Characterization and Comparison of Wood charcoal from Traditional Charcoal Burning Using Different Processes

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Abstract. This research aimed to study the physical and chemical characteristics of wood charcoals burned using three traditional burning processes, i.e., burning by the clay kiln, the cement kiln and the high temperature kiln. The physical and chemical characteristics of the charcoal samples were studied as follows density, carbon content, application efficiency, general appearance, moisture content, heating value, fire flakes and smoke. Then, the tested results of charcoal samples were compared with the community standard for charcoal production, 658/2547. Moreover, the chemical compositions of samples were also investigated by Energy Dispersive X-ray spectroscopy (EDS). The studied results shown that the amount of compositions elements found in all three charcoal were composed of Carbon, Oxygen and Potassium as the main elements. It was found that the carbon content of charcoal sample burned by the high temperature kiln process was highest as compared to the charcoals obtained from two burning processes.

1. Introduction

Wood charcoal have been using as fuel for cooking in Thai daily life for a very long time. They can also easily make in household by using the local materials. Nowadays, using the charcoal as cooking fuel is still continually popular and also increasing. However, the wood charcoal is quite expensive and not enough for the demand as the booming grill-restaurants. So the wood charcoal is definitely still important cooking fuel for both in household and community no matter nowadays and in the future [1-5].

Charcoal burning in each community that they have the process which inherited from ancestor is wisdom or learnt from individual experiences, workshops, promotion from some organizations or from many types of teaching materials. It reveals that there are many charcoal burning process in the area of communities. From the research in charcoal burning with traditional process in 4 communities nearby Haui Sa Naeng reservoir, they are Ban Khok Phet, Ban Ta Tung Tha Ngai, Ban Khok Ka Phor, and Ban Ta Kae.

According to the area of these communities that surrounded with high fertile forest which is the community forest preserved by government agencies and the people in community cooperate to maintain. Especially the forest is situated around the reservoir so varieties of tree and many of wood for the people who live there collect them for charcoal material throughout the year. After seeing the traditional charcoal burning process in the communities, we found that the people use the old-fashioned process and the process that developed in energy technology such as the soil covering technique, the husk covering technique, the burning with kiln built from clay, the burning in gasoline barrel and the burning with cement kiln which all of them is not complicated to operate and can do it around the house or in paddy field after harvesting time. Moreover, it can be make an
income for their family as well. From the primary survey, they found that some burning processes can provide the good quality wood charcoal for market demand as they keep burning for long time and give high heat energy as in the charcoal from the kiln clay, the cement kiln and the high temperature kiln as showed in Figure 1.

![Figure 1. Type of kilns (a) the clay kiln (b) the cement kiln and (c) the high temperature kiln.](image)

Nevertheless, the prior research did not aim to study in the physical and chemical characteristics of wood charcoals from all 3 burning process types to compare with the community product standard, 658/2547. Then the wood charcoal can be promoted to be OTOP products in community level which can make more income for their family and community as well.

Thus, in this research we aimed to study the physical and chemical characteristics of wood charcoals burned using three traditional burning processes, i.e., burning by charcoal kiln built from clay, clinker for Portland cement and a high temperature kiln. After that we will compare all the data with the community standard for charcoal production, 658/2547. Then we will have database on the wood charcoal and as a guideline to promote the energy conservation and the local wisdom preservation. This will lead to transmission of knowledge of charcoal burning in traditional way of community further and can also promote careers for other interested parties.

2 Experimental procedure

In this research we aim to study in the physical and chemical characteristics of wood charcoals which our team have collected data from 3 burning process types as in the charcoal from the clay kiln, the cement kiln and the high temperature kiln by according procedures.

2.1 The study of physical characteristics

The physical characteristics of wood charcoal samples were studied in the laboratory. Some characteristics of the samples were compared with the community standard for charcoal production, 658/2547. The density of wood charcoal, the Moisture Content of wood charcoal was tested following the standard of ASTM D 7582, the carbon content of wood charcoal was tested following the standard of ASTM D 5373, the heating value of wood charcoal was tested following the standard of ASTM D 5865 with Bomb calorimeter, the application efficiency is the studying heat efficiency of wood charcoal by using wood charcoal to be fuel in boiling water and then calculate from the according formula

\[
\text{Application efficiency} = \frac{\text{Total obtained heat of water}}{\text{Heat from charcoal burning}} \times 100 \tag{1}
\]

or

\[
\mu = \frac{\Sigma mc(t_2 - t_1) + \Delta ml}{WQ} \times 100\% \tag{2}
\]

as  
\(\mu\) is thermal efficiency of charcoal (\(\%\))
\(W\) is mass of charcoal (g)
\(Q\) is the calorific value of charcoal (cal/g)
Then we compared some characteristics such as general characteristics, moisture content, heat content, generation of spark and generation of smoke with community standard for charcoal production, 658/2547 to consider in suitability for further use.

2.2 The study of chemical characteristics

For testing some chemical characteristics of wood charcoal, we did it with the technique of Energy Dispersive X-ray spectroscopy; EDS by elaborately crushing the wood charcoal and pouring it into sample container for testing with EDS machine and did analysis within system condition, then recorded the X-ray spectrum of samples for considering the compound in the samples in the reference database.

3. Results and discussion

From studying in the physical and chemical characteristics of wood charcoals which our team have collected data from 3 burning process types as in the charcoal from the kiln clay, the cement kiln and the high temperature kiln we had results as following

3.1 The study of physical characteristics

After we brought sample of wood charcoals to study in physical characteristics, we found that the samples were in consistent black as in Figure 2. The density, carbon content and application efficiency of the wood charcoal samples are showed in Table 1.

![Figure 2](image-url) characteristics of wood charcoal obtained from different types of burning (a) the clay kiln (b) the cement kiln (c) the high temperature kiln.

|                      | Density (g/cm³) | Carbon content (%) | Application efficiency (%) |
|----------------------|-----------------|--------------------|---------------------------|
| The clay kiln burning| 0.49            | 85.43              | 24.97                     |
| The cement kiln burning| 0.37            | 77.99              | 20.10                     |
| The high temperature kiln| 0.47            | 90.11              | 23.73                     |

For the Table 1, it revealed that the density of the wood charcoal samples from the clay kiln and the high temperature kiln were slightly similar as 0.49 g/cm³ and 0.47 g/cm³. The density of wood charcoal from the cement kiln was the lowest as 0.37 g/cm³.

For the studying carbon content in the charcoal sample, it was found that the carbon content of the charcoal sample obtained from the high temperature kiln is about 90.11% and the later was the wood.
charcoal sample from the clay kiln as 85.43%. The wood charcoal sample from the cement kiln had the least carbon content as 77.99%. As the carbon content will indicate how long the power stay and the quality of wood charcoal. The higher carbon content is the better wood charcoal, the longer flame stays and the higher heat (7).

The result from application efficiency testing showed that the wood charcoal samples from the clay kiln process and the high temperature kiln were slightly similar as 24.97% and 23.73%. The application efficiency of wood charcoal from the cement kiln was the lowest as 20.10%.

Then we did compare between the samples in some characteristics with the community standard for charcoal production, 658/2547 which has set several qualifications for charcoal but in this research will compare in some characteristics as showing in Table 2.

### Table 2 Comparison in some characteristics with the community standard for charcoal production, 658/2547

|                          | General appearance | Moisture content (%) | Heat value (cal/g) | Fire Flakes | Smoke |
|--------------------------|--------------------|----------------------|-------------------|-------------|-------|
| The clay kiln burning    | Consistent black   | 10.15                | 7,400             | No          | No    |
| The cement kiln burning  | Consistent black   | 6.23                 | 7,260             | No          | No    |
| The high temperature kiln| Consistent black   | 5.80                 | 7,620             | No          | No    |
| The 658/2547 standard    | Consistent black   | < 8                  | > 7,000           | No          | No    |

After we compared the wood charcoal samples from all 3 burning procedures such as burning by charcoal kiln built from clay, clinker for Portland cement and a high temperature kiln. We found that all of them pass the community standard for charcoal production, 658/2547 in the property of general appearance, moisture content, heat content, generation of fire flakes and generation of smoke. The wood charcoal sample from the high temperature kiln got the highest heat content as 7,620 cal.g. For the moisture content we found that only samples from the cement kiln and the high temperature that passed the community product standard. The sample from the clay kiln got higher moisture content than the standard defined.

#### 3.2 The studying of chemical characteristics

The chemical characteristics of wood charcoals from 3 burning process types as in the charcoal from the clay kiln, the cement kiln and the high temperature kiln by compound analysis with the technique of Energy Dispersive X-ray spectroscopy; EDS are studied. After we considered in qualification by AC-COM, the data results are show in Table 3-5. and Figure 3-5.
Table 3 Amount of compound element (wt%) of AC-COM from the clay kiln burning wood charcoal

| Element | Wt%  |
|---------|------|
| C       | 90.49|
| O       | 6.32 |
| K       | 1.53 |
| Au      | 1.66 |
| Total   | 100  |

Figure 3 The chemical composition of wood charcoal sample of the clay kiln from EDS in AC-COM.

From the analysis of qualitative characteristics with Energy Dispersive X-ray spectroscopy (EDS) technique we found that the wood charcoal from the clay kiln burning had Carbon (C), Oxygen (O) and Potassium (K) as the main elements. The existence of Gold (Au) was from the sample preparation procedure. The result from the analysis of qualitative characteristics with EDS technique show in Table 3 which could fine the main elements as inorganic substances with Carbon ratio in 90.49 % by weight, Oxygen ratio in 6.32 % by weight and Potassium ratio in 1.53 % by weight.

Table 4 Amount of compound element (wt%) of AC-COM from the cement kiln burning wood charcoal.

| Element | Wt%  |
|---------|------|
| C       | 84.67|
| O       | 13.01|
| K       | 0.42 |
| Au      | 1.91 |
| Total   | 100  |
Figure 4. The chemical composition of wood charcoal sample of the cement kiln from EDS in AC-COM.

From the analysis of qualitative characteristics with EDS technique we found that the wood charcoal from the cement kiln burning had Carbon (C), Oxygen (O) and Potassium (K) as the main elements. The existence of Gold (Au) was from the sample preparation procedure. The result from the analysis of qualitative characteristics with EDS technique will show in Table 4 which could fine the main elements as inorganic substances with Carbon ratio in 84.67% by weight, Oxygen ratio in 13.01% by weight and Potassium ratio in 0.42% by weight.

Table 5. Amount of compound element (wt%) of AC-COM from the high temperature kiln burning wood charcoal.

| Element | Wt% |
|---------|-----|
| C       | 94.45 |
| O       | 3.38 |
| K       | 0.45 |
| Au      | 1.71 |
| Total   | 100 |

Figure 5. The chemical composition of wood charcoal sample of the high temperature kiln from EDS in AC-COM.
From the analysis of qualitative characteristics with XRF technique we found that the wood charcoal from the high temperature kiln had Carbon (C) Oxygen (O) and Potassium (K) as the main elements. The existence of Gold (Au) was from the sample preparation procedure. The result from the analysis of qualitative characteristics with EDS technique will show in Table 5 which could fine the main elements as inorganic substances with Carbon ratio in 94.45 % by weight, Oxygen ratio in 3.38 % by weight and Potassium ratio in 0.45 % by weight.

4. Conclusions
This research aimed to study the physical and chemical characteristics of wood charcoals burned using three traditional burning processes, i.e., burning by charcoal kiln built from clay, clinker for Portland cement and a high temperature kiln. We could conclude and discussion the results as following.

From the studying of wood charcoal in physical characteristics, we found that all of 3 burning processes had the similar consistent black color in general appearance and the density of the wood charcoal samples from the clay kiln and the high temperature kiln were slightly similar as 0.49 g/cm³ and 0.47 g/cm³. The density of wood charcoal from the cement kiln was the lowest as 0.37 g/cm³. The density of wood charcoal will affect in the strength of the biomass charcoal as if they have less density, they will have many spaces or a lot of internal pores. From the studying in carbon content we found that the wood charcoal sample from the high temperature kiln had it the most as 90.11 % and the later was the wood charcoal sample from the clay kiln as 85.43 %. The wood charcoal sample from the cement kiln had the least carbon content as 77.99 %. As the carbon content will indicate how long the power stay and the quality of wood charcoal. The higher carbon content is the better wood charcoal, the longer flame stays and the higher heat. Because the wood charcoal was the charcoal that is obtained by burning in thin air situation as during the wood is decomposed with heat, there would be the water removing within the wood as well as oil, soil and other compounds. So the remain was a charcoal with more than 80 % carbon with no moisture, as this result the charcoal can provide twice as much energy as dry wood. The result from Application efficiency testing showed that the wood charcoal samples from the clay kiln and the high temperature kiln were slightly similar as 24.97 % and 23.73 %. The application efficiency of wood charcoal from the cement kiln was the lowest as 20.10 %. We found that the application efficiency of the charcoal would tend to come along with the heat content and the carbon content [9,11].

After we compared the wood charcoal samples from all 3 burning processes such as burning by charcoal kiln built from clay, clinker for Portland cement and a high temperature kiln. We found that all of them pass the community standard for charcoal production, 658:2547 in the property of general appearance, moisture content, heat content, generation of fire flakes and generation of smoke. The wood charcoal sample from the high temperature kiln got the highest heat content as 7,620 cal/g. For the moisture content we found that only samples from the cement kiln and the high temperature that passed the community product standard.

The moisture content of the charcoal samples from the clay kiln are higher than the defined standard. So we can conclude that the wood charcoal from the cement kiln and the high temperature kiln can provide high quality efficient charcoal and can use for further commercial use.

From samples analysis in all 3 burning processes, the result from technique EDS showed the quality compound that the charcoal had Carbon (C) Oxygen (O) and Potassium (K) as main elements. But Gold (Au) had occurred in the sample preparation period. And the studying in quantity by technique EDS that can show us the main compound in the inorganic substances which had Carbon the most in between 80-95 % by weight. With the high temperature furnace gave the highest amount of carbon ratio as 94.45 % by weight which the amount of carbon [12,14].
Therefore, from this study, it is an interesting database for the further development of wood charcoal to increase the value of them in many characteristics and to promote the wood charcoal to be renewable energy for using in household and probably in some industries. So, there should be promotion and transfer knowledge and technology for wood charcoal burning to the local people continually along with the studying in other dimension of the charcoal as well (15-19).

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References
[1] Bailis R 2004 Encyclopedia of Energy (Berkeley) vol 6 (California: United States) p 509
[2] Polthanee A, Suphanchaimat N and Na-Lampang 2013 Wood Fuel Flows, Field, Field D 26 169
[3] Huda S N 2017 IOP Conf Series: Materials Science and Engineering (Yogyakarta) 185 (Indonesia) p 012016
[4] Than P and Suluksna K 2019 IOP Conf Series: Materials Science and Engineering (Muang District) 501
(Nakhon Ratrasima: Thailand) p 012066
[5] Kajina W A et al 2019 J Sustainable Energy and Environment 10 19-25
[6] Menemencioglu K 2013 J Food, Agriculture and Environment (Cankiri) vol 11 (2) (Turkey) p 1136-1142
[7] Jutajan W 2019 Proc Int Conf on Industrial Technology (Ubon Ratchathani Rajabhat University) vol 9 (2),
(Ubon: Thailand) p 135-146
[8] Youme P 2015 J Kku Sci (Khon Kaen University) vol 43 (4) (Khon Kaen: Thailand) p 788-798
[9] Sayakoummane V and Ussawarujikulehai A 2009 J Environment and Natural Resources (Mahidol University)
vol 7 (1) (Nakonpathom: Thailand) p 12-24
[10] Omar QM A et al 2017 J Austin Chemical Engineering (Universityn of the Punjab Lahore) vol 4 (1) (Pakistan)
p 1048
[11] Ruiz-Aquino A et al 2019 J Wood Research (Oaxaca) vol 64 (1) (Mexico) p 71-82
[12] Febnero L A et al 2015 J Sustainability (University of Vigo) vol 7 (Campus Lagoas-Marcosende: Spain) p
5819-5837
[13] Mopoung S A et al 2015 J Hindawi Publishing Corporation the Scientific World (Naresuan University) vol
2015 (Phitsanulok: Thailand) p 415961
[14] Morgan T A et al 2015 J Energy Fuels (Westerduijnweg) vol 29 (LE Petten: The Netherlands) p 1669-1685
[15] Achow O and Afrane 2008 J Science Direct Microporous and Mesoporous Materials 112 284-290
[16] Matos J, Nahas C, Rojas L and Rosales M 2011 J Hazardous Materials 196 360-369
[17] Belgacem A, Belmedani M, Rebiai R and Hadoun H 2013 J Chemical Engineering Transactions 32 1705-
1710
[18] Thammachot N, Homjabok W and Thadee N 2014 J Kku Engineering 41(3) 383-391
[19] Kasian P, Nilmoung S and Pukird S 2019 J Phys.: Conf Series 1259 012013