Charcoal produced from mangrove in center Thailand

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Abstract:
In Thailand, Charcoal has been used as a fuel in the household for a long time especially in the rural area. Mostly charcoal is produced from both woody biomass and agricultural residues. For the last decade, the consumption of charcoal has been increasing. This study investigated the Thai's charcoal producing practices in order to assess the type of biomass and technologies used by local producers. Based on charcoal production data collected, the Central region with Yisan in Amphawa District has been identified as one of the places with a high charcoal production potential. Charcoal is produced from mangrove plantations which remain relatively intact and good due to a sustainable management. The technology used by the 2 producers surveyed, are brick kilns using internal heating based on the partial combustion of woody mangrove. The average yields observed are quite high with 30-35% and 38-45%, due to a low pyrolysis temperature and short holding time. Chemical results revealed a fixed carbon comprised between 63-69%. The moisture and ash content are lower than 2 %. The HHV of charcoal ranged from 6200 to 6800 cal/g.

Keywords: *Mangrove; Agricultural residue; Charcoal*

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1. Introduction

In Thailand, most of charcoal is produced from woody biomass and agricultural residues. According to the country's energy consumption statistics from the department of alternative energy development and efficiency, the trend of charcoal consumption has increased in the last five years. Charcoal is mainly used in the household sector, with a total of about 4.2 million households (EPPO, 2015). The rural area represents about 97% of the total charcoal consumption. A recent project funded by NSTDA investigated the Demand-Supply Chain of Charcoal Situation in Thailand through field surveys in the four regions northern, eastern, central and southern. The main objectives were to describe the different technologies performed to produce charcoal and also to characterize the charcoal physicochemical and energy properties. In this study, Thai's charcoal producing practices was investigated in order to assess the type of biomass and technologies used from local producers in the central region (Yisan) in Amphawa District, Samut Songkhram. The qua lity of charcoal was compared to the Thai standards which are currently used to estimate the quality of charcoal for cooking.

2. Methodology

In order to investigate charcoal practices, since the whole of Thailand could not be surveyed, the regions with the greatest charcoal production potential was first considered to perform the investigations. Based on charcoal production data collected from the Thai Ministry of industry, central region was identified as the region with one of the greatest potential. Following this first assessment, a social survey was conducted in Yisan, Samut Songkhram province, central Thailand on community-based mangrove conservation measures. This province presents a great production potential. The Fig. 1 shows the Step-by-step processes for the charcoal study. The field survey was conducted using a questionnaire to investigate charcoal production practices, including biomass production. According to criteria like amount of charcoal produced by year, type of biomass, type of business, etc. The interviews were made with two different target groups. While the producer 1 is targeting charcoal for domestic market, the second producer is intended his charcoal for exportation

in Arabic country. From each producer visited, charcoal was sampled to be further analyzed in a laboratory and the results were compared to the Thai standard which is used by the Community Product Standard no. 657/2547 to control the quality as cooking fuel (TISI, 2004).

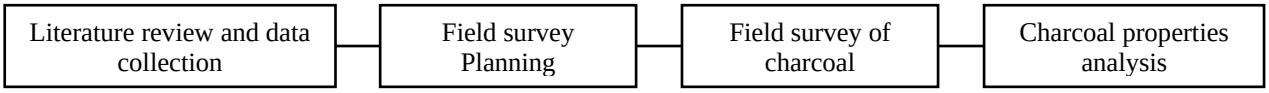

Fig. 1 Step-by-step process for the charcoal study

The Moisture Content (MC), Volatile Organic Carbon (VOC), ash content and High Heating Value (HHV) have been characterized. Proximate analysis and high heating value were determined using the Thermal Gravimetric Analyzer (TGA, model Perkin-Elmer) and a bomb calorimeter model LECO.

3. Results and discussion

Despite the fact that the degradation of mangrove forest is growing, the Yisan mangrove biosphere remains relatively intact and good due to a sustainable management. In terms of factors affecting mangrove plantation' sustainability, the rotation to be harvested is important and take around 12-15 years. The charcoal producers encountered much difficulty in finding sufficient labor to carry out wood harvesting; this was especially the case among the group of smallholder charcoal producers who rented kilns. The inheritance of mangrove planting knowledge and skills from generation to generation has caused the occupation of mangrove planting to remain in Yisan community. Fig. 2 shows the charcoal production chain from mangrove (Jintana et al., 2012)

Fig. 2 The local charcoal production chain

The kilns used by Yisan producers are brick kilns using the principle of internal heating (Fig. 3). Based on the partial combustion of the feedstock to manufacture charcoal. These kilns are the most widespread kilns worldwide, due to its simplicity and low cost, especially for small producers. They are built with baked bricks, clay and sand mortar. The brick kiln is a significant development over the traditional mound and pit kilns, which can produce higher quality of charcoal for yields (FAO, 1983). The kilns size about 4.5-5 meter height and a 5 to5.5 meter diameter. The kilns have one main door opening to load and unload charcoal. After loading, the door can both close with simply brick over and sealed with mud during the carbonization process. The vents around the base of kiln are used to controlled air infiltration. Only on way smoke can exhausted from the kiln by the hold on the top of the kiln called "eye hold".

In Yisan region, charcoal is producing for more than 70 years ago. The biochar production know-how is transferred from generation to generation. Mangroves branch and stems were cut into 1.3 m length before storage. After air drying, the wood pieces are transported to the charcoal plant by boat or trucks. One kiln is loaded with 21 tons of feedstock. About 8 to 9 tons of charcoals are produced per carbonization cycle and by kilns. The main phases of the pyrolysis during a complete carbonization cycle for the producers are shown in the Table 1. Pyrolysis and cooling phase are well

balanced with 12 and 11 days duration respectively. Cooling phase is one of the most critical phases as the kilns are not operational during this step.

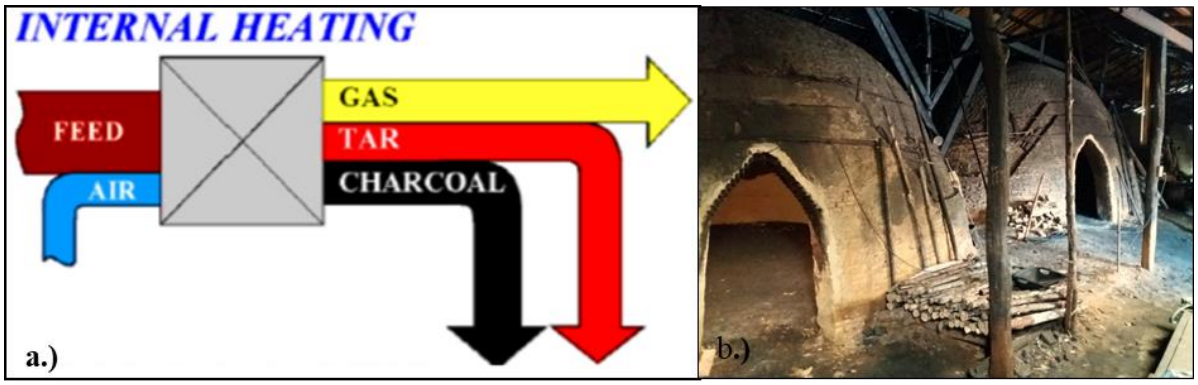

Fig. 3 a.) Internal heating diagram, b.) Brick kilns

Table 1 The main phases of the pyrolysis during a complete carbonization cycle for the producers

Days	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Loading	—												
Ignition and Chimney open		—	—	—	—	—	—	—	—	—	—	—	—
Days	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**
Cooling down	—	—	—	—	—	—	—	—	—	—	—		
Unloading												—	

Table 2 Comparison charcoal properties with standard

Samples	**Proximate analysis**				**HHV (cal/g)**	**Among (Ton)**		**Yields**
	Moisture (% wt)	**VM (% wt)**	**Fixed carbon (% wt)**	**Ash (% wt)**		**Feed stocks**	**Charcoal**	
Producer 1	1.66	29.15	69.19	1.66	6,799.38	~21	8-9	38-45
Producer 2	1.35	28.45	63.20	1.53	6,122.90	~21	6-7	30-35
Standard	≥10	≤ 25.00	≥ 57.0*	≤ 8.00	≤ 6,000	n/a	n/a	n/a

*Calculates the carbon Fixed from the equation, 100 - (%moisture + %volatile matter + %ash) – VM = Volatile matter

Table 2 shows the properties of charcoal compared to the Thai standard. Yields of charcoal production from both producers are high (average of 35%) when compared with the literature (30%) (Lehmann and Joseph, 2015). The highest yield was found to be 38-45% for the producer who produces for exportation. The percent moisture content for both producers (1.66 and 1.35%wt) is in accordance with the standard. Because of a low temperature and a short residence time, the VM content is higher than the standard (25%) with an average of 29%. As expected, the fixed carbon value is not very high with 69% and 63% for producer 1 and producer 2 respectively. It is well known that the fixed carbon affects significantly to the heating value (HHV). Higher the carbon content better is the heating value. The standard sets up HHV higher or equal to 6,000 cal/g. All charcoal is compliant with this standard. The result shows the highest HHV found in charcoal from producer 1 with 6,800 cal/g.

4. Conclusion

This study investigated the Thai's charcoal producing practices in order to assess the type of biomass and technologies used by local producers in Yisan district where producers are using mangrove plantations as feedstock. All kilns are built with bricks. The properties of charcoal are compliant with the Thai standards. The moisture content and ash content are less than 2%wt. The

fixed carbon of charcoal was founded between 63-69%wt. The result shows HHV of charcoal is 6,800 and 6,100 cal/g from the producer 1 and 2, respectively. From this study it can be concluded that charcoal produced from local producers has the quality required (compare with Thai standard) to use it as fuel for cooking. A sustainable management of plantation is an important step in order to keep charcoal production to continue smoothly. In addition, the efficient production of charcoal is another important factor to increasing the quantity and quality of charcoal and has to be targeted by all local producers.Therefore, the cooperation between producer, and the academic sector is likely to be another important factor in driving the charcoal production to a high efficiency.

Acknowledgements
The Joint Graduate School of Energy and Environment (JGSEE), Center of excellence for Energy Technology and Environment at King Mongkut's University of Technology Thonburi, Thailand, and National Science and Technology Development Agency (NSTDA), Thailand are graciously acknowledged for providing the financial support required to perform this study.

References
Energy Policy and Planning Office, Ministry of Energy (EPPO), Thailand. 2015. Thailand Energy Statistics 2009-2013.
FAO, F. 1983. Agriculture Organisation of the United Nations. Simple technologies for charcoal making. FAO forestry paper, 41.
Kammen, D.M. and Lew, D.J. 2005. Review of Technologies for the Production and Use of Charcoal. Renewable and appropriate energy laboratory report, 1.
Lehmann, J. and Joseph, S. 2015. Biochar for environmental management: science, technology and implementation: Routledge.
Jintana, Vipak, Takeda Shinya, and Wanida Chaiyasan. 2012. Sustainability of mangrove forest management by local people in Thailand.Warasan Kanchatkan Pamai.
Thai Industrial Standards Institute (TISI). 2004. Community Product Standards [Online]. Available at: http://tcps.tisi.go.th/pub/tcps657_47.pdf [Accessed on 15 July 2018].