JFHB Journal of Food Health and Bioenvironmental Science

Journal of Food Health and Bioenvironmental Science
Journal homepage : http://jfhb.dusit.ac.th/

The Improvement of Hydroponics Growth Media by Using the Corncob Biochar

Pannipha Dokmaingam[a,b]*, Sitang Kongkratoke[a,b], Amornrat Anuwatnonthakate[a] & Sarayut Yongprapat[c]

[a] *School of Health Science, Mae Fah Luang University, Chiang Rai 57100, Thailand*
[b] *Research Group Circular Economy for Waste-free Thailand, Mae Fah Luang University, Chiang Rai 57100, Thailand*
[c] *Venus supply Co., Ltd., Bangkok 10900, Thailand*

Article info

Article history:
Received : 10 September 2020
Revised : 10 December 2020
Accepted : 14 December 2020

Keywords:
Corncob, Biochar, Hydroponic growth media, Crop production

Abstract

Corncob is one of the main agricultural wastes in the northern part of Thailand. It is utilized in many proposes such as wood pellet, activated carbon or biochar. Biochar has several excellent properties that could provide benefits for agriculture applications such as water absorption, ionic exchange, water holding capacity, and conductivity. These properties could also offer an advantage for the hydroponics system. This study selected corncob biochar for improving the growth of hydroponic plants. Firstly, the commercial biochar will be characterized it's chemical and physical properties and then hydroponic plants, namely Red Oak lettuces, Green Oak lettuces, and Cos lettuces, were grown in the growth medium with and without biochar in order to compare the growth of plants. It was found that corncob biochar has high aliphatic carbon content with 99.27 % fixed carbon. As the morphology properties, it's surface area, total pore volume and mean pore diameter are 40.4695 m^2/g, 0.0385 cm^3/g, 3.85875 nm., respectively. These advantage for promote nutrients utilization in the hydroponics system. These are also affected to different number of leaves of Cos lettuce and dry weight of Green Oak lettuce from growth media with and without biochar which is reached a significant difference level ($p<0.05$). It was suggested that adding a small amount of corncob biochar could endorse nutrients used in a hydroponics system. This would advantage for put forth shoots of hydroponic plants. However, the biochar would benefit for microbial activity that is important to water and nutrient uptake. This would more advantage if biochar is applied to the soil.

Introduction

During 2012-2014, around 4,000,000 tons/year of maize was produced in Thailand (Centre for Agricultural Information, 2017) which are mostly used as raw material for industrial animal feed. One of the main residuals of this industrial is corncob. This is around 15% of the maize yield and is more than 1,000,000 tons/year. (Tangtaweewipat et al., 2012). Burning becomes the most common method to dispose of this large amount of agriculture residual because it is easy and fast. However, this also causes air pollution (especially pm 2.5) in Thailand. This problem

* Corresponding Author
e-mail: pannipha.dok@mfu.ac.th

has been extremely concerning for the last decade. This pollution affects health, economics and environment. The Kasikorn research center reported that the impact of air pollution on the economy of the Bangkok Metropolitan Region could be around 3,200–6,000 million baht for 1 month (Kasikorn research center, 2020). Additionally, the quality of soil is also reduced from the burning. This might be because of the annihilation of the microorganism and porosity destruction in soil by burning. As the environmental problem from agriculture waste burring, many alternative solutions were developed to use the corncob, instead of burning, such as wood pellet (Tangtaweewipat et al., 2012), activated carbon (Khoomsab et al., 2015) or biochar (Angmanee et al., 2017; Tansathit et al., 2016). Among them, biochar is preferred for agricultural proposes. Generally, biochar is produced via the pyrolysis process. Several previous studies applied biochar to improve solid properties (Angmanee et al., 2017; Novak et al., 2009; Zhu et al., 2017). The conditions for pyrolyzed different feedstock types are also studied (Ronsse et al., 2013; Zhu et al., 2017). As the agricultural benefit, biochar is interesting because it could be used as soil amendments. This is the result of the physical properties of biochar which are high porosity and surface area. These properties could improve water absorption, ionic exchange and reduce the density of soil structure, water holding capacity, conductivity, porosity, and adjusting pH (Angmanee et al., 2017; Awad et al., 2017; Fryda & Visser, 2015; Tansathit et al., 2016). Moreover, biochar could limit the heavy metal and over secondary macronutrients into the plant nutrients absorption process (Rizwan et al., 2016). The pyrolysis biochar could improve the water-holding capacity and reduce water and nutrient leaching (Jahromi et al., 2018). As these advantages, biochar is suggested as a growth media for hydroponics (Awad et al., 2017; Blok et al., 2017; Vaughn et al., 2015). Moreover, the biochar molecules are stable and highly resilient to microbial degradation (Blagodatskaya et al., 2014; Singh et al., 2017). Hence, the introduction of biochar may not only maintain suitable nutrients for plant growth but may also restrict the unwanted algal growth around the plant root, preventing the adverse effect of these microbial on crop yield. However, further research is required to proof the practicality and benefits of using corncob biochar as a growth medium in hydroponic systems.

Now a day, biochar could be used for hydroponics growing medium. These could be produced from rice husk biochar (Awad et al., 2017; Blok et al., 2017), rice straw biochar (Vaughn et al., 2015) or agriculture residual biochar (Blok et al., 2017). It might be assumed that the properties of growth medium for Hydroponics could be improved by adding some of the biochar. This study has produced significant evidence backing this claim. The aim of this work is to study the benefits of biochar from corncob as the growth medium for hydroponics plants. Three common hydroponics plants are selected in this study which are Red Oak lettuces, Green Oak lettuces, and Cos lettuces. We hope that by increasing the applicability of the biochar and increasing the productivity of hydroponic plants, the inappropriate burning of the agriculture residual should be lowered.

Materials and methods

In this study, the commercial biochar was sent from Mae Chaem, Chiang Mai, Thailand which are the major source of the corncob. The biochar was pyrolyzed from corn crop at an operating temperature around 650˚C. This biochar was characterized by both chemical and physical properties. The functional group of this biochar is analyzed by using Fourier-transform infrared spectroscopy (FTIR). The surface area and the surface morphology of the activated carbon were determined by Brunauer-Emmett-Teller (BET) and a scanning electron microscope (SEM), respectively. Nuclear magnetic resonance spectroscopy (NMR) is used for analyzing the core-structural characteristics of biochar. It was evaluated via Fourier Transform Nuclear Magnetic Resonance Spectrometer 400 MHz. (Solid) – NMR 400 MHz. (Bruker, Germany). It was operated at 13C frequency of 75.5 MHz. Their chemical composition was studied via Ultimate analysis process. The pH of the biochar was evaluated by mixing biochar with De-ionized water with a ratio of 1 % (w/v) and shaking for 24 h. pH was measured by using multimeter (Multi 350i/SET, WTW, Germany) (Novak et al., 2009).

After that, the benefit of addition biochar in to support culture for hydroponic plants was investigated in the experimental field. The size of hydroponics systems is 160 cm. x 600 cm. x 80 cm., combined with a nutrient solution container for growing 160 plants. All testing samples were cultivated in the hydroponic system with commercial liquid fertilizer (N=268.5 ppm, P=56.724 ppm, K=326.19 ppm). Three types of hydroponic plants were selected in this testing which are Red Oak lettuces (*Lactuca sativa* var.*crispa* L.), Green Oak lettuces

(*Lactuca sativa* L.), and Cos lettuces (*Lactuca sativa* L.). Note that these seed were obtained from Maejo 68 Seed company, Chiang Mai, Thailand.Ten of these plants will be implanted in the support culture with and without biochar. The pots of all testing seed were distributed uniformly in the hydroponic growth systems were placed without a greenhouse. For the support culture with biochar, 1g. of biochar added to the support culture before seeding. Meanwhile, the control sample is directly seeding in the support culture. These were harvested after 45 days of seeding. After that, their growth was measured. The growth of hydroponic plants from these two-difference support cultures was identified by measured width and length of leaf, the number of leaf and dry weight of plants. The differences in each treatment were adjudged by Tukey test ($P \leq 0.05$).

Results and discussion

1. Fourier-transform infrared spectroscopy (FTIR)

From FTIR spectrum from range between 500-4000 cm^{-1}, as presented in Fig. 1, shows the absorption band of aliphatic carbon (2869 cm^{-1}: C-H stretching and 1540: C=C stretching). The band at 2358 cm^{-1} is designated as the O=C=O stretching from the adsorbed CO_2 which absorbed on the alkaline biochar. The wideband from 1700-1600 cm^{-1} are assigned to C=O stretching of ketone, aldehyde or carboxyl groups. As a result, the carbonyl carbon has a large partial positive charge and the oxygen has a large partial negative charge as denoted (Smith, 2016). These functional groups benefit for ionic exchange of nutrient utilization at the roots of plants.

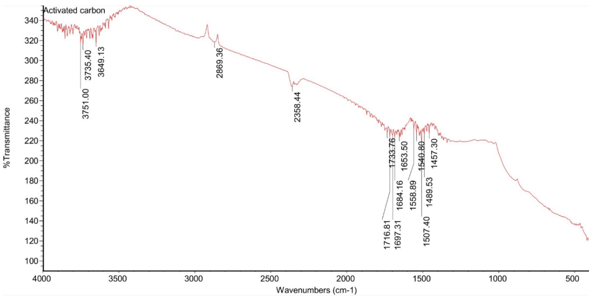


Fig. 1 The FTIR spectrum of the biochar from corn crop

2. Nuclear magnetic resonance spectroscopy (NMR)

As seen in Fig. 2, the ^{13}C NMR of biochar was dominated by the aliphatic C=C and aromatic-C centered at 124 ppm. Two other peaks centered at 206 and 47 ppm indicates the presence of carboxyl and aliphatic C-C. Biochar with high aromatic-C contents is probably appropriate for long-term C sequestration. Moreover, biochar with high aromatic-C are resistant to microbial mineralization (Novak et al., 2009).

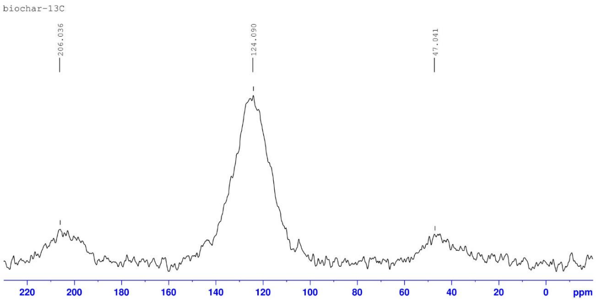


Fig. 2 ^{13}C NMR spectral scan of the biochar from corn crop

3. Biochar porosity

In this study, SEM images of biochar from corncob shown in Fig. 3 with different magnifications. The surface morphology of the biochar was structure with different diameters of pores. In Fig.3 (b), the pore size in range of 1 to 7 µm. were observed, which is classified as storage pores (0.5 to 50 µm.) (Batista et al., 2018). The BET results are shown in Table 1. This is influence to capable of holding water and the retention of nutrients in the growth media.

Table 1 Porosity properties of corncob biochar

Parameter	Porosity Property
Surface area	40.4695 $m.^2/g$
Total pore volume	0.0385 $cm.^3/g$
Mean pore diameter	3.85875 nm.

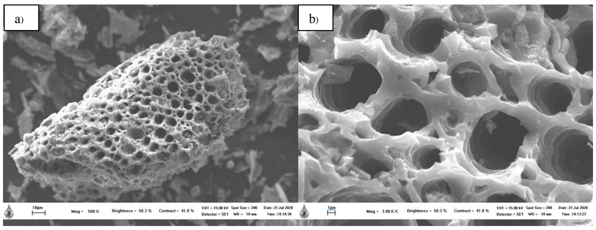


Fig. 3 SEM of the biochar from corncob at magnification of (a) 500 x and (b) 3000 x.

4. Chemical properties of biochar

The solution from biochar is in the alkaline pH region (Table 2). However, Nurhidayat & Mariati (2014) recommends that pH in range of 5.0 - 7.5 is the suitable range for nutrient accessibility for the plant. Outside this range, the nutrient loading for the plant will be imbalanced. This might advantage to change the acidic growth media to improve nutrient utilization for plants.

The proximate results indicate that the fixed carbon was a dominant content at more than 90% in the biochar which is consistent with the ^{13}C NMR result.

Table 2 Chemical properties of corncob biochar

Sample	pH	Volatile (%)	Ash (%)	Fixed carbon (%)
1	8.33	0.58	0.11	99.32
2	8.32	0.70	0.06	99.24
3	8.30	0.67	0.09	99.25
Average	8.32	0.65	0.09	99.27

5. Effect of biochar on plants growth

The effect of biochar on hydroponic plants growth were shown as followed. The plants were seeded and grown in hydroponics growth media with and without biochar, as seen in Fig. 4 and 5. All of them were put in the control condition and nutrient.

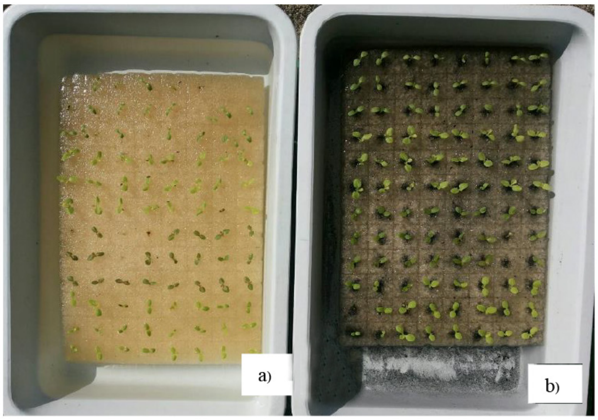


Fig. 4 Hydroponic plants seeding in the support culture with biochar (a) and without biochar (b)

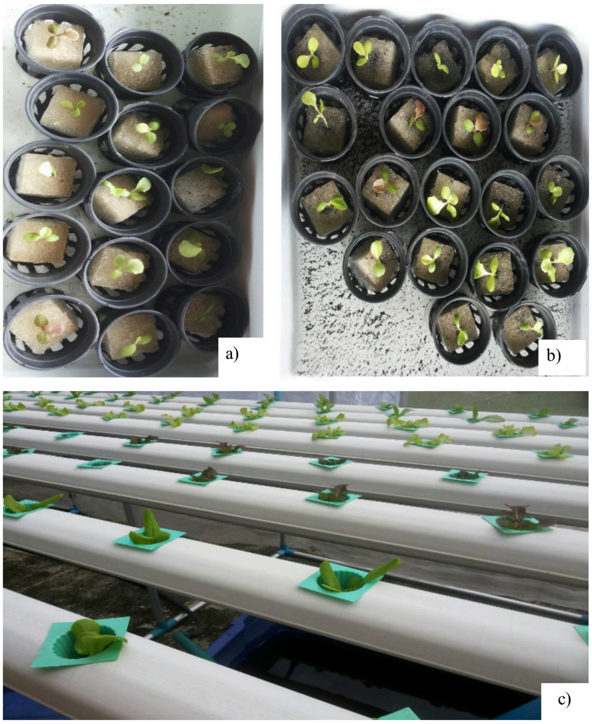


Fig. 5 Hydroponic plants growth from the support culture (a) with biochar and (b) without biochar in the (c) hydroponic system

All results compare the growth in the term of number length and width of leaves. It could be seen in Tables 3-6, the different number of leaves of Cos lettuce from growth media with and without biochar is significant ($p<0.05$). The number of leave greatly increased for all three plants. Meanwhile, the length and width of Cos lettuce, Red Oak lettuce, Green Oak lettuce from growth media with and without biochar are not different.

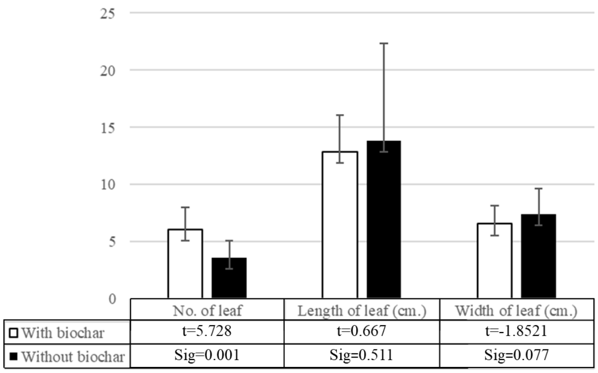


Fig. 6 Comparison of Cos lettuce growth from hydroponic growth media with and without biochar (n=10)

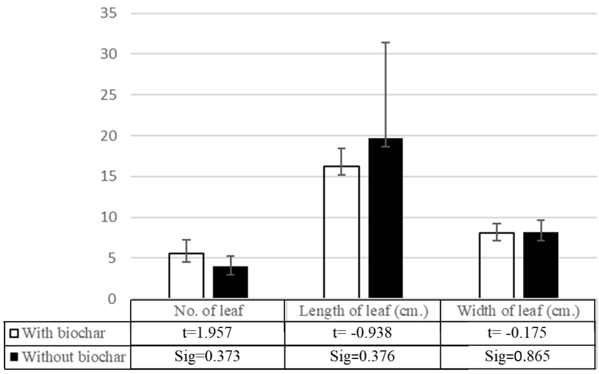
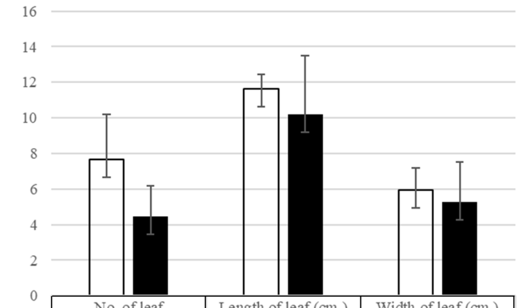


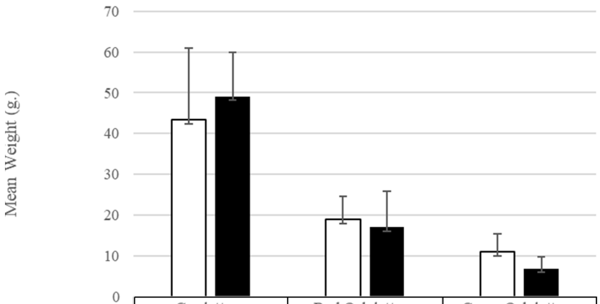
Fig. 7 Comparison of Red Oak lettuce growth from hydroponic growth media with and without biochar (n=10)



	No. of leaf	Length of leaf (cm.)	Width of leaf (cm.)
□ With biochar	t= 3.277	t= 1.278	t= 0.846
■ Without biochar	Sig=0.017	Sig=0.249	Sig=0.430

Fig. 8 Comparison of Green Oak lettuce growth from hydroponic growth media with and without biochar (n=10)

When compared the dry weight of these three hydroponic plants, it is seen that the difference of Green Oak lettuce dry weight from hydroponic growth media with and without biochar is significant (p<0.05). While this is disparate for Cos lettuce and Red Oak lettuce.



	Cos lettuce	Red Oak lettuce	Green Oak lettuce
□ With biochar	t= 1.146	t= 0.539	t= 2.420
■ Without biochar	Sig=0.281	Sig=0.602	Sig=0.039

Fig. 9 Comparison of the dry weight of Cos lettuce, Red Oak lettuce, and Green Oak lettuce from hydroponic growth media with and without biochar (n=10)

From the result from Fig. 6-9, the hydroponic plants which grow from the growth media with biochar grows better. Since the aliphatic carbon content with 99.27% fixed carbon and the high porosity of biochar, these have the advantage that they promote nutrition, from liquid fertilizer, to hydroponic plants (Awad et al., 2017). However, the differences in each treatment were showed to be non-significant according to result off the pH range of biochar which was in the alkaline region. These should inhibit the nutrition accessibility of plants (Nurhidayat & Mariati (2014). Furthermore, the addition of biochar might impact to reduce Nitrogen (N) and Manganese (Mn) availability but increased Phosphorus (P) availability (Atkinson et al., 2010). The biochar property for water holding capacity was not accounted in this hydroponics system which was operated under water-saturated conditions (Mukherjee & Zimmerman, 2013). However, the benefit of adding biochar on plant growth might effective when applied in the soil. As the study of Zheng et al., (2013) and Ding et al., (2016), suggested that biochar could improve the rhizosphere and microbial activity that are important to water and nutrient uptake which do not exist in the hydroponic environment.

Conclusion

The commercial corncob biochar has high aromatic carbon and carbonyl group proportion. Their surface morphology and porosity are advantages for water retention. These properties may offer several advantages for the hydroponics system such as provide resistance to microbial and better nutrient utilization. Moreover, this biochar also shows an appropriate pH and high ionic exchange capacity which should benefit the growth of the hydroponic plants. All these properties were proved benefits on the growth of the plants depending on the type of plant. The different number of leaves of Cos lettuce and dry weight of Green Oak lettuce from growth media with and without biochar is significant (p<0.05). It could recommend that adding some corncob biochar could endorse nutrients used in the hydroponics system. This would advantage for put forth shoots of hydroponic plants.

Acknowledgment

The authors are grateful to the Mea Fah Luang University research found for financially supporting the research project (project no.611B05007)

References

Angmanee, R., Chuangcham, K., & Homchan, U. (2017). Properties of corn waste biochar and potential for soil improvement. *VRU Research and Development Journal Science and Technology. 11*(1), 11.

Atkinson, C.J., Fitzgerald, J.D., & Hipps, N.A. (2010). Potential mechanisms for achieving agricultural benefits from biochar application to temperate soils: A review. *Plant and soil, 337*(1-2), 1-18.

Awad, Y.M., Lee, S.-E., Ahmed, M.B.M., Vu, N.T., Farooq, M., Kim, I.S., Al-Wabel, M. (2017). Biochar, a potential hydroponic growth substrate, enhances the nutritional status and growth of leafy vegetables. *Journal of Cleaner Production, 156,* 581-588.

Batista, E.M., Shultz, J., Matos, T.T., Fornari, M.R., Ferreira, T.M., Szpoganicz, B., ... & Mangrich, A.S. (2018). Effect of surface and porosity of biochar on water holding capacity aiming indirectly at preservation of the Amazon biome. *Scientific Reports, 8*(1), 1-9.

Blagodatskaya, E., Blagodatsky, S., Anderson, T. H., & Kuzyakov, Y. (2014). Microbial growth and carbon use efficiency in the rhizosphere and root-free soil. *PloS one, 9*(4), e93282.

Blok, C., Van der Salm, C., Hofland-Zijlstra, J., Streminska, M., Eveleens, B., Regelink, I., . . . Visser, R. (2017). Biochar for horticultural rooting media improvement: Evaluation of biochar from gasification and slow pyrolysis. *Agronomy, 7*(1), 6.

Centre for Agricultural Information. (2017). *Total maize: Cultivated area, area of harvest, yield and yield per area: Year 2555 - 2557.* Retrieved March 3, 2018, from http://aginfo.oae.go.th/ewtnews/maize.html

Ding, Y., Liu, Y., Liu, S., Li, Z., Tan, X., Huang, X., . . . Zheng, B. (2016). Biochar to improve soil fertility. A review. *Agronomy for sustainable development, 36*(2), 36.

Fryda, L., & Visser, R. (2015). Biochar for soil improvement: Evaluation of biochar from gasification and slow pyrolysis. *Agriculture, 5*(4), 1076-1115.

Jahromi, N.B., Walker, F., Fulcher, A., Altland, J., & Wright, W.C. (2018). Growth response, mineral nutrition, and water utilization of container-grown woody ornamentals grown in biochar-amended pine bark. *HortScience, 53*(3), 347.

Kasikorn research center. (2020). *How much does the economy affect?* Retrieved January 20, 2020, from https://kasikornresearch.com/th/analysis/k-social-media/Pages/FB-PM25-23-01-20.aspx

Khoomsab, R., Pongpian, W., Winyakul, C., & Chomchalao, P. (2015). Preparation and analysis on adsorption of activated carbon from waste corncob by chemical activation method. In *the National Conference on Research for Sustainable Development* (pp. 1393-1400). Retrieved June 14, 2019, from http://www.rdi.ssru.ac.th/researchconference/index.php/proceeding-online

Mukherjee, A., & Zimmerman, A.R. (2013). Organic carbon and nutrient release from a range of laboratory-produced biochars and biochar–soil mixtures. *Geoderma, 193-194,* 122-130.

Novak, J.M., Lima, I., Xing, B., Gaskin, J.W., Steiner, C., Das, K., . . . Busscher, W. J. (2009). Characterization of designer biochar produced at different temperatures and their effects on a loamy sand. *Annals of Environmental Science, 3,* 195-206.

Nurhidayati, N., & Mariati, M. (2014). Utilization of maize cob biochar and rice husk charcoal as soil amendment for improving acid soil fertility and productivity. *Journal of Degraded and Mining Lands Management, 2*(1), 223.

Rizwan, M., Ali, S., Qayyum, M.F., Ibrahim, M., Zia-ur-Rehman, M., Abbas, T., & Ok, Y.S. (2016). Mechanisms of biochar-mediated alleviation of toxicity of trace elements in plants: A critical review. *Environmental Science and Pollution Research, 23*(3), 2230-2248.

Ronsse, F., Van Hecke, S., Dickinson, D., & Prins, W. (2013). Production and characterization of slow pyrolysis biochar: Influence of feedstock type and pyrolysis conditions. *Gcb Bioenergy, 5*(2), 104-115.

Singh, B., Dolk, M.M., Shen, Q., & Camps-Arbestain, M. (2017). Biochar pH, electrical conductivity and liming potential. In *Biochar: A Guide to Analytical Methods,* (pp.23-38). Clayton, Australia: Csiro Publishing.

Smith, P. (2016). Soil carbon sequestration and biochar as negative emission technologies. *Global change biology, 22*(3), 1315-1324.

Tangtaweewipat, S., Pongpiachan, P., Yammuenart, S., Tapingkae, W., Banziger, S., & Kornkal, C. (2012). *Smong reduction corn village "reduction of the smog problem and the environment conservation through science and integrated agricultural technology on highland" case study Baanbonna Mae Chaem, Chiang Mai, Thailand* (Research report). Chiang Mai: Chiang Mai University.

Tansathit, T., Rotchanamekha, S., & Thepwong, R. (2016). Biochar production from stubble and rice straw for water holding in soil. In *the 1st National RMUTR Conferenc 2559 (Building Innovation 2016 : B-inno 2016)* (pp.401-410). Retrieved June 14, 2019, from http://repository.rmutr.ac.th/123456789/269

Vaughn, S.F., Eller, F.J., Evangelista, R.L., Moser, B.R., Lee, E., Wagner, R.E., & Peterson, S.C. (2015). Evaluation of biochar-anaerobic potato digestate mixtures as renewable components of horticultural potting media. *Industrial Crops and Products, 65,* 467-471.

Zheng, H., Wang, Z., Deng, X., Herbert, S., & Xing, B. (2013). Impacts of adding biochar on nitrogen retention and bioavailability in agricultural soil. *Geoderma, 206,* 32-39.

Zhu, X., Chen, B., Zhu, L., & Xing, B. (2017). Effects and mechanisms of biochar-microbe interactions in soil improvement and pollution remediation: A review. *Environmental Pollution, 227,* 98-115.