METHANE MITIGATION POTENTIALS OF BIOCHAR

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Abstract

The increasing demand for livestock products due to improved living standards raises environmental concerns, especially regarding greenhouse gas (GHG) emissions from ruminants. Enteric methane, a potent GHG, contributes significantly to climate change and represents an energy loss of about 12% in ruminants. Biochar, a carbon-rich product obtained through pyrolysis, has shown potential in mitigating methane emissions. Therefore, this study investigated the effect of biochar on in vitro gas characteristics and methane production. Biochar was included in feed at 0.5%, 1.0%, and 1.5%, with feed and biochar alone serving as controls in a completely randomised design ($p<0.05$). Results showed that gas production was higher ($p<0.05$) in feed alone (16.8 mL) and lower in biochar alone (3.3 mL). Inclusion of 0.5% biochar promoted gas production similar to feed, while higher inclusions reduced it. Methane production decreased significantly ($p<0.05$) with increasing biochar levels in feed, with the lower at 1.5% inclusion. These findings suggest that biochar can enhance fermentation efficiency and reduce methane emissions, offering a sustainable strategy for mitigating GHG emissions in ruminant production systems.

Keywords: Biochar, methane, ruminants, greenhouse gas, *in vitro*

Description of the problem

The rising demand for livestock products, driven by better living standards, raises concerns about environmental impacts, especially climate change. Increased livestock production boosts greenhouse gas emissions, notably enteric methane, which harms both the environment and animal efficiency, causing an estimated 12% energy loss. Methane also reacts with oxygen to form ozone, posing health risks to over 3 million people [11]. To combat this, one potential solution is biochar, a solid carbon-rich product created through pyrolysis - heating biomass at 300-700°C without oxygen [8]. Biochar offers benefits such as carbon sequestration, waste management, soil enhancement, and climate change mitigation, potentially reducing up to 12% of human-caused GHG emissions [13]. It also improves livestock health, stable environments, and product quality [10]. Importantly, biochar has shown potential to reduce enteric methane in ruminants [5]; therefore, there is a need for further in-vitro analysis of its effects.

Materials and methods

The experiment was conducted at the Ruminant Laboratory, Department of Animal Science, University of Ibadan (Latitude 7.450615°, Longitude 3.892418°), Ibadan, Nigeria. Maize stover biochar, produced at 450°C using a coal pyrolyser, was incorporated into feed at 0.5%, 1.0%, and 1.5% inclusion levels. Feed alone and biochar alone served as controls in the *in vitro* gas production assay. Rumen liquor was sourced from West African Dwarf goats fed a diet of 60% concentrate (corn, fish meal, oyster shell, salt, brewers' grain, soybean meal, groundnut cake, palm kernel cake, and wheat offal) and 40% *Panicum maximum*, following the method of [1]. Liquor was collected into pre-warmed flasks (39°C) and filtered through cheesecloth, then mixed with a buffer (1:4 v/v) for inoculation. Each 60 mL syringe received 200 mg of substrate and 30 mL of inoculum under CO_2 flushing. Incubation occurred at 39 ± 1°C following [7].

Gas production was recorded at 3, 6, 9, 12, 15, 18, 21, and 24 hours. Methane output was estimated by adding 4 mL of 10M NaOH to each syringe post-incubation [3]. The methane volume was determined by subtracting gas from blanks. Gas production parameters were calculated using the (10) model: $Y = a + b(1 - e^{-ct})$. Metabolizable Energy (ME), Organic Matter Digestibility (OMD), and Short Chain Fatty Acids (SCFA) were estimated using established equations from [7] and [4], based on gas volume, crude protein, crude fibre, and ash content. A Completely Randomised Design was used, and data were analysed using ANOVA with Duncan's Multiple Range Test via SAS 9.2 (2012).

Results and discussion

The *in-vitro* gas production of biochar with different inclusion levels is presented in Figure 1. It was observed that at 24 hours, feed had the highest gas production of 16.8 mL while biochar alone had the lowest value of 3.30 mL. From the *in-vitro* gas production at 24 hours, it was observed that biochar alone had the least value, while the highest value was obtained from feed alone. *In vitro* total gas production increased with the addition of biochar, which might be because biochar contains a wide surface area, which encourages a range of molecular interactions, making it an excellent adsorption material. When biochar is supplemented, an increase in gas production could mean that biochar is stimulating fermentation and rumen microbial activity. This could also be because of the unavailability of degradable nutrients in biochar that can encourage digestibility. This reveals that biochar is not degradable by the microbes in the rumen, but it can be degraded if it is mixed with feed. The high value obtained from feed alone could be a result of nutrients present in the feed which encourage digestibility and also lead to production of gas. The findings corroborate the research of [5] who stated that biochar alone cannot work effectively without feed inclusion when offered to ruminants.

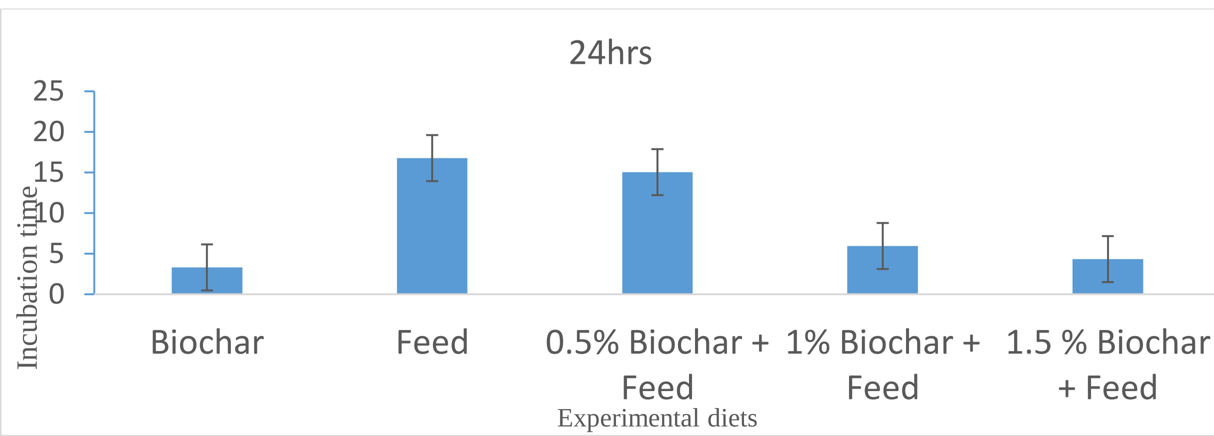

Figure 1: *In vitro* Gas Production of Biochar at Different Inclusion Levels

In-vitro fermentation characteristics of biochar from different inclusion levels were illustrated in Figure 2. It was observed that the soluble fraction (a) did not produce any gas for biochar alone, 1.0% biochar inclusion and 1.5% biochar inclusion, but gas production was observed for feed (3.11 mL) and 0.5% biochar inclusion (2.57 mL), which was not significantly different from one another. The potential gas production fraction (a+b) of 16.8 mL for feed was similar to 15.0 mL for 0.5% biochar but significantly higher ($P<0.05$) than biochar alone, 1.0% biochar and 1.5% biochar. The time 't' for 0.5% biochar (11.6 hrs) was lower compared to other treatments across the board, while the 'Y' value for feed (14.4 mL) was significantly higher than biochar alone (3.77 mL), (2.77 mL) 1.0%biochar and (1.77 mL) 1.5% biochar, respectively. In this study, it was noted that the soluble fraction (a) for biochar alone, 1.0% biochar, and 1.5% biochar did not produce any gas. This absence could be attributed to the lack of fermentable carbohydrates capable of producing a noticeable gas, as gas production relies solely on fermentable carbohydrates from the substrates. Additionally, the gas production from the insoluble but degradable fraction 'b' of the feed (16.8 mL) and 0.5% biochar (15.1 mL) was significantly higher than other values obtained from the treatments. This observation may be due to a substantial amount of fermentable carbohydrates present in these two components compared to the other treatments. The increased gas output (a+b) exhibits the same pattern as (b). The lower time 't' recorded for 0.5% biochar could be a result of increased microbial degradation activity.

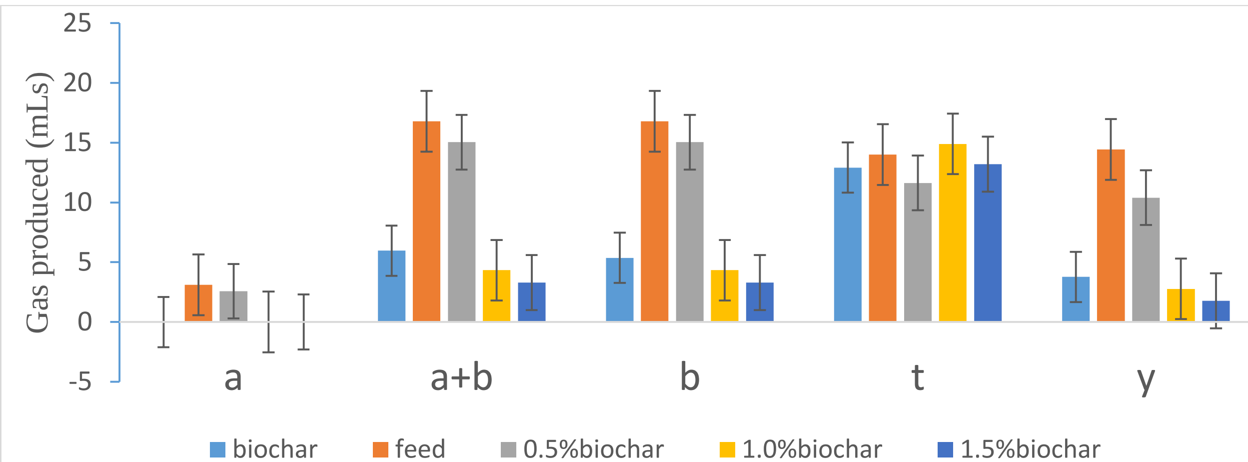

Figure 2: *In vitro* Fermentation Characteristics of Biochar with Different Inclusion Levels

Where y = gas volume produced at time "t", a = gas produced from soluble fraction, b = potential gas production from insoluble fraction, a+b = potential gas production fraction

Methane production

Methane production of biochar at different graded levels was presented in Figure 3. It was observed that methane production was higher in feed alone (5.11mL/200mg) while the lowest production was seen in 1.5% biochar with feed, followed by 1.0% biochar with feed, 0.5% biochar with feed and biochar alone. It was observed that the methane value decreased with increasing biochar inclusion. This could be because of biochar having a wide surface area and porosity, which could favour the growth of methanotrophic bacteria in the rumen and enable the anaerobic methane oxidation. It is anticipated that biochar generated at higher temperatures (with a lower oxygen to carbon ratio) will function as π donors, whereas biochar manufactured at lower temperatures will function as π acceptors [14]. Methane production in the rumen will reduce if biochar in the feed acts as an electron acceptor [5&6]. The lower methane production is essential in ruminants' production in order to reduce the greenhouse gas production caused by these animals.

Nevertheless, [2] discovered that incorporating biochar resulted in a reduction in methane emissions while possibly stimulating methanogenic archaea. This suggests that the production of methane surpassed its utilisation by methanotrophs. Biochar amendment to soil has been shown to enhance aeration, creating more conducive conditions for methanotrophs and promoting increased oxidation of methane [12]. Furthermore, similar conditions were found in the rumen [5&6], where inclusion of biochar provides a habitat and stimulates the development of methanotrophs. Consequently, methane oxidation by methanotrophs is significantly improved within the gastrointestinal tract of ruminants. Methane in the rumen is absorbed by the porous structure of biochar, which gives different bacterial communities, including methanogens and methanotrophs, a place to live [6].

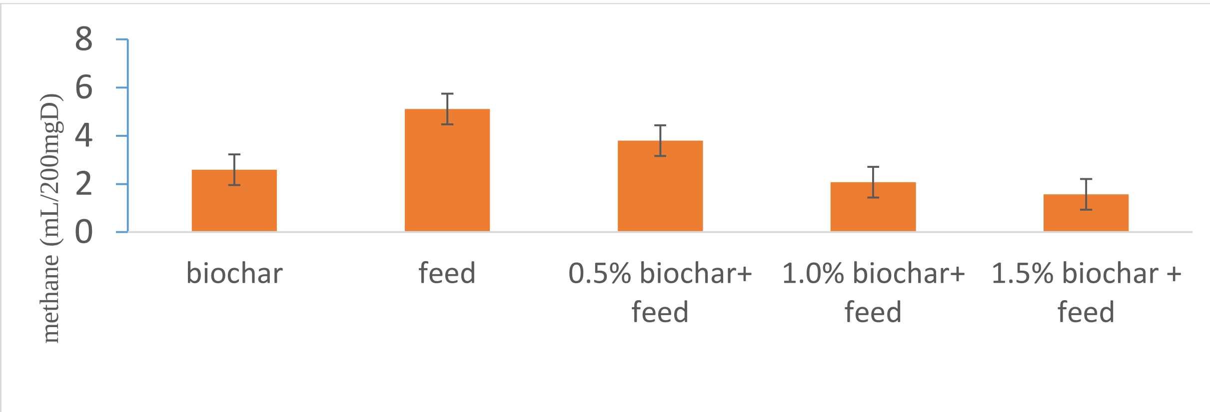

Figure 3: Methane Production of Biochar included at Different levels

Conclusion and Application

Biochar inclusion reduces enteric methane emissions while supporting fermentation. Thus, biochar offers a sustainable strategy for improving ruminant efficiency and mitigating greenhouse gas emissions in livestock animals. This can be applied in all ruminant farms.

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