that of the common photocatalyst, TiO$_2$ semiconductor (3.05 to 3.26 eV) [36]. The findings suggest that g-C$_3$N$_4$ can be used as a visible light driven catalyst, whereas BC/g-C$_3$N$_4$-M is beneficial in the UV region.

| Catalyst         | Average Yield (%) | $S_{\text{BET}}$ (m$^2$.g$^{-1}$) | $E_g$ (eV) |
|------------------|-------------------|---------------------------------|----------|
| BC(SB)           | 1.5               | 425.1                           | 3.28     |
| BC(SB)/g-C$_3$N$_4$-M25 | 1.8           | 360.6                           | 3.28     |
| BC(SB)/g-C$_3$N$_4$-M50 | 2.0           | 327.5                           | 3.28     |
| BC(SB)/g-C$_3$N$_4$-M75 | 2.1           | 188.3                           | 3.27     |
| g-C$_3$N$_4$     | 10.4              | 14.6                            | 2.60     |

### 3.3. Photocatalytic degradation of anthracene

#### 3.3.1. Effect of thermal polycondensation synthesis temperature

Adsorption in the dark and degradation of anthracene under visible light irradiation were used to evaluate the photocatalytic degradation of g-C$_3$N$_4$ derived at various thermal polycondensation synthesis temperatures. When exposed to visible light, anthracene self-degrades in the absence of a catalyst, demonstrating that it has a self-degradation process. Surprisingly, the thermal polycondensation synthesis temperature of g-C$_3$N$_4$ had an effect on photocatalytic degradation towards anthracene. Adsorption removals of g-C$_3$N$_4$-M450, g-C$_3$N$_4$-M500, g-C$_3$N$_4$-M550 and g-C$_3$N$_4$-M600 for 2 ppm anthracene in dark were approximately 6.2%, 8.8%, 8.4% and 9.7%, respectively, with constant catalyst dosage (1.0 g/L) and original pH anthracene (pH 9). Figure 4 shows that photocatalytic degradation increased as the synthesis g-C$_3$N$_4$ temperature increased from 450 to 600 °C, with anthracene degradation of 62.4%, 64.8%, 82.2% and 100%. The highest degradation efficiency of g-C$_3$N$_4$-M600 could be assigned to its higher visible light absorption efficiency, which could lead to better photogenerated electrons generation, more efficient separation charge and thus improved photocatalytic activity [37]. However, the lowest degradation efficiency by g-C$_3$N$_4$-M450 could be possibly due to the insufficient reaction of melamine during thermal polycondensation process to produce g-C$_3$N$_4$, as demonstrated by the FTIR
spectra in figure 2, resulting in fewer reaction sites to produce photogenerated electrons to react with radicals for anthracene degradation [33, 13].

Figure 4. Photocatalytic degradation by g-C\textsubscript{3}N\textsubscript{4} synthesized at different synthesis temperature.

3.3.2. Effect \textit{pH} of anthracene. The \textit{pH} of the solution influences the photocatalytic degradation of anthracene, as shown in figure 5. The \textit{pH} of the anthracene affects the surface charge of g-C\textsubscript{3}N\textsubscript{4} via electrostatic attraction [37], thereby shifting the potential of photocatalytic degradation reactions. The surface of g-C\textsubscript{3}N\textsubscript{4} can be protonated (positively charged) or deprotonated (negatively charged) under acidic or alkaline conditions, respectively. By varying the initial \textit{pH} of the anthracene solution, the effect of \textit{pH} on the photocatalytic degradation of g-C\textsubscript{3}N\textsubscript{4} was investigated with constant catalyst dosage (1.0 g/L) and initial concentration of anthracene at 2 ppm. Figure 5 shows that the degradation efficiency of g-C\textsubscript{3}N\textsubscript{4} achieved complete removals of 100\% for both \textit{pH} 3 and \textit{pH} 9 anthracene solutions. However, the anthracene solution at \textit{pH} 3 demonstrated higher adsorption (15.3 \%) and a faster rate of anthracene degradation than the \textit{pH} 9 solution. The photocatalytic degradation of anthracene under high alkaline conditions at \textit{pH} 12 is not favoured by 61.1\% efficiency, presumably due to competitive adsorption by hydroxyl groups onto the surface of g-C\textsubscript{3}N\textsubscript{4} [4].

Figure 5. Photocatalytic degradation by g-C\textsubscript{3}N\textsubscript{4} at different \textit{pH} medium.
3.3.3. Effect of BC(SB)/g-C$_3$N$_4$-M ratios. Melamine ratios in BC(SB)/g-C$_3$N$_4$-M have a great impact on the performance of the catalyst for anthracene degradation. Different initial ratios of melamine and SB were investigated during photocatalytic degradation of 2 ppm anthracene at pH 3 with a catalyst dosage of 1.0 g/L. Figure 6 clearly shows that the BC(SB)/g-C$_3$N$_4$-M composites with the highest degradation efficiency are BC(SB)/g-C$_3$N$_4$-M75%, which reached 72.8% degradation, while anthracene degradation efficiency was only 47.6% for BC(SB)/g-C$_3$N$_4$-M25%. All of the BC(SB)/g-C$_3$N$_4$-M composites, on the other hand, had lower anthracene degradation than g-C$_3$N$_4$, which had a 100% degradation efficiency after 240 minutes of light exposure. This is because the biochar content on the g-C$_3$N$_4$ surface may have reduced the light transmission opportunity and thus the photocatalytic degradation performance to anthracene. When the BC(SB) sample was saturated with anthracene molecules, horizontal anthracene removals revealed that it lost its decontamination ability. Due to the integration of g-C$_3$N$_4$ materials that are light reactive, all BC(SB)/g-C$_3$N$_4$-M exhibits different capability towards anthracene. Even though it is already saturated during adsorption in dark conditions, the material can degrade the molecules when exposed to light. Contrary to the findings of Pi et al. [19], where BC/g-C$_3$N$_4$ composites derived from chestnut leaves and melamine demonstrated that increasing biochar content could improve photocatalytic degradation of methylene blue (MB) and p-nitrophenol by implying the adsorption process played more crucial role in photocatalytic activity.

![Figure 6. Photocatalytic degradation by BC(SB) and BC(SB)/g-C$_3$N$_4$-M composites.](image)

3.3.4. Effect of catalyst dosage. In photocatalytic degradation with 2 ppm anthracene and pH 3, the dosage of g-C$_3$N$_4$ and BC(SB)/g-C$_3$N$_4$-M75% was varied from 0.5 to 2.0 g/L to analyses the effect on anthracene degradation, as shown in figures 7 and 8, respectively. When the dosage of both g-C$_3$N$_4$ and BC(SB)/g-C$_3$N$_4$-M75% was increased from 0.5 to 1.0 g/L, photocatalytic degradation was found to be increasing. This could be due to high availability of active sites on the catalyst surface to receive light photons, resulting in an increase in the formation number of active radicals that participate in anthracene degradation. Increases in g-C$_3$N$_4$ and BC(SB)/g-C$_3$N$_4$-M75% dosage above 1.0 g/L may reduce degradation due to anthracene molecules light penetration, which could be due to the light scattered domination at higher heterogeneous photocatalyst dosage [37]. The generation of electrons and holes was reduced as a result of the reduced light intensity, and thus the photocatalytic degradation of anthracene was also reduced. As a result, the optimum catalyst dosage for both g-C$_3$N$_4$ and BC(SB)/g-C$_3$N$_4$-M75% was determined to be 1.0 g/L.
3.3.5. Effect initial concentration of anthracene. Figure 9 shows that increasing the initial anthracene concentration from 1 to 2 ppm increased the degradation efficiency from 97.2 to 100%. This is explained by the fact that at low anthracene concentrations, fewer anthracene molecules approach the g-C_3N_4 surface, where the active radicals present may be deactivated. Increased anthracene initial concentrations above 2 ppm decreased photocatalytic degradation anthracene possibly due to anthracene molecules saturating the active sites of g-C_3N_4 by adsorption, resulting in a reduction in the total number of photons that can reach the catalyst surface, resulting in fewer active radicals formed and thus lower degradation efficiency [39]. Figure 10 shows that increasing the initial anthracene concentration from 1 to 4 ppm with 1.0 g/L dosage of BC(SB)/g-C_3N_4-M75% at pH 3 results in a significant decrease in anthracene degradation efficiency from 75.2 to 51.1%. The main reason was that as anthracene concentration increased, so did the number of anthracene molecules that needed to be degraded, but the catalyst dosage, the amount of electron-hole pairs generated, light intensity, and irradiation time remained constant during the photocatalytic degradation process [34].
3.4. Reusability of catalyst

Photocatalyst reusability is a method of determining the stability and actual cost of anthracene photocatalytic degradation. The reusability of g-C₃N₄ and BC(SB)/g-C₃N₄-M75% was investigated using anthracene degradation at 2 ppm solution with pH 3 and 1.0 g/L catalyst dosage over 5 cycles, as shown in figure 11 and figure 12, respectively. From the 1ˢᵗ to the 5ᵗʰ cycle, the reusability of g-C₃N₄ and BC(SB)/g-C₃N₄-M75% both decreased by 11.6% and 17.4%, respectively. This could be due to the used catalyst is lost during each sampling [39] or the catalyst surface could be clogged with anthracene molecules that the ethanol washed process could not effectively remove.
Figure 11. Reusability of g-C$_3$N$_4$ for anthracene photocatalytic degradation.

Figure 12. Reusability of BC(SB)/g-C$_3$N$_4$-M75% for anthracene photocatalytic degradation.

4. Conclusions
In summary, the average yield produced decreased with increasing of SB ratios due to higher developed of porous structure that resulting in improved the g-C$_3$N$_4$ surface area, which biochar can act as an attachment to reduce the g-C$_3$N$_4$ reunion and stacking. However, the agglomeration of biochar onto the surface of BC(SB)/g-C$_3$N$_4$-M has shifted the light absorption within UV range with larger bandgap while narrow bandgap g-C$_3$N$_4$ able to absorb light photon in visible light regions. The g-C$_3$N$_4$ that is derived at 600 °C thermal polycondensation synthesis temperature has the highest photocatalytic degradation of anthracene (100%) at pH 3 with 1.0 g/L catalyst dosage and 2 ppm anthracene initial concentration. The BC(SB)/g-C$_3$N$_4$-M75% have the highest photocatalytic degradation among BC(SB)/g-C$_3$N$_4$-M composites at same pH medium and catalyst dosage as g-C$_3$N$_4$ but in the optimum 1 ppm anthracene initial concentration with 75.2% anthracene degradation. The efficiency of the g-C$_3$N$_4$ and BC(SB)/g-C$_3$N$_4$-M75% slightly reduced in photocatalytic degradation of anthracene after 5 complete cycles that proved the reusability of the catalyst in pollutants degrading. To conclude, BC(SB)/g-C$_3$N$_4$-M that is derived from agricultural waste, SB successfully prepared by thermal polycondensation but the challenges to improve the photocatalytic degradation performance and catalyst features required further research. It should be noted this research provide a new sight in
utilization of agricultural waste biomass as a visible light driven photocatalyst in degrading the organic pollutants.

Acknowledgements

The authors gratefully acknowledge financial support by the Ministry of Higher Education (Fundamental Research Grant Scheme (FRGS) (Ref: FRGS/1/2019/STG07/UNIKL/02/4)). The author would also like to acknowledge HICOE AMTEC (A.J090301.5300.07092) for their collaborative research work undertaken at Advanced Membrane Technology Research Centre (AMTEC), Universiti Teknologi Malaysia.

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