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DESIGN, FABRICATİON AND SENSITVTY TESTING OF AN EFFICIENT BONE PYROLYSİS KILN AND BIOCHAR BASED INDIGENOUS FERTILIZER PELLETIZING MACHINE FOR LINKING RENEWABLE ENERGY WITH CLIMATE SMART AGRICULTURE

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ABSTRACT

Biochar has the potential to improve soil nutrient status, increase crop yield and sequester carbon in the soil. However, storage, transportation and soil application of biochar are challenging because biochar is brittle, and has wide particle size distribution and low density. Its loss could be as high as 30% by wind-blown during handling, transport to the field and soil application.Composting biochar with animal manure and other feed stocks helps in specific soil fertility management However compost itself has high moisture content and to facilitate handling and transportpelletization is required. The objective of this study is design and develop biochar based indigenious fertilizer pelletizing machine and bone pyrolysis kiln to help the small holder farmers in developing countries through organic fertilizer supply, improving the poor soil fertility, and subsequently reduce agricultural carbon emissionand sequastrate atmospheric carbon. Biochar produced from bone pyrolysis combines the advantages of biochar along with phosphorous addition. An experimental investigation has been carried out in this regard for biochar production from bone pyrolysis and subsequent pelletization of the biochar based indigenous fertilizer. A sensitivity testing has been done on the machine to ascertain the effects ofthe moisture content,particle size, binder, operating speed and the drying process on the qulaity and durability of the pellets produced for standardization.The pellets are produced using different moisture content of the compost and 5% water solution activated starch and 15-29% of molasses diluted with 15% of water are used as binder. The results show that the moisture content and lubricant oil addition are critical parameters for pelleting process. The optimum moisture content of the compost for quality pellet production with the builted machine is 20 to 25%. The bone pyrolysis kiln also produces uniformoly heated bone char with low fuel consumption, as well as 15-20Kg of bio char.

Keywords: biochar, bone char, compost, carbon sequestration, soil fertility, pelleting.

INTRODUCTION

We have far too much carbon in the air, our soils are losing fertility, and we need local means to produce cheap energy as well as organic fertilizer. The majority of the persistently hungry are smallholder farmers in developing countries who practice subsistence agriculture on marginal soils, lack access to inputs and financial resources to procure costly commercial inorganic fertilizer and other agrochemicals that might enhance the productivity of their land. Biochar has the potential to be the possible solution of soil fertility amendment and atmospheric carbon sequestration.

The 'Amazonian Dark Earths' were the result of incompletely combusted biomass from domestic fires and infield burning. The amount of char deposits suggests the deliberate applications of char addition to manage low soil fertility. Similar soils have been documented elsewhere within the region, namely Ecuador and Peru, in West Africa (Benin, Liberia), and the savanna of South Africa. Researchers suggested that soil quality elsewhere could be improved and concurrently contribute to climate change mitigation by the addition of charcoal [1]. Biochar is a carbon -rich product obtained by thermal decomposition of wide range of biomass feedstock at relatively low temperatures (<700C) and low oxygen concentration, in a process known as pyrolysis. During this process heat, flammable gases and liquids are produced together with a solid residue, biochar [2].

Energy can be produced from pyrolysis of biomass while producing biochar. As literatures dictates, producing bio oil, syngas and biochar at the same time reduces GHG gasses emission and increases C stock in the soil for the long time [3,4,5].With respect to different biochar properties, biochar affects soil biota and increase crop yield subsequently by increasing sorption of nutrients and organic matters, improve aeration and water holding capacity due to its porous structure, change PH of soil, improve cation exchange capacity and create micro location which promotes microorganisms' abundance and efficiency of soil biota [1,6,7].

In addition to biochar which supplies organic carbon and nutrients, plants require phosphors fertilizer. Production of phosphors fertilizer exploits the natural rock phosphate by 80-90%. Rock phosphate is finite resource, hence recovering phosphors from organic waste like bone and converting it through pyrolysis into fertilizer is necessary. Bone can be softened and its structure can be modified by applying 500-750 ℃ pyrolysis temperature. With increasing pyrolysis temperature the calcium phosphate (CaP) crystallinty and total phosphors product increases while solubility decreases [8].

ARPN Journal of Engineering and Applied Sciences

Even though biochar has been proposed as a future solution for the degradation of soil fertility, carbon sequestration and significant increment of crop yield, storage, transportation and soil application of biochar are still challenging because biochar is brittle, and has wide particle size distribution and low density. Blue Leaf Inc. reported 2% of the material was lost during loading, 3% was lost during transporting to the field and 25% of the biochar applied was lost during spreading to the field. Totally 30% of the biochar is lost due to transporting, loading unloading and field application [9,10]. 20-53% of biochar incorporated into soil was also lost by surface runoff during intense rain events especially when biochar is applied to sloping terrain[11].In addition biochar powder usages for agriculture poses health effect and large concentration of biochar in an enclosed area might be explosive [12].

Application of biochar alone for crop yield improvement is not enough and it should be incorporated with nutrient rich organic fertilizer and even NPK fertilizer. Hence composting biochar with bone char, animal dung and poultry litter is the possible solution for the problems aforementioned. However, composted livestock manure usually has high moisture content, and a high volume per unit of weight. As a result, it is difficult and costly to transport. And also, the quality of the compost and its nutrient content will not be constant which limits the efficient use of compost [13,14].

Therefore the objective of this study was to design and build an efficient bone pyrolysis kiln and biochar based indigenous fertilizer pelleting machine. Fabricating using locally available materials, testing of the machines and the pellets durability, reduce fire wood consumption of pyrolysis kiln by improving the design and characterizing the phosphorous content and PH of the bone char.

METHODOLOGY

Productionof biochar

Air dried coffee husk and corn cob were taken from local coffee processers and farmers around Jimma City. The dried coffee husk and corn cob then pyrolyzed at 400 °C for an hour using an electric pyrolysis kiln. In addition bone meal prepared by collecting raw bone and grinding using the grinder machine, and subsequently pyrolyzed at a temperature of 600 °C or above based on the requirement of the PH of the bone char.

Pyrolysis of bone char is an energy intensive process, which requires an external energy source to activate the energy which held in the bone. To do so, bone pyrolysis kiln is built and tested (Figure-1). The kiln has a trough kind of pyrolysis unit with cylindrical shell and manually rotating paddle, to mix the bone for uniform heating. The pyrolysis unit is covered by bricks building which has enough space for combustion of fire wood which is the main energy source of the process.

Figure-1. Bone pyrolysis kiln & flame produced from the bone pyrolysis gas and fire wood combustion.

Bone is put in the cylinder (pyrolysis chamber) and covered and sealed using gaskets, in order to remove leakages of combustible gasses from the pyrolysis chamber to the atmosphere. Fire wood is put in the combustion chamber and ignites thoroughly and heats the surface of the pyrolysis chamber. Consequently the bone is mixed by the manually driven rotating paddle and the temperature is recorded using J-type thermocouple and voltmeter. By controlling the rate of addition of wood and adjusting the cover of air opening the temperature of the bone can be monitored. Just after the required temperature of the bone char is maintained, all the fuel and char is taken out from the combustion chamber and the kiln cools down slowly.

Pelletization of nutrient-embedded biochar

The coffee Husk char produced by the kiln (pyrolysis oven) was blended with poultry litter and farm yard manure (with high moisture content) with 3:1:1 ratio. To increase the microbial activity of the compost 3 to 4% of soil was added. Either biochar or animal dung does not have phosphorous which is vital nutrient to the plants. Hence bone charwas added to the compost as one substrate to increase its phosphorous content. Then the blended biochar and bone char would be composted for one to two months. The longer it is composted the smaller the particle size of the biochar becomes and it reduces preprocessing costs of pelletization.

The composted biochar which has more than 48.5% moisture content should be dried by air or oven until its' moisture content becomes less than 30%, since liquid binder addition itself increases the moisture content of the compost and it will make difficult the pelletization process. After drying the compost was rammed to disintegrate large particles and agglomerated things created during the composting process and subsequently sieving was done to less than 8mm mesh size, to remove large particles, pebbles, and small piece of hard materials which might block the holes of the die or damage the roller and die.

5 to 20% of liquid binder(molasses, activated starch) and vegetable oil is added(for lubrication) to fixed amount of somewhat dried compost and then it is mixed by cement mixer machine thoroughly, to make sure the binder touches each surface of the particle. Then the mixed compostis added to the hopper of the flat die disc pelletizer which is designed and manufactured by the researcher for pelletization of biochar based fertilizer.

Pelletization of biochar based compost is done when the rollers rotate on the die keeping a gapof 3mm between them, the moisturized compost pushed down or compressed to the 8mm diameter holes, at the same time the spline like rollers rotates on their own axis and squeezes the compost rather than sliding over the material. Hence the compression and squeezing action by the rollers creates friction and develops heat and it helps the compost to easily flow through the holes and produce the quality pellet. Pellets ejected at the back of the die then get cut by the knife to adjust the pellet length and t drop out from the machine by gravity. Finally the produced pellets was taken to the oven and dried at 105°C at different time and it is characterized for different properties of the pellets, specially; durability, stability, bulk density and moisture content of green pellets.

Figure-2. Compost pelleting machine and pellets made from compost.

Characterization of biochar pellets

The actual density of Pellets is calculated by measuring diameter length and mass of cylindrical type biochar based pellets. Testing is also done by dropping a pellet in the water filled cylinder and checking whether it floats or sinks. If it sinks the pellet is produced with good compression and its quality is good. On the contrary if the pellet floats it is not produced with good compression force.

Durability of the pellet is checked by selecting 10 random samples of single pellet (both green and dried pellets) and dropping it from the height of 50cm on the hard surface until the pellets break down in to dust. In addition 100g of pellet is put in plastic bag and dropped on the floor from 1.8m height for 10 times. After dropping, the pellets were screened using a 2mm sieve and then particles that fall through screen are weighed and percentage loss of pellet calculated.

Characterization of bonchar

The bone char produced using this kiln was uniformly heated, soft, and very good visual appearance. It was also easy to grind in to powder which was very important characteristics for pelletization. In addition it was highly porous and low bulk density regardless of the temperature.

RESULTS AND DİSCUSSİONS

The moisture content of the compost used in this study was 48.5%. This high moisture content of compost makes the pelleting process difficult. Hence the compost sample used in this study was dried to 5% moisture content by oven at 105°C for 5hours. When the moisture content was higher than 30% the material clogs the holes and reduce rate of production. On the contrary below 20% moisture the material easily fall throgh the holes with out making pellet.

Pelleting of the compost with or with out addition of binder was done. Pellets produced with out binder had less density than water, which means when a pellet was dropped on a glass of water, it floats. On the contrary pellets produced with the addition of eithr acctivated

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starch or molasses sanks just as it was dropped in to the water. The actual density of the pellet was calculated as follows.

$$density\ of\ pellet = \frac{mass\ of\ the\ pellet}{volume\ of\ the\ pellet} \quad (1)$$

$$\therefore Actual\ density\ of\ pellet\ with\ 23.5\%\ binder = 1230.4 Kg/m^3$$

$$Actualdensityof\ the\ same\ size\ but\ 0.95g\ ofpellet\ produced\ with\ outbinder = 630.4 Kg/m^3$$

Pellet durability was done for 10 samples of single green pellet and oven dried pellet by droping it on the rough steel surface. In both cases 95% of pellets survived more than 50 times of drops. Inaddition bag drop test was done for the oven dried pellets. Depending on the addition of the binder, percent loss of the pellet was 1 to 5% using molasses binder. As it is shown on Figure-3& 6with increasing binder content percentage loss of pellets was reduced in both single pellet and bag drop test. However at higher moisture and binder content (Figure-6) the percentage loss was radicaly increased. The higher moisture contennt in a sense was higher binder content and it leads to high energy consumption, during pelletization. Through the experment conducted for the machine, the optimum moisture content determined was 20 to 25% of compost.

As shown on the Figure-4&7,the pellet density was completly increased with increasing binder content in any kind of binder. However percentage pellet loss was increased at 33% molasses content (Figure-7), even if the pellet density was increased.

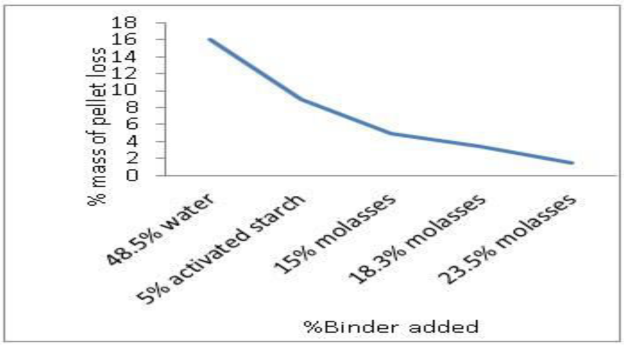

Figure-3. Percentage loss of pellet due to bag drop test.

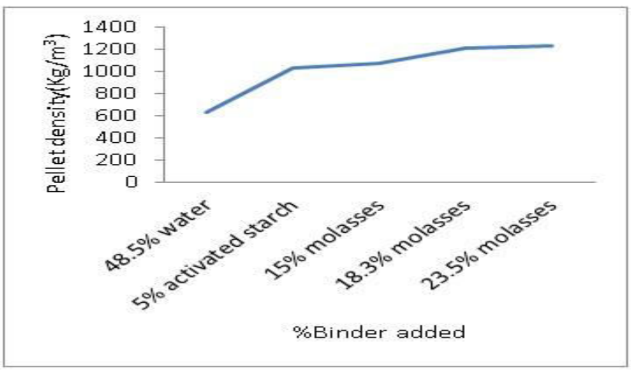

Figure-4. Effect of binder on pellet density.

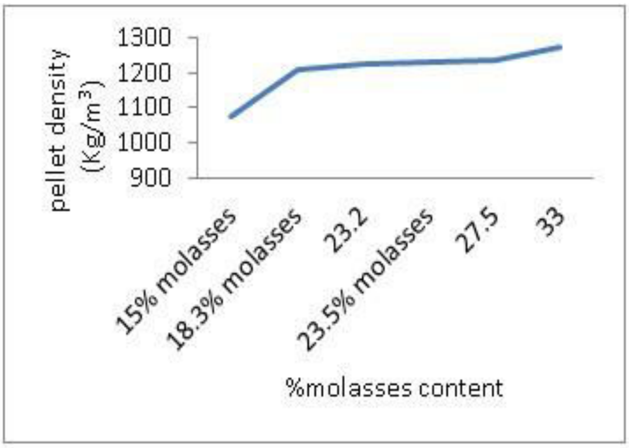

Figure-5. Effect of percent binder content on the pellet density.

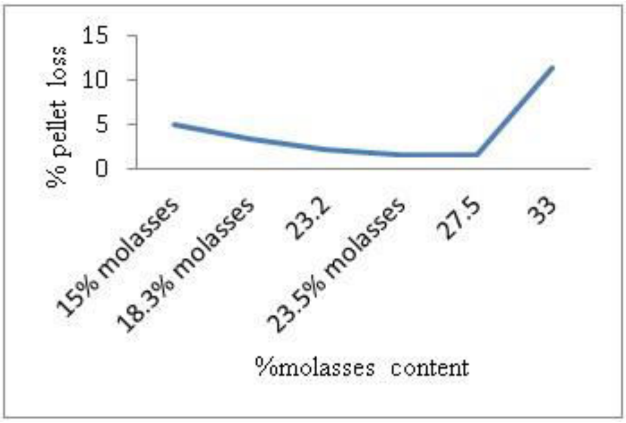

Figure-6. Effect of percent binder content on perccentage loss of pellets during gravity test.

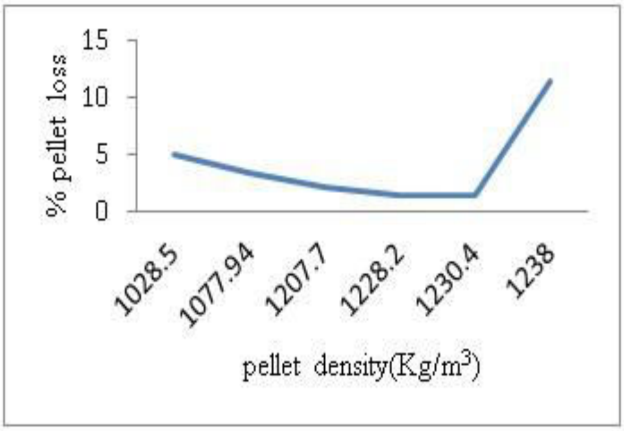

Figure-7. Relation of pellet density with percentage pellet loss.

BONE PYROLYSIS TEST RESULT

Pyrolysis process is an energy intensive process. Hence instead of using electrical energy, fire wood was used as energy source. During the first test of pyrolysising bone, it consumed about 116 kg of fire wood and there was a lot of smoke all over the body of the bricks building,

ARPN Journal of Engineering and Applied Sciences

due to the drying process of the wet building (Figure-8,9&10) and it took 3hours to get 500 °C. At second test the bone temperature reaches 500 °C with in 118minutes (1:58hour) (Figure-9) and the fuel consumption reduced to 68.08 kg. After the first three tests, the bone temperature gets 500 °C with in 90minutes. Every test was done with in 24hour interval.As shown in the (Figure-8 to 10) time-to-temperature graph the temperature was not increasing smoothly with respect to time. This was because, the rotating padle mixs the bone at every five minute and the heated bone turns over the top and low temperature bone which was at the top surface moves down to the hot surface. During this tumbling action the termocouple which attached at the bottom surface of kiln, reads the temperature of the low temperature bone.

The bone char should be prepared based on the requirement of the PH of the bone char. Hence it was required to test the PH of the bone char at different temperature to determine the right temperature for feature application of the kiln. To measure the PH, a samples of bone char was taken from different temperature samples and seaved by 0.8 mm mesh size. Then three samples of 10 gram bone char powder was taken from each temperature sample and added to the beaker and stirred for one minute with 25 ml. distilled water. After that the solution puts for 30 minute with out stearing and finally the PH is calibrated using PH meter. As the reading shows,the PHincreases with increasing pyrolysis temperature (Figure-11).

Making bone char at higher temperature incurs more cost on the fertilizer cost, due to the high amount of fire wood consumption. Figure-12, shows that the fuel consumption increases with increasing pyrolysis temperature. On the contrary the bone char yield reduced with increasing pyrolysis temperature (Figure-13).This is because the weight of the bone char reduces when it is burned for long time and loosing its combustible gases.

Further more at each bone pyrolysising process there is 15-20 kg of char production for 20-30 kg of bone char production. However the char found from the process is not produced in a controlled temperature condition and it is difficult to maintain the required PH of the biochar.

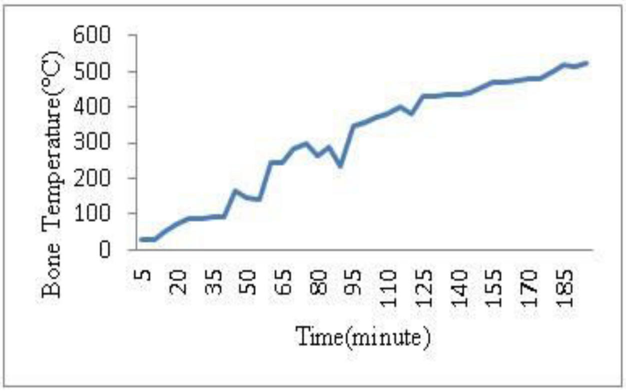

Figure-8. Temperature distribution of bone char with respect to time(at first test).

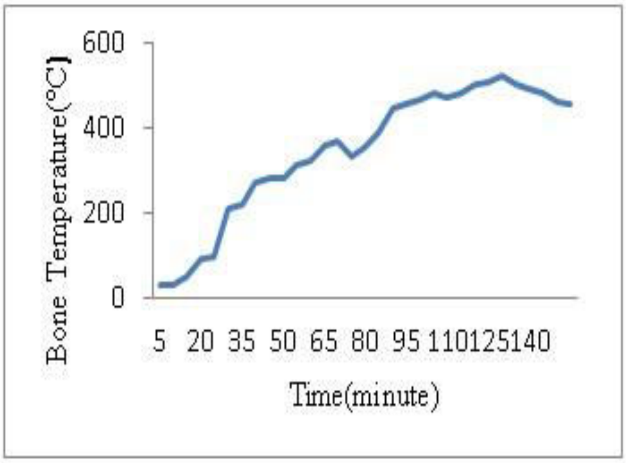

Figure-9. Temperature distribution of bone char with respect to time(at second test).

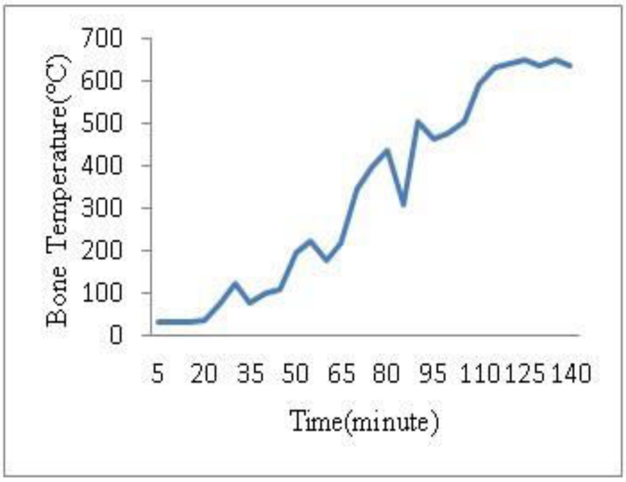

Figure-10. Temperature distribution of bone char with respect to time(at fifth test).

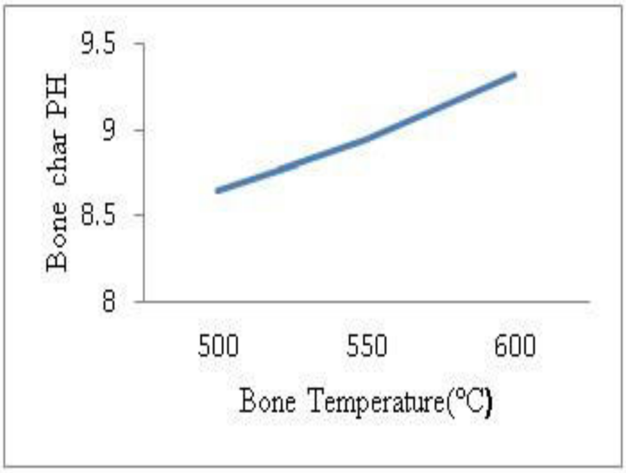

Figure-11. Effect of temperature on bone char PH.

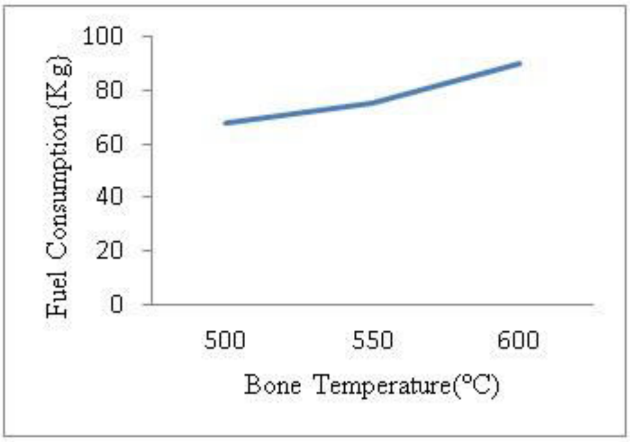

Figure-12. Fuel wood consumption of bone pyrolysis at different temperature.

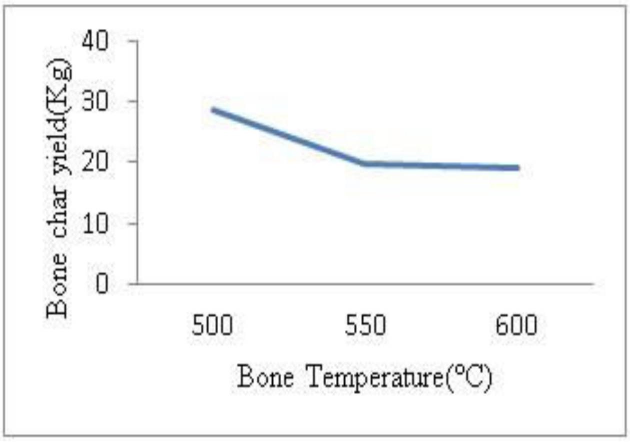

Figure-13. Bone char yield at different temperature.

CONCLUSIONS

The bone pyrolysis Kiln was much efficient than an electric kiln which tooks 5hour to get 500 °C. Bone char produced was uniformly heated. Compared to the kiln built before which does not have rotating paddle, fire wood consumption was much lower, easy for operating, easy for loading and unloading of the material(bone) and almost no smoke at the chimney.

Pelleting machine in pilot scale was developed in this study along with bone pyrolysis kiln. By developing this new system, it can directly produce biochar based fertilizer pellet from wet compost comprising different particle sizes. The pelletizing effectiveness of the machine was highly affected by high moisture content of the compost. When the roller rotates at low speed, rate of pellet yield was decreased. The weight and volume of pellet was reduced through drying process, and it makes the pellet easy to handle for transport and spread to land as fertilizer. However by fabricating and testing different hole size thickness for the die as such, it will be important to compare the pellets, regarding durability, stability, production rate, energy consumption (KWh/tonne), and solubility.

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