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AMARANTHUS CAUDATUS AS A PUTATIVE BIOENERGY PLANT FOR PREPARATION OF BIOCHAR TO ENHANCE BIOMASS PRODUCTION

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ABSTRACT
Conversion of low-density wood into biochar faces many problems and results in ash formation. Development of three-container indirect heating retort can help to combat with this problem and could lead to production of good quality biochar. To validate, the *Amaranthus spp*. biomass has been dried, ground <0.1 mm and put it in a small container which was placed in a bigger container and finally surrounded by a large stainless-steel container which was filled with feedstock and allowed to combust for two hours under limited oxygen condition. Analysis of prepared biochar showed alkaline pH, high water holding capacity and electrical conductivity. Pot scale study was performed on *Amaranthus caudatus* L. var. gibbosus rubra which showed that application of 1% biochar has not only enhanced fresh and dry shoot biomass but also improved biometric growth parameters (length of shoot and number of leaves) as compared to control plants. The study showed that the application of a low dose of biochar from *Amaranthus spp.* improved the growth of *A. caudatus* plants and thus increased the lignocellulose content which can be used for bioenergy production.

Keywords: *Amaranthus, biochar, retort, plant biomass, lignocellulose*.

INTRODUCTION
Continuous use of non-renewable fuels is a serious global concern. The best possible way to minimize the problem is to replace these with sustainable resources. Currently, lignocellulosic crop, which is the most abundant available biofuel feedstock on earth, is being used to reduce this dependency. In one way application of pesticides and fertilizers has resulted in enhanced productivity however, on the other side they contaminated the soil with heavy metals (Tripti et al., 2017). High lignocellulosic biomass plants can help in mitigating such problems and can help in many other ways. Firstly, they can immobilize metals by sequestering them in roots (Limayem and Ricke, 2012). Secondly, the biomass can

be used for preparation of biochar and biofuel by enzymatic hydrolysis. Biochar is a carbonaceous material produced by burning in limited oxygen condition (Hussain et al., 2017; Vecstaudza et al., 2017). It has very high surface area, rich in macro- and microelements, with a high ability to absorb metals. It is also a suitable carrier for the immobilization of microorganisms because of its high porosity (Li et al., 2022). Since high density woods produces good quality biochar, low density woods often convert into ashes. Thus, it is very crucial to know at what temperature the biomass should be burnt and for this, a good quality biochar retort is required. There are three types of pyrolysis conventional or fast, slow and ultra-fast or flash which can be direct or indirect. Both direct and indirect heating of biomass in a retort is a popular method of production of biochar however direct method fail sometimes in case of low-density wood as biomass will convert in ashes at higher temperatures. An approach has taken to develop and construct a retort which can produce good quality biochar. To check the efficiency of produced biochar a pot scale plant growth experiment with fixed percentage of biochar as additive is required which will help to evaluate the biometric growth and developmental parameters of plant.

Thus, the aim of the study was to prepare a three-stage container-based biochar retort to produce biochar with minimum ash content. In addition, to evaluate the efficiency of produced biochar the pot scale experiment was performed to see its efficiency on *Amaranthus caudatus* L. growth and development.

MATERIALS AND METHODS

To produce a high-quality biochar from *Amaranthus* biomass, a suitable torrefaction oven is must. A torrefaction oven/pyrolysis retort was prepared using cylindrical stainless-steel containers of different sizes. The retort comprises of 3 containers with lids and a chimney (40 cm height) attached at the top to remove the fumes and gases during operation of retort. The volume of the bigger, medium and small container was 1.27×10^5 cm^3, 0.62×10^5 cm^3 and 0.01×10^5 cm^3, respectively. The dry wood of tree was collected and dried to use it as feedstock (fuel) for the retort.

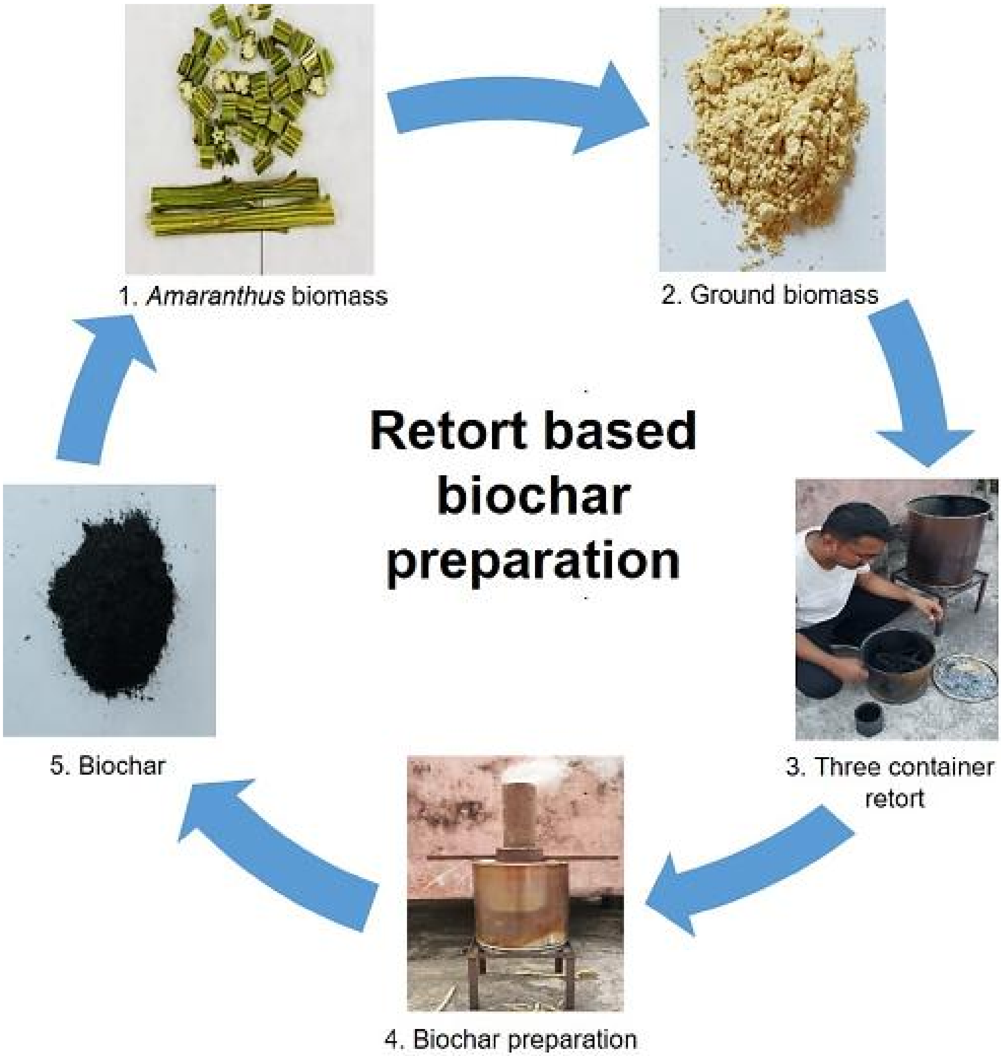

Figure. Schematic diagram showing conversion of biochar from biomass using a retort.

A total of 8 small holes were made at the bottom of the big and medium container to allow a limited amount of oxygen to pass through the bottom to the upper side to burn the feedstock and biomass (*Amaranthus* plants were collected from the Botanical garden of the Ural Federal University, Ekaterinburg) filled in medium container for a longer duration of time to produce a better-quality biochar. This process is called as indirect heating of biomass were biomass burns slowly for a longer duration of time. Since the ground raw biomass can convert into ash if burned directly, they were placed in small container to prepare a biochar with low ash content and minimum loss in ignition and pyrolysis was performed during autumn season of 2021 in the pyrolysis unit of the University campus A schematic representation of the biochar production process is presented in Figure.

Amaranthus caudatus L. var. gibbosus rubra a plant rich in lignocellulose content and can produce big biomass in a short period of time. The seeds were collected from the Botanical garden of University. The healthy seeds were selected and soaked overnight in distilled water. Next morning, a 25-well seedling tray, each well filled with 20 g of soil was sown with one seed. A total of 3-replicates of such seedling trays were prepared. The plants were watered every evening and allowed to grow for next 20 days under natural day:night regime. Once the seedlings reached a height of 7–10 cm, they were transferred in big pots of 10 L soil capacity. A total of 12 pots were prepared and divided into two sections to prepare two treatments, i.e., garden soil (as a control) and another with 1% biochar. The plants were watered regularly every evening and allowed to grow for a period of another 40 days. At harvest, shoot fresh and dry biomass, length, and number of leaves were determined (Kumar et al., 2021).
The seeds from plants were collected, and then harvested to collect the biomass for further analysis. The stem of plants was carefully separated from root and washed several times to remove any adhered soil particles. The samples were dried to obtain moisture-less biomass and cut into small pieces of about 1 cm using an electric cutter and further ground below < 0.1 cm using a 30000× high speed grinder. The prepared biochar was characterized for its physicochemical parameters such as water holding capacity, pH, and electrical conductivity (EC) (Kumar et al., 2017).

RESULTS AND DISCUSSION

The stainless-steel constructed biochar retort was able to withstand the high temperature ranged between 200–500 °C. It was observed that the feedstock was completely burned in the first hour of operation whereas the energy transferred into second container remain ignited for next one and half hour. The feedstock was mainly converted into ash whereas the ash content in the second container was lower than feedstock. The ground biomass kept in the small container converted into high carbon rich (>60%) biochar. The produced biochar showed an alkaline pH of 9.75 ± 0.25, with water holding capacity 52.00 ± 4.40 and ES of 10.05 mS/cm which showed its suitability in agroecosystem especially for acidic soil.
The pot scale study was conducted using *A. caudatus* plant species and shoot fresh and dry biomass and length was recorded in the presence and absence of biochar (Table). It was observed that application of biochar (1%) has significantly improved the biomass of the plant. Both dry weight and fresh weight has improved by 21 and 33%, respectively. It also helped in elongation of shoot length which was increased by 24%. Tripti et al. (2017) and Kumar et al. (2021) had also reported that application of biochar enhanced the plant growth and development.

Table 1. Shoot fresh and dry biomass, length and number of leaves in the control and biochar treated soil (Mean ± SD, n = 6) of *A. caudatus*.

Treatment	Fresh biomass, g	Dry biomass, g	Length, cm	Number of leaves, n
Control soil	35.0 ± 8.0	11.5 ± 1.5	18.5 ± 2.0	5.0 ± 1.0
Soil + 1% biochar	52.5 ± 4.5*	14.0 ± 1.2*	25.5 ± 1.5*	8.0 ± 1.0

**Significantly different according to the independent sample t-test at $p < 0.05$.*

Altogether, the detailed methodology for production of biochar and its use in plant growth experiment reported will give a clear idea for early researchers, scientists, and stakeholders to produce biochar in most efficient manner which can be used in agriculture to reduce dependency on chemical fertilizers and exhaustible fuels.

CONCLUSIONS

The study showed a detailed pictorial method for preparation of retort for the generation of biochar using plant biomass. The three-container biochar retort showed a significant result in production of biochar by minimizing the ash content. Moreover, the biochar produced showed a high water holding capacity with alkaline pH and high electrical conductivity which showed ability for its use in acidic environment. A pot scale experiment using biochar prepared from *Amaranthus spp*. showed enhanced shoot fresh and dry biomass as well as length depicting its role in plant growth improvement which could help to increase the lignocellulose content in *Amaranthus caudatus* plant for bioenergy production.

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