Application of tobacco stems briquetting in tobacco flue-curing in rural area of China

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Abstract: To reduce the conventional energy consumption in rural area of China, tobacco stems briquetting (TSB) was used as fuel during the process of tobacco flue-curing, compared with honeycomb briquette (HB). Three fire furnaces with different heat exchangers using TSB were compared using the tobacco flue-curing. The results showed that the smog temperature of TSB was higher than that of HB, the efficiency of bio-fuel system with TSB was from 43.5% to 54%, while the efficiency of traditional fuel system was 51.5%. And the cost of tobacco flue-curing per hectare with TSB and HB was \$750.0 and \$1282.5, respectively. It is proved that TSB is an alternative choice using for the industry of tobacco flue-curing, and the improvement in the structure of fire furnace could optimize the process of tobacco flue-curing.

Keywords: biomass, briquetting, tobacco flue-curing, bio-fuel, fire furnace
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1 Introduction

China, as the biggest developing country in the world, has a great number of farmers living in the countryside. In rural areas, fuel is important in farmers' daily life. Biomass energy is becoming an alternative energy in rural areas. For its abundant amount and wide spread, it is convenient for farmers to achieve and use in daily life. Compared to conventional energy, bio-fuel is harmless to the environment and using the bio-fuel can save money to improve the living standards of people. However, a lot of households still use HB which is partly made of coal as their cooking fuel. Meanwhile, agricultural residues are partly burnt or abandoned in the field. Taking advantage of biomass and protecting the agricultural environment have drawn people's attention. To protect the environment in rural areas and provide the green energy for rural areas instead of primary energy sources, the government has issued a lot of policy and laws to encourage people to use bio-fuel[1]. In recent years, small and medium-large projects about bio-fuel have been carried out, such as bio-methane, bio-hydrogen and biomass briquetting[2].

In 2011, there were 1.35×10^6 hm^2 for cultivating tobacco in China and the total weight of tobacco was 2.87×10^6 t[3]. The production of dried tobacco reached

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2124 kg/hm^2. Because the weight of tobacco leaves and tobacco stems were the same, the tobacco stems were a great amount waste for disposing. Once these residues are made into bio-fuel, it will not only protect the environment but also produce energy for people. According to the current briquetting technology in China, the tobacco stems could be used as briquetting fuel replacing the conventional energy in some areas[1].

Although briquetting is becoming an advanced technology used in the rural areas of China, flue-cured tobacco is still using coal or HB at present. Facing this phenomenon, many researchers are using biomass to replace coal[2,3] or blend biomass with coal[4]. Han[5] blended coal with tobacco stems which were usually abandoned as a kind of fuel used in tobacco flue-curing. By blended with tobacco stems, the needed amount of coal was decreased by about 30%. Peševski et al.[6] defined the possibilities for production of briquettes from tobacco stems and evaluated this kind of raw material on briquettes properties. Xiao et al.[7] used coal and biomass briquettes as fuels in industrial scale bulk curing barns at six locations in Yunnan Province of China and demonstrated that briquettes can completely replace coal as a fuel for tobacco leaf curing in centralized barns.

In this study, TSB took an advantage in the process of tobacco flue-curing compared with HB. By carrying out the experiment of TSB burned in different firing furnaces with different heat exchangers, it was proved that changing the structure of biomass-based firing furnace is a potential method to improve performance of firing furnace. This study provides a feasible way for tobacco flue-curing in rural area of China.

2 Experiment set-up

2.1 Experiment design

The experiment was carried out in a tobacco flue-curing factory, a rural area of Henan Province, China, with FDYL-1 tobacco curing furnaces.

Diagram of the furnace structure with different kinds of heat exchangers was shown in Figure 1. For the fuel addition in the firing furnace, HB made of anthracite and TSB was used in the ordinary firing furnace. A: OHB, ordinary firing furnace was cylinder-shaped with HB. B: OTSB, ordinary firing furnace was cylinder-shaped with TSB.

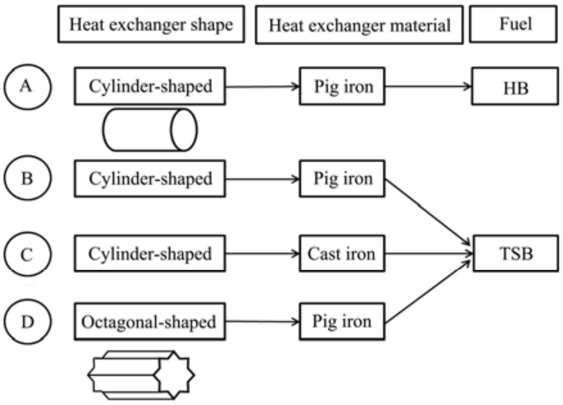

Figure 1 Diagram of the furnace structure with different kinds of heat exchangers

For the heat exchanger of biomass-based firing furnace, TSB was used in three different heat exchangers of firing furnaces. B: OTSB, ordinary firing furnace was cylinder-shaped with TSB; C: MTSB, heat exchanger of firing furnace was cast iron with TSB; D: OCTSB, heat exchanger of firing furnace was octagonal with TSB. B, C, and D fire furnace system was equipped with a digital machine to control temperature.

2.2 Analysis methods

Features of the fuel, such as water content, volatile solid, char residue, fixed carbon, ash content and net calorific value were tested by the Chinese standard methods GB/T212-2008[8]. The temperatures of smog were detected in the first 30 min of the three stages by a capable temperature instrument (WSK-101, Shanghai Longfei instrument company, China). All of the samples were tested three times, and the data were shown on average.

The standard coal per dry tobacco weight was calculated by using the following Equation (1).

$$f=\frac{Q\cdot F}{q} \tag{1}$$

where, f is the weight of standard coal consumption, kg; q= 29 307 kJ/kg[9], the net calorific value of standard coal; F is the weight of fuel consumption, kg; Q is the net calorific value of the fuel, kJ.

The system efficiency was calculated using the following formula[10].

$$Efficiency=\frac{W\cdot H}{F\cdot Q} \tag{2}$$

where, W is the lost water weight of tobacco leaves, kg; $H=2575$ kJ/kg, latent heat of vaporization of water; F is the weight of fuel consumption, kg; Q is the net calorific value of the fuel, kJ.

3 Results and discussion

The characteristics of TSB and HB were shown as Table 1. The fuel addition process was shown in Figure 2.

Table 1 Characteristics of HB and TSB

Item	Water content/%	Volatile solid/%	Coke slag	Fixed carbon/%	Ash content/%	Net calorific value/(kJ·kg^{-1})
HB	11.99±0.35	11.09±0.23	2	44.76±0.57	43.59±0.44	15 757±210
TSB	10.84±0.27	59.05±0.58	1	15.73±0.32	22.82±0.32	12 744±300

a. Traditional fuel filling process with HB

b. Fuel filling process with TSB

Figure 2 Process of fuel addition with HB and TSB

3.1 Process of fuel addition with HB and TSB

During the process of tobacco flue-curing, both of the two kinds of process needed addition of fuel. The fuel addition times of HB and TSB was 4 and more than 100, respectively. Once HB was on fire, the temperature of the HB was very high and it seemed impossible to precisely control the temperature to meet the requirement of tobacco flue-curing. The temperature outside of the fire furnace was quite high when replacing HB. Compared with HB, the amount of TSB that put into the firing furnace for once was smaller, it needed the worker to fill the fuel more frequently in case of fuel burning out, and it was easier to adjust the temperature for the tobacco drying. Moreover, the TSB firing furnace was equipped with a special air valve which was controlled by an automatic machine to open and close the valve automatically. When the needed temperature is lower than 0.5°C, it will open to let more air in; when it is higher than 0.1°C, the valve will close to isolate the air.

3.2 Three stages of the tobacco flue-curing process

The tobacco flue-curing process consists of three stages[11] in most cases of China: the first stage (Dry bulb temperature is lower than 40°C), the tobacco leaf drying period; the second stage (Dry bulb temperature is 40°C to 55°C), the tobacco leaf dried period; the third stage, the whole tobacco dried period (Dry bulb temperature is higher than 55°C).

The three stages of tobacco flue-curing process were shown in Table 2.

From the Table 2, the dry bulb temperatures of A were not suitable for tobacco flue-curing: the dry bulb temperature of the first stage was higher, and that of second and third stage was lower. The three stages smog temperatures of A were lower than that of B, C, and D. The reasons may be that HB was made of anthracite, and the smoke was less than TSB. Additionally, the volatile solid of TSB was higher than that of HB and that was easier to flow with the smog.

Table 2 Three stages of tobacco flue-curing process

	A			B			C			D		
	Stage 1	Stage 2	Stage 3	Stage 1	Stage 2	Stage 3	Stage 1	Stage 2	Stage 3	Stage 1	Stage 2	Stage 3
Dry bulb temperature/°C	41	43	54	36	50	67	39	46	60	37	54	57
Wet bulb temperature/°C	37	33	37	35	38	40	36	36	41	35	36	37
Smog temperature/°C	50	43	75	57	131	111	52	129	81	77	147	113
Energy consumption/kg	ND	ND	ND	183	583	229	206	327	128	120	422	300
Time period/h	ND	ND	ND	23	71	20	20	44	11	32	61	14

ND: not detected.

The second and third stage smog temperatures of TSB system were above 100°C, which were lower than the results of Siddiqui[12]. And this may be because the material and structure of the fire furnace were different.

The energy consumption of three stages was also recorded (Table 2). The second period of the three bio-fuel system was the longest time period, which was longer than the first period, and the third period was the shortest. Also, the amount of fuel of the second used was the largest, while B and C used least fuel in the first stage, D used least fuel in the third stage. When it comes to HB, the consumption of energy and time period was not detected. Because the fuel was put into the tobacco flue-curing firing furnace for four times, it was hard to analyze.

3.3 The operation of the firing furnaces with TSB and HB

The consumption of different fuels flue-curing tobacco was shown in Table 3.

Table 3 Process of the flue-cured tobacco

Furnace	Wet tobacco weight/kg	Dry tobacco weight/kg	Total time /h	Fuel weight /kg
A	2890	408	90	788
B	2100	288	107	842
C	2805	396	114	995
D	2890	408	75	928

From Table 3, it was easy to find that the total time and the total fuel consumption of the firing furnaces needed were not the same. And total time that D cost was the least compared with B and C, using this kind of firing furnace will save a lot of time in flue-curing the same amount tobacco. In this study, the total time of tobacco flue-curing was above three days, shorter than that of Lü[13] and longer than M. Siddiqui's study[12], which may be due to the wet tobacco weight, water content, fire furnace and the tobacco flue-curing process.

The fuel consumption per kilo dry tobacco was ranked as B=2.92 kg > C=2.51 kg > D=2.27 kg > A=1.93 kg. According to Equation 2, it could work out firing furnace with HB need 0.84 kg standard coal per kilo dry tobacco, and the three biomass-based firing furnaces with TSB equals 1.27 kg, 1.09 kg and 1.22 kg standard coal, respectively. So biomass-based firing furnaces with TSB used more fuel compared to firing furnace with HB. However, with the improving of heat exchanger, C and D consumed less fuel than B.

Using existing traditional barns, obtaining 1 kg of cured tobacco requires 14 kg of dry wood consumption[14], while obtaining 1 kg dry tobacco needs below 3 kg fuel here. The difference may be due to different tobacco flue-curing processes.

Compared with green leaf to dry leaf ratio of 8.0[15], in this study, the green leaf to dry leaf ratios were 7.08, 7.29, 7.08 and 7.08, respectively, which meant that more dry leaf were obtained from per unit weight of green leaf, and that could make more profit.

3.4 The efficiency of the firing furnace

The efficiency of the firing furnace was listed in Table 4.

Table 4 The efficiency of the firing furnace

Furnace	Efficiency of system/%
A	51.5
B	43.5
C	48.9
D	54.0

The system efficiency from high to low was D > A > C > B, this meant the structure of biomass-based firing furnace can improve the efficiency of the system.

Pei et al.[16] worked on the heat exchanger structure of the firing furnace, and found the efficiency of the system was affected by many factors , such as material, size and appearance of heat exchanger. Improving of the heat exchanger structure of firing furnace is necessary and useful.

3.5 Economic analysis

It is well-known that bio-energy is not only useful to protect the environment, but also beneficial to the energy resource. Using tobacco stem as fuel to cure tobacco could reduce the cost of the tobacco and increase the income of the farmers. In this study, a rural area of Henan in China, it can produce 13 500 kg tobacco stems per hectare and about 2200 kg tobacco leaves could be used for tobacco flue-curing for six times. The labor, material and the briquetting cost is about $750 per hectare. A piece of HB costs $0.095 and the tobacco flue-curing per hectare needs about 13 500 pieces HB accounting to $1282.5. Thus, this saves farmers a lot of money.

Additionally, using BST as fuel is easier to control the temperature of the firing furnace and the quality of flue-cured tobacco is better than that of HB.

When it comes to environment, TSB is used in tobacco curing instead of being abandoned or burnt in the field. Moreover, burning biomass is a relatively minor source of NO_X, CH_4, NH_3, and SO_2 emissions[17].

4 Conclusions

Biofuel is feasible to be used in tobacco flue-curing and the structure of fire furnace should be improved. The advantages of biomass-based firing furnace in tobacco curing are: easier to control temperature accuracy within 0.5°C, higher quality of tobacco leaves, smaller volume of the ash residue and easier decomposition as fertilizers in the field, saving $532.5 per hectare and improving the farmers' income. The highest efficiency of TSB system was 54.0% and better than that of HB system which was 51.5%. Still, there are some disadvantages for usage of TSB: the temperature of the TSB smog is high over 100 °C and the times of filling fuel is frequent.

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