Combination of Biogas-dual Fuel Engine Method and Activated Charcoal Adsorbent to Minimize Emissions from Two-wheeler

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Abstract. Two-wheelers emissions have been reduced by using sustainable fuels, mainly biogas, in conjunction with adsorbents made from corncob charcoal. Biogas is obtained by purifying biogas from fermented cow dung. In addition, activated charcoal adsorbents obtained from corn cobs are used in the biogas purification process. This process yields biogas with a methane concentration of 93.4%. Purified biogas is then mixed with liquid fuel. Therefore, this study employs the dual fuel combustion method, in which liquid fuel serves as the pilot fuel. The experiment was conducted by introducing biogas at a rate of 1 L/minute and without load at a constant engine speed of 900 rpm. The findings demonstrate a strong synergy between biogas and activated carbon adsorbents in significantly reducing CO and HC emissions. Notably, the adsorbent's capacity to adsorb exhaust emissions improves as the concentration of NaCl activator in activated charcoal increases. HC emissions can be reduced by up to 20%, while CO emissions can be reduced by up to 5.6%. However, CO emissions show an increase, particularly during biogas combustion. Yet, this increase is reversed when combined with activated charcoal adsorbent. The NaCl activator has been proven to widen charcoal pores effectively, enhancing absorption efficiency.

1 Introduction

Fossil-fueled vehicles have been shown to produce harmful emissions that are adverse to health and the environment. Internal combustion engines emit harmful emissions for a variety of reasons. These factors include the quality of the fuel used in two-wheelers, which can impact on emission levels [1]. Fuels with high sulfur content, for example, can increase particulate matter and other pollutants emissions [2]. Emission control systems in older or poorly maintained two-wheeled vehicles are less effective. This results in increased emissions when compared to newer, well-maintained cars [3]. Congestion, poor road conditions, and traffic congestion might all lead to inefficient engine operation, resulting in higher emissions [4]. Driving aggressively or frequently accelerating or braking suddenly can increase emissions from two-wheelers. Furthermore, overpowering acceleration or high speed can increase fuel consumption and emissions [5].

Efforts to mitigate or reduce motor vehicle emissions are essential, given the negative consequences that those emissions may cause. Vehicle emissions, particularly fine particulate matter (PM 2.5) and other pollutants such as nitrogen dioxide (NO_2), can all contribute to increased air pollution. Long-term exposure to environmental pollutants can lead to respiratory diseases such as asthma, bronchitis, and upper respiratory infections. It may additionally increase the risk of cardiovascular disease, including stroke and heart disease. Furthermore, air pollution from vehicle emissions may interfere with the human immune system, making individuals more susceptible to respiratory infections, allergies, and other immunological disorders [6].

Vehicle emissions also contribute to air pollution, which can harm air quality and disrupt ecosystems. Pollutants such as nitrogen oxides (NOx) and volatile organic compounds (VOCs) can interact with sunlight to produce harmful tropospheric ozone, disrupting ecosystem balance and affecting plant and aquatic life [7]. Furthermore, emissions of greenhouse gases from vehicles, such as carbon dioxide (CO_2), are a significant contributor to global climate change. Vehicle emissions increase global temperatures, cause modifications to extreme weather, and harm ecosystems and human life [8].

Based on the adverse impacts that emissions from these engines might have, the use of renewable fuels is

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one option. Biogas is one of the most promising fuels to use. Biogas is a gas produced by the anaerobic decomposition of organic materials such as agricultural, food, and animal waste. Biogas has the potential to be a more environmentally friendly alternative fuel because it is renewable and emits fewer emissions compared to fossil fuels [9]. However, there are some challenges when employing biogas as a vehicle fuel, such as the accessibility and quality of biogas varying depending on the source [10]. Biogas with a high methane concentration is necessary to minimize the risk of engine damage and improve engine performance. As a result, the biogas used in this study was purified biogas containing a methane concentration greater than 90%.

Employing activated charcoal adsorbents is a further attempt that can be made. Activated charcoal has a high capacity for adsorption on a various of chemicals and pollutants, including some components of vehicle emissions [11]. However, there are various issues and limitations to using activated charcoal as an adsorbent to reduce vehicle emissions [12]. Activated charcoal's adsorption capacity may vary based on the specific components of vehicle emissions. It might be more effective at adsorbing certain pollutants than others. Achieving a balance between selectivity and overall efficiency is essential to ensure that the adsorbent effectively captures a broad range of harmful compounds [13]. Furthermore, activated charcoal becomes saturated over time as it adsorbs pollutants from exhaust gases. Regenerating the adsorbent and restoring its adsorption capacity can be energy intensive and may involve complex processes, which could impact the overall feasibility and practicality of using activated charcoal in real-world applications [14]. In addition, the production and disposal of activated charcoal have environmental implications. Assessing the overall life cycle impact, including potential environmental burdens associated with production and disposal, is essential for evaluating the net environmental benefits of using activated charcoal as an adsorbent [15].

Despite the potential benefits of combining biogas and activated charcoal adsorbents to reduce vehicle emissions, there is currently a research void regarding the most effective way to combine these strategies. While previous studies have explored the individual impacts of biogas utilization and activated charcoal adsorption on emission reduction, limited research has investigated their combined effects in the context of motor vehicle emissions, particularly for two-wheeled vehicles. The synergistic interactions between biogas fuel properties and activated charcoal adsorption mechanisms remain largely unexplored. Furthermore, previous research has often focused on larger vehicles or general combustion processes, and there is a scarcity of specific studies that address the unique challenges and requirements of two-wheeled vehicles. Factors such as engine size, fuel consumption patterns, and emissions profiles may differ significantly between two-wheelers and four-wheelers. This presents an opportunity to delve into the specific nuances of emission reduction strategies tailored to the characteristics of two-wheelers.

Addressing this research gap is crucial for developing effective emission reduction strategies are tailored to the unique context of two-wheeled vehicles. This study intends to provide useful insights into improving emission reduction for this specific vehicle type by thoroughly examining the combined impact of biogas utilization and activated charcoal adsorption. Such insights can guide the development of targeted policies and technologies that align with the distinct attributes and challenges of two-wheeled transportation systems, further advancing the field of sustainable and environmentally responsible transportation.

2 Experimental Setup

This study was carried out on a two-wheeler, and the results are shown in Table 1. Corncob waste will be used as the adsorbent. The process of producing activated charcoal begins with preparing corncobs and then drying them in direct sunlight (dehydration). Sun-dried corncobs are then carbonized (the carbonization process). Furthermore, the charcoal is activated using a NaCl solution.

Table 1. Engines Specification.

Engine type	4-stroke spark ignition engines
Valve configuration	SOHC 2 valve
Cooling system	Air cooler
Bore x Stroke	52.4 x 57.9 mm
Stroke capacity	124.8 cc
Compression rate	9.0 : 1
Max. Power	9.3 PS / 7,500 rpm
Max. Torque	1.03 kgf.m / 4,000 rpm
Transmission	Manual
Gear shifting	N-1-2-3-4
Fuel system	Conventional carburettor

Activated corncob charcoal was created by mixing the prepared NaCl solution with corncob charcoal, stirring until homogeneous, and leaving it in a desiccator for 24 hours. The weight impregnation ratio used is 1:1. The charcoal is subsequently cleaned with distilled water until the pH getting 7. The charcoal is wrapped in aluminum foil and activated in the furnace at 300°C for 3 hours after reaching pH 7. Following the activation procedure, the charcoal will be kept in a desiccator to reduce the possibility of the activated charcoal absorbing other substances. Data will be collected by varying the activation of corncob charcoal without treatment and with a percentage of NaCl solution as an activator at 5%, 10%, and 15%. The biogas used was obtained by purifying biogas from fermented cow dung. The adsorbent used in the biogas purification is activated charcoal adsorbent 15% NaCl. Table 2 shows the compounds identified in biogas before and after purification.

Table 2. Biogas Concentration Before and After Purification

	iogas components		
	CH_4 (%)	***CO_2 (%)***	***H_2S (ppm)***

Before purification	60,5	32,2	290
After purification	93.4	2.2	0

The data collected in this study throughout the emission testing process was acquired from the NHA-405 exhaust gas analyzer in the form of the percentage of CO, CO_2, and HC emissions from the two-wheelers tested for exhaust emissions. Subsequently, a small sample of charcoal utilized as an adsorbent is taken for SEM and EDX analysis. The goal of this test is to determine the chemical composition, and morphology of a corncob-activated charcoal sample.

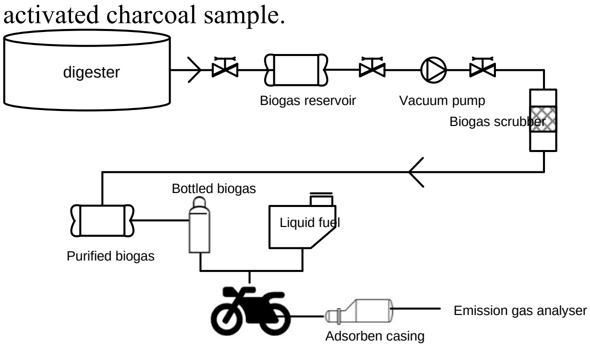

Fig. 1. Schematic diagram of the research

Following the purification of biogas, the biogas is bottled to facilitate its intake into the engine. A bulb flow meter adjusts the volume of biogas introduced by setting it to 1 L/min. Meanwhile, the activated adsorbent is placed in the casing, with a mass of 300 grams of adsorbent used. Figure 1 depicts the research scheme, which begins with the fermentation of cow dung and ends with the analysis of emissions on two-wheelers. Before taking emission data, the two-wheeler is warmed up in order to preserve a constant engine oil temperature.

3 Result and Discussion

The purpose of this study was to determine the concentration of CO, CO_2, and HC exhaust emissions from two-wheelers operating on modified traditional liquid fuel (called pertalite) biogas dual fuel with the addition of corncob-activated charcoal adsorbent. SEM and EDX data will be applied to present the results of observations on the adsorbent after it has been passed by the emission. Carbon monoxide (CO) is a toxic gas compound produced during the motor work process due to of incomplete combustion caused by a lack of air in the fuel mixture entering the combustion chamber or a lack of time available to complete combustion [16]. The results of this emission measurement are shown in Figure 2.

From the figure it is known that P is pertalite, PB is pertalite and biogas, PB+WT is pertalite and biogas with adsorbent without treatment, PB+5% is pertalite and biogas with 5% NaCl activated adsorbent, PB+10% is pertalite and biogas with activated adsorbent 10% NaCl, and PB+15% is pertalite and biogas with 15% NaCl activated adsorbent.

According to Figure 2, the highest content of CO exhaust emissions is obtained when only liquid fuel is used. The lowest CO concentration, on the other hand, can be achieved when dual fuel is employed and an activated adsorbent with 15% NaCl is used. With regard to the findings, it can be concluded that the use of dual fuels in conjunction with activated charcoal adsorbents can reduce CO content in two-wheelers.

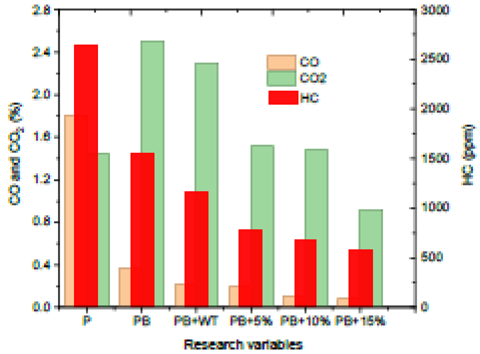

Fig. 2. Emissions concentration from two-wheelers

The CH4 molecule in biogas has a high octane rating of 120 and a high heating value of 44.22 MJ/m3, resulting in a more complete combustion process and less knocking [17]. It is additionally supported by the process of mixing oxidants, which makes it to be easier because methane (CH4) is a gas [18].

The results of the tests show that the dual-fuel engine method is ineffective at reducing CO_2 emissions, but that incorporating adsorbents can reduce these emissions. When biogas is introduced into the combustion chamber and involved in the combustion process, CO_2 emissions increase by an average of 75%. The increase in these emissions is consistent with the following equation (Equation 1 and 2) for burning hydrocarbons:

$$CxHy + \left(x + \frac{y}{4}\right) O2 \rightarrow xCO2 + \frac{y}{2} H2O \qquad (1)$$

$$CH4 + 2O2 \rightarrow 2H2O \qquad (2)$$

Hydrocarbon fuels derived from liquid fuels, as well as methane, will emit more CO_2. The presence of methane in the combustion process causes the majority of the fuel particles to burn, resulting in a higher CO_2 concentration. Methane quickly reaches all parts of the combustion chamber. This causes the volume of burning fuel to increase, resulting in hot spots spreading throughout the combustion chamber quickly [19]. However, when combined with the adsorbent, these emissions were significantly reduced. However, employing a 15% NaCl-activated adsorbent leads to lower emission concentrations than using a single fuel. This condition demonstrates that it is not viable to use biogas in double-fuel combustion when it is not combined with adsorbents.

Hydrocarbons (HC) in exhaust gas are fuel compounds that are not entirely burned in the combustion chamber during the combustion process [20]. Figure 2 depicts a comparison graph of the HC content of all research variables based on the emission test findings.

The results showed that utilizing a dual-fuel blend and an activated charcoal (AC) adsorbent reduced HC emission significantly. The reduction in HC emissions due to dual fuel combustion of biogas leads to improved combustion effectiveness where most liquid fuel atoms are burned, and just a tiny amount of liquid fuel is not burned even at low engine speed conditions. As a result of the presence of biogas in the combustion chamber, the concentration of liquid fuel decreases. This condition promotes the formation of a more even flame distribution in the combustion chamber. As a result, most of the fuel particles can be burned, resulting in less HC emissions in the exhaust line. Similarly, the presence of an adsorbent reduces HC emissions because it is absorbed within the adsorbent's pores. Since absorption performance improves as the concentration of the activator solution increases, so does the adsorbent's effectiveness.

Figures 3 and 5 show the results of the SEM and EDX analyses. All those shown are the result of the adsorbent that have been passed by the emission. The SEM-EDX test results show differences in the surface of activated and non-activated corncob charcoal. Figure 3 shows that the surface of untreated corncob charcoal has fewer pores and is smaller than seen in the SEM results. The activated adsorbent produced the opposite result, with larger pores or voids. Chemically activated charcoal has a larger surface area than regular charcoal. The activation of charcoal with NaCl creates pores and increases the available surface area. The increased surface area allows for more adsorption sites, increasing the capacity of the adsorbent to absorb particles or gases [21]. The pore structure of charcoal is also altered by chemical activation, resulting in a more developed network of pores.

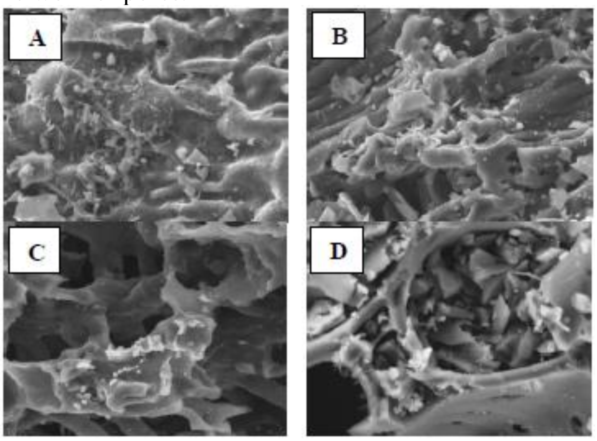

Fig. 3. SEM results of the adsorbent. 3a are adsorbents without activation and 3b, c, and d are adsorbents with NaCl activation of 5, 10, and 15%, respectively

Chemically activated charcoal contains numerous micropores and mesopores, which are particularly effective at adsorbing small particles or gases [22]. Chemically activated charcoal has a higher adsorption capacity than regular charcoal due to the increased surface area and modified pore structure. Due to its increased adsorption capacity, it can effectively capture and retain more particles or gases passing through it [23]. The low emissions recorded in the exhaust gas channel confirm this. Compounds derived from combustion are thought to have become trapped in activated charcoal's pores and crevices. The adsorbent's selectivity toward specific particles or gases can also be influenced by the activation process. Activated charcoal can be tailored to selectively adsorb specific contaminants or gases while minimizing the adsorption of others by changing the chemical treatment [24]. This benefit can be seen in that certain gases, such as HC, CO, and CO_2, can be adequately absorbed.

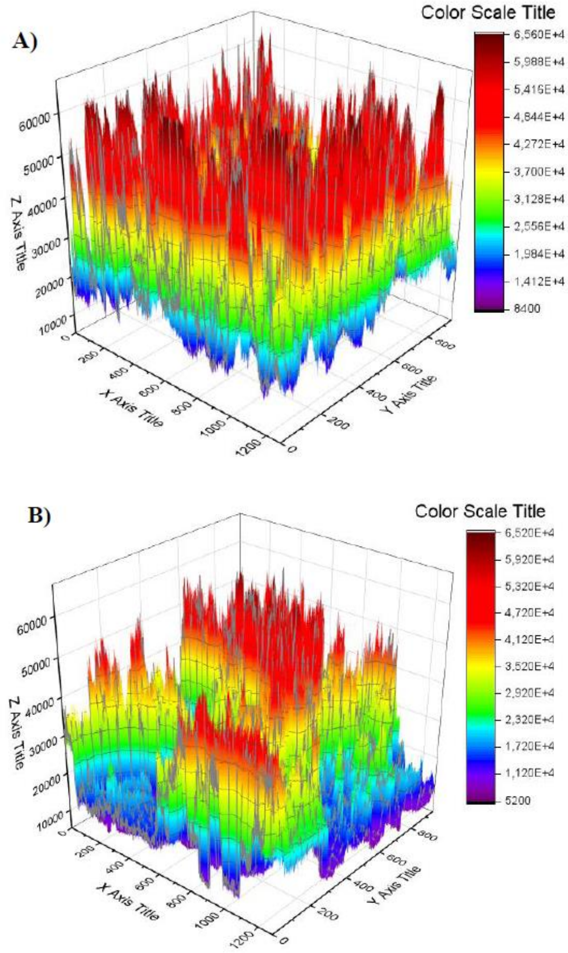

Fig. 4. Fig. 5. 3D graph of corncob charcoal porosity a) without activation, b) with 10% NaCl activation

Figure 4 depicts the percentage porosity of each corncob charcoal sample. Porosity was calculated using OriginPro software by inputting the results of the charcoal's surface morphology. Each sample's porosity value differs, but only charcoal samples without activation and activated charcoal with 10% NaCl are shown. This is because the two samples have the lowest and highest porosity levels. The porosity of untreated corncob charcoal passed by exhaust emissions is 63.6%. The porosity of corncob charcoal activated by 5% and 10% NaCl and passed through exhaust emissions is 68% and 72%, respectively. These findings suggest that increasing the NaCl activator concentration can make the activated charcoal sample appear transparent or thinner, resulting in more excellent carbon absorption. However, at a 15% NaCl activator concentration, it dropped to 62% (not shown). This is attributed to the potential presence of activator compounds in the pores on the surface of the activated charcoal, which may not dissolve during washing. Additionally, there could be substances adhering to the pores on the surface of the activated charcoal that do not evaporate during the carbonization process. The NaCl concentration of 15%

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may be excessively high, causing it to remain in the pores of the charcoal.

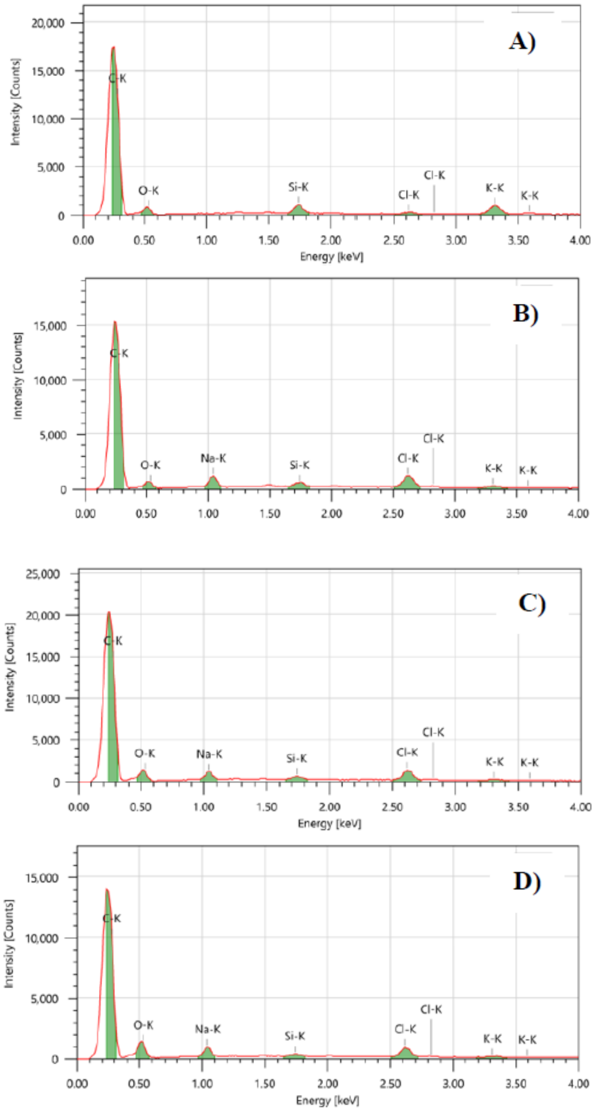

Fig. 5. EDX results of the adsorbent. 4a are adsorbents without activation, and 4b, c, and d are adsorbents with NaCl activation of 5, 10, and 15%, respectively

The EDX results in Figure 5 show that CO_2 emissions primarily caused by the combustion of methane, are absorbed by the adsorbent. This is demonstrated where the concentration of the carbon-oxygen combination is very dominant, and the value increases as the concentration of the NaCl compound increases. However, as the percentage of NaCl compounds increased, the concentration of carbon decreased, and the concentration of oxygen increased. This phenomenon arises due to the higher relative atomic weight of oxygen compared to carbon. The presence of CO compounds trapped in the adsorbent contributes to an increased oxygen composition relative to carbon.

The concentration of silicon (Si) in activated charcoal decreases proportionally as the mass percentage decreases. Moreover, the concentration of Si decreases as the concentration of NaCl increases. This demonstrates that the ability to absorb exhaust emission compounds will improve [25]. By lowering the Si content of the charcoal, the absorption capacity of activated charcoal for compounds that bind to silica increases. However, these modifications may impact the selectivity of activated charcoal absorption for certain substances [26]. As the Si content of activated charcoal decreases, it may become more effective in adsorbing some types of substances and less effective in adsorbing certain compounds bound to silica. However, the findings of this study demonstrate that activating charcoal with NaCl is effective because exhaust emissions are reduced.

4 Summary

The biogas-pertalite dual fuel combustion method proves highly effective in reducing vehicle emissions, particularly carbon monoxide (CO) and hydrocarbons (HC), in two-wheelers. However, it is not the case with CO_2 emissions. CO_2 emissions have increased as the combustion process became more efficient, causing the combustion process to approach stoichiometric conditions. CO and HC emissions can be reduced by up to 80% and 45%, respectively. CO. CO_2, and HC will be significantly reduced if activated charcoal is placed in the exhaust gas line. The NaCl activator is very effective in increasing the absorption capacity of charcoal, with the higher the concentration of NaCl, the greater the adsorbent's effectiveness. Since the severe environmental risks associated with CO_2 emissions, which can contribute to global warming when released into the atmosphere, it is imperative to integrate adsorbents into the efforts aimed at reducing emissions in two-wheelers powered by biogas-premium dual fuel.

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