TRADITIONAL CHARCOAL MANUFACTURING METHODS AND ITS QUALITY IN YOGYAKARTA
(Metode Pembuatan Arang Tradisional dan Kualitasnya di Yogyakarta)

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ABSTRACT

Facing the autonomy era, Yogyakarta Province is forced to develop its own potential commodities that can increase the income. Several commodities that neglected, actually can be developed. For example, charcoal that manufactured traditionally by the people. Government does not have a program to develop it. Charcoal commodity developing becomes important because it contact directly with people empowering. Besides, it has an effect on natural resources such as forests. Meanwhile charcoal has a good prospect in overseas market which has a higher price than local one, but their standards quality have not been reached by traditional charcoal makers. Until now, the charcoal quality from traditional manufacturing is not known and it is sold at a low price. The development of exporting commodity of charcoal, as the first step, needs an inventory on the methods of charcoal manufacturing and its quality in several charcoal maker centrals. The objectives of this research were to determine traditional charcoal manufacturing methods in Yogyakarta and its quality and also to give suggestion to improve the charcoal quality.

This research was conducted by inventory on traditional charcoal manufacturing methods. Besides, the charcoal which was manufactured by people was brought to Wood for Energy Laboratory – Faculty of Forestry – Universitas Gadjah Mada, and then charcoal properties, included specific gravity, moisture content, ash content, fixed carbon content, volatile matter content, and calorific value, were tested. All test procedures were based on ASTM D-5 & D – 2359 (1959), except calorific value was based on ASTM D – 2015 standard methods.

Charcoal makers in Yogyakarta province manufactured it by using traditional methods i.e. earth mound vertically stacked kiln, earth mound horizontally stacked kiln, and pit kiln. The species that the most used as raw materials were sonokeling, mahagony, teak, akasia and asem that commonly can be found in surrounding the villages. The charcoal makers had a low production capacity (2 – 3 m³ each processing and 3 – 4 times processing in a month), average yield of 10 – 20% on the dry-weight based and fulfilled local market surrounding Yogyakarta. Manufacturing methods and species of raw material highly significantly affected charcoal properties mentioned above. Earth mound vertically stacked kiln produced charcoal that had the highest volatile matter content (27.37%) so that its fixed carbon content (58.09%) and calorific value (7568.90 cal/gr) were the lowest. Charcoal from horizontally stacked mound kiln had a better quality, with its properties i.e. volatile matter content of 17.02% as the carbon content of 70.42% and calorific value of 7929.01 cal/gr were higher than those of vertically stacked. Charcoal form pit kiln had the best quality, with its properties i.e. volatile matter content of 8.12%, fixed carbon content of 83.418%, and calorific value of 7908.94 cal/gr.

I. INTRODUCTION

Facing the autonomy era, Yogyakarta Province is forced to develop its own potential commodities that can increase the income. Several commodities that neglected, actually can be developed. For example, charcoals that manufactured traditionally by the people. Government does not have a program to develop it. Charcoal commodity developing becomes important because it contact directly with people empowering. Besides, it has an effect on natural resources such as forests.

Recently, charcoals have been produced and provided for local market at a low price. The manufacturing has used traditional methods and it is far from being an exact science. Most of its
manufacturing depend on the skill of charcoal makers. Technology development to increase charcoal quality has not been done. Until now, the charcoal quality from traditional manufacturing remains unknown. Nevertheless, charcoal has a good prospect in overseas market which it has a higher price than the local one, but they have quality standards which has not been achieve by charcoal makers in Yogyakarta. It is needed a development in methods of charcoal making so that people can improve their product qualities. There are many obstacles such as marketing and financial aspect, but methods of charcoal making which can increase the quality, become the most important aspect to make charcoal as export commodity. The development of exporting commodity of charcoal, as the first step, needs an inventory on the methods of charcoal making and its quality in several charcoal maker centrals in Yogyakarta.

The main methods of charcoal making currently used in the developing world. According to Foley (1986) and Smith et al (1998), it can be divided into earth mound and pit kilns; transportable steel kilns; oil drum kilns; brick, concrete, and fired-lay kilns. A number of Dutch researchers observed that the methods mentioned above were utilized by people to make charcoal in Indonesia, even though earth mound and pit kilns were the most utilized (Anonymous, 1982).

The yield of charcoal making was 22.88-35.98% (Pari, 1992), meanwhile Foley (1986) observed that the yield charcoal on a small horizontally stacked circular mound kiln gave a yield of 23% (in India), vertically one gave a yield of 31.4% (in France), pit kiln gave a yield of 20 - 25% (in Philippines). Smith et. al (1998) reported that the charcoal yield from earth mound is 30%, brick beehive is 33%, mud beehive is 31%, and single drum is 29%. Fengel and Wegener (1995) observed that the yield of charcoal making dependent on wood species, diameter of raw materials, carbonisation system, time of processing, and end-temperature which average yield is about 35%.

The important properties of charcoal included the amount of pure carbon content, its moisture content, density, ash content and calorific value. The specifications of charcoal for iron making, are as follow:

<table>
<thead>
<tr>
<th>No</th>
<th>Item</th>
<th>Spec 1</th>
<th>Spec 2</th>
<th>British</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fixed carbon (%)</td>
<td>80 (min)</td>
<td>80-90</td>
<td>75.33</td>
<td>60-80</td>
</tr>
<tr>
<td>2</td>
<td>Volatile matter (%)</td>
<td>16 (max)</td>
<td>10-18</td>
<td>16.41</td>
<td>25-30</td>
</tr>
<tr>
<td>3</td>
<td>Ash content (%)</td>
<td>4 (max)</td>
<td>1-2</td>
<td>8.26</td>
<td>3-6</td>
</tr>
<tr>
<td>4</td>
<td>Moisture content (%)</td>
<td>11 (max)</td>
<td>5-8</td>
<td>3.50</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>Size mm</td>
<td>15-150</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Bulk density (kg/m³)</td>
<td>0.20-0.30</td>
<td>0.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Calorific value (cal/g)</td>
<td></td>
<td></td>
<td>7289</td>
<td>6000-7000</td>
</tr>
</tbody>
</table>

Source: Charcoal Production From Woodwaste.htm (1999)¹
Fengel and Wegener (1995)²
Harutoyo et.al. in Soeparno et.al (2000)³

II. METHOD

This research was conducted by inventory of traditional charcoal manufacturing methods in Yogyakarta province. The charcoal which was manufactured by people was brought to Wood for Energy Laboratory – Faculty of Forestry – Gadjah Mada University. The charcoal properties, included specific gravity, moisture content, ash content, fixed carbon content, volatile matter content and calorific value, were tested. All test procedures were based on ASTM D-5 & D – 2359 (1959), except calorific value was based on ASTM D – 2015 standard methods. Equipments that were used to observe the
properties of charcoal in this research included analytical weight, oven, calorimeter bomb, thermolyne and thermometer.

III. RESULT AND DISCUSSION

Traditional Manufacturing of Charcoal in Yogyakarta Province

Among the five districts in Yogyakarta province, only three districts, according to Trade and Industry Agency and charcoal sellers information, which have a central of charcoal manufacturing i.e. Bantul, Kulon Progo and Gunung Kidul. For that reason, the inventory has been conducted and focused in the three districts mentioned (Table 1-3).

Main occupation of charcoal makers in Yogyakarta province was farmers and carpenters. They make charcoal just only as their part-time occupation. In a rainy season, which commonly people must cultivate agriculture plants, the amount of charcoal makers tend to decrease. In contrast, they tend to increase in dry season. Commonly, charcoal makers use sonokeling (*Dalbergia latifolia*), mahagony (*Swietenia mahagony*), teak (*Tectona grandis*), akasia (*Acacia auriculiformis*) and asem (*Tamarindus indica*) as their raw materials. All wood species, that be used as raw material of charcoal, can be found surrounding their villages as planted trees.

All parts of tree that commonly have 15 – 20 cm of dbh (diameter of breast height), were used to be the raw materials. But others just only used branches and twigs. The raw material was bucked into wood billets about 20 – 30 cm length, but in other cases were about 80 – 120 cm. The raw material could be obtained from their own land but other cases some of them were bought. The need of raw material was range about 6 – 9 m$^3$ in a month. But in another case, as an intensive charcoal maker, the need was greater, about 37 m$^3$ a month.

Most of charcoal makers used traditional methods to manufacture charcoal. Most of them used vertically stacked mound kiln. But other methods could be found included horizontally stacked mound kiln and pit kiln. The capacity of each processing was found in a range about 2 – 3 m$^3$ while the frequency of manufacturing was 2 – 4 times a month but another was 10 times in a month. The yield of processing was in a range about 10 – 35% on the dry-weight based. It was same with Foley (1986); Pari (1992); Fengel and Wegener (1995); and Smith et. al. (1998) that reported about 20 – 35%. But Foley (1986) noted that the yield of charcoal manufacturing in developing countries such as India and Mozambique using mound kiln ranged between 10 – 15 %, meanwhile in South Africa and Srilanka using pit kiln range between 12.5 – 20%. Duration of carbonisation process was found in a range of 2 – 7 days, and this case was the same as Foley (1986) which noted that small kiln requires 3 – 7 days of carbonisation. It depend on the need of charcoal makers or charcoal sellers, time of order, etc. The quality of charcoal product, according to the makers, was visually found in medium – good level.
Table 2. The Result of Observation in Several Charcoal Manufacturing Centrals

<table>
<thead>
<tr>
<th>Description</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Ngadirin</td>
<td>Supriyanto</td>
<td>Asmowiyono</td>
<td>Maryadi</td>
<td>Joyo Karsono</td>
<td>Joyo Utomo</td>
</tr>
<tr>
<td>Address</td>
<td>Sukorame sub village</td>
<td>Mangunan sub village</td>
<td>Mangunan sub village</td>
<td>Nawungan sub village</td>
<td>Girimulyo village</td>
<td>Giripuro village</td>
</tr>
<tr>
<td></td>
<td>– Mangunan village -</td>
<td>– Mangunan village -</td>
<td>– Dlingo sub district –</td>
<td>– Selopamioro village –</td>
<td>– Panggang sub district –</td>
<td>– Purwosari sub district –</td>
</tr>
<tr>
<td></td>
<td>Dlingo sub district –</td>
<td>Dlingo sub district –</td>
<td>Bantul district</td>
<td>Imogiri sub district –</td>
<td>Gunung sub district –</td>
<td>Kulon Progo district –</td>
</tr>
<tr>
<td></td>
<td>Bantul district</td>
<td>Bantul district</td>
<td></td>
<td>Bantul district</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main Occupation</td>
<td>Farmer</td>
<td>Carpenter</td>
<td>Farmer</td>
<td>Farmer</td>
<td>Farmer</td>
<td>Charcoal maker &amp; carpenter</td>
</tr>
<tr>
<td>Charcoal Raw Material</td>
<td>Mahagony, Akasia, Teak &amp; Sonokeling</td>
<td>Sonokeling &amp; Mahagony</td>
<td>Sonokeling, Akasia, Mahagony</td>
<td>Akasia</td>
<td>Teak &amp; Akasia</td>
<td>Asem</td>
</tr>
<tr>
<td>Wood Species</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size: Length</td>
<td>80 cm</td>
<td>40 cm</td>
<td>30 cm</td>
<td>20 – 30 cm</td>
<td>25 – 35 cm</td>
<td>1.2 m</td>
</tr>
<tr>
<td>Diameter</td>
<td>15 – 20 cm (tree diameter on dbh)</td>
<td>15 – 20 cm (tree diameter on dbh)</td>
<td>10 – 15 cm</td>
<td>20 cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part of Tree</td>
<td>Branches and twigs</td>
<td>All part of tree which can’t be used to be furnitures</td>
<td>All part of tree</td>
<td>All part of tree</td>
<td>Branches and twigs</td>
<td>All part of tree</td>
</tr>
<tr>
<td>Source of Raw Material</td>
<td>Surrounding Dlingo</td>
<td>Surrounding Dlingo</td>
<td>Surrounding Imogiri</td>
<td>Imogiri</td>
<td>Purwosari</td>
<td>Sentolo</td>
</tr>
<tr>
<td>The Way of Raw Material Getting</td>
<td>From own trees</td>
<td>Some raw material are bought, other from own trees</td>
<td>Some raw material are bought, other from own trees</td>
<td>From own trees</td>
<td>From own trees</td>
<td>All raw material are bought</td>
</tr>
<tr>
<td>The Need of Raw Material a Week or a Month</td>
<td>9 m³ a month</td>
<td>6 m³ a month</td>
<td>6 m³ a month</td>
<td>8 m³ a month</td>
<td>8 m³ a month</td>
<td>37 m³ a month</td>
</tr>
</tbody>
</table>
### Table 2. Continued

<table>
<thead>
<tr>
<th>Charcoal Production</th>
<th>Vertically stacked mound kiln</th>
<th>Vertically stacked mound kiln</th>
<th>Vertically stacked mound kiln</th>
<th>Vertically stacked mound kiln</th>
<th>Pit kiln</th>
<th>Horizontally stacked mound kiln</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing Method</td>
<td>Vertically stacked mound kiln</td>
<td>Vertically stacked mound kiln</td>
<td>Vertically stacked mound kiln</td>
<td>Vertically stacked mound kiln</td>
<td>Pit kiln</td>
<td>Horizontally stacked mound kiln</td>
</tr>
<tr>
<td>Capacity Each Processing</td>
<td>3 m³</td>
<td>3 m³</td>
<td>2 m³</td>
<td>2 m³</td>
<td>2 m³</td>
<td>3.7 m³</td>
</tr>
<tr>
<td>Frequency Carbonitation in A Week or A Month</td>
<td>3 times a month</td>
<td>2 times a month</td>
<td>3 times a month</td>
<td>4 times a month</td>
<td>4 times a month</td>
<td>10 times</td>
</tr>
<tr>
<td>Yield</td>
<td>16%</td>
<td>11%</td>
<td>10%</td>
<td>12%</td>
<td>14%</td>
<td>20%</td>
</tr>
<tr>
<td>Duration of Carbonitation</td>
<td>2-6 days each processing</td>
<td>4-8 days each processing</td>
<td>4-7 days each processing</td>
<td>2-4 days each processing</td>
<td>2 days</td>
<td>3 days each processing</td>
</tr>
<tr>
<td>Quality</td>
<td>Medium – good</td>
<td>Medium – good</td>
<td>Good</td>
<td>Medium</td>
<td>Medium – good</td>
<td>Good</td>
</tr>
<tr>
<td>Marketing System</td>
<td>Buyers come to him</td>
<td>Buyers come to him</td>
<td>Buyers come to him</td>
<td>Buyers come to him</td>
<td>Buyers come to him</td>
<td>Buyers come to him</td>
</tr>
<tr>
<td>Buyer</td>
<td>Charcoal trader</td>
<td>Charcoal trader</td>
<td>Charcoal trader</td>
<td>Charcoal trader</td>
<td>Charcoal trader</td>
<td>Charcoal trader</td>
</tr>
<tr>
<td>Destination</td>
<td>Imogiri &amp; Yogya</td>
<td>Imogiri &amp; Yogya</td>
<td>Imogiri &amp; Yogya</td>
<td>Yogya</td>
<td>Imogiri &amp; Yogya</td>
<td>Yogya</td>
</tr>
<tr>
<td>Enumerator</td>
<td>Agus Kholik</td>
<td>Agus Kholik</td>
<td>Agus Kholik</td>
<td>Agus Kholik</td>
<td>Agus Kholik &amp; Mufti</td>
<td>Agus Kholik &amp; Tommy L.</td>
</tr>
</tbody>
</table>
Table 3. Averages of Charcoal Properties from Several Charcoal Makers in Yogyakarta Province

<table>
<thead>
<tr>
<th>Area and Method of Carbonisation</th>
<th>Species</th>
<th>Carbonisation Time</th>
<th>Raw Material Diameter</th>
<th>Volatile Matter Content (%)</th>
<th>Moisture Content (%)</th>
<th>Specific Gravity</th>
<th>Ash Content (%)</th>
<th>Fixed Carbon Content (%)</th>
<th>Calorific Value (cal/gr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imogiri-Bantul Earth Mound Kiln Stacked Vertically</td>
<td>Sonokeling (Dalbergia latifolia)</td>
<td>6 days Big Medium - Small</td>
<td>15.56 17.54</td>
<td>5.76 6.27</td>
<td>0.63 0.51</td>
<td>1.93 1.54</td>
<td>76.736 74.63</td>
<td>7834.04</td>
<td>7830.94 7666.67</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 days Big Medium - Small</td>
<td>15.96 13.33</td>
<td>6.37 6.85</td>
<td>0.61 0.54</td>
<td>7019.70 8106.26</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teak (Tectona grandis)</td>
<td>2 days Big Medium - Small</td>
<td>14.27 22.78</td>
<td>6.87 6.19</td>
<td>0.57 0.54</td>
<td>4.46 5.54</td>
<td>74.39 65.47</td>
<td>7834.04</td>
<td>7830.94 7666.67</td>
<td></td>
</tr>
<tr>
<td>Akasia (Acacia mangium)</td>
<td>2 days Big Medium - Small</td>
<td>36.48 22.15</td>
<td>12.36 10.04</td>
<td>0.55 0.48</td>
<td>3.78 5.14</td>
<td>40.74 56.04</td>
<td>7834.04</td>
<td>7830.94 7666.67</td>
<td></td>
</tr>
<tr>
<td>Mahoni (Swietenia mahagoni)</td>
<td>4 days Big Medium - Small</td>
<td>26.20 38.66</td>
<td>5.34 4.80</td>
<td>0.54 0.64</td>
<td>6.30 3.02</td>
<td>58.74 50.83</td>
<td>7834.04</td>
<td>7830.94 7666.67</td>
<td></td>
</tr>
<tr>
<td>Sentolo - Kulon Progo District Earth Mound Kiln Stacked Horizontally</td>
<td>Asam (Tamarindus indica)</td>
<td>3 days Big Medium - Small</td>
<td>21.71 10.44</td>
<td>6.59 6.59</td>
<td>0.61 0.62</td>
<td>3.58 9.12</td>
<td>65.79 75.04</td>
<td>7830.98 8027.03</td>
<td></td>
</tr>
<tr>
<td>Panggang - Gunung Kidul District Pit Kiln</td>
<td>Teak (Tectona grandis)</td>
<td>2 days Big Medium - Small</td>
<td>11.46 3.83</td>
<td>4.12 7.82</td>
<td>0.34 0.45</td>
<td>1.62 3.18</td>
<td>83.28 85.16</td>
<td>7908.94</td>
<td>7908.94</td>
</tr>
<tr>
<td></td>
<td>Akasia (Acacia mangium)</td>
<td>2 days Big Medium - Small</td>
<td>9.85 5.69</td>
<td>0.432 3.38</td>
<td>81.80</td>
<td>7908.94</td>
<td>7908.94</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Charcoal Properties from Several Charcoal Manufacturing Centrals

The analysis of variance showed that charcoal manufacturing methods – species highly significantly affected charcoal properties included volatile matter content, moisture content, specific gravity, ash content, and fixed carbon content. Post-hoc test, which used Tukey HSD test, was conducted on factors that significantly affected charcoal properties.

a. Volatile Matter Content

Tukey HSD test of the effect of charcoal manufacturing methods – species on volatile matter content can be seen as below:

Table 4. Tukey HSD Test of the effect of Method-Species on Volatile Matter Content Properties of Charcoal

<table>
<thead>
<tr>
<th></th>
<th>Subset 1</th>
<th>Subset 2</th>
<th>Subset 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teak G</td>
<td>7.91</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sono B</td>
<td>14.64</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asem F</td>
<td>16.07</td>
<td>16.07</td>
<td></td>
</tr>
<tr>
<td>Sono A</td>
<td>16.55</td>
<td>16.55</td>
<td></td>
</tr>
<tr>
<td>Teak C</td>
<td>18.53</td>
<td>18.53</td>
<td></td>
</tr>
<tr>
<td>Akasia D</td>
<td></td>
<td>29.32</td>
<td>29.32</td>
</tr>
<tr>
<td>Mahagony E</td>
<td></td>
<td></td>
<td>32.43</td>
</tr>
</tbody>
</table>

Remark: means for groups in homogenous subsets are displayed
Sono A: Sonokeling – Vertically stacked mound kiln – 6 days of carbonisation
Sono B: Sonokeling – Vertically stacked mound kiln – 2 days of carbonisation
Teak C: Teak – Vertically stacked mound kiln – 2 days of carbonisation
Akasia D: akasia – Vertically stacked mound kiln – 2 days of carbonisation
Mahagony E: Mahagony – Vertically stacked mound kiln – 2 days of carbonisation
Asam F: asam – Horizontally stacked mound kiln – 3 days of carbonisation
Teak G: Teak – Pit kiln – 2 days of carbonisation

Volatile matter content of charcoals that manufactured by vertically stacked mound kiln methods using sonokeling, teak, akasia and mahagony ranged between 14.64% - 32.43% and was the highest value although it can meet Japan and British charcoal standard. That value was higher than others such as from pit kiln which had average value of 7.91% and from horizontally stacked mound which had an average value of 16.07% that can meet British standard. The lowest volatile content from pit kiln (Anonimous, 1999) had characters included difficult to light and burn very cleanly. According to Foley (1986), charcoal for domestic cooking requires a higher volatile content which ranges about 20 – 30%. Because high volatile charcoal is easy to ignite but it may burnt with a smoky flame.

The low of volatile content of charcoal manufactured from pit kiln and horizontally stacked mound kiln, that constructed with a stone on the base of the kiln, might reach a high temperature in long time, in contrary with vertically stacked mound kiln. When the carbonisation temperature is low and time in the retort is short, the volatile matter content increase (Anonimous, 1985). When the kiln can be controlled to reach a high temperature, the minimum volatile content is about 10%.
b. Moisture Content

Tukey HSD test of the effect of charcoal manufacturing methods – species on moisture content can be seen as follow:

Table 5. Tukey HSD Test of the effect of Method-Species on Moisture Content Properties of Charcoal

<table>
<thead>
<tr>
<th></th>
<th>Subset 1</th>
<th>Subset 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mahogany E</td>
<td>5.07</td>
<td></td>
</tr>
<tr>
<td>Teak G</td>
<td>5.96</td>
<td></td>
</tr>
<tr>
<td>Sono A</td>
<td>6.01</td>
<td></td>
</tr>
<tr>
<td>Teak C</td>
<td>6.53</td>
<td></td>
</tr>
<tr>
<td>Asem F</td>
<td>6.59</td>
<td></td>
</tr>
<tr>
<td>Sono B</td>
<td>6.61</td>
<td></td>
</tr>
<tr>
<td>Akasia D</td>
<td></td>
<td>11.20</td>
</tr>
</tbody>
</table>

Remark: means for groups in homogenous subsets are displayed

Charcoal of akasia manufactured by using vertically stacked mound kiln methods in 2 days of carbonisation had the highest volatile content so that it had the highest moisture content and was highly significant to others. On the contrary, charcoal of teak which was manufactured by using horizontally stacked mound kiln in 2 days carbonisation and had the lowest volatile content, it had a low moisture content. The equilibrium moisture content of charcoal with a low volatile content is 3 – 5% by weight (Foley, 1986). Moisture content properties of all charcoal can be qualified on low moisture content and meet Japan charcoal standard. Their moisture content also in accordance with Fengel and Wegener (1995) which note the quality specification usually limit the moisture content to around 5 – 15%.
c. Specific Gravity

Tukey HSD test of the effect of charcoal manufacturing methods – species on specific gravity can be seen as bellow:

Table 6. Tukey HSD Test of the effect of Method-Species on Specific Gravity

<table>
<thead>
<tr>
<th>Properties of Charcoal</th>
<th>Subset</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teak G</td>
<td>0.400</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Akasia D</td>
<td>0.520</td>
<td>0.520</td>
<td></td>
</tr>
<tr>
<td>Teak C</td>
<td>0.563</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sono A</td>
<td>0.575</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sono B</td>
<td>0.575</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mahagony E</td>
<td>0.597</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asem F</td>
<td>0.618</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Remark: means for groups in homogenous subsets are displayed.

All of charcoal samples that produced by earth mound vertically stacked and horizontally stacked were found good enough in specific gravity value included charcoal from teak, whereas other charcoal from teak that produced by pit kiln method had the lowest specific gravity. The result was showed that wood species affected specific gravity of charcoal.
The result of specific gravity test of charcoal samples showed that almost all of samples had higher specific gravity value than the value that reported by Fengel and Wegener (1995) i.e 0.45, except charcoals of teak produced by pit kiln method in 2 days of carbonisation, had the lowest specific value (0.40). But all specific gravities of samples met Foley’s range (1986), that the charcoal used to domestic cooking tends to have a bulk density in a range of 250 – 400 kg/m$^3$ (≈ 0.25 – 0.40 g/cm$^3$).

Figure 3. The Effect of Charcoal Manufacturing Methods on Specific Gravity

Remark: # same with mentioned above

d. Ash Content

Post-hoc test using Tukey HSD showed that the effect of charcoal manufacturing methods – species can be seen as follow:

Table 7. Tukey HSD Test of the Effect of Method-Species Factor on Ash Content Properties of Charcoal

<table>
<thead>
<tr>
<th></th>
<th>Subset</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Sono A</td>
<td>1.74</td>
</tr>
<tr>
<td>Teak G</td>
<td>2.40</td>
</tr>
<tr>
<td>Sono B</td>
<td></td>
</tr>
<tr>
<td>Akasia D</td>
<td></td>
</tr>
<tr>
<td>Mahagony E</td>
<td></td>
</tr>
<tr>
<td>Teak C</td>
<td></td>
</tr>
<tr>
<td>Asem F</td>
<td></td>
</tr>
</tbody>
</table>

Remark: means for groups in homogenous subsets are displayed # same with mentioned above

Ash content of all of samples met the standard. The ash content of charcoals varied from about 0.5% to more than 5% depending on the species of wood, and the amount of bark (Anonymous, 1985). The result showed that species and manufacturing methods highly significantly affected ash content. Sonokeling had the lowest ash content (1.74%) whereas asem had the highest ash content (6.35%). The effect of methods
showed the differences between charcoals of teak i.e from pit kiln (2.40%) and from earth mound vertically stacked kiln (5.00%). As it had the low ash content, the using charcoal of sonokeling is preferred to others by charcoal users as like iron smiths, sate sellers, etc.

![Figure 4. The Effect of Charcoal Manufacturing Methods on Ash Content](image)

**Figure 4.** The Effect of Charcoal Manufacturing Methods on Ash Content

Remark: # same with mentioned above

e. Fixed Carbon Content

Post-hoc test using Tukey HSD on charcoal manufacturing method-species can be seen as follow:

**Table 8.** Tukey HSD Test of the Effect of Method-Species Factor on Fixed Carbon Content Properties of Charcoal

<table>
<thead>
<tr>
<th>Methods &amp; Species</th>
<th>Subsets</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Akasia D</td>
<td>48.39</td>
</tr>
<tr>
<td>Mahagony E</td>
<td>54.78</td>
</tr>
<tr>
<td>Sono B</td>
<td>67.24</td>
</tr>
<tr>
<td>Teak C</td>
<td></td>
</tr>
<tr>
<td>Sono A</td>
<td></td>
</tr>
<tr>
<td>Asem F</td>
<td></td>
</tr>
<tr>
<td>Teak G</td>
<td></td>
</tr>
</tbody>
</table>

Remark: means for groups in homogenous subsets are displayed # same with mentioned above

The result showed that charcoal manufacturing methods highly affected on fixed carbon content. Charcoals from pit kiln and earth mound horizontally stacked had the highest values and the lowest volatile content. Charcoals from pit kiln met British charcoal standard. The high content of fixed carbon is very important for metallurgical industry. Charcoal required for industry or metallurgical uses should have a fixed carbon content of 85 – 90% (Anonymous, 1985; Foley, 1986). However, based on Japan charcoal standard, all of samples can meet on that standard (60-80%). Except for akasia and mahagony that manufactured in the earth mound vertically stacked, they could meet that standard.
Figure 5. The Effect of Charcoal Manufacturing Methods on Fixed Carbon Content
Remark: # same with mentioned above

f. Calorific Value

The averages of calorific values of each charcoal manufacturing method can be seen as below and its relation with volatile content and fixed carbon content.

Table 9. Relation among Volatile Content, Fixed Carbon Content, and Calorific Value on Each Charcoal Manufacturing Method

<table>
<thead>
<tr>
<th>Method</th>
<th>Volatile content (%)</th>
<th>Fixed carbon content (%)</th>
<th>Caloric value (cal/gr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth mound vertically stacked kiln</td>
<td>27.37</td>
<td>58.09</td>
<td>7568.90</td>
</tr>
<tr>
<td>Earth mound horizontally stacked kiln</td>
<td>17.02</td>
<td>70.42</td>
<td>7929.01</td>
</tr>
<tr>
<td>Pit kiln</td>
<td>8.12</td>
<td>83.41</td>
<td>7908.94</td>
</tr>
</tbody>
</table>

Table 9 showed that the higher the volatile content, the lower calorific value of a charcoal. This case in accordance with Foley (1986) that the calorific value of a particular charcoal depends on the proportion of fixed carbon and volatiles which it contains. The charcoals that produced by earth mound vertically stacked had the highest volatile content so that its fixed carbon content and calorific value were the lowest. In contrary with charcoal properties from the pit kiln. It can be said that charcoal manufacturing methods highly significantly affected on the three charcoal properties mentioned above. The graphic that showed the relation among the three charcoal properties can be seen as follow:
CONCLUSIONS

Charcoal makers in Yogyakarta Province manufactured it by using three kinds of traditional methods i.e. earth mound vertically stacked kiln, earth mound horizontally stacked kiln, and pit kiln.

1. The species that the most used as raw material are sonokeling (*Dalbergia latifolia*), mahagony (*Swietenia mahagony*), teak (*Tectona grandis*), akasia (*Acacia auriculiformis*) and asem (*Tamarindus indicus*) that commonly can be found surrounding the villages.

2. As a part time occupation, charcoal makers have a low production capacity (2 – 3 m$^3$ on each processing and 3 – 4 times processing in a month), average yield of 10 – 20% and fulfill local market surrounding Yogyakarta.

3. Manufacturing methods and species of the raw material highly significantly affected charcoal properties i.e. volatile content, moisture content, specific gravity, ash content, fixed carbon content, and calorific value.

4. Earth mound vertically stacked kiln produced charcoal that has high volatile matter content so that its fixed carbon content and calorific value was low. Charcoal properties that can not meet quality standard were volatile matter content (British standard), fixed carbon content (British and Japan Standard), and moisture content (Japan standard).

5. Charcoals from horizontally stacked mound kiln had a better quality than vertically stacked, but several of its properties that could not meet quality standard were volatile matter content and fixed carbon content (British standard), and moisture content (Japan standard).

6. Charcoals from pit kiln had the best quality, but its properties that could not meet quality standard were volatile matter content (Japan standard) and moisture content (British standard).
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