Effect of the Flue of Charcoal Retort Kilns on Production Charcoal Using Drum Kilns for Households

Rungtawee Padakan

***Abstract*—Experiment was carried out to obtain the more charcoal and decreased ashes and exhaust gas after production. Effect of the installation of the flue of charcoal retort kilns on production charcoal was investigated. In this study the product from charcoal retort kilns consists of weight of charcoal, ashes and gas exhaust from process. The charcoal was produced in 0.2 m^3 of the vertical drum kilns. The results indicated that weight of charcoal increased 7.38 % whereas the weight of ashes decreased 18 % at the flue was installed within charcoal retort kilns. Moreover, the gas exhaust from process at the flue was installed inside charcoal retort kilns less than the gas exhaust at the flue was installed outside charcoal retort kilns. Furthermore, the efficiency of charcoal kiln where were installed outside and inside of charcoal retort kilns were 29.83 % and 32.63 %, respectively.**

***Index Terms*—Charcoal production, flue, drum kiln.**

I. Introduction

The Drum kiln was developed from the traditional kiln and was widespread used for the production a charcoal in developing countries. The charcoal was widely used as a household fuel because it was easier and cleaner to use than wood. A low cost retort–kiln used to produce charcoal from sustainable managed forests in India and East Africa as well as more environmentally friendly which reduces emissions to the atmosphere about 75%. The efficiency of the improved charcoal production system approximated 30%–42% more than the traditional charcoal production methods which was about 10%–22% [1]. The operation of small-scale charcoal production consists of growing the fuel, harvesting the wood, drying and preparing the wood for carbonization, carbonizing the wood to charcoal, screening, storage and transport to warehouse, respectively. However, the charcoal production may be effect on the surrounding environment because of the gas emission on processes.

The factor in the efficient conversion of wood to charcoal for the traditional charcoal production was the careful operation of the kiln. Especially, the moisture content of the wood, air through the kiln and sufficient time for reactions were considered. The operated correctly of kiln effect to yields of charcoal. The main process of charcoal production was divided into the 4 stages as combustion, dehydration, exothermic reaction and cooling, respectively. A simple charcoal kiln for hardwood or other dense biomass was present by Hassan Gomaa and Mohmed Fathi [2]. The main features of a simple charcoal kiln were without mechanical or electrical components, the cycle duration of 3-5 hours and 10-12 hour cooling time, high charcoal yield, suitable capital cost and low running cost, Moreover, all wood gases released during carbonization were controlled and burned as a fuel for the process to reduce emissions. The earthen charcoal-making kiln extensively used in the developing countries. The conversion efficiency of the earthen charcoal-making kiln was on average 6-10 % on dry basis [3]. The 200 litre horizontal oil drum was applied to construct the charcoal kiln which was appropriate for household charcoal production because it was easy to construct and low cost. The maximum capacity per drum was 80 kg of wood yield and 18 kg of charcoal. The carbonizing time was depending on the wood type and size which was about 10 hours. The typical efficiency of the 200 litre horizontal oil drum kiln was about 20%. Not only was able to convert even small branches and farm residues to charcoal but also yields wood vinegar which was a by-product with significant farming applications [4]. The biomass charcoal production system was developed that was obtained a high charcoal yield and low cycle time. The gasifier was applied in this system which led to the biomass char yield increased and the carbonization time was reduced more than traditional kiln [5].

This research considers a yield of charcoal using the vertical drum kiln. The installations of flue between outside and inside of the vertical drum kiln were evaluated. The effects were investigated of the installed flue on the weight of charcoal, ashes and gas exhaust from process. Moreover, the efficiency of charcoal kiln was also studied.

II. Material and Methods

A. Carbonization

The carbonization process was to attain high carbon content solid residues which were formed from organic material usually by pyrolysis in an inert atmosphere. The process of carbonization depended on the carbonization temperature, the moisture content of the wood and the condition of the wood. The moisture and volatile were driven from biomass or wood and leaving a solid residue which was the charcoal during thermal decomposition process. Cellulose was a main composition of solid biomass. Thermochemical equilibrium of cellulose pyrolysis was analyzed using the stoichiometric equation at constant pressure (1 MPa), as (1). In this equation showed that the yield of carbon from cellulose was 27.7% by weight and 62.4 % by mole of cellulose carbon was transformed into carbon. Moreover, no carbon yield

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converted from biomass which has been found that exceeded the theoretical thermochemical equilibrium limit as shown in equation (1) [6].

$$C_6H_{10}O_5(cellulose) \rightarrow 3.74C + 2.65H_2O + 1.17CO_2 + 1.08CH_4 \quad (1)$$

The equation approximates stoichiometric reaction for the carbonization of wood at 400 °C, as (2). The yield of charcoal ($C_{16}H_{10}O_2$) in equation (2) was 36.7%, and the tarry vapors ($C_{28}H_{34}O_9$) led to a significant loss of carbon [7].

$$2C_{42}H_{60}O_{28}(biomass) \rightarrow 3C_{16}H_{10}O_2 + 28H_2O + 5CO_2 + 3CO + 1.08C_{28}H_{24}O_9(tar) \quad (2)$$

Slow pyrolysis process brings about the maximum charcoal yield by slow heating rates (5-80°C/min) and low temperatures (300–600 °C). Pyrolysis of biomass was modeled on the basis of kinetics for the primary decomposition reactions which was formed directly from the solid-phase biomass carbon atoms and the secondary decomposition reactions was formed from volatile that redeposit within the structures of the initial primary charcoal [8]. The pyrolysis temperature, heating rate, residence time and reactor pressure have influenced on charcoal yields [9]. Moreover, the pyrolysis conditions for the high production of charcoal yields included high lignin and nitrogen, low moisture content in the biomass, pyrolysis temperatures less than 400 °C, elevated process pressure (1MPa), long vapor residence time, large biomass particle size and efficient heat transfer to feedstock to minimize biomass burn off [10].

B. Kiln Efficiency

The efficiency of the kiln indicated the success of the carbonization process which was presented rate of the mass of charcoal obtained expressed per the mass of wood initially put into the kiln , as in (1)[11]. Factor showed in equation (3) consist of kiln efficiency (E_k), mass of charcoal (M_c) produced and mass of wood put into the kiln (M_w), respectively.

$$E_k = \frac{M_c}{M_w} \quad (3)$$

The recovery efficiency and the conversion efficiency were calculated on wet/dry air or oven dry basis. The moisture content can be considered between mass of water and mass of wood (dry or wet), as in (4).

$$Moisture\ content = \frac{mass\ of\ water}{mass\ of\ wood\ (dry\ or\ wet)} \times 100 \quad (4)$$

C. Charcoal Kiln Design

The important materials used for the preparation of the charcoal kiln were drum and pipe. The drum is a cylindrical container which was generally used for the transportation and storage of liquids and powders. It can be made of steel, plastics or dense paperboard which is commonly called a fiber drum. The steel drum was used in this study because of strong structure and good thermal resistance. The component of a charcoal retort kiln were a lid, flue, pyrolysis chamber, chimney, partition wall, combustion chamber, fuel inlet door, air inlet door, and tray. The flue was a duct for smoke and waste gases produced from combustion which was installed outside the kiln shown in Fig. 1. Moreover, the flue was installed inside the kiln shown in Fig. 2. The pyrolysis chamber was designs and installed on the combustion chamber with a partition wall. The chimney was installed in the central of the pyrolysis chamber for released the exhaust gas after repeated burning in the combustion chamber. The pyrolysis chamber was connected via small pipe, known as flue, through the wall of pyrolysis chamber to outside. The flue was connected with the air chamber that was installed on the bottom of the combustion chamber as in Fig. 1. The role of flue was the way for smoke and waste gases that was return to the combustion chamber in order to burn again and to reduce smoke before discharged to outside. Fig. 3 presented the charcoal retort kiln and the flues were installed outside and inside of the kiln.

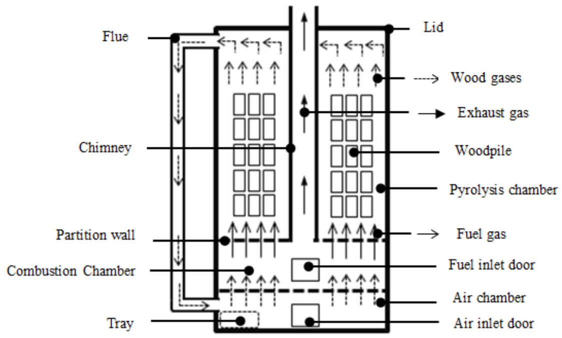

Fig. 1. Diagram of the charcoal retort kiln and the flue was installed outside of the kiln.

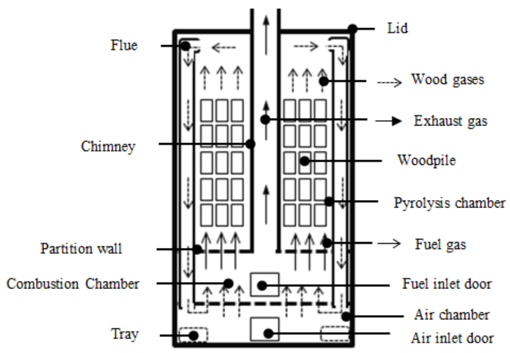

Fig. 2. Diagram of the charcoal retort kiln and the flue were installed inside of the kiln.

(a.) (b.)

Fig. 3. The charcoal retort kiln.
(a.) the flue was installed outside of the kiln;
(b.) the flue was installed outside and inside of the kiln.

A Designs of Experiments

The eucalyptus woods were used to test the kilns in this study because it was locally available materials and high heating value. It was prepared in cylinder shapes having diameter about 5 cm and 10 cm long. The maximum capacity of drum kiln was 80 kg of eucalyptus wood. In this study, 30 kg of the eucalyptus wood was used per testing. The pieces of wood were arranged into the kiln and closed it using the top lid. The biomass was fuel and light a small fire in the combustion chamber at the same time opened the air inlet door. Heat from burning fuel was transferred through the partition wall to the woodpile in the pyrolysis chamber. The smoke and exhaust gas from combustion flow through the flue to the air chamber and it was burned again before released to outside using the chimney. The drum kiln were tested and evaluated of charcoal production. These consist of charcoal ashes and gas exhaust and these were compared between outside flue and inside flue of the kiln.

III. Results and Discussion

The averages of temperature of the kilns for different position of the flue outside and inside of the kilns are shown in Fig. 4. The results showed that the average of temperature both the flue outside and the flue inside of the kilns obviously increased with increasing time. The maximum temperatures of the kiln were 284.85 °C of the flue outside and 277.83 °C of the flue inside. It can be observed that the temperature of the flue outside increased from 46.71°C to 284.85 °C with increasing time up to 340 min and then decreased from 284.85 °C to193.28 °C and from 340 min to 400 min. Moreover, the temperature of the flue inside increased from 50.33 °C to 277.83 °C with increasing time up to 280 min and then decreased from 277.83 °C to 100.33 °C) and from 280 min to 400 min. The results showed that the average temperature and time in process of the drum kiln with flue inside less than the average temperature and time in process of the drum kiln with flue outside. However, the result gave the good trend in the pyrolysis process because one of the pyrolysis conditions for the high production of charcoal yields was the pyrolysis temperatures less than 400 °C and this explanation was in line with Duku *et al*. [10].

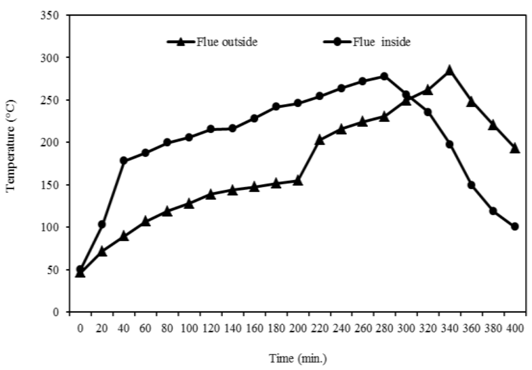

Fig. 4. The average of temperature of the kilns for different position of the flue outside and inside of the kilns.

The average moisture contents of the 10 sample after pyrolysis process using the drum kiln with the flue outside and the flue inside shown in Table I. The results showed that the average moisture content of the flue outside and the flue inside were 62.52% and 62.55, respectively. The high moisture of wood influenced on the charcoal production because the efficient conversion of wood to charcoal depended on the moisture contents [2]. Furthermore, the result could be explained by considering the smoke and exhaust gas which were released to atmosphere with different installation of the flue during the test as shown in Fig. 5. The images showed that the volume of smoke and exhaust gas of the drum kiln decreased with an increasing the time. It can be seen that the volume of the smoke and exhaust gas of the drum kiln with the flue outside and the flue inside differed clearly when it were compared at the same time. Moreover, the volume of smoke and exhaust gas of the drum kiln with the flue inside less than the drum kiln with the flue outside. When smoke and exhaust gas flowed to the air room, some of smoke and exhaust gas were burned from heat within the kiln before it was burned again in the combustion room.

TABLE I: The Moisture Content after Pyrolysis Process Using the Drum Kiln with Different Installation of the Flue

Sample	Outside			Inside		
	Wood (g)	Charcoal (g)	Moisture(g)	Wood (g)	Charcoal (g)	Moisture (g)
1	135	52.24	61.3	245	97.7	60.12
2	105	36.41	65.32	215	73.96	65.6
3	70	25.01	64.27	150	55.23	63.18
4	100	38.65	61.35	215	82.56	61.6
5	205	84.54	58.76	200	75.08	62.46
6	230	76.37	65.49	140	45.6	67.43
7	96	38.54	60.11	110	41.59	56.74
8	196	79.03	59.68	85	32.71	61.52
9	120	44.1	63.25	190	58.31	69.31
10	100	34.29	65.71	195	82.66	57.61
Average	135.7	50.918	62.52	174.5	64.54	62.55

Fig. 5. Images of smoke and exhaust gas were released to atmosphere with different installation of the flue.

Comparisons of charcoal production using the drum kiln between installation the flue outside and installation the flue inside as well as moisture and kiln efficiency shown in Table II.

TABLE II: COMPARISONS OF CHARCOAL PRODUCTION USING THE DRUM KILN BETWEEN INSTALLATION THE FLUE OUTSIDE AND INSTALLATION THE FLUE INSIDE

Flue	Wood (kg)	Charcoal (kg)	ashes (kg)	Moisture (%)	Kiln Efficiency (%)
Outside	30	8.95	168	62.52	29.83
Inside	30	9.78	147	62.55	32.63

IV. CONCLUSION

The charcoals from the kiln with the flue inside more than the charcoal from the kiln with the flue outside and the weight of ashes from the kiln with the flue inside less than the weight of ashes from the kiln with flue outside were 0.83 kg and 21 kg, respectively. The weight of charcoal increased 7.38 % whereas the weight of ashes decreased 18 % at the flue was installed within charcoal retort kilns. Moreover, the efficiency of charcoal kiln where were installed outside and inside of charcoal retort kilns were 29.83 % and 32.63 %, respectively.

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