The effect of different forms of additive carbon in small-scale synthetic food waste composting: An empirical study in a high school cafeteria

Yuchuan Ma
Virginia Episcopal School, 400 VES Rd, Lynchburg, Virginia.
Email: hma@ves.org

Abstract. Treatment of food waste has attracted widespread social attention. Home composting has been proved repeatedly to be a feasible practice to divert food waste from landfills and produce useful finished compost. The objective of this experiment is to find ways to improve the efficiency of such beneficial practice based on a school cafeteria setting and practical small-scale composting. Three additives, including activated carbon, biochar and wood ash are studied, and the efficiency and effectiveness of these three high carbon materials on small-scale synthetic food waste are compared by analysis of 30-days sample reports and comparison of pile temperature during the whole process. Experimental results showed that all three additives improved composting efficiency, though their effects varied. The addition of wood ash resulted in the most organic matter, total carbon and total nitrogen among all four trials (including one control group without additive). Small scale synthetic food waste composting is indicated to be a practical and feasible approach. And with the help of wood ash addition, a more efficient mesophilic period is achieved.

1. Introduction
The United States generated more than 38 million tons of food waste in 2014, with only 5.1 percent of them composted [1]. The discarded food not only overwhelms the landfills under current operation, but also creates an enormous waste of energy and a threatening source of methane gas. Diversion and reduction of food waste is thus of great importance.

Composting is a biochemical process that produces relatively stable humus-like substance from various and complex components in organic waste [2]. This alternative of waste disposal can also effectively reduce greenhouse gas emissions and leachate in landfills, which is considered a hazardous threat for surface and groundwater [3].

The finish product of composting is widely recognized as an organic fertilizer or soil amendment. A comparable amount of studies has suggested that compost is a great long-term source of nitrogen, organic matter, and many essential trace minerals [4], [5]. A study of compost application over a three-year course showed a significant increase in total concentration and bioavailability of Cd and Zn [6]. Improvement on aggregate stability, porosity, and soil water holding capacity was also observed [5]. More specifically, sandy soils with low productivity could be improved by compost to sustain crop production [7].

Previously, researchers had successful examples of small scale or home composting [9], [10]. Home composting is a novel mean to recycle food waste in local communities, because it requires fewer budgets and produces small batches of hummus. One relative experiment achieved an efficiency
of 77% reduction of organic waste, and another one reached 80% [11], [12]. Smaller piles also produced less methane gas and less ammonia lost [13].

Tumblers, or drums, are recommended as composting site for urban residential settings [14] due to their easy operation process. Numerous studies focused on the determination of best turning frequency. A 24-hour turning frequency achieved longer thermophilic period and contained more total nitrogen and phosphorous [15]. However, another study showed that a 12-hour rotating rate had the optimal resulted product [16]. On the consideration of time and school-environment setting, a 24-hour turning rate would be more feasible for our study.

A successful composting process requires properly monitored temperature, aeration, moisture, Ph level, and carbon to nitrogen ratio. Temperature is vital for microorganism population and microbial activity. A temperature range of 54 to 60 °C is favourable [17]. A 30% free air space is suggested to be most effective for aeration facilitation of aerobic composting [18]. Water is a necessary factor for microbial activity; so ideally, the moisture content should be kept between 40 to 60% [19]. A Ph range between 6.5 to 7.5 is recommended for composting to start [18]. The factors mentioned above have been proved by great amount of experiments, so our study follows them as independent factors.

Microbial activity is also significant during the composting because it breaks down organic materials and volatile acids [20], [21]. A drum composting on food waste primarily suggested that microbial inoculum caused thermophilic phase within a week [21]. Commercial compost starters contain microorganisms and therefore serve a similar purpose. We consider including compost starters in order to shorten time duration.

Most of the composting handbooks available to the public specify that an addition of dairy and meat product should be avoided. However, two studies have proved that the presence of meat in home composting is applicable, even favorable [22], [23]. One current concern is that synthetic food waste contains excessive fat, which could prohibit microbial activity and slow down the decomposition. Nonetheless, in a co-digestion experiment trial of sludge and fat, the digester eventually self-recovered and functioned after an initial period of failure [24]. On the subject of synthetic food waste home composting, a lack of case study exists and further verification of previous results is necessary.

Research also focuses on treatments of their compost subjects that serve as bulking agency, including straws and wood-shavings to maintain neutral pH scale, reduce odor and absorb leachate [25], [26]. There are a number of experiments evolving different forms of high-carbon material, including wood ash, charcoal and biochar. Wood ash can control composting odor and provide effective treatment of volatile fatty acids [27]. Finished products with wood ash performed more plant nutrient and organic matter mineralization [28]-[30]. Noticeably, one of the experimental products actually failed to reach the highest quality standards established by the Austrian Compost Ordinance, so whether wood ash results in a best result remains a doubt [30].

Biochar is a precursor of activated carbon [31]. Its addition is able to accelerate the composting process [32], achieve a higher pile temperature, and retain less Nitrogen lost and ammonia emission [33], [34]. Its co-composting of catering waste in drum improved the availability of organic matter and reduced the formation of odorous gases, especially H2S [35]. A 10 percent addition is proved to be the most effective on the elimination of gaseous ammonia [36]. Although our study does not consider gas emission as a parameter, a 10 percent application of biochar is applicable. Other addition of additives follows this setup.

Like the application of biochar and wood ash, addition of charcoal, an activated carbon that is made out of the same manner as biochar, improved the compost maturity and the quality of compost [37]. However, a little correlated experiment currently exists. One study on amending soil with a mix of charcoal and finished compost suggested an increase of all gas emission, including CO2 and Nitrogen gas [38]. The result could lead to suspect of whether charcoal would have positive effect on composting. Empirical studies are necessary for further conclusion.
Although various experiments have been conducted on the three carbon additions mentioned above separately, there is a lack of general evaluation and comparison of the performance of wood ash, biochar and activated carbon. The former two have demonstrated strong positive effects while the last remains an unsure factor. From a composition perspective, the three materials all have high-carbon content and similar properties [27]. According to previous studies, all three agencies are supposed to accelerate the composting process to a degree and improve the quality of end product. However, the question is that which of the three performs a shorter and more effective compost process on same subject. Therefore, our study will focus on this parameter and evaluate the efficiency and effectiveness of activated carbon, biochar and wood ash as additive to compost synthetic food waste from high school dining hall.

2. Methodology

2.1. Experimental Design and Setup

The experiments were conducted on the campus of a small high school in Virginia, US. Two 140-Liter compost drums (91.4 cm x 78.7 cm x 71.1 cm) were used, each of which was characterized by two separate chambers with aeration holes, deep fins for aeration, and a removable lid. The compost bins were filled with vegetal food and meat waste from the high school’s dining hall. Food scraps were comprised of fruit and vegetable scraps, meat scraps, and dairy products such as egg. The composition of vegetal waste was heterogeneous depending on the availability of fruit and vegetables prepared by the dining hall. Meat waste was consisted of cooked meat scraps of edible parts with fat, including beef, chicken and fish. Dry wheat straws were mixed in as bulking agent.

The experiment took place in east part of Virginia. The town has a four-season humid subtropical climate. In 2016, the average temperature ranged from 22.67°C in September to 0.61°C in January with an annual precipitation of 42.50 [39]. The two compost drums were located on the edge of the school campus. Human interference was rare. Due to the utilization of tumblers, animal interference (except insects) was ignored. The location was in partial shading condition and faced direct sunlight in an average of 4 to 6 hours a day.

In this study, four treatments were evaluated. The first three treatments comprised 10% of an additive and 90% synthetic waste (food waste with straws). The fourth control treatment is comprised 100% kitchen waste mixed with straws with no additive. The total weight of waste for each trial is 12 kilograms. We call the first three trials AC (activated carbon), BI (Biochar), and WA (wood ash) treatments. Activated carbon was adopted from Aquarium Masters, Premium Laboratory Activated Carbon. Biochar was a commercial product from California Greenest’s company. Clean wood ash was acquired from a farm in Virginia named Mr. Dirtfarmer.

Food waste was collected in one day for a total of three meals. Faculties and students voluntarily separated their food scraps from paper tissue and cups. Any other contaminant, for example plastics debris, was picked out manually. Large chunks were teared manually into pieces with less than 5 centimeters in diameter. Wheat straws, acquired locally from a farm, were proportionally added (food waste to straw in a ratio of 1:19) to maintain airspace and adjust carbon-to-nitrogen-ratio. After loading the waste into their designated chambers, additives were weighed and added. Then each tumbler was turned for ten times to ensure a thorough mix. No additional water was added since the mixture was considered within proper moisture content. Two grams of commercial compost starter (Ringer 3050 Plus) were added to each chamber to help germinate microorganisms and accelerate the initial heating process.

The school dining hall rotated its menu in an average rate of three weeks. Daily menu varied. We collected and analyzed a full cycle of menu. Dishes were classified into different categories, including dairy, vegetable and fruit, cereal (bread, rice, pasta, etc.), meat and fat [40]. According to the weekly posted menu, one round of the menu contained 8.23% of diary, 28.25% vegetable and fruit, 41.23% of
cereal (high carbon products), 20.02% of meat and 3.29% of pure fat. A sample of the mixed food waste without any additive was sent to the Laboratory of University of Pennsylvania for content testing (see Table.1).

2.2. Monitoring the Composting Process

The experimental trial investigated the first three months of the composting process. Each trial would have a different performance in terms of maturity and content of elements due to the presence of differentiated additives.

A squeeze test [41] was used to monitor moisture content of the experimental trials every three days during the process. This method involves squeezing a sample in the fist. A proper moisture content means that the sample would remain compact. If it is too wet, water would appear from the fist; if it is too dry, the sample would crumble and fall apart.

Temperature and pH were measured every three days with a compost thermometer and pH scale. Each trial was tested by the average of three dips, from the top to the bottom of the chamber. The drum was turned five rounds every 24 hours to ensure enough aeration and prevent anaerobic composting. Parameters other than temperature and pH scale, such as total Nitrogen and concentration of other trace elements, were evaluated by sending samples to a compost testing laboratory when the pile is 90 days old. The experiment assumes that though the full composting process might not finish at the time of testing, additives in each trial would influence the state and content of the experimental piles during the composting period.

3. Results

3.1. Temperature and pH Scale Profiles

The composting process started with a rising internal temperature due to a likable weather condition. All the trials performed increasing temperature, which indicated active decomposition process. Pile temperatures slightly differed from each other in a range of 5.55 °C. All piles reached mesophilic within the first six days, but a high thermophilic phase (60°C) was never reached. As weather became colder from day 13 to day 16, all pile temperatures fell sharply as shown in Fig.1. The microbial process in both drums completely stopped due to the cold weather since day 21. No more heat was generated by any decomposing reaction, so the pile temperatures remained constant with local weather. The climate temperature fell below 10 °C after the first month. The average climate temperature was 15.61°C in the second month and 7.78°C in the third month. Pile temperature remained the same with the climate temperature after day 30, so it is not illustrated in table or figure. The fallen trend effectively reflected a rise and fall behaviour that fluctuates in accordance with seasonal changes [42].

Only two major temperatures peak up to 40 °C as shown in Fig.1—-the Activated Carbon group and Biochar group on the third day. Wood Ash group was only 0.6 degrees away from the other high temperature piles, while the control group was constantly 2 to 3 degrees colder from day 3 to day 6, shown in Figure 1. The initial peak could be interpreted as a result of aerobic biodegradation of the fast decomposing sugars [43]. AC and BI had a falling temperature from day 6 after reaching maximums. WA only reached its peak in a slower rate at day 6, but performed a similar biodegradation process because it was only slightly less than 40 °C. For WA and the control group, there is a possible correlation between a low initial pH and a delayed rise of the process temperature [44]. However, all three experimental groups had a higher peak temperature than the control group due to presence of high-carbonated additives that accelerate the process [33]. The highest temperature slightly over 40 °C indicated that the process was mostly mesophilic rather than thermophilic.
pH scale reflects the acid accumulation and acid decomposition which would break down organic materials and produce heat. Because acid accumulates constantly in a rate faster than the one of acid decomposition, all trials experienced a fall in pH level in comparison with the initial material, which can be concluded from Table 1. However, the accumulation process did not result in a strong acidic mixture; instead, the samples all perform alkalinity in various degrees. The initial composting material of each trial (food waste with straws) was acidic, but the pH level was mitigated by additives in the first three trials and acid decomposition during compost process. For example, the addition of biochar would result in a higher observed pH value because biochar has a higher pH. It contains more basic...
cations, like Ca\(^{2+}\), Mg\(^{2+}\), K\(^{+}\), etc. [45]. Wood ash also has similar cations that have strong cation exchange capacity and result in the highest pH among all lab-tested samples [46].

3.2. Physical Characteristics of Composts

All four samples had similar appearance, mainly composed of dark brown fragments of wheat straws and small chunks of food waste. AC group appeared darker with concentrated activated carbon pieces and WA was in a lighter color due to the original white color of wood ash. BI looked alike the control group.

Solid percent is different for each trial, due to each additive’s unique physical property. According to Table 1, AC has the highest solid percent 59.8%, WA the second 55.4%, and BI has 43.8%. The control group has a significant lower solid because of the absence of additive. Small pieces of activated carbon were still distinct to human eyes when the pile was sampled, which could explain the high solid percent. Other two additives were smaller in diameter and therefore larger in total surface area, so they could decompose faster.

3.3. Chemical and Physio-Chemical Characteristics of Composts

The organic matter (OM) content (%) showed a trend of decrease in all four piles. The initial OM of food residues was 95.2% (dry weight basis). The OM of the sampled composts varied from 64.0% (WA) to 90.2% (AC). Noticeably, the organic matter in AC is higher than the one of control group. The significant decrease of OM in WA is a suggestion of fast decomposition of organic matters through microbial respiration and mineralization of organic matter [47].

Total carbon (C) is a direct measurement of all organic and inorganic carbon in the compost sample. The carbon content in WA is the lowest (38.2% on a dry weight basis), while AC, BI, and the control group varied from 48.5%, 46.6%, 58.9%. Total carbon content decreased, probably because organic carbon was lost as carbon dioxide through microbial activities, which used carbon as a source of energy [47]. The reduction is the highest in the WA, probably due to the fact that the addition of wood ash accelerates decomposition in a rate faster than the other three groups.

The total nitrogen (N), including organic and inorganic form, of each trial decreased over the experimental period except the control group. More decrease was observed in WA, from 5.141% (initial total nitrogen) to 2.970%. Other two trials varied above 3%. The significantly higher total nitrogen of the control pile might be due to the absence of high-carbonated additives and its lower carbon to nitrogen ratio. Decrease in nitrogen is a signal of the digestion and mineralization of organic matter [47]. Nitrogen is lost in the form of ammonia volatilization during heating phase, which explained the highest ammonium level (8639.1 mg/kg) of the control pile where a little ammonia volatilization happened.

4. Conclusion

The addition of activated carbon, biochar and wood ash all ameliorated the compost process in terms of efficiency and temperature profile in comparison with the control group. This result is in accordance with previously existed research. Meanwhile, each additive’s degree of impact varies based on their distinct characteristics. Although it results in a potential delay in initial rise of temperature, WA group lost the most organic matter, total carbon and total nitrogen among all four trials, which indicates that it has the most efficient influence on composting the synthetic residues. Its best performance in the four trials shows that wood ash addition is beneficial to reduce the total time length of composting. AC only causes a small decrease in organic matter and has a relatively high percentage of solid remains and total carbon when compared with other two experimental trials, so it is not an ideal amendment for compost. BI has a fair influence on the composting. As previous experiments have proven the addition of biochar increased the pile temperature and improved compost
efficiency if compared with the control group. However, overall the three experimental additives, WA achieved the most effective mesophilic composting phase.

The small-scale composting of high school synthetic food waste in an outdoor setting appears to be feasible. Weather has an important role during the process, but if the temperature is favorable, the compost process would occur naturally. Householders or individual composters can voluntarily add bulking agency and additives to achieve a faster composting, especially when the bulking materials, like wood ash and biochar are readily available and cheap to purchase. As our study has shown, wood ash has the best performance, and based on previous study showing that wood ash can also efficiently reduce odor emission, it should be applied more in small scale composting and household composting. It is more successful at decomposing organic matter than activated carbon and biochar in our study, which might be ascribed to its effective treatment of volatile fatty acids and mineralization of organic matter. Further research should focus on this area, analyze reasons behind and figure out the best application ratio of wood ash addition.

References
[1] United States Environmental Protection Agency, Sustainable Management of Food Basics, Accessed 6, December 2017, Retrieved from https://www.epa.gov/sustainable-management-food/sustainable-management-food-basics/what
[2] Chen, S. (2015). Evaluation of Compost Topdressing, Compost Tea and Cultivation on Tall Fescue Quality, Soil Physical Properties and Soil Microbial Activity. Master of Science. doi:10.13016/M22F0R
[3] Pablos, M., Martini, F., Fernández, C., Babin, M., Herraez, I., Miranda, J., & ... Tarazona, J. (2011). Correlation between physicochemical and ecotoxicological approaches to estimate landfill leachates toxicity. Waste Management, 31(8), 1841-1847. doi:10.1016/j.wasman.2011.03.022
[4] Arthur, E., Cornelis, W., & Razzaghi, F. (2012). Compost Amendment to Sandy Soil Affects Soil Properties and Greenhouse Tomato Productivity. Compost Science & Utilization, 20(4), 215.
[5] Martinez-Blanco, J., Lazcano, C., Boldrin, A., Muñoz, P., Rieradevall, J., Möller, J., Antón, A., Christensen T. H. (2013). Assessing the environmental benefits of compost use-on-land through an LCA perspective. Sustainable Agriculture Reviews.12, p. 255-318.
[6] Baldantoni, D., Leone, A., Lovieno, P., Morra, L., Zaccardelli, M., Alfani, A. (2010). Total and available soil trace element concentrations in two Mediterranean agricultural systems treated with municipal waste compost or conventional mineral fertilizers. Chemosphere. 2010 Aug; 80(9):1006-13. doi: 10.1016/j
[7] Emmanuel Arthur UGent, Wim Cornelis UGent and Fatemeh Razzaghi(2012) COMPOST SCIENCE & UTILIZATION. 20(4). p.215-221
[8] Levis, J., Barlaz, M., Themelis, N., & Ulloa, P. (2010). Assessment of the state of food waste treatment in the United States and Canada. Waste Management, 30(8/9), 1486-1494. doi:10.1016/j.wasman.2010.01.031
[9] Matteson, T. L., & Sullivan, D. M. (2006). Stability Evaluation of Mixed Food Waste Composts. Compost Science & Utilization, 14(3), 170-177.
[10] Oliveira, L. S., Oliveira, D. S., Bezerra, B. S., Silva Pereira, B., & Battistelle, R. G. (2017). Environmental analysis of organic waste treatment focusing on composting scenarios. Journal of Cleaner Production, 155229-237. doi:10.1016/j.jclepro.2016.08.093.
[11] Wong, J. W., Fung, S. O., & Selvam, A. (2009). Coal fly ash and lime addition enhances the rate and efficiency of decomposition of food waste during composting. Bioresource Technology, 100(13), 3324-3331. doi:10.1016/j.biortech.2009.01.063
[12] Vázquez, M., & Soto, M. (2017). The efficiency of home composting programmes and compost quality. Waste Management, 6439-50. doi:10.1016/j.wasman.2017.03.022
[13] Storino, F., Menéndez, S., Muro, J., Aparicio-Tejo, P. M., & Irigoyen, I. (2017). Effect of Feeding Regime on Composting in Bins. Compost Science & Utilization, 25(2), 71. doi:10.1080/1065657X.2016.1202794
[14] Growing Local Fertility: A Guide to Community Composting. Institute For Local Self-Reliance, Accessed 6, December, 2017. Retrieved from https://ilsr.org/size-matters-report-shows-small-scale-community-based-composting/

[15] Kalamdhad, A. S., & Kazmi, A. (2009). Effects of turning frequency on compost stability and some chemical characteristics in a rotary drum composter. Chemosphere, 74(10), 1327-1334. Doi: 10.1016/j.chemosphere.2008.11.058

[16] Rodriguez, L., Cerrillo, M. I., García-Albiach, V., & Villaseñor, J. (2012). Domestic sewage sludge composting in a rotary drum reactor: Optimizing the thermophilic stage. Journal of Environmental Management, 112284-291. doi:10.1016/j.jenvman.2012.08.005

[17] Rynk, R. F., van de Kamp, M., Willson, G.B., Singley, M.E., Richard, T.L., Kolega, J.J., Gouin, F.R. Laliberty, L.L., Kay, D., Murphy, D.W., Hoitink, H.A.J., Brinton, W.F. (1992). On-Farm composting handbook. Ithaca, NY.

[18] Haug, R.T., 1993. Compost Engineering, the Practical Handbook. Lewis Publishers, USA, p. 214.

[19] Hamoda, M.F., Abu Qdais H.A., and Newham J. 1998. Evaluation of municipal solid waste composting kinetics. Resources, Conservation and Recycling 23:209-223.

[20] Boulter J.I., G.J. Boland and J.T. Trevors, 2000a. Review Compost: A study of the development process and end-product potential for suppression of turf grass disease. World Journal of Microbiology & Biotechnology. 16:115-134.

[21] Manu, M. K., Kumar, R., & Garg, A. (2017). Performance assessment of improved composting system for food waste with varying aeration and use of microbial inoculum. Bioresource Technology, 234167-177. doi:10.1016/j.biortech.2017.03.023

[22] Storino, F., Arizmendiarrieta, J. S., Irigoyen, I., Muro, J., & Aparicio-Tejo, P. M. (2016). Meat waste as feedstock for home composting: Effects on the process and quality of compost. Waste Management, 5653-62. doi:10.1016/j.wasman.2016.07.004

[23] Namkoong W, Hwang E, Cheong J, Choi J. A Comparative Evaluation of Maturity Parameters for Food Waste Composting. Compost Science & Utilization [serial online]. Spring99 1999; 7(2):55. Available from: Academic Search Complete, Ipswich, MA. Accessed December 17, 2017.

[24] Wan, C., Zhou, Q., Fu, G., Li, Y. (2011). Semi-continuous anaerobic co-digestion of thickened waste activated sludge and fat, oil and grease. Waste Management. 31(8). 1752-1758.

[25] Yuan, J., Yang, Q., Zhang, Z., Li, G., Luo, W., & Zhang, D. (2015). Use of additive and pretreatment to control odors in municipal kitchen waste during aerobic composting. Journal Of Environmental Sciences (Elsevier), 3783-90.

[26] Liang, Y., Leonard, J., Feddes, J., & McGill, W. (2006). Influence of carbon and buffer amendment on ammonia volatilization in composting. Bioresource Technology, 97(5), 748-761. doi:10.1016/j.biortech.2005.03.041

[27] Rosenfeld, P.E., Henry, C.L. (2001) Activated Carbon and Wood Ash Sorption of Wastewater, Compost, and Biosolids Odorants. Water Environment Research. 73(4). 388-393.

[28] Fernández-Delgado Juárez M, Gómez-Brandón M, Insam H. Merging two waste streams, wood ash and biowaste, results in improved composting process and end products. Science of the Total Environment [serial online]. December 2015; 511:91-100.

[29] Fernández-Delgado Juárez M, Prähauser B, Walter A, Insam H, Franke-Whittle I. Co-composting of biowaste and wood ash, influence on a microbially driven-process. Waste Management [serial online]. December 2015; 46:155-164.

[30] Campbell, A. G., & Folk, R. L. (1997). Wood ash as an amendment in municipal sludge and yard.. Compost Science & Utilization, 5(1), 62.

[31] Azargohar R., Dalai A.K. (2006) Biochar as a Precursor of Activated Carbon. In: McMillan J.D., Adney W.S., Mielenz J.R., Klasson K.T. (eds) Twenty-Seventh Symposium on Biotechnology for Fuels and Chemicals. ABAB Symposium. Humana Press.

[32] Xingyong, J., Meng, W., Wenqiao, Y., Xiaotang, J., & Baozhu, Y. (2016). The Influence of Biochar Addition on Chicken Manure Composting and Associated Methane and Carbon Dioxide Emissions. Bioresources, 11(2), 5255. doi:10.15376/biores.11.2.5255-5264
[33] Liu, W, Huo, R., Xu, J., Liang, S., Li, J., Zhao, T., Wang, S. (2017). Effects of biochar on nitrogen transformation and heavy metals in sludge composting. Bioresour Technol. 2017. 235. 43-49. doi: 10.1016/j.biortech.2017.03.052.

[34] Agyarko-Mintah, E., Cowie, A., Van Zwieten, L., Singh, B. P., Smillie, R., Harden, S., & Fornasier, F. (2017). Biochar lowers ammonia emission and improves nitrogen retention in poultry litter composting. Waste Management, 61129-137. doi:10.1016/j.wasman.2016.12.009

[35] Chen, W., Liao, X., Wu, Y., Liang, J. B., Mi, J., Huang, J., & ... Wang, Y. (2017). Effects of different types of biochar on methane and ammonia mitigation during layer manure composting. Waste Management, 61506-515. doi:10.1016/j.wasman.2017.01.014

[36] Janczak, D., Malińska, K., Czekała, W., Cáceres, R., Lewicki, A., & Dach, J. (2017). Biochar to reduce ammonia emissions in gaseous and liquid phase during composting of poultry manure with wheat straw. Waste Management, 6636-45. doi:10.1016/j.wasman.2017.04.033

[37] Kołtowski, M., & Oleszczuk, P. (2016). Effect of activated carbon or biochars on toxicity of different soils contaminated by mixture of native polycyclic aromatic hydrocarbons and heavy metals. Environmental Toxicology & Chemistry, 35(5), 1321-1328. doi:10.1002/etc.3246

[38] Jordan, G., Predotova, M., Ingold, M., Goenster, S., Dietz, H., Joergensen, R. G., & Buerkert, A. (2015). Effects of activated charcoal and tannin added to compost and to soil on carbon dioxide, nitrous oxide and ammonia volatilization. Journal of Plant Nutrition & Soil Science, 178(2), 218-228. doi:10.1002/jpln.20140023

[39] NOWData - NOAA Online Weather Data, National Weather Service Forecast, Accessed 6, December 2017, Retrieved from http://w2.weather.gov/climate/xmacis.php?wfo=rnk

[40] The Food Guide Pyramid, United States Department of Agriculture, Accessed 6, December 2017, Retrieved from https://www.cnpp.usda.gov/sites/default/files/archived_projects/FGPPamphlet.pdf

[41] Robert R. (2014). Monitoring Moisture In Composting Systems, Biocycle, Accessed 6, December, Retrieved from http://compostingcouncil.org/wp/wp-content/uploads/2014/02/7-MonitoringMoisture.pdf

[42] Tatàno, F., Pagliaro, G., Di Giovanni, P., Floriani, E., & Mangani, F. (2015). Biowaste home composting: Experimental process monitoring and quality control. Waste Management, 3872-85. doi:10.1016/j.wasman.2014.12.011

[43] Chang, J. I., & Hsu, T. (2008). Effects of compositions on food waste composting. Bioresource Technology, 99(17), 8068-8074. doi:10.1016/j.biortech.2008.03.043

[44] Kurola, J. M., Arnold, M., Kontro, M. H., Talves, M., & Romantschuk, M. (2011). Wood ash for application in municipal biowaste composting. Bioresource Technology, 102(8), 5214-5220. doi:10.1016/j.biortech.2011.01.092

[45] Xingyong, J., Meng, W., Wenqiao, Y., Xiaotang, J., & Baozhu, Y. (2016). The Influence of Biochar Addition on Chicken Manure Composting and Associated Methane and Carbon Dioxide Emissions. Bioresources, 11(2), 5255. doi:10.15376/biores.11.2.5255-5264

[46] Saarsalmi, A., Smolander, A., Kukkola, M., & Arola, M. (2010). Effect of wood ash and nitrogen fertilization on soil chemical properties, soil microbial processes, and stand growth in two coniferous stands in Finland. Plant & Soil, 331(1/2), 329. doi:10.1007/s11104-009-0256-y

[47] Rama Lakshmi, C. S., Rao, P. C., Padmaja, G., Sreelatha, T., Madhavi, M., & Sireesha, A. (2014). Evaluation of Different Vermicomposts and Conventional Composts for Their Maturity Indices. Indian Journal of Agricultural Research, 48(3), 205-210. doi:10.5958/j.0976-058X.48.3.034