

## **Biochar Technology as a Go Green Movement in Indonesia**

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### **ABSTRACT**

Charcoal has long been known by the community in its use either as energy sources or for agriculture/forestry-related aspects. Beginning from the discovery of the so-called Terra Preta, the role of charcoal in improving soil fertility and enhancing its productivity at agriculture as well as forestry lands has attracted remarkable attention internationally ever since. Raw material for charcoal can be wood or other ligno-cellulosic stuffs (e.g. coconut shells, oil-palm shells, rice husks, wood sawdust, nut shells, etc). Technology in charcoal manufacture commonly employed by the community comprises heaping-kiln, drum kiln, and dome-shaped kiln systems. Such manufacture technology is simply carbonizing the ligno-cellulosic stuffs inside the kiln into charcoal. The charcoal yield usually ranges about 20-25% (w/w), implying that as much 75-80% of the stuffs is lost as smoke that further escape to the air. Environment concerns arise since such escaped smoke can pollute the atmosphere and hence contribute to the global warming. Measures are urgently needed to reduce the amount of such escapes among others, as developed by the Center for Research and Development on Forestry Engineering and Forest Products Processing (CRDFEFPP, Indonesia) by cooling the smoke, during the carbonization of ligno-cellulosic stuffs, thereby condensing it into liquid smoke (popularly called as wood vinegar). Through intensive and tedious researches, it is found out that the wood vinegar (as charcoal by-product) could effectively function as bio-pesticides and bio-fertilizers. Meanwhile, application of charcoal to the seedlings of forestry plant species reveals positive responses as shown by the increase in biomass weight of those plants on other positive plant-growth aspects (e.g. stem height and diameter). Likewise, the use of charcoal combined with compost (i.e. organic fertilizer that results from bio-conversion of biomass stuffs) could enhance as much 2-3 times the production of vegetables plants as the control (untreated plants). This in all strongly indicates the charcoal and wood-vinegar manufacture entirely called as essentially the bio-char technology, can convert biomass stuffs (previously regarded as not or less useful) into value-added or more useful products (charcoal and wood vinegar).

**Keywords:** Biochar technology, charcoal and wood vinegar

### **INTRODUCTION**

Charcoal refers to a product predominated in content by carbon which results from the carbonization process on carbon-containing stuffs particularly ligno-cellulosic biomass. Such biomass contains also other elements than carbon (C) such as hydrogen (H), oxygen (O), sulfur (S), phosphor (P), and inorganic constituents (ash). The carbonization on ligno-cellulosic biomass proceeds at elevated temperature (400-800°C) without oxygen or under the limited oxygen, yielding the ultimate the solid product, called charcoal.

This charcoal product finds its main uses as energy source.

Other uses include among others as raw material for activated charcoal, compost charcoal, nano-carbon, lithium battery, silicon carbide, and take remarkable role as carbon sequestration. Such charcoal uses depend on its carbon content and processing manner.

Indonesia has long been known as a charcoal-producing country, whereby most of the produced charcoal is exported throughout market worldwide. It is recorded that Indonesia has ranked among the five greatest

charcoal-exporting countries, comprising China, Malaysia, South Africa, and Argentine. In 2008, Indonesia export of charcoal reached 29,867,000 kg, that consisted of coconut-shell charcoal (15.96%), mangrove-wood charcoal (22.31%), and other-wood charcoal (61.73%) (Biro Pusat Statistik, 2009).

The technique of charcoal production in Indonesia usually employs the traditional manner, whereby some amount of ligno-cellulosic stuffs in heaped in the soil, and it is therefore called as the heaping-kiln system. In Indonesia, such heaping kiln numbers over ten thousand units. In Mataram, charcoal manufacture with this heaping system has proceeded over four successive generations. Likewise, the wood wastes generated by the community-owned sawmills, such as slabs and small woody pieces can be carbonized into charcoal using the heaping-kiln system. Meanwhile, the carbonization system that takes place in the dome-shaped kiln constructed of red-colored bricks, in number tends to diminish due to scarcity of ligno-cellulosic biomass material. Raw materials commonly used for charcoal manufacture cover ligno-cellulosic wastes from forestry, agriculture, and crops estate such as wood sawdust, wood slabs, woody end cut, stumps, corncobs, coconut, kemiri (*Aleuritus molucana*) nuts, coconut shells, oil-palm shells, coffee-seed shells, etc., which so far have not yet been utilized optimally.

Charcoal-manufacturing process commonly conducted by the community and industry afford the charcoal yield which usually ranges about 20-25%, indicating that as much 70-85% of the carbonized ligno-cellulosic materials is lost as condensable gases/vapors (e.g. acetic acid, methanol, ketones, and phenols) and as incondensable gases (e.g. CO<sub>2</sub>, CO, H<sub>2</sub>, and CH<sub>4</sub>). Those condensable as well as incondensable gases that escape or release to the air, will pollute the earth atmosphere and therefore can contribute the so-called global warming. To minimize such release or emission, there has been conducted a series of researches which

aimed to increase the charcoal yield and concurrently to condense the evolved gases (particularly the condensable fractions) into the distillate liquid, more popularly called as wood vinegar, that may bring valuable benefits. Applied technologies which are proper and environmentally friendly that deserve for development and dissemination include among others technology of wood vinegar production concurrently integrated with charcoal product in one simultaneous process.

This technology model seems favorable to be thoroughly developed and applied by considering that ligno-cellulosic materials and tool/equipment as made-up of local components are easily obtained and relatively inexpensive in price, while the production capacity can vary, depending on the tool/equipment capability.

## **TECHNOLOGY OF CHARCOAL MANUFACTURE**

### **Charcoal Manufacture Using Traditional Kiln**

The ligno-cellulosic materials for such can be tree-logging wastes, wood slabs, and end cuts. This manner is implemented the most by the community due to being simple as well as cheap in operation. In principle, this manner proceeds by at first heaping in soil a pile containing pieces of ligno-cellulosic materials that further will be carbonized into charcoal, and therefore this traditional set-up is known as the heaping kiln. Initially, such kiln is prepared by digging-in the soil to particular depth. Further, particular amount of ligno-cellulosic materials is put into the dug-soil piece- by-piece forming a pile with its height not exceeding the surface soil.

Afterwards, the upper part (top) of the pile is covered with dry leaves and soil, while in the lower part some air holes are provided for assisting the carbonization process by venting out the evolved smoke. The charcoal yield as obtained by this heaping kiln reaches 20% in average, with its moisture content of 4.7%,

ash content 2.3%, volatile matters 17.6%, and fixed carbon 80.0%.

### **Charcoal Manufacture Using the Modified Drum Kiln**

Ligno-cellulosic wastes such as wood slabs, woody end-cut, and tree twigs or branches from wood-processing industries; coconut shells; kemiri nuts; and oil-palm shells can be carbonized into charcoal in the kiln constructed of used drum, which previously has been modified. The drum kiln consists of four main parts, comprising the drum body whereby one of its ends has been opened; cover for the upper end (upper part) of the drum; smoke chimney (installed at the upper part); and air holes at the lower portion of the drum, which function to assist the ignition or initial burning of the ligno-cellulosic materials.

As such, the carbonization process lasts for 6-8 hours, during which the exothermic course that occurs can be recognized with the evolvment of thin smoke with bluish color coming out of the chimney. This drum kiln can further be equipped with a cooling device made of bamboo, or with a continuous cooler constructed of stainless steel pipe for water circulation to condense the evolved condensable smoke into the liquid form called as wood vinegar. In this way, the evolved incondensable gases, such as CO<sub>2</sub> and CO can also be reduced to significant amount that otherwise escape to the air, since during their trapping inside the cooling bamboo pipe or stainless steel pipe they can react with also other evolved gases to form liquid condensates (e.g. methanol and acetic acid).

The charcoal yield obtained by the drum-kiln method can reach 24%, with moisture content of 5.5%, ash content 2.4%, volatile matters 11.6%, and fixed carbon content 85.9%. Meanwhile, the yield of wood vinegar as concurrently obtained varies about 5-30%, depending on the cooler type as used and characteristics of the carbonized ligno-cellulosic materials.

### **Manufacture of Charcoal from Rice Husk using Semi-continuous Kiln**

This kiln is very favorable in use for carbonizing particular ligno-cellulosic materials into charcoal, such as rice husk. The semi-continuous kiln can be made permanent if constructed of red bricks, or movable if thin zinc metal is used as the construction material. In principle, the carbonizing process takes place by heating the rice husks already inside the kiln at the lower part (base), into charcoal, whereby that part is previously heated (preheated).

Afterwards, the carbonized rice husks are extinguished by pouring water or by putting them into the chest that already contains water, placed in front of the kiln. In one day (9 hours), this kiln affords the carbonization with intake capacity of 150-200 kg of rice husks per batch, yielding 20-24% as charcoal. Meanwhile, the resulting rice-husk charcoal exhibits its specific properties such as moisture content at 3.49%, ash content 5.19%, volatile matters 28.93%, and fixed carbon 65.88%.

### **Carbonizing of Wood Sawdust Using Semi-continuous Kiln**

Wood sawdust can also be carbonized favorably using this kiln. As such, the semi-continuous kiln is constructed of red bricks, equipped with air-circulation system, smoke chimney. In principle, the carbonization procedures takes place almost similarly to those for rice husks as described above. Initially, the kiln that already contains wood twigs inside at the lower part (base) is preheated. Afterwards, the wood sawdust is added into the kiln above the heated wood twigs, and in this way the sawdust will be automatically heated and carbonized. The addition of sawdust should be conducted in stages little by little (layer by layer), awaiting when the layer of previously added sawdust looks already carbonized into charcoal. Whether the sawdust in such layer is already carbonized or not can be recognized by

visually observing the charcoal formation that occurs at the sawdust surface. Further, in order that the evolved smoke can be drawn into the chimney, its lower part is heated. The charcoal yield from the wood sawdust using this kiln can reach 14% in average, with its corresponding properties, i.e. moisture content at 3.2%, ash content 4.8%, volatile matters 23.12%, and fixed carbon 72.1%.

### **Charcoal Manufactured Using Dome-shaped Kiln**

This kiln affords the intake of ligno-cellulosic materials (e.g. wood logs) with the diameter over 8 cm. Principally, the carbonization process for charcoal manufacture using this kiln does not differ much from that of the drum kiln. The difference lies at the capacity, raw-material size, and the carbonization duration. The construction material for this kiln type is made-up of red bricks layered with clay soil. This kiln is able to yield charcoal as much as 23% in average, with its specific characteristics, i.e. moisture content at 4.9%, ash content 2.3%, volatile matters 17.2%, and fixed carbon 80.4%. In operating this kiln, it can also be equipped with a cooling device as also the case of the modified drum kiln.

The charcoal yield that reaches 20-30% implies that as much 70-80% of the carbonized material (e.g. wood) has escaped to the air as smoke which further can bring about pollution impacts on environments. By implementing the cooling technology, significant part of the smoke can be condensed in the liquid form more popularly called as wood vinegar. The wood vinegar has found numerous uses as among others biopest repellent and soil activator. Some related experiments reveal that the agriculture and forestry plants treated with the wood vinegar exhibited greater resistance against the attack by pests, and more over the amount (bulk) of biomass stuffs as formed increased remarkably. Several countries such as Malaysia, Thailand, Japan, and Brazil, have performed the wood-vinegar production

commercially; and even the charcoal as produced simultaneously became just a secondary product.

### **CHARCOAL APPLICATION FOR PLANTATION**

Morphologically, charcoal has a lot of minute pores thereby increasing its effective surface area and hence in its uses associated with the soil affording high adsorptive as well as absorptive capabilities to hold together, store soil nutrients, and release them gradually. Therefore, the application of charcoal combined with compost on unfertile or nutrient-poor lands can expectedly bring in several convenient impacts, among others: improving soil fertility, regulating soil pH, enhancing soil aeration, stimulating the forming of endo- and ecto-mycorrhizza spores, and absorbing the excess of CO<sub>2</sub> in the soil. In this way, the productivity of land and forest plantation area can considerably increase.

Results of experiment reveal that the incorporation of bamboo charcoal and activated bamboo-charcoal as the mixture in the plant media for *Eucalyptus urophylla* plants was able to increase their growth either at nursery or at seedling stage. Meanwhile, the addition of sawdust charcoal and vegetation-litter charcoal to the growth media of *Acacia mangium* and *Eukaliptus citriodora* plants brought about an increase as much 30% growth of their seedlings as those of the control (without charcoal addition). Likewise, similar phenomena occurred in the field trial whereby the addition of charcoal increased the diameter of *E. urophylla* stem. In another occasion, incorporation of bamboo charcoal and rice-husk charcoal that amounted to 5% and 10% respectively in the plant-growth media enabled the agriculture plants such as red peppers to increase as much 11% of their height as that of the untreated red peppers (control). Nevertheless, such height growth would be even more enhanced if on the occasion of red-pepper planting the charcoal as incorporated was mixed with compost. Temporary results revealed that the

addition of wood-sawdust charcoal and composted sawdust to the plant growth media brought greater diameter (7.9-cm increase) of the particular tree species compared to that without such addition (Gusmailina, 1999).

Research conducted by Komarayati (1996) showed that bioconversion of tusam-wood (*Pinus merkusii*) sawdust and rubber-wood (*Hevea brasiliensis*) sawdust with the aid of the so-called EM4 microorganisms and animal manure, which lasted for 4 days, brought out compost with 85% yield and C/N ratio at 19.94.

Komarayati (2011) also performed the related experiment and further stated that the addition of charcoal as much as 10-30% to the compost brought about increase as much 1.00-1.17 times in the diameter of particular plant species as that of the control (untreated plants). Meanwhile, the incorporation of 1-4% wood vinegar into the compost enhanced the height of the corresponding plants as much 1.42-1.67 times as the control. The use of wood vinegar at 2% concentration for such seemed the most optimum. This was shown from the results of other related experiments that among others revealed wood-vinegar use at 2% proved quite adequate to enhance the growth of particular plants and production of their corresponding crops (Nurhayati, 2007; Komarayati and Santoso, 2011).

Still related, the particular experiment indicated that the use of wood vinegar as well as charcoal individually to jabon plants seems less effective to enhance their growth in diameter and height. However, the combined use of both wood vinegar and charcoal for such did so more effectively. It seemed that wood vinegar and charcoal interacted hence affecting the growth of jabon plants in their diameter and height remarkably. Further, although both jabon and sengon plants belong to fast growing species, each of them however differs in its own characteristics and therefore exhibited different responses against wood vinegar. This is because wood vinegar, which results from the condensation of smoke as evolved concurrently from the carbonization of ligno-cellulosic materials (e.g. wood),

contains particular organic compounds that might be essential to improve soil qualities as well as enable the plant to grow better and stronger.

The addition of charcoal to the soil which was further planted with sengon seedlings seemed affecting the organic carbon content in the soil, and such effect became more pronounced 6 months afterwards. There occurred an increase in soil organic-carbon content from about 2.46-2.54% to approximately 2.95-3.10%. Correspondingly, the soil added with wood vinegar revealed an increase in its organic content from 1.98-2.32% and 2.71-3.20%. Meanwhile, the addition of charcoal as well as wood vinegar to the soil did not seem affecting its available total nitrogen (N) and phosphor (P) contents. On the other hand, the potassium (K) content in the soil after being added with charcoal did increase from initially about 0.82-0.96 meq/100 grams to 1.15-2.54 meq/100 grams.

Conversely, addition of wood vinegar to the soil did not affect its K content. It seems that the particular ash content (notably K element) in the original ligno-cellulosic stuffs (e.g. wood) remains practically intact after being carbonized into charcoal and therefore get carried away in the soil after charcoal addition. Meanwhile, the carbonization on wood or other ligno-cellulosic materials apparently does not volatilize their particular ash content (among others K) to further mix with the evolving smoke from which the wood vinegar is obtained through smoke condensation.

Almost similar phenomena obviously occurred to the soil 6 months afterwards, whereby initially it was added with charcoal as well as wood vinegar, and further planted with jabon seedlings. As such, there occurred an increase in the soil organic-carbon content from about 2.38-2.42% to some 2.31-2.55% after addition. Likewise, the soil after being added with wood vinegar increased its organic carbon content from 2.07-2.55% to 2.20-2.71%. Meanwhile, the available total N and P contents in the soil remain practically unchanged after being added with charcoal as

well as wood vinegar. However, K content in the soil after charcoal addition tended to increase from 0.79-0.83 meq/100 grams to 1.11-2.06 meq/100 grams.

On the contrary, K content in the soil following wood-vinegar addition remained virtually unchanged. On the other hand, the wood-vinegar addition brought about significant increase in diameter of jabon plants. Such diameter increase of those plants was even greater than that due to charcoal addition. Further, the growth response of jabon plants in their diameter increase was quite high compared to that of sengon plants. This again confirms that although both belonging to fast-growing species, sengon and jabon plants however each reacted differently to such wood-vinegar addition. This is as described before attributed to different specific characteristics exerted by each of those two plant species. This occurrence favors the statement by Anomim (2010) who stated that wood vinegar also as alleged previously contains particular organic compounds which could remarkably improve soil qualities and therefore render the plant growth healthier and stronger. Results on analysis of macro- as well as micro-elements in organic liquid fertilizer derived from wood vinegar indicatively contained particular inorganic elements such as sodium (Na), phosphor (P), potassium (K), calcium (Ca), magnesium (Mg), manganese (Mn), zinc (Zn), and others that could serve as natural pesticide.

Activated charcoal manufactured from kemiri (*Aleurites molucana*) nut shells and further mixed with animal manure, which was further used as particular components in plant-growth media could in fact remarkably increase the growth in height and diameter of the stem of melina-plant species as well as the bulk (weight) of its biomass. As such, the addition of activated charcoal with the varying portions, i.e. 5%, 10%, and 15% to the melina growth media significantly affected the growth of its diameter, roots, and total microbe as well as the development of its nutrient elements. The activated charcoal

addition regarded as the most optimum came up at 15% portion, in that it enabled the melina plants to grow as much consecutively 8.2% of their stem height, 45.95% of their stem diameter, and 58.82% of their biomass weight as the control (untreated) plants (Lempang, 2009).

The compost charcoal that resulted from the composting of market organic-garbage using bio-decomposer EM4; the mixture of organic decomposer (orgadec), EM4, and liquid smoke (wood vinegar); or the mixture of orgadec, bio-decomposer (EM4), charcoal, and liquid smoke/wood vinegar besides accelerating the maturing process of compost also afforded to yield it with high quality and could satisfy the Indonesian Standard. The use of compost that resulted from such bio-conversion of market organic garbage could significantly increase the height of stem of dewa-plant species, number of its leaves, and number of its sprouts as well as the weight of its biomass. This occurred particularly following the use of the mixture of so-called compost – tanabu, added with activated charcoal. Such mixture consisted of activated charcoal yielded by activation of charcoal using super-heated water vapor, and pesticide as methanol that resulted from the fractionation of liquid smoke as obtained by condensing the smoke evolving from the pyrolysis of organic garbage (Gani, 2007).

Still related, research on the application of compost charcoal at agroforestry area that comprised tusam (*Pinus merkusii*) tree stands as the core plant species, and saicin and pokchai vegetables as the intercropped plant species brought out favorable results. As such, the addition of compost charcoal besides increasing the soil pH (from 3.5 to 6.0) also enhanced as much 2-3 times the vegetable production as the control (untreated vegetable plants). Other convenient impacts were that among others after 10 year period the soil pH became 5.5, and the harvesting remain high.

## **CHARCOAL APPLICATION FOR ENERGY**

Such charcoal is regarded as one of the most recently developed charcoal products yielded by employing a sophisticated special method. This method is usually applied to charcoal composite, classified as pyrogenetic charcoal, in that it is subjected to extremely high temperatures at about 700 - 2700°C in a very short time. Further, this technique is effective to produce charcoal product in fine grained and fully dense materials, or called as sintered charcoal. The combination of fast-heating rate, short-processing time, fast-cooling rate, particular pressure, and atmospheric control as implemented in such technique affords the use of the resulting sintered charcoal as material development, micro-structural optimization, and computer devices.

The characteristics of the sintered charcoal are such that its bulk density, thermal constants, and electrical conductance exceed those of the charcoal manufactured in a high-temperature electric furnace and of the glass-like carbon chemically synthesized from thermosetting-synthetic resin. Such situation is brought about by spark plasma mechanisms that occur during sintered charcoal processing. The mechanisms render the properties and structure of the sintered charcoal becoming close to those of graphite.

Results of the experiment revealed that when, during the sintering of charcoal, the temperature was raised to and then kept at 850°C, its thermal conductivity figured to 0.747. However, when the sintering of charcoal proceeded at much higher temperature (i.e. 2450°C), the thermal conductivity rose to 3.26 (Yamane 1998). Judging from this fact, the method can afford the manufacture of silicon carbide (SiC) by at first mixing charcoal powder with silicate, and then sintering the mixture at extremely high temperature (1500 – 2200°C) for 30 minutes. Further, there are some derivation products of SiC such as high-quality polycrystal and single crystal silicon carbide

which have found their potential applications. For examples, internal circuit (IC) structures need pure polycrystals for chip production, while single crystal is used for particular devices operating at high-power and high-temperature condition.

## **CONCLUSIONS**

With the introduction of applied technologies, it strongly indicates that the particular materials (e.g. biomass stuffs) which are previously regarded as not or less useful can be processed into value-added products. The extent of their usefulness depends on among others the level, advancement, and compatibility of technologies which are applied. In this regard, charcoal and wood vinegar also belong to bio-materials.

Application of charcoal as well as wood vinegar to the seedling media, cultivation field, or agro-forestry area can come with favorable results, e.g. higher soil pH, and better growth of plants with respects of their diameter, height, as well as biomass total particularly their root part. Charcoal are the remaining solid product yielded from the pyrolysis of ligno-cellulosic stuffs (particularly wood) in the carbonization kiln of various types, while some portion of the stuffs is lost as smoke that escapes into the air. By installing the condensing device to the carbonization kiln, large portion of such evolving smoke can be converted into liquid form (wood vinegar). In this way, not only can the condensing of smoke mitigate the possible air pollution (environment concerns), but the resulting wood vinegar has also found its remarkable uses as bio-fertilizer and bio-pesticide for either forestry or agriculture plants. To sum-up, the charcoal-manufacturing process and wood-vinegar-collecting attempt therefore can be entirely regarded as bio-char technology. This is because such technology converts ligno-cellulosic stuffs (biomass) into useful products (charcoal and wood vinegar), and those products are indicatively able to among

others enhance the growth of forestry/agriculture plants. .

With high technology charcoal also can develop to make high energy by using spark plasma sintering for biosensor and bioenergy.

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