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The Potential of Rice Husk and Softwood Biochar in Enhancing Nutrient Enrichment of Soil Following Digestate Application

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Abstract

As global consumption of agricultural products continues to rise due to population growth, the volume of agricultural waste generated also increases, necessitating sustainable waste management strategies. Digestate, a nutrient-rich byproduct of anaerobic digestion, has been widely utilized as an organic fertilizer. However, concerns persist regarding environmental pollution caused by nutrient leaching and ammonia volatilization, particularly when excessive nutrients are applied to soil. This study investigates the potential of standard biochar derived from rice husk and softwood to mitigate these environmental risks. A pot trial was conducted using 300g of loamy soil per pot, with treatments including rice husk biochar, softwood biochar (both at 1:10 w/w), and a control group with untreated soil, all prepared in duplicate. Anaerobic digestate was applied to each treatment at a ratio of 1:10 v/w. The experiment simulated heavy rainfall to assess nutrient leaching under different soil amendment conditions. Nutrient concentrations in the resulting leachates were measured using HACH Lange cuvette kits. Results revealed the short-term impact of biochar amendments on nutrient retention in loamy soils. The findings suggest that both rice husk and softwood biochar have potential to reduce nutrient loss through leaching, thus offering a promising strategy for sustainable nutrient management in agricultural systems.

Keywords: Digestate; Biochar; Nutrient Leaching; Rice Husk; Softwood; Sustainable Agriculture

INTRODUCTION

The world heavily relies on agriculture for its food and some raw materials required for industrial activities. Wastes from agriculture such as crop residues are generated as by-products of production and processing of agricultural products, leading to significant quantities of agricultural waste produced globally. Other sources of agrarian waste include fertilisers which although supplies plants with nutrients such as potassium, phosphorus and nitrogen for improved growth and yield but can be a source of eutrophication when released into the open environment (Ramírez-García *et al.,* 2019). On the other hand, lack of food security is still a predicament in many parts of the world, especially in emerging countries, with the number of hungry people increasing globally from nearly 804 million to 821 million from 2016 to 2017. That is around one in every nine persons in the world (FAO, 2018). Therefore, there is a need to improve agricultural activities worldwide, but this will translate into a corresponding increase in the amount of waste produced globally. Hence, it is highly desirable if this waste can be reused to improve agricultural production. One of the most promising ways of managing agricultural wastes, such as animal manure, is anaerobic digestion. Anaerobic digestion of animal manure can produce beneficial products such as biogas, which can be used as a source of energy, and digestate –a liquid by-product with a high nutrient value which can be used as organic fertiliser with less odour, reduced pathogen and higher fertiliser value compared to the feedstock (Holm-Nielsen *et al.,* 2009). However, there have been concerns over the direct application of digestate to the soil. Excess leaching of nitrogen and phosphorus can be a potential source of groundwater pollution while ammonia volatilisation can contribute to air pollution (T Lukehurst *et al.,* 2010). Biochar produced from agricultural waste, especially waste from crop farming, and have shown great potential for agronomic and environmental management. It has gained recognition in science and engineering application for carbon sequestration in mitigating climate change, and a low-cost adsorbent for removal of organic and inorganic pollutants from soil and water (Ahmad *et al.,* 2014). Also, Biochar can enhance soil nutrient as evidenced by the black earth in Terra Petra de Indio in the amazon forest (Lehmann and Joseph, 2015). However, the physical and chemical properties of Biochar are greatly influenced by the type of feedstock and pyrolysis temperature used for its production (Ahmad *et al.,* 2014).

Therefore, it is crucial to investigate how products such as Biochar and anaerobic digestate, produced from materials initially regarded as agricultural waste could be combined to improve soil nutrient and mitigate the potential risk of groundwater pollution. This study focused on how Biochar, a low-cost adsorbent with massive recognition for its impact in reducing pollution and improving soil fertility, could be used to ameliorate concerns related to direct application of digestate to soils. This is crucial for resource management, pollution control and increase in agricultural productivity.

Defination

Biochar The earliest usage of biochar is attributed to the locally known Terra Petra de Indio in the Amazon region which used slash-and-char technique to create dark earth (Lehmann and Joseph, 2015). The international biochar initiative (IBI) defines biochar as a solid material obtained from the thermochemical conversion of biomass in an oxygen-limited environment. Biochar is also defined as the carbon-rich product obtained from the thermal decomposition of organic matter such as biomass, leaves or manure in a closed container with little or no air (Lehmann and Joseph, 2015). While Shackley et al. (2012) defined biochar as a porous carbonaceous solid produced by the thermochemical conversion of organic matter in an oxygen depleted atmosphere with physiochemical properties sufficient for safe and long-term storage of carbon in the environment. The difference between biochar and charcoal is in their operational use. While charcoal is used for producing fuel and energy, biochar is used in the soil for carbon sequestration, improving soil quality and filtration of seeping soil water (Lehmann and Joseph, 2015). Biochar is known for its excellent soil amendment for improved soil fertility and sustainability, with the potential to improve agriculture and mitigate climate change (Ahmad et al., 2014; Lehmann and Joseph, 2015; Mia *et al.,* 2017).

Aim and Objectives

The study aims to investigate, the potential of biochar produced from rice husk (RB) and softwood (SB) on nutrient retention on soil amended with anaerobic digestate.

Objectives

The objectives are to validate experimental methods by examining the effect of autoclaving on the nutrient composition of anaerobic digestate, examine the effect of Rice husk (RB) and Softwood biochar (SB) on soil pH, the effect of digestate application on soil nutrient leaching, and the effects of digestate application on ammonia volatilization.

MATERIAL AND METHOD

Sampling Site

Initial sampling of soil and digestate used for the experiment was carried out at Cockle Park farm, Newcastle, United kingdom. Soil Samples were collected from the top layer of arable land used for growing wheat and barley crops while digestate was collected from an anaerobic digester fed with swine manure.

Standard biochar made from rice husk and softwood pellets produced at pyrolysis temperature of 700^{o}C at the UK biochar research centre Edinburg was used for the experiment.

Biochar Preparation and Mixing

30g each of standard biochar made from rice husk and softwood were pulverised in a fume hood using a pestle and mortar. The pulverised biochar was carefully sieved using a 1mm sieve. The filtered biochar (<1mm) was mixed gently with 300g of loamy soil using a spatula and transferred to a pot. Each treatment was set up in duplicate including the control samples which contains soil only.

Collection, Storage and Application of Digestate

More than 20 litres of anaerobic digestate were collected from the effluent of primary reactor of the anaerobic digester fed with swine manure at Cockle Park farm. It was stored in a refrigerator at 4^{o}C. Before being applied, the digestate was autoclaved at 120^{o}C for 30 minutes. This precaution was to reduce the risk of contact with pathogens contained in the digestate.

Laboratory Experimental Set-up

Trial pots were used for amending 300g of soil with either softwood or rice husk biochar in the ratio 1:10 (w/w), each biochar-soil treatment made in duplicate. The prepared mix were placed in pots made of truncated cone of. 30ml of anaerobic digestate was applied evenly on the surface of each pot. 100ml of Distilled water was applied at an interval of two (2) hours, three (3) times daily. This is to stimulate the maximum daily rainfall in Newcastle, so as determine the most severe condition of nutrient leaching in the soil.

Adsorption of Nutrients on RH and SW Biochar

A 50ml digestion tube was use to convey 1.5g of biochar. This was followed by the addition of 30ml digestate diluted at 1: 100 using DI water. This was performed in duplicate for both rice husk and softwood biochar in addition to two sets of control. Control A contained only 30ml of diluted digestate solution while Control B contained 1.5g of biochar mixed with 30ml of DI water. The pH of the mixtures were measured using a Jenway pH meter. The samples were subsequently mixed rigorously using A Stuart Orbital Shaker oscillating at 101 RPM for a period of 16 hours. The samples were then filtered through a 0.2µm syringe filter with the aid of a sterile syringe shortly after measuring the pH after mixing. Nutrients concentration of the samples and controls were measured using Hack Lange LCK cuvette kits according to the manufacturer's instructions.

Norg was calculated as the difference between total nitrogen and the sum of inorganic nitrogen as shown in the Equation below: Norg = TN – (NH4+-N + NO2--N + NO3--N) (Equation 3) Where Norg = Organic Nitrogen, TN = Total Nitrogen, NH3--N = Ammonium Nitrogen, NO3-- N and NO2--N = Nitrite Nitrogen.

Nutrient Leaching and Ammonia volatilization Batch experiment

Nutrient leaching and ammonia volatilization was set up to stimulate the maximum rainfall event in Newcastle and to determine the effect of Biochar amendment nutrient leaching and ammonia volatilisation following digestate application in a closed system as depicted in figure 2. This was to stimulate the maximum daily precipitation of (value) Newcastle. On a rain gauge with standard surface area of (source). Acidic solution of pH was prepared by dissolving 250µL of 2M HCl in DI water. 100ml of the acidic DI water was placed in a beaker inside the closed system as shown in Figure 2; and was used to solubilize ammonia to ammonium making it possible to determine the concentration of ammonia volatilizing from the surface of the soil through the dissolved ammonium concentration in the acidic solution. 100ml of distilled water was added to each sample every 2 hours, 3 times a day (300ml per day). Leachate samples were collected daily at the end of every stimulated rainfall event through a 500ml beaker placed under the pot and filtered using a 0.45µm syringe filters.

Nutrient leaching and ammonia volatilisation experiment was carried out for a period of six days with nutrient leaching experiment carried out on day 1, 2 and 4; while ammonia volatilization was carried out on 3, 5 and 6. In the ammonia volatilization experiment, NH4+-N concentration was measured every 2 hours, 3 times a day using LCK 304 (0.015 - 2.0mg/L NH4-N) according to the manufacturer's instructions. While TN, NH4+-N, NO2--N, NO3--N and PO43- were measured in nutrient leaching experiment using LCK338 (20-100mg/L TN-N), LCK 304 (0.015 - 2.0mg/L NH4-N), LCK 342 (0.6 -6 mg/L NO2--N), LCK339 (0.23 – 13.50 mg/L NO3--N) and LCK350 (2-20 mg/L PO43--P) respectively in a HACH DR6000 Ultraviolet and Visible Spectrum Spectrophometer. Norg was determined using Equation 3. The same procedure was followed to investigate nutrient leaching and ammonia volatilization before and after digestate application. Heavy metals comprising Cadmium, Chromium, Copper, Nickel, Lead and Zinc were measured in the leachate samples collected following digestate application. This was carried out using inductively coupled plasma mass spectrometry (ICP-MS) according to manufacturer's instructions. This enables the detection of metals at a very low concentration, making it possible to determine the potential of biochar in mitigating metals pollution.

Data Evaluation and Statistical Analysis

Average values were reported as mean plus or minus the standard deviation of the mean. Excel (Microsoft office) and SPSS (IBM). Two-tailed t-Test in excel was used to test the significance of variables under different treatments under confidence level of 95% ($p > 0.05$). F-test was used to check for the equality of variance prior to carrying out t-Test. both at significance level of 95% using Excel 2016 ® (Microsoft office). An f-value of ≥ 0.05 suggests that the two variables have equal variances and therefore the t-Test will be performed under assumption of equal variances otherwise the test will be carried out for unequal variances. One tail t-Test was used were the relationship is apparent for instance when comparing the impact of biochar amendment on soil pH. Soil chemical parameters were statistically tested using SPSS v22 to assess the effect of biochar additions on soil properties compared to the control.

RESULTS AND DISCUSSION

Effect of biochar amendment on soil pH

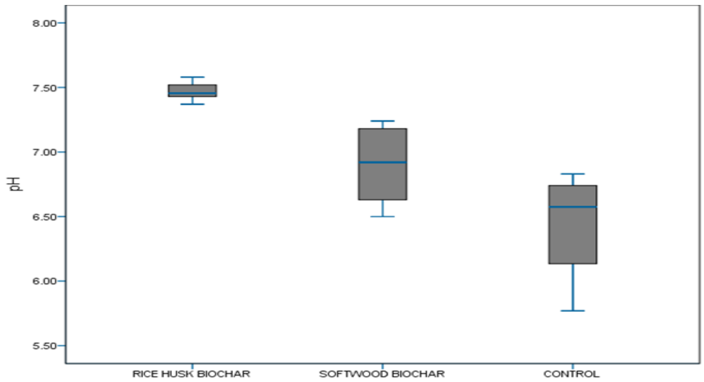

Figure 1. Effect of biochar-amendment on soil pH

Increase in soil pH recorded following soil amendment with RB (6.34 ± 0.412 to 7.47 ± 0.059, p = 0.0289) and SB (6.34 ± 0.412 to 6.9 ± 0.264, p = 0.09). This highlights the potential of biochar in tackling soil acidity leading to improvement in crop productivity.

Adsorption of RH and SW biochar to nutrients

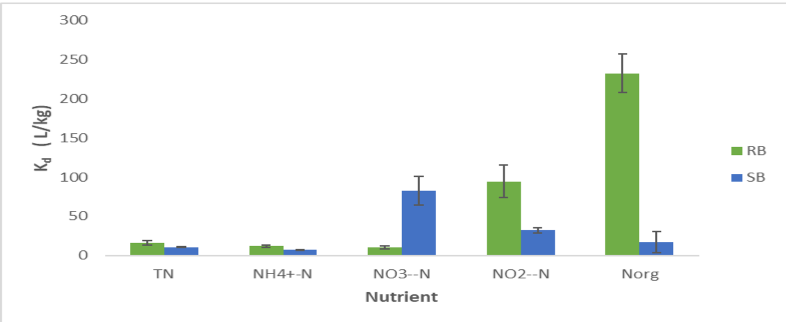

Figure 2. Sorption coefficients (K_d) of biochar to nutrients.

It can be deduced from figure 2, that biochar made from Rice husk has the highest sorption coefficient for organic nitrogen while biochar made from softwood has highest sorption coefficient for nitrate. Both biochar, have negative sorption coefficients for phosphate, which suggests that they desorb phosphate.

Table 1: Initial nutrient concentration on RB and SB

	TN (mg/kg)	PO_4^{3-}-P (mg/kg)	NH_4^+-N (mg/kg)	NO_3^--N (mg/kg)	NO_2^--N (mg/kg)	Norg (mg/kg)
RB	18.6 ± 2.8	79.4 ± 5.4	0	7.03 ± 2.31	1.24 ± 0.16	65 ± 8.48
SB	20.9 ± 4.5	8.3 ± 0.13	0	25.9 ± 2.2	1.1 ± 0.25	12.4 ± 1.45

It can be discerned from the table above, that significant concentrations of phosphate and organic nitrogen can be found on RB. While Initial nutrient addition following amendment with biochar, declines as the biochar ages.

Effect of soil amendment with biochar on nutrient leaching following digestate application

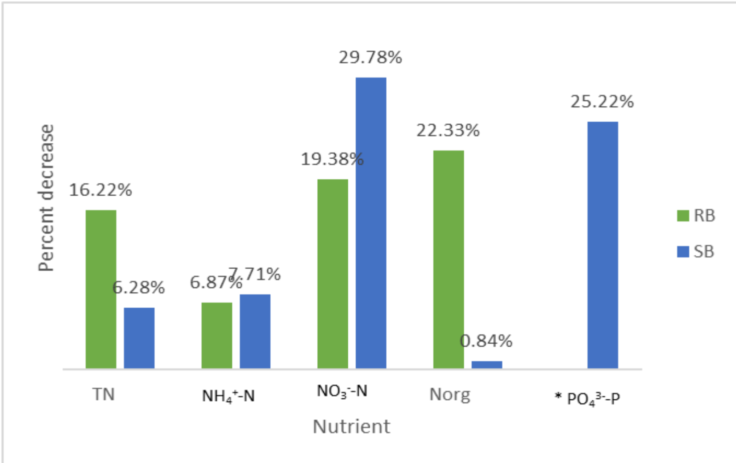

Figure 3. Decrease in leachate nutrient concentration in soil amended with biochar

From the figure above, significant decrease in nitrate concentration with RB and SB (p= 0.0077 and 0.0117). This suggests potential for nutrient retention. significant increase in phosphate concentration with RB (p = 0.0213). Since RB has poor sorption capacity to nitrate, is there an alternative mechanism other than adsorption governing the decrease in nitrate leaching?

Effect of biochar on ammonia volatilisation following digestate application.

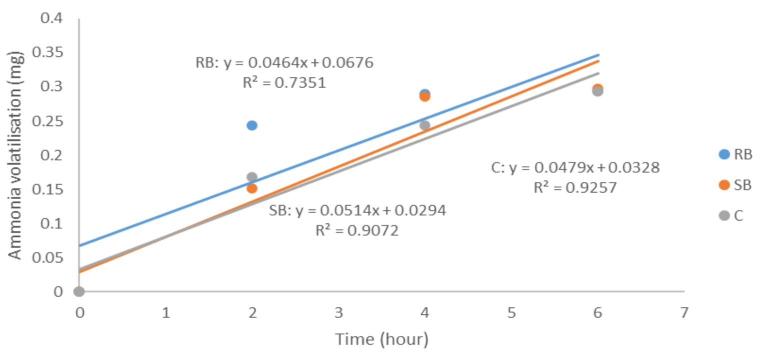

Figure 4. Effect of soil amendment with biochar on ammonia volatilisation

Soil amendment with RB and SB showed no influence on ammonia volatilisation rate (p = 0.5 and 0.482). Possibly influenced by digestate application at the surface of the soil instead of mixing with the soil. Low ammonia concentrations unlikely to be problematic

CONCLUSION

After soil amendment with biochar made from rice husk and softwood in a closed system following digestate application; and short term stimulation of rainfall event, the effect of biochar on nutrient retention and the prevention of ammonia volatilization and nutrient leaching from the soil has been investigated and the following conclusions have been drawn.

1. Autoclaving digestate proved no significant effect on nutrient concentration of digestate.
2. Amending soil with RB significantly increases the soil pH while SB shows apparent increase but not significant.
3. Applying digestate to soil significantly increases the leaching of TN, PO3, NO3 and Nh3 in the soil and shows significant increase in ammonia volatilization rate.
4. •Soil amendment with RB and SB reduced nitrate leaching but showed no impact on ammonia volatilisation in the soil.
5. •Overall decision on the widespread application of Biochar will depend on the outcome of the cost-benefit analysis in using Biochar. The benefits to be derived should not only outweigh the cost but should also prove to be more beneficial than other alternative uses of the feedstock.

Recommendations

It is well documented that Biochar initially increases the nutrient in soil therefore conflicting results may be obtained if the study is conducted short term. Therefore, a long-term investigation is recommended which will involve testing various types of Biochar produced at various pyrolysis temperatures and employing various soil conditions, as biochar properties changes significantly with type of feedstock and pyrolysis temperature used in its production. Finaly it is recommended that a cost- benefit analysis be carried out so that the potential benefits of using biochar instead of other materials or using waste for producing biochar instead of application in other areas could be ascertained.

REFERENCES

Ahmad, M., Rajapaksha, A.U., Lim, J.E., Zhang, M., Bolan, N., Mohan, D., Vithanage, M., Lee, S.S. and Ok, Y.S. (2014) 'Biochar as a sorbent for contaminant management in soil and water: A review', Chemosphere, 99, pp. 19-33.

FAO (2018) 'The State of Food Security and Nutrition in the World', SOFI 2018.

Holm-Nielsen, J., Seadi, T. and Oleskowicz-Popiel, P. (2009) 'The future of anaerobic digestion and biogas utilization', Bioresource technology, 100, pp. 5478-84.

Lehmann, J. and Joseph, S. (2015) Biochar for environmental management : science, technology and implementation. Second Edition.. edn. New York : Routledge.

Mia, S., Dijkstra, F.A. and Singh, B. (2017) 'Chapter One - Long-Term Aging of Biochar: A Molecular Understanding With Agricultural and Environmental Implications', in Sparks, D.L. (ed.) Advances in Agronomy. Academic Press, pp. 1-51.

Ramírez-García, R., Gohil, N. and Singh, V. (2019). 'Chapter 21 - Recent Advances, Challenges, and Opportunities in Bioremediation of Hazardous Materials', in Pandey, V.C. and Bauddh, K. (eds.) Phytomanagement of Polluted Sites. Elsevier, pp. 517-568.

Shackley, S., Carter, S., Knowles, T., Middelink, E., Haefele, S., Sohi, S., Cross, A. and Haszeldine, S. (2012) 'Sustainable gasification–biochar systems? A case-study of rice-husk gasification in Cambodia, Part I: Context, chemical properties, environmental and health and safety issues', Energy Policy, 42, pp. 49-58.

T Lukehurst, C., Frost, P. and Seadi, T. (2010) 'Utilisation of digestate from biogas plants as biofertili