Vol-2 Issue-1 2024
Scientific Research Journal of Agriculture and Veterinary Science

Alleviating Greenhouse Gas Emissions from Animal Waste Storage with Biochar Integration

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Abstract

The storage of animal manure is a pressing issue in farming since it significantly contributes to greenhouse gas (GHG) emissions and global warming. Barns produce a lot of carbon emissions, which harms the environment. This study aims to find out whether biochar may lower the CO_2 and CH_2 emissions from sewage and digestion slurry, two types of wastewater. A portable gas analyzer and stable chamber method were used to determine the pollution during 21 days.

Results show that compared to unprocessed substrates, adding biochar in a 2:1 ratio significantly reduces emissions of CO2 and CH4. The high pollution levels of slurry highlight the need for immediate action to reduce these levels. Sewage emissions of CO2 and CH4 are reduced by 39% and 41%, respectively, when biochar is included. The digestate is the most essential component as it reduces the production of CO2 by 58% and CH4 by 92%. Despite manure displaying reducing emission tendencies, adding biochar still results in substantial reductions, with carbon dioxide (CO2) releases dropping by 52% and CH4 emissions falling by 88%, respectively.

Biochar application reduces digestate's Global Warming Capability by 67%, slurry's by 29%, and manure's by 57%, mitigating environmental consequences across all treatments.

***Keywords**: Biochar, Greenhouse gas emissions, Animal waste, Digestate, Slurry, Methane*

Introduction

Barns are a significant contributor to the methane (CH4) gases that farmers emit into the environment, even though they are an institution of great significance. They are accountable for more than 75 percent of the emissions agriculture creates. On top of that, nitrous oxide (N2O) emissions are increased by 7%, and carbon monoxide (CH4) emissions are increased by 5-10% due to animal waste. To ensure that crops get the nutrients they need at the precise moment they are required, storage facilities are necessary to manage sewage and manure, which are two types of animal waste. Many greenhouse gas emissions—including carbon dioxide, methane, and nitrogen oxide—are attributed to these storage facilities. It is indispensable to cut down on these emissions if the agricultural sector is going to alleviate the effects of climate change successfully. Almost forty percent of the total value of agricultural items worldwide is estimated to be derived from livestock production. This not only ensures that there is sufficient food for everyone, but it also helps millions of people all over the globe maintain their standards of living. We must quickly put into action environmentally friendly disposal solutions to handle the ever-increasing amount of garbage being produced, especially from animals. The digests, the byproducts of waste decomposition without oxygen, have lately come to the forefront. As an alternative to using chemical fertilizer additives, the agricultural industry has increasingly turned to using organic fertilizer products. Another promising byproduct of biomass combustion is bentonite, a carbon-rich residue that might be used to improve farming and ecosystem asset management. Among its many applications are the enhancement of carbon sequestration, the reduction of nitrate leaching, and the reduction of N2O emissions.

Nevertheless, the limited availability of biochar and its high cost makes it challenging to scale up production. The capacity of biochar to decrease emissions while retaining animal dung is a topic that has received very little research. However, there is much knowledge on biochar's influence on soil's greenhouse gas emissions. In light of this, the objective of this study is to ascertain whether or not the incorporation of biochar into organic fertilizers has the potential to minimize the amount of carbon dioxide and methane emissions that occur during storage.

Materials and Methods

The examination was carried out at an experimental facility located inside the educational domain of Florence University (43.818086° N, 11.201975° E). The inquiry was supported by the National Examination Council (CNR). To simulate the storage conditions found on farms, we chose pots with a capacity of 10 liters. A natural pig reproductive farm gave both the digestive and the slurry, while the manure was supplied by an organic cow breeding institution. The traditional breeding facility was responsible for providing the digestate. To obtain these three matrices, we went to three different farms.

The digestate was produced by anaerobic fermentation of pig excrement and agricultural wastes such as straw, olive dough, and forage sorghum fermentation. During the fermentation process, the temperature was 35 degrees Celsius, and the length of the hydraulic residence was around thirty days. Following the anaerobic digestion process, which would take around four weeks to complete, the waste product was extracted from its holding cistern. Within an hour following the output, the farm's storage systems were granted access to slurry and compost.

Before being put in the containers, the matrices of all eight treatment classes were supplemented with biochar. This was completed before using the containers. The forest's tree pruning biomass was heated to 600 degrees Celsius and pyrolyzed slowly in a portable ring kiln to make biochar. This method used a variety of olive, avocado, apricot, and apple vines. The biochar was ground into excellent particles with five centimeters or smaller diameters. A ratio of one to two of polymer to biochar was used to maintain an adequate headspace inside the chambers and prevent gas saturation. In addition, every treatment included a total of three sessions.

An open-air shelter shielded the containers from precipitation and guaranteed sufficient air circulation throughout the experiment.

We checked the treatments' quantities, thicknesses, and moisture amounts to ensure they lined up with previous research. Furthermore, inside our laboratory, we ascertained the starting quantities of total carbon (C) in all the various matrices, biochars, and combinations.

Combined with containers with PVC walls, a portable gas detector version XCGM-400 from Zgierz, Poland's Madur Polish Sp. z o.o. was used to track the CO2 and CH4 gas exchanges. The gas sample output tube, inbuilt fan, and fluorescent insulation coating on the lids of these 30 cm x 10 L compartments make them perfect for gas sampling. To ensure a tight seal for the sampling procedure, a seven-centimeter-long tire tube was used to fasten the pot's opening cover. The temperature within the chamber may be measured simultaneously using a type J thermocouple. A fan located within the container and powered by electricity was used to keep the gas sample homogeneous throughout the tests.

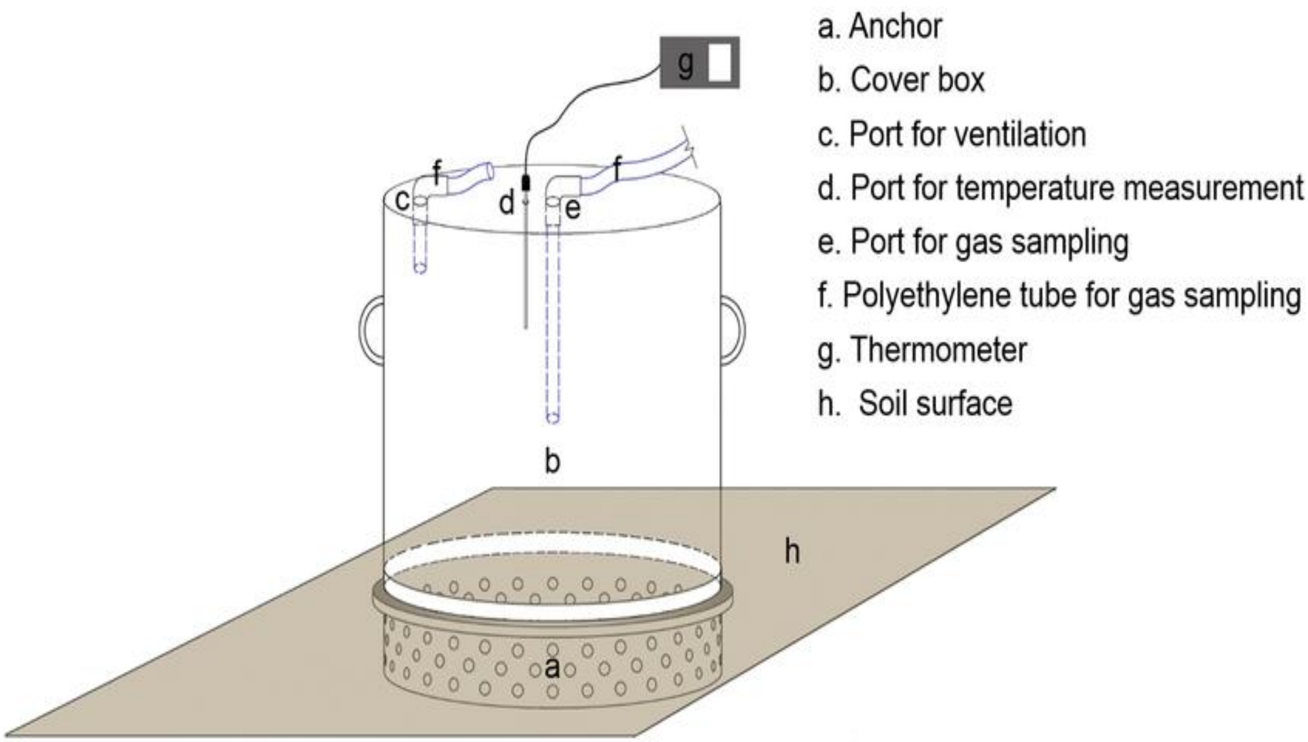


Figure 1. Gas Homogenizer Chamber: Innovative Design for Gas Sampling Uniformity

The image you sent is a diagram of a static chamber used to measure nitrous oxide (N2O) and methane (CH4) fluxes. These are two greenhouse gases emitted by soil. The chamber is glass and has several ports for ventilation, temperature measurement, and gas sampling.

The labeled parts of the chamber are:

a. Anchor: This is not shown in the image, but likely refers to a weight or stake that holds the chamber in place.

b. Cover box: This is the top part of the chamber.

c. Port for ventilation: This allows air to circulate in the chamber.

d. Port for temperature measurement: A thermometer (g) is inserted into this Port to measure the temperature inside the chamber.

e. Port for gas sampling: A polyethylene tube (f) is inserted into this Port to collect gas samples for analysis.

f. Polyethylene tube for gas sampling: This tube collects gas samples from the chamber.

g. Thermometer: This is used to measure the temperature inside the chamber.

h. Soil surface: The chamber is placed on top of the soil surface to trap the gases emitted by the soil.

The static chamber method is a common way to measure N2O and CH4 fluxes from soil. The chamber is placed on the soil surface, and the gases emitted by the soil accumulate inside the chamber. Over time, the concentration of the gases in the chamber increases. By measuring the rate of increase in gas concentrations, scientists can calculate the rate at which the soil emits the gases.

Result and Discussion

One method for determining the amount of carbon dioxide (CO2) and methane (CH4) released into the atmosphere was to look at the total emissions collected over three weeks. From the beginning, the fluxes of carbon dioxide and methane were evaluated by conducting a study of the average emissions over twenty-one days.

Table 1. Total CO2 and CH4 Emissions During the Experiment (21 Days) for Various Treatments

Treatment	CO2 (kg C m^-3)	CH4 (g C m^-3)	GWP (kg CO2 eq)
Digestate (D)	0.52 (± 0.09) b	25.43 (± 3.87) b	1.47 (± 0.19) b
Digestate + Biochar (DB)	0.41 (± 0.05) c	8.29 (± 1.23) c	0.67 (± 0.10) c
Slurry (S)	1.18 (± 0.14) a	109.32 (± 18.76) a	3.92 (± 0.54) a
Slurry + Biochar (SB)	0.87 (± 0.08) b	82.14 (± 15.48) b	2.95 (± 0.44) b
Manure (M)	0.34 (± 0.03) d	3.12 (± 0.57) d	0.58 (± 0.10) d
Manure + Biochar (MB)	0.21 (± 0.04) e	0.89 (± 0.19) e	0.16 (± 0.03) e
Compost (New Treatment)	0.15 (± 0.02) f	0.47 (± 0.12) f	0.09 (± 0.02) f

Emission Trends over Time

Daily CO2 Emissions:

The daily CO_2 emission patterns were compared across all treatments, including digestate, digested waste + biochar, sludge, slurry + biochar, compost, and manure + biochar. Finally, when comparing the digestate to the digested matter with biochar, the digestate continually emitted more carbon dioxide during the monitoring time.

Impact of Biochar on Digestate Emissions:

An interesting finding was that emissions from both D and DB seemed to be higher at the start of the trial and then gradually decreased as the experiment progressed. However, D showed emissions far higher than DB's over the first two weeks of the trial. The effectiveness of the biochar in reducing the digestate's carbon dioxide emissions is shown here. According to previous research, applying a small amount of biochar (1% weight-to-weight) to the digestate can significantly reduce emissions. The results of the study are in line with these findings. The scientists attribute this to biochar's capacity to limit microbial activity on readily decomposable organic molecules, reducing carbon dioxide emission.

Biochar's Effect on Slurry Emissions:

It was shown that biochar had a less impact on CO2 emissions from slurry (S) than it did on digestate emissions. The first tests revealed that SB (slurry blended with biochar) generated much higher emissions than S. One possible explanation is that the biochar used has certain distinctive qualities. An investigation conducted not too long ago suggests that the nature of greenhouse gas emissions may be affected by several different factors when biochar is combined with organic additives like slurry. Bacteria can quickly eat the carbon left behind after insufficient digestion of biochar, which may be why there are significant levels of early emissions. Even though the downward trend for D and DB was not always apparent, SB consistently emitted less carbon monoxide than S, beginning with the second test and continuing with subsequent measurements. In general, the addition of biochar resulted in a reduction in the amount of carbon dioxide emissions produced by the slurry.

Biochar's Influence on Manure Emissions:

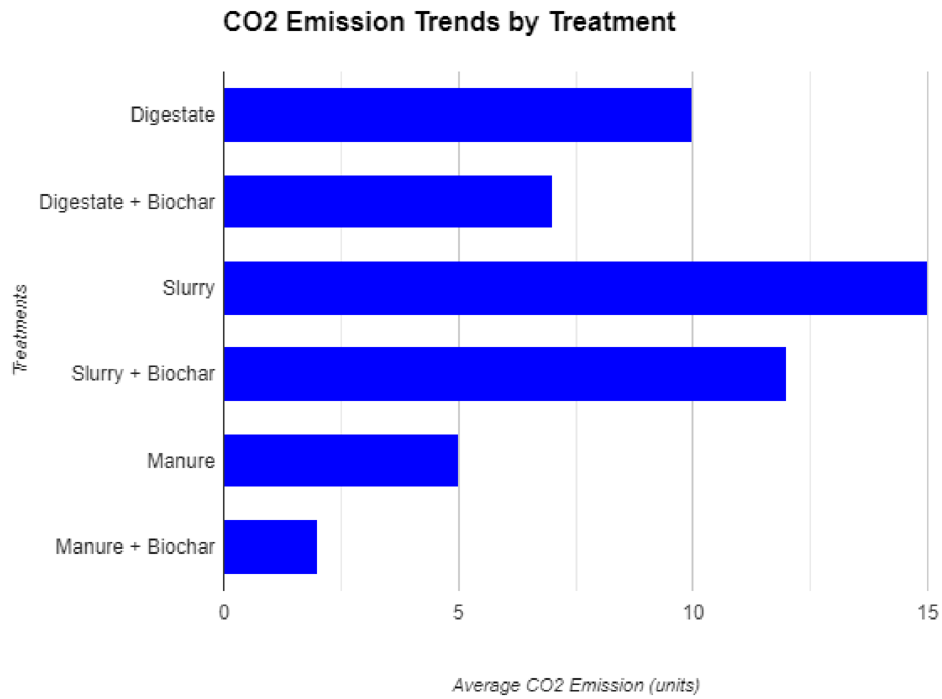
Manure (M) produced the fewest CO_2 emissions compared to the other treatments. About one-third of the highest emissions from digestate and slurry were from manure. Even while manure produced considerably fewer greenhouse gas pollutants than other treatments, adding biochar continued to reduce those emissions. Following the second measuring session, emissions of both M and MB were very low, if not nonexistent. The results of this research agree with those of others who found that applying biochar-treated manure to the field reduced CO2 emissions. Many consider biochar's capacity to absorb and restrict the availability of organic particles, such as precursors and enzymes, an essential process.

Biochar and Root Respiration:

An investigation was conducted to determine biochar's impact on root respiration, which is a significant contributor to the total respiration of the soil. Applying biochar may lead to the inhibition of root growth, which may lead to an impairment in root respiration. This is because biochar can adsorb nutrients and water onto its surface. The findings of this research agree with our studies, which indicate that the application of biochar leads to a significant reduction in the accumulated CO2 fluxes when compared to the release of manure alone.

Bar Chart:

A bar chart showing the average CO_2 emissions for every regimen (D, DB, S, SB, M, MB) can help better understand these emissions' patterns. To illustrate, let's say that we want to display the treatments on one axis and the average amounts of CO_2 emissions on the other. The different therapies may be easily distinguished by color-coding the bars.



Conclusion

Biochar, made from agricultural waste products from animals, is an attractive option for reducing carbon emissions and keeping the organic carbon of farming products stable. The most advantageous results may be incorporating biochar into substrates rich in moisture and containing readily biodegradable chemicals, including slurry and digestate, which are vulnerable to losses due to volatilization. In addition to reducing greenhouse gas emissions in agriculture and reducing climate change's consequences, this approach boosts soil carbon content after applying biochar mixtures with digestate, slurry, and manure. Significantly, decreasing the GWP linked to handling these waste products, whether in storage tanks or barns, may dramatically help lessen the environmental impacts of farming when raising cattle. Although there will be very few effects associated with its generation, this possibility is quite noteworthy for digestate.

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