Research article

Effects of adding Rice Husk Biochar on GHG Emission and Compost Quality during Cow Manure Composting

SARVESH MASKEY
Graduate School of Agriculture, Tokyo University of Agriculture, Tokyo, Japan
Email: smaskey27@gmail.com

MACHITO MIHARA*
Faculty of Regional Environment Science, Tokyo University of Agriculture, Tokyo, Japan
Email: m-mihara@nodai.ac.jp

Received 31 December 2020 Accepted 30 June 2021 (*Corresponding Author)

Abstract Agriculture is a major anthropogenic source of Green House Gases (GHG) and contributes 24% of total GHG emitted (IPCC, 2014). Livestock sector forms a significant part of agriculture and is responsible for major GHG emission. According to FAO, 2016, livestock manure contributes 23% to total GHG emitted in agricultural sector. N_2O, CO_2 and CH_4 are important GHG emitted during management of livestock manure. Against the background of global warming, there is increased motivation in reducing GHG emission. Therefore, this study deals to see the effects in N_2O, CO_2 and CH_4 emission by adding 5%, 10% and 15% of rice husk biochar during cow manure composting. In addition, degradation rate and C/N ratio of manure samples were analyzed for determining the final compost quality. Subsequently, a composting experiment was conducted using rice husk biochar and gases emitted were measured periodically with static gas chamber method. The experimental results indicated that biochar was effective in reducing N_2O and CO_2 emissions. The cumulative emission of N_2O was reduced by 40% in 5% treatment, 46% in 10% treatment and 60% in 15% treatment. Similarly, there was decrease of CO_2 by 69% in 5% treatment, 68% in 10% treatment and 48% in 15% treatment. Biochar's well developed pore structure and adsorption capacity reduced the gas emission. Furthermore, addition of biochar enhanced degradation rate and better C/N ratio. Biochar addition provided necessary nutrients and habitat, facilitating growth of various microorganisms. The results of CH_4 emission did not show any significant difference between the treatments. The obtained results indicate that rice husk biochar addition is beneficial in reducing GHG emission and improving compost quality with faster degradation and better C/N ratio.

Keywords GHG emission, cow manure composting, rice husk biochar, compost quality

INTRODUCTION AND BACKGROUND

As the human civilization has evolved, the global climate change has been continuously changing. In recent years, global climate change issues and its relation to human activities has gathered widespread attention. IPCC, 2007, IPCC, 2013, states that global warming is significantly affected by human activities. Furthermore, these reports states that fossil fuel use and land use change are the major contributor of GHGs. AFLOU, which represents agriculture, forestry and other land uses is a major anthropogenic source of GHGs emission and contributes 24% of total GHG emitted (IPCC, 2014). GHGs are mainly composed of CO_2 (76%), CH_4 (16%), N_2O (6%) (IPCC, 2013). Agricultural activities contributes 20% of CO_2, 70% CH_4 and 90% of N_2O (Cole et al., 1997; Yousefi, Damghani and Khoramivafa, 2016). Livestock sector forms a significant part of agriculture and is responsible for major GHGs emission. FAO, 2016, reports that management of livestock manure contributes 23% to total GHGs emitted in agricultural sector. Generally, livestock manure has been used as a soil amendment in the form of compost. Composting is an efficient way of manure management, but also releases GHGs. N_2O, CO_2 and CH_4 are important GHGs emitted during composting of livestock manure. In recent years, biochar has gained significant interest in various environmental applications. Biochar is a product of pyrolysis characterized with microscopic structure having large surface area and has affinity to absorb nutrients, ions etc. (Dünisch et al., 2007; Major et al., 2009), and has been applied in soil to mainatain soil fertility and reducing GHG emission (Van Zwieten et al., 2015). Due to its unique properties, it is an efficeint, cost effective and environmentally friendly material for diverse purposes. Against the background of global warming, there is increased motivation in reducing GHG emissions. Therefore, this study focus to see the effects of adding rice husk biochar during cow manure composting in reducing GHG gases emission and better compost quality.

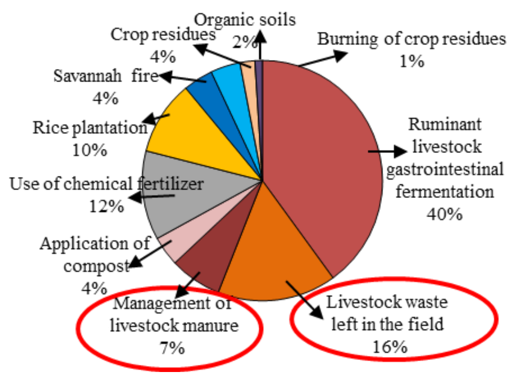

Fig. 1 GHGs contributor in agricultural sector (FAO, 2016)

METHODOLOGY

Compost Box and Gas Chamber

A glass container of dimension 30 cm^3 was used as a compost box. The box was covered with styro-foam sheets of thickness 2 cm on five sides for minimizing the heat loss (Fig. 2) during composting process. A static gas chamber made up of acrylic sheet was used to measure the gas flux. Acrylic sheet was used as it is inert to the target gases. A digital thermometer and a fan were attached inside the chamber for measuring temperature and uniform circulation of air during measurement of gas respectively (Fig. 2 and 3). The volume of air inside the chamber was calculated as 0.017705 m^3.

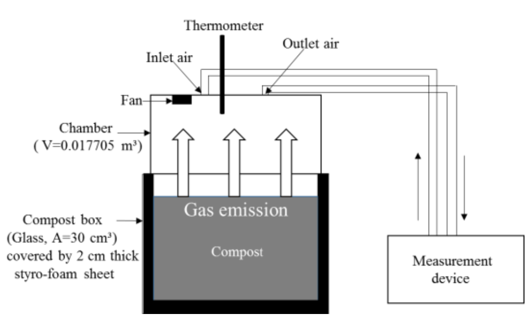

Fig. 2 Schematic diagram of composting box and gas flux analysis

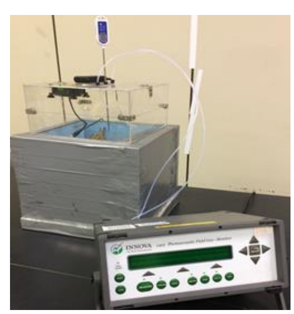

Fig. 3 Apparatus used during gas flux measurement

Conditions of the Experiment

The composting experiment was performed from 8 August 2019 to 7 October 2019 in Laboratory of Land and Water Use Engineering, Tokyo University of Agriculture. The average temperature was 23.0℃ during the experiment period. Cow manure, rice straw and litter was used as main components for composting. The nitrogen content in cow manure and rice husk biochar was 23695 mg/kg and 1241 mg/kg respectively at the start of the experiment. Rice husk biochar was added in three different variations (Table 1). These variations were made to see the most effective composition. The initial water content of the composting material was set at 70±2% for all the treatments.

Table 1 Composition of treatments

Composition	Control	5% Treatment	10% Treatment	15% Treatment
Cow manure (g)	3200	3200	3200	3200
Litter + rice straw (g)	1800*	1800*	1800*	1800*
Rice husk bio-char (g)		250*	500*	750*

*Note: * represents air-dry weight basis*

Gas Flux Measurement

Gas flux was measured using static gas chamber method with photoacoustic spectrometer. The spectrometer used in this study was INNOVA 1412 Photoacoustic Field Gas Monitor (Fig.3). Gas flux was calculated using linear aggression method showed in Equation 1 (Minamikawa et al., 2015).

$$F = \rho \times \frac{V}{A} \times \frac{\Delta c}{\Delta t} \times \frac{273}{T} \quad (1)$$

Where,

F is gas flux (mg m^{-2} hr^{-1}),

ρ is density of gas (kg m^{-3}) where density of NH_3 is 0.772 kg m^{-3} and of N_2O is 1.96 kg m^{-3},

A is bottom surface area of chamber (m^2),

V is volume of air inside the chamber (m^3),

△c/△t is average increase rate of gas density inside the chamber (10^{-6} m^3 m^{-3} hr^{-1}),

T is average temperature inside the chamber (K)

Determination of Degradation Rate

Loss of organic content during a composting process is a measure of biological decomposition and is expressed in the form of degradation rate. The degradation of composting substrates as a function of time follows first order kinectics (Haug 1993, Kulcu and Yaldiz, 2004) and can be expressed as following,

$$\left\{\frac{OM}{OM_0}\right\} = - kt \quad (2)$$

Where,

OM is mass of biodegradable organic matter at any time of composting,

OM_0 is initial mass of biodegradable organic matter,

t is time in day,
k_t is reaction rate constant in days^{-1}

Compost Sampling and Analysis

Compost was sampled at 5, 10, 20, 30, 40 and 60 days to analyze its quality. Temperature of the compost pile was measured using Custom CT-0580 data logger and digital thermometer on daily basis. Organic content was analyzed using Ignition loss method. Carbon content was determined by using the formula C=0.580* IL. Total nitrogen was analyzed by absorption spectroscopy using HC-1000 (Central Science Corp.) as measurement device (Mihara and Ueno, 2000).

RESULTS AND DISCUSSIONS

Biochar Effect on Nitrous oxide Emission

Composting of high organic content materials has been shown to produce N_2O by nitrification and denitrification under aerobic and low oxygen conditions respectively. Fig. 4 shows the periodic change in emission between the treatments. The cumulative gas emission (Fig. 5) was lowered by 40%, 46.4% and 60.4% in 5%, 10% and 15% biochar added treatments compared to control. The result observed is supported by that of Jeffery et al., 2015, which states that addition of biochar can decrease the emission of nitrous oxide. Although the mechanisms of N_2O formation during composting process of animal manure is not studied in details, N_2O emission is mainly associated with nitrification and denitrification process (Sanchez-Monedero et al., 2010). These microbial process is regulated by the quantity of mineral nitrogen, presence of carbon sources and oxygen concentration in composting maerial. Wang et al., 2013, showed 31% lower emissions in biochar treated piles and linked this result in reduction to change in the abundance and composition of denitryfying bacteria. It has been well reported that addition of biochar increases pile porosity, thus increasing oxygen content, weaking denitrification enzyme activity and inhibiting denitrification reaction under anaerobic conditions (Singh et al., 2010).

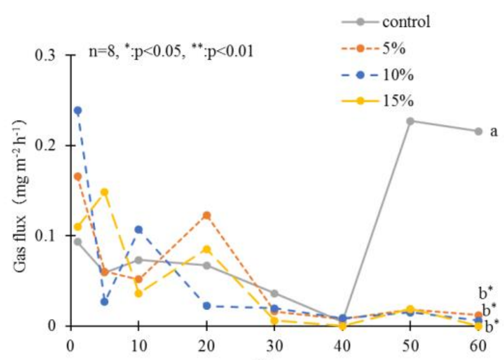

Fig. 4 Periodic change in N_2O flux

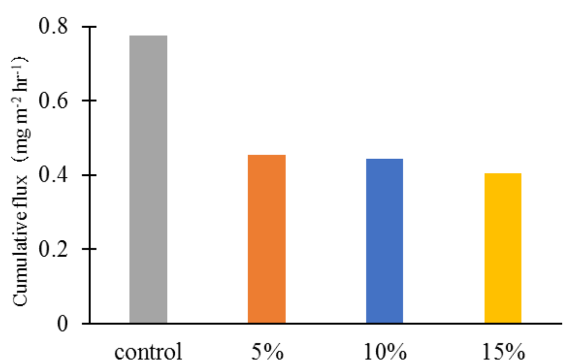

Fig. 5 Cumulative gas flux of N_2O

Biochar Effect on Carbondioxide Emission

The result of periodic changes in CO_2 flux is shown in fig 6. The concentration of CO_2 was highest in control amongst the treatments which conincides to the studies from Awasthi et al., 2017 and Jiang et al., 2016, according to which biochar reduces CO_2 emission. The periodic change in CO_2 flux showed an initial rise and fall at the later stage of the composting process, which was consistent with change in temperature.

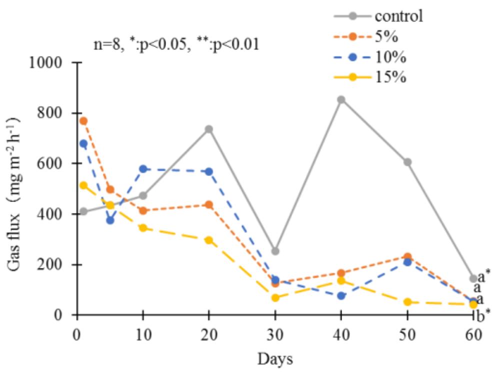

Fig. 6 Periodic change in CO_2 flux

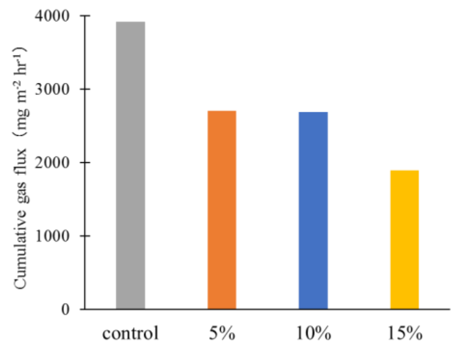

Fig.7 Cumulative gas flux of CO_2

The cumulative gas flux (Fig.7) showed that there was decrease of CO_2 by 69% in 5% treatment, 68% in 10% treatment and 48% in 15% treatment. According to the obtained results, biochar added treatments could reduce the emission of CO_2. This result coincides to the ones reported by Ngo et al., 2013, which states that biochar could increase carbon sequestration of exogenous organic matter when applied in compost mixtures.

Biochar Effect on Methane Emission

Fig. 8 shows the results of periodic change of CH_4 flux and fig. 9 shows the cumulative gas flux emission. CH_4 emission was observed in early stage of the composting period for all the treatments with biochar added treatments having higher emission compared to control. The emission was seen during first week of the experiment with no emission observed after a week for all the treatments. Although, studies have shown that biochar addition enabled to inhibit CH_4 emission in cow manure (Sonoki et al., 2013) and muncipal solid waste composting (Vandecasteele et al., 2013), similar results could not be observed in our study. CH_4 production during composting is mainly associated to anaerobic processes.

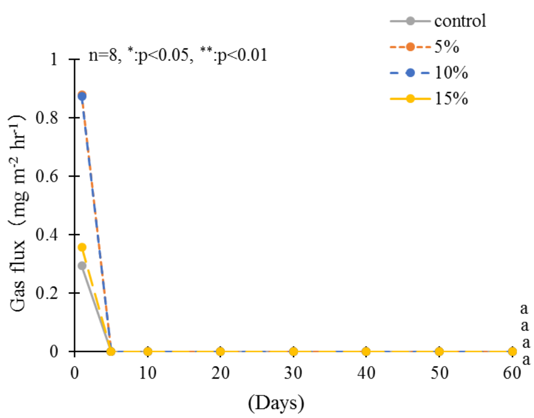

Fig. 8 Periodic change in CH_4 flux

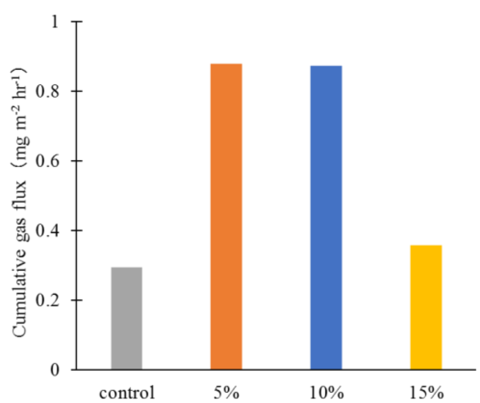

Fig. 9 Cumulative gas flux of CH_4

According to Sanchez et al., 2015, favourable conditions for CH_4 emission can be found in the early stages of composting process, where large amount of nutrients and organic matter are available which enhances microbial growth, depleting the oxygen levels in the pile. Refering to the results of temperature, (fig. 11) where biochar added treatments showed higher temperature gain, showes increased microbial activity, creating anerobic environment. To support this, general bacteria count in the early stage of composting showed higher microbial presence in biochar added treatments.

Biochar Effects on Quality of Compost

C/N ratio and temperature profile are oftenly used as a criteria for determining the quality of compost. C/N ratio is used as an indicator of compost stability and nitrogen availability. Wheareas, increased temperature shows higher microbial activity and faster decompostion of organic substrates. The periodic change of C/N ratio showed better values in biochar added treatments compared to control (Fig. 10).

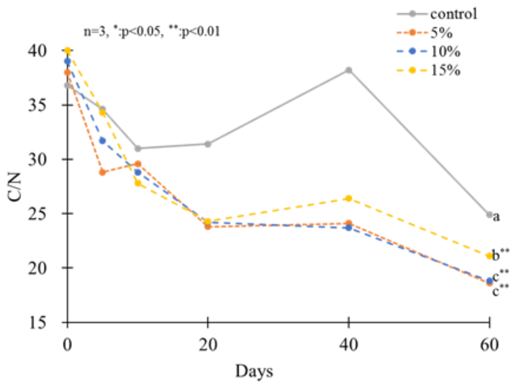

Fig. 10 Periodic change in C/N ratio

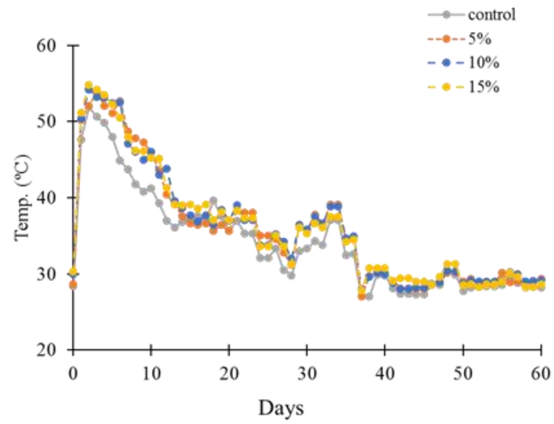

Fig. 11 Periodic change in temperature

Better C/N ratio amongst the biochar added treatments compared to control may be due increased surface area and moisture content favouring microbial activity for degradation and humification of organic material. In addition, biochar increased sorption of nitrogeneous compounds in its microspores, providing microorganism with sufficient nitrogen for their metabolism.Temperature results (Fig. 11) showed rise in temperature in early stages of composting, followed by fall after one week and stabilising around 30 ºC at later stage of composting. Biochar added treatments had higher temperature gain during early stages of composting compared to control due to faster degradation due to reduced heat loss as addition of biochar filled the air pores (Zhang and Sun, 2014). Khodadad et al., reports that adding of biochar increases the relative abundance of Actinobacteria, which are generally able to degrade more organic material, resulting in heat generation.

Biochar Effect on Degradation Rate

The results of degradation rate of organic substrates is shown in table 2. The highest biodegradability after 5 days of composting was seen in 15% treatment with rate constant of 0.034 d^{-1}, followed by 5% treatment with rate constant of 0.032 d^{-1}, followed by 10% treatment with reaction rate of 0.031 d^{-1}, with the least in control having 0.013 d^{-1} of reaction rate. For 60 days of composting, the degradability was in order of 10% treatment with 0.0056 d^{-1}, 15% treatment with 0.0054 d^{-1}, 5% treatment with 0.0052 d^{-1}, followed by control with 0.0045 d^{-1}. The obtained results shows that adding of biochar enhances decomposition of organic matter and degradation rate of the composting substrates. The degradation rate was higher during early and decreased with time. The results of increased degradation in biochar added treatments also agree to that of Zhang and Sun, 2014, which states that biochar amendment increased composting rate, increasing temperatures due to denser substrates with filled pore spaces reducing the heat loss that occurs because of greater air space. Moreover, adding of biochar increased the oxygen uptake, moisture retention and increased the microbial activity resulting in better degradation. Steiner et al., 2015, biochar is a highly porous material having high capacity to retain excess water, improve aeration conditions and provide suitable conditions for microorganisms, promoting microbial activity and increasing organic matter degradation.

Table 2 Degradation rate at 5 and 60 days passed

Treatments	5 days k_t (d^{-1})	60 days k_t (d^{-1})
Control	0.013 a	0.0045 a
5%	0.032 b**	0.0052 a
10%	0.031 c**	0.0056 a
15%	0.034 c**	0.0054 a

*Note: Significance difference at *:p<0.05, **:p<0.01*

CONCLUSIONS

This study was conducted to see the effects of adding rice husk biochar in reducing GHG emission and enhancing final compost quality during cow manure composting. According to the results of this study, addition or rice husk biochar was efficient in reducing GHG emission and significantly enhancing degradation and mineralization of organic substrates during cow manure composting. In the given conditions, addition of biochar was effective in decreased N_2O and CO_2 emission. However, no significance difference was seen in CH_4 emission. On the other hand, compost quality with better degradation and nitrogen mineralization was observed. Although, 15% treatment (750 g in 5 kg) had highest reduction of GHG emission and enhanced compost quality, relatively small amount of 5% (250 g in 5 kg) treatment was also effective. Considering these findings, rice husk biochar could be an effective and beneficial practice for management of cow manure for reducing GHG emission and better quality of cow manure compost.

REFRENCES

Awasthi, M.K., Wang, M., Chen, H., Wang, Q., Zhao, J., Ren, X., Li, D., Awasthi, S.K., Shen, F., Li, R. and Zhang, Z. 2017. Heterogeneity of biochar amendment to improve the carbon and nitrogen sequestrtation through reduce the greenhouse gas emission during sewage sludge composting. Bioresour. Technol, 221, 428-438.

Cole, C.V., Duxbury, J., Freney, J., Heinomeyer, O., Minami, K., Moiser, A., Paustian, K., Rosenberg, N., Sampson, N., Sauerbeck, D. and Zhao, Q. 1997. Global estimates of potential green house gas by agriculture. Nutrient Cycling in Agroecosystems, 49, 221-228.

Dünisch, O., Lima, V.C., Seehann, G., Donath, J., Montoia, V.R. and Schwarz, T. 2007. Retention properties of wood residues and their potential for soil amelioration. Wood Sci. Technol. 41, 169-189.

FAO. 2016. The state of food and agriculture. FAO, Rome.

Haug, R.T. 1993. The practical handbook of compost engineering. LEWIS, Boca Raton, FL, USA.

IPCC. 2007. Climate change 2007. The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC. 2013. Climate change 2013. The physical science basis. Working group I. Contribution to the fifth assessment report of the IPCC. Cambridge University Press.

IPCC. 2014. Climate change 2014. Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Chang IPCC, Geneva, Switzerland, 151.

Jiang, T., Ma, X., Tang, Q., Yang, J., Schuchardt, F. and Li, G. 2016. Combined use of nitrification inhibitor and struvite crystallization to reduce NH_3 and N_2O emissions during composting. Bioresour. Technol, 217, 210-218.

Kulcu, R. and Yaldiz, O. 2004. Determination of aeration rate and kinetics of composting some agricultural wastes. Bioresour. Technol, 93 (1), 49-57.

Major, J., Steiner, C., Downie, A. and Lehmann, J. 2009. Biochar effects on nutrient leaching. 271-288. In Lehmann, J. and Joseph, S. (eds.), Biochar for Environmental Management, Science and Technology, Earthscan, London.

Mihara, M. and Ueno, T. 2000. Nitrogen and phosphorus transfer in soil erosion process, IAHS Publication, No. 263.

Minamikawa, K., Tokida, T., Sudo, S., Pare, A. and Yagi, K. 2015. Guidelines for measuring CH_4 and N_2O emission from rice paddies by a manually operated closed chamber method. National Institute for Agro-Environmental Sciences, Tsukuba, Japan.

Ngo, P.T., Rumpei, C., Ngo, Q.A., Alexis, M., Velasquez Vargas, G., Mora Gil Mde, L., Dang, D.K. and Jouquet, P. 2013. Biological and chemical reactivity and phosphorus forms of buffalo manure compost, vermicompost and their mixture with biochar. Bioresour. Technol, 148, 401-407.

Sanchez-Monedero, M.A., Serramia, N., Civantos, C., Fernandez-Hernandez, A. and Roig, A. 2010. Greenhouse gas emissions during composting of two-phase olive millwastes with different agroindustrial by-products. Chemosphere, 81 (1), 18-25.

Singh, B.P., Hatton, B.J., Balwant, S., Cowie, A.L. and Kathuria, A. 2010. Influence of biochar on nitrous oxide emission and nitrogen leaching from two constrasting soils. J. Environ. Qual., 39 (4), 1224-1235.

Sonoki, T., Furukawa, T., Jindo, K. and Suto, K. 2013. Influence of biochar addition on methame metabolism during thermophilic phase of composting. Journal of Basic Microbiology, 53, 617-621.

Steiner, C., Sanchez-Monedero, M.A. and Kammann, C. 2015. Biochar as an additive to compost and growing media. In Lehmann, J. and Joseph, S. (Eds.), Biochar for Environmental Management: Science, Technology and Implementation EarthScan, 2, 715-733.

Van Zwieten, L., Kammann, C., Cayuela, M.L., Pal Singh, B., Joseph, S., Kimber, K., Donne, S., Clough, T. and Spokas, K. 2015. Biochar effects on nitrous oxide and methane emissions from soil. In Lehmann, J. and Joseph, S. (Eds.), Biochar for Environmental Management: Science, Technology and Implementation EarthScan, 2, 487-518.

Vandescateele, B., Mondini, C., D'Hose, T., Russo, S., Sinicco, T. and Quero Alba, A. 2013. Effect of biochar amendment during composting and compost storage on greenhouse gas semissions, N losses and P availability. 15th RAMIRAN International Conference. Recycling of Organic Residues for Agriculture: From Waste Mangement to Ecosystem Services, Universite de Versailles St-Quentien-Yvellines, Versailles.

Yousefi, M., Mahdavi, A. and Khoramivafa, M. 2016. Comparison greenhouse gas (GHG) emissions and global warming potential (GWP), Effect of energy use in different wheat agroecosystems in Iran. Environmental Science and Pollution Research, 23. 10.1007/s11356-015-5964-7.

Zhang, L. and Sun, X. 2014. Changes in physical, chemical, and microbiologicalproperties during the two-stage co-composting of green waste with spentmushroom compost and biochar. Bioresour. Technol, 171 (1), 274-284.