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HOUSE WASTES DISPOSALS USING PYROLYSIS TECHNIQUES TO RECYCLE IN TO USABLE BIOCHAR AND REDUCE ENVIRONMENTAL POLLUTIONS

SUTUMA EDESSA

Addis Ababa University, KedirHusein (Wolkite), Ethiopia

ABSTRACT

The main objective of the research conducted on recycling solid household wastes is to convert rubbishes into biochar through pyrolysis techniques and use as source fuel energy, soil fertilizer and cleanse environmental pollutions.

Pyrolysis technique was used as a method of converting organic solid wastes into biochar a fine charcoal like material with high organic carbon and basic nutrient contents and largely resistant to decomposition. To employ pyrolysis techniques or thermo dynamic methods of partially combusting feedstock of wastes in the absence or limited oxygen barrel kilns were improvised. The feedstock was prepared from solid household and Khat wastes to feed the Barrel Kilns and process pyrolysis and produce two types of biochar with required temperatures. The research was extended to attest the soil amendment capacity of biochar on field based experiment on carrot and salad crops.

As a result, recycling wastes into a multipurpose biochar was effective and successful that the byproduct biochar was found usable for alternate fuel energy, soil fertilizer and reduction of environmental pollutions. It was investigated that biochar added soils have effectively improved the yielding capacity of carrot by 50% and salad by 22%.

Biochar is a simple product usable for fuel energy and as a means of income generation, soil amendment to improve crop productivity and saving money from buying fertilizers while it cleanses the environment by reducing pollutants and mitigate climatic changes.

KEYWORDS*:* Amendment, Biochar, Disposal, Feedstock, Pyrolysis, Wastes and Yields

INTRODUCTION

The ever increasing city dwellers population has accelerated the production of enormous wastes invading all ecosystems that knock at every door of the world at flying rates.

The volumes of the waste are timely increasing both in urban and rural areas due to improper handling of the wastes; causing everywhere overflowing of rubbishes or dirt on streets, residence areas creating shelters for nuisance pathogenic organisms, which produce unpleasant odor and pollute ecosystems.

The sources of all wastes are mostly humans said to be anthropogenic activities including packaging industries, fabrics, food wastes, grass clippings, residence areas and commercial centers (hotels, restaurants). It includes kitchen wastes (food leftovers, rotten fruits, vegetables, potato peelings, pits of onions, papers, straws, leaves, vegetables), crop residues, maize, coffee husks, Khat residues, animal excreta, bones and leathers that aggravate and overwhelm cities.

House wastes are currently problematic issues of plastic wastes (bottles and bags) showing intensive landfills along streets, roads, high ways, range lands, farmlands and forest areas and release greenhouse gas (carbon dioxide, methane and nitrous oxide) emissions, cause environmental pollutions and menace the whole life style of the society (Figure 1).

The growing population size of the capital of Ethiopia is associated with the generation of numberless rubbish accounting for about 200,000 tons per year ever causes disastrous landfills due to the lack of dumpsites, proper disposals and scientific solutions. One of the unforgettable tragedies of landslide of “Koshte” waste dumpsite in the capital killed 125 people on March 11, 2016 due to improper handling of wastes (Plate 2).

Plate 1: Rubbish Landfill Disposals at Addis Ababa Streets
Source photo: Sutuma Edessa (2019)

Plate 2: Rubbish Dumpsite Landslide Tragedy in Addis Ababa
Source: Media report (2016)

House wastes are simply thrown away on streets, sideways, bio-corridors, rivers, water ecosystems due to the lack of adequate waste disposal systems. In fact, unless systematic and scientific waste disposals are well-dressed, residence ecosystems are jeopardized with rubbish landfills and residents face uncontrollable environmental problems.

Converting wastes into substantial usable materials is one of the scientific methods of solving the issues of rubbishes causing environmental problems. Recycling is one of the processes of converting wastes into usable materials or resetting rubbishes into the sequential of normal cycles of materials. It is managing wastes by converting rubbishes into a byproduct biochar that could be used for fuel energy, soil amendment, eradication of pollutants and support to mitigate climatic changes.

Converting house wastes into biochar through pyrolysis techniques solves issues of dumping systems (collection mechanisms, recycling and disposals)and creates social awareness and sources of income generations.

Pyrolysis is a **thermal treatment technology** for biodegradable wastes with a potential to convert feedstock into usable biochar. It is a black byproduct material with high contents of carbon produced by pyrolysis techniques including fast or slow pyrolysis and gasification.

Most people are familiar with charcoal produced by combusting wood and used for fuel energy. Biochar is also produced in a similar fashion through fast or slow gasification pyrolysis techniques and will be meaningful when applied for soil amendment. It is processed by placing wastes inside an oxygen limited container and heating that heats up wastes, moistures, vaporize and create positive pressure in the container by displacing the initial charge of air.

The efficiency of the traditional Kilns systems is as low as 8% since it allows air entering and gasifying biochar to produce carbon monoxide and carbon dioxide with excess heat (Brown, 2009) and biochar yields do not exceed 40% of the feedstock weight that a large fraction of the biomass is lost (Lehmann and Josef, 2007).

Fast pyrolysis produces bio-oils and lowers biochar yielding whereby slow pyrolysis and gasification produces higher yields of biochar without bio-oil.

According to Brown et al (2009), pyrolysis technique is a partial combustion in a controlled and oxygen deprived environment, which is designed to minimize emissions to simply burn wastes or woods and produce charcoals by releasing smokes, soot and other volatiles into the atmosphere. Biochar is heavily affected by the extent of pyrolysis technique, types of feedstock, Kiln size and residence time and temperature rates.

The objective of the research is to convert organic wastes into usable biochar using pyrolysis recycling techniques.

Pyrolysis recycling technique is one of the solutions to convert wastes into biochar, which production of usable material for fuel energy, soil amendment, carbon sequestration and reduction of environmental pollutions.

MATERIALS AND METHODS

Materials

Modern and locally improvised materials:

- Barrel Kiln with chimney pipe for pyrolysis technique of biochar production
- Waste collection materials: hand gloves, plastic bags and sacks for feedstock
- Technical tools: crucibles, oven, gas flow meters, pH meter and elemental analyzer
- Farm materials: spades, mattock, axe, measuring tape, weighing balance and carrot and salad seeds

Methods

Biochar Production Methods

Recycling pyrolysis techniques were applied to convert house organic wastes into biochar, useful material for fuel energy and soil amendment.

The method employed for recycling wastes was pyrolysis technique through which houses wastes were collected from various areas of landfills, bagged, left to dry for a few days, transported to the pyrolysis station.

Consecutively, only combustible organic wastes were sorted, chopped into small pieces or ground, weighed and made a ready feedstock to process pyrolysis.

A metal barrel kiln with a chimney covered by mud was locally improvised that the chimney hole on the top of the barrel kiln with a lid to allow gases escaping while preventing oxygen.

The feedstock were fed to the barrel kiln and lit with fire at the entrance and waited until it is filled with smoke and the temperature reaches the point of pyrolysis to completely close the entrance airtight to allow pyrolysis in anaerobic condition.

The temperature of the inner barrel kiln was adjusted to between 176 and 260°C for quick start of the pyrolysis process, which was gradual, increased the temperatures to 350°C, 400,°C and 450°C to enable convert feedstock into biochar. Once the entrance was completely closed, little amount of smoke or pyrolysis gas leaves out the barrel kiln through the chimney pipe filter or dissolves in water.

The feedstock is partially combusted into the byproduct biochar, which is removed from the barrel kiln to the ambient temperature and quenched by spraying water to stop further combustion.

Biochar Application Methods

1. Biochar for Fuel Energy

Biochar is a combustible material that can be used for fuel energy in wide spectrums. Biochar is used for cooking and income generation, which is packed and sold on the market like charcoal.

2. Biochar for Soil Amendment

Pyrolysis technique of converting wastes into biochar and field based experiments of biochar application for soil amendments were conducted in Welkite town (155 km southwest of the capital).

Field based experiment was conducted to test the effectiveness of biochar in improving soil fertility and increasing yields by growing carrot and salad crops.

For the field based experiments, 4 units of land plots with 2x1.5m in size and 6 rows were prepared and equally divided into two sections with spacing rows of 10 cm for sawing carrot and 20cm for sawing salad seeds on equally prepared land unit plots.

Sampled biochar was tested in the laboratory using pertinent parameters, fined and added to the depth of soil profile of 20 cm on two of the land unit plotsat about 20t/ha whereby the other two land unit plots were left without. Soil pH levels, moistures, nitrogen, phosphorus, potassium and organic carbon contents were measured.

Carrot and Salad seeds were sawn and grown in rows bilaterally with equal care including adequate sun light, watering, weeding and insect control until crops are ripening. Both crops were harvested (picked) from both treated and untreated land units, weighed and yield increments were identified.

3. Comparative Tests of Biochar Soil Amendment

Soil samples of 1kg was collected from the soil profile depth of 20cm of both biochar treated and untreated experimental land units using auger, kept to dry, ground, sieved, combusted at standardized temperatures in the pyrolysis furnace for 10 minutes and nutrient contents were measured and compared.

4. Data Analysis and Evaluation

Converting combustible solid house wastes into a black byproduct biochar, which is usable as sources of fuel energy, soil fertilizer and reduction of soil acidity, cleanse of environment and mitigation of climatic changes was successful.

In the process of pyrolysis, increased temperatures from 350 to 450^{0}C in the Barrel Kiln have also decreased the contents of Nitrogen from 0.299 to 0.134% for Khat residue and 0.40 to 0.168% for the other house waste biochar. As pyrolysis temperature increased, the carbon contents of Khat residue and other house wastes biochar increased from 3.12 to 3.47 and 1.95 to 4.68% and began to volatilize at 100°C. Nonetheless, with the increase of pyrolysis temperatures, the contents of carbon were increased, but the contents oxygen and hydrogen were decreased.

Likewise, the contents of Phosphorus of Khat residue and other house waste biochar increased from 108.4 to 194.0 and from 98.6 to 148.4 ppm with the increase of temperature and volatilized at about 700°C.

At the increase of pyrolysis temperature, Potassium contents of Khat residue and other house wastes biochar increased from 77.6 to 105.4 and 40.7 to 87.4 and the pH level increased from 8.2 to 9.9 and 8.2 to 10.7 for Khat and house waste feedstock.

Table 1: Biochar Contents at Different Pyrolysis Temperatures

Feedstock	Temp ^{0}C	K mg/kg	P ppm	N%	C %	PH
Khat residues *(Catha edulis)*	35o	77.6	108.4	0.299	1.56	8.2
	400	98.4	184.6	0.269	3.12	8.9
	450	105.6	194.0	0.134	3.47	9.9
House wastes (others)	350	40.7	98.6	0.403	1.95	8.2
	400	65.9	129.3	0.336	3.9	10.7
	450	87.6	148.4	0.168	4.68	10.7

Biochar application to soil amendment has enriched the soil contents using recycled and transformed nutrients by converting into oxides, hydroxides and carbonates and increased soil carbon, bulk density and the pH levels as well as decreased nitrogen leaching activities.

Biochar has improved water retention capacity of the soil for long duration and attracted positively charged nutrient ions and prevented soils from being leached away by water.

The soil carbon contents were slightly increased from 1.35% to 2% by the treatment whereby Nitrogen contents of the soil was increased from 0.12 to 0.17 and reduced leaching and increased uptakes by plants.

The phosphorus contents of the biochar treated soil were increased from 14.8ppm to 18.7ppm whereby the soil bulk density was decreased from 0.98 g/cm^3 to 0.94g/cm^3 due to biochar application that increased better penetration of surface area water by reducing soil compactions and boosted soil productivity.

The contents of treated (biochar added) soils were tested and found containing high Phosphorous, Potassium, Nitrogen and Carbon with porous structures that serve as small reservoirs for storing nutrients and water than untreated soils of land units.

Biochar adding to soils is a good treatment for increasing the contents of Potassium from 24.6 mg/kg to 28.5 mg/kg and the pH levels from 7.3 to 7.9 that allowing plants to grow at maximum potentials.

The yielding capacity of biochar added soil (treated soil) was compared with the yielding productivity of soil without biochar (untreated soil) soil through growing carrot and salad crops revealed greater yielding capacity differences significantly (table 2).

Table 2: Effects of Biochar on Soil Yielding Capacity of Carrots and Salads Crops

Experimental Crops	Yielding Capacity of Biochar added soils	Yielding Capacity of Soils without Biochar (Untreated)	Yielding Increment
Carrots	4.8 Kg/m^2	3.2 Kg/m^2	50%
Salads	7.2 Kg/m^2	5.9 Kg/m^2	22%

RESULT AND DISCUSSIONS

As a result, field based experiment of soil treatment for the amendment of soil fertility demonstrated that Carrots and Salads crops grown on biochar treated soil have improved productivity by 50 % and 21.64% of yielding increment respectively (table 2).

The research conducted on recycling organic solid household wastes into biochar through pyrolysis techniques was resulted as converting rubbishes into usable materials.

As attested by the experiment conducted on the biochar soil amendment capacity, carrot crops improved yielding by 50% and salad crops increased yielding by 21.64% in comparison with the untreated soils.

Figure 3: Barrel Kiln.

Figure 4: Biochar.

Figure 5: Salad Crops on Treated Soil

Figure 6: Salad Crops on Untreated Soil.

Figure 7:Carrot Crops on Treated Soil Figure 8: Carrot Crops on Untreated Soil.

DISCUSSIONS

Pyrolysis technique is an old practice with a new concept of biochar production from organic house wastes using different technical parameters of anaerobic styles of combusting feedstock to produce biochar. It is a low density material that reduces soil bulk density; increases water infiltration, root penetration and soil aeration (Laird et al., 2010).

The pyrolysis operating conditions and biomass feedstock affect both the composition and structure of biochar resulting in significant differences in nutrient contents.

According to Sohi et al (2010), as pyrolysis temperatures increase the pH of the biochar increases and at about 500^0c pyrolysis temperature, phosphorus contents slow and potassium accumulates in the biochar (Hossain et al., 2007).

Adding biochar to soils has direct impact upon plant growth and improves the physical makeup of the soil horizons, supports the penetration of air and water deep into the root zones (Chan et al., (2008).

Application of biochar to soils for the improvement of fertility is adding nutrients and micronutrients and retaining mechanisms (Lehmann et al., 2006).

CONCLUSIONS

Human beings are responsible for causes of environmental pollutions across the world. Land and water ecosystems are predominantly the residence areas polluted by anthropogenic activities and waste landfills. It necessitates shouldering and finding solutions for all environmental pollutions of the current worldwide wastes including lethal, chemicals, gaseous, molecular and nuclear or radiation wastes.

Recycling wastes into usable materials such biochar serves as sources of energy from small unit to higher electric power plants as one of the primary actions to solve environmental problems. It is helpful as a source of fuel energy for cooking, heating, cost saving that producers generate incomes by selling on markets.

Biochar also serves as fertilizers to enrich soil fertility, increase soil productivity by improving yielding capacity of crops to secure food, feed and fodder and reduce costs of buying fertilizers.

Amended soils grow crops and other plants useful for balancing ecosystems stability and reducing pollutions.

Ecologically, biochar is applicable for cleansing the environment, eradicating pollutants, reducing greenhouse gases and mitigating climatic changes in decreasing atmospheric CO2 concentrations.

Modern pyrolysis plants can produce electric power energy and run power stations using waste feedstock efficiently, but pyrolysis furnaces could be constructed locally available metal barrel Kilns, Pits, low costing stoves from bricks and concretes and used to produce biochar.

REFERENCES

1. Brown, R., Lehmann, J. and Joseph, S. (2009). Biochar Production Technology: Biochar for
2. Environmental management, Earth Scan, 127-144 PP, London, UK
3. Chan, et al (2008): Using poultry litter biochar as soil amendments. Australian Journal of Soils, Australia
4. Hossain, M. K., Strezov, V.& Nelson, P. (2007): Evaluation of agricultural char from sewage sludge. Proceedings of International Agro-char Imitative, Terri gal, Australia
5. Laird, et al (2010): Impact of biochar amendments on the quality of a typical Midwestern agricultural soil. *Geoderma.*
6. Lehmann, J. and S. Joseph (2009): Biochar for Environmental Management: Science and Technology. Earthscan, London & Sterling, VA.
7. Sohi, et al (2010): A review of biochar and its use and function in soil. *Advances in Agronomy*