Influence of molding parameters on the properties of molding fuel derived from agroforestry biomass waste by pyrolysis

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Abstract. Biochar is now recognized as an excellent fuel with excellent performance in the combustion process and environmental friendliness. As the main raw material of biochar, agricultural, and forestry biomass waste has a high waste rate. Therefore, researchers have conducted long-term research on the technology of generating biochar from agricultural and forestry biomass. Based on the current research and analysis of the existing molding fuel technology, the influence of different research parameters on the preparation of different biomass fuel is explored. The influences of molding temperature, molding pressure, raw material moisture content and the ratio of adhesive to toner on the performance of biomass fuel are focused on analysis. Finally, a conclusion is drawn based on the experimental data.

1 Introduction

Biomass is converted into biofuels through several ways, including biochemical, mechanical, and thermochemical processes. Thermochemical conversion methods include combustion, gasification, liquefaction, and pyrolysis [1]. At present, biomass can be developed and used in various ways. For example, palm oil residue biomass is used as a direct solid fuel instead of traditional diesel in Ecuador [2]. In addition, compared with traditional coal fuel, biomass charcoal molding fuel has the following advantages: high fuel purity; high calorific value; clean and hygienic; and no sulfur phosphorus.

At present, the main method for preparing biomass molding carbon fuel is to crush the biomass raw materials and then carbonize them. However, this method leads to a serious loss on equipment. For example, in Lithuania, about 3 million tons of stalks are collected yearly, but only 130,000–140,000 tons are used for producing solid biofuel [3]. A new process was put forward as follows. The biomass is charred first and then ground to powder [4]. An increasing amount of attention is given to the preparation technology of this new biomass that can be used to form carbon fuel.

However, the waste rate of agroforestry biomass as raw material is very high. Learning about agriculture and forestry biomass pyrolysis carbonization molding fuel preparation research progress, knowing the basic mechanism and research status, understanding the transformation pathways of agriculture and forestry biomass pyrolysis carbonization, and analyzing the challenges of current research to promote the economic development globally (especially in rural areas) is very important for the preparation of molding pyrolytic carbon.

2 Pyrolytic carbonization from agroforestry biomass

Agroforestry biomass includes plants and plant-based materials and is specifically called lignocellulosic biomass. Agroforestry biomass is a typical lignocellulosic biomass that is composed of a variety of complex organic polymers, such as cellulose, hemicellulose, and lignin [5-9].

Pyrolysis is the thermochemical decomposition of carbonaceous materials in an inert atmosphere at high temperature. In the biomass pyrolysis process, biochar, bio-oil, and volatile gas are usually generated [10]. Biomass is generally composed of cellulose, hemicellulose, and lignin. The decomposition temperature of cellulose is in the range of 325 °C–375 °C, whereas those of hemicellulose and lignin are in the ranges of 225 °C–350 °C and 250 °C–500 °C, respectively. Lignin decomposition begins at low temperatures (approximately 150 °C) albeit at a very slow rate, because lignin has different chemical bonds and chemical bond energies, especially carbon–carbon bonds that require a high cracking temperature. At around 180 °C, hemicellulose decomposition begins, followed by cellulose decomposition at approximately 260 °C. These two polysaccharides decompose in a narrower temperature range (up to 400 °C) and at a faster rate than lignin [11-13].

In the preparation process of different specific fuels, the influence of different parameters on the fuel is high. Summarizing their rules is the main approach to elucidate the research progress on the preparation of pyrolytic carbonization molding fuel from agroforestry biomass in recent years (Tables 1, 2, and 3).

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Table 1. Influence of Temperature and Heating Rate on the Preparation of Different Fuels.

Biomass	Temperature (°C)	Heating rate (°C/min)
Pine	450	/
Oak wood and bark	/	/
Herb residue	400	100
Herb residue	800	100
Coconut fiber	300	15
Refuse derived fuel	800	10
Tamarind seed	120-455	10
Tamarind seed	100-500	60
Jute stick	220~390	10
Jute stick	200-460	60
Japanese cedar	200-330	10
Japanese cedar	210-390	60
RDF	300-500	/
Cellulose	300	/
HN coal	650	/
Miscanthus	300	/
PVC	215/300	/
Pine	600	10
BAF	250	10
BAF	800	10
BAW	250	10
BAW	800	10
CTSWs	350	20
CTSWs	550	20

MSW	700	30
MSW	800	30
Malewood and Malewood leaves	1300	/
Rice husk	1300	/

Table 2. Effect of Reaction time and Gas on the Preparation of Different Fuels.

Biomass	Reaction time (h)	Gas
Pine	1	N ₂
Oak wood and bark	0.5	N ₂
Herb residue	0.43	N ₂
Herb residue	0.43	N ₂
Coconut fiber	0.34	Ar
Refuse derived fuel	0.5	Inert gas
Tamarind seed	0.3	N ₂
Tamarind seed	0.1	N ₂
Jute stick	0.23	N ₂
Jute stick	0.1	N ₂
Japanese cedar	0.21	N ₂
Japanese cedar	0.26	N ₂
RDF	0.34-1	N ₂
Cellulose	/	inert gas
HN coal	/	Inert gas
Miscanthus	/	Inert gas
PVC	/	Inert gas
Pine	/	Ar

BAF	1h	N ₂
BAF	1h	N ₂
BAW	1h	N ₂
BAW	1h	N ₂
CTSWs	0.34h	N ₂
CTSWs	0.34h	N ₂
MSW	0.5h	N ₂
MSW	0.5h	N ₂
Malewood and Malewood leaves	12h	N ₂
Rice husk	12h	N ₂

Table 3. Relevant Results of Table 1 and Table 2.

Biomass	Biochar yield (%)	Calorific value of biochar	Reference
Pine	27.5%	26.5 MJ/kg	[14]
Oak wood and bark	20%	30 MJ/kg	[14]
Herb residue	20%	54 MJ/kg	[15]
Herb residue	30%	/	[15]
Coconut fiber	/	/	[16]
Refuse derived fuel	/	/	[17]
Biomass	Biochar yield (%)	Calorific value of biochar	[18]
Tamarind seed	24.5%	16.0 kJ/mol	[18]
Tamarind seed	22.8%	16.3 kJ/mol	[18]
Jute stick	15.6%	42.9kJ/mol	[18]
Jute stick	14.5%	44.2 kJ/mol	[18]

Japanese cedar	13.5%	22.1kJ/mol	[18]
Japanese cedar	12.6%	25.2kJ/mol	[18]
RDF	/	19-21MJ/k	[19]
Cellulose	/	/	[20]
HN coal	/	/	[21]
Miscanthus	/	/	[21]
PVC	/	/	[21]
Pine	65%	/	[22]
BAF	72%	21.3MJ/kg	[22]
BAF	32%	28.0MJ/kg	[22]
BAW	74%	21.4MJ/kg	[22]
BAW	24%	27.0MJ/kg	[23]
CTSWs	67.5%	21.8MJ/kg	[23]
CTSWs	33.2%	19.9MJ/kg	[24]
MSW	25.9%	/	[24]
MSW	35.1%	/	[25]

3 Influence of molding process parameters on the properties of molding fuel

3.1 Molding temperature

The carbonization temperature of biomass affects the physical properties of biochar [26] (Table 4). Mochizuki et al. [27] found that the specific surface area of the coke and tar obtained from wood chips pyrolysis reached the maximum value at 550 °C, and the tensile strength of the obtained molded coke decreased with increasing molding temperature. In a study investigating the preparation of straw biochar, Wang et al. [28] found that reducing the heating rate and prolonging the carbonization time could improve the specific surface area, pore volume, and pore size of straw biochar.

When Oginni et al. [29] studied the carbonization temperature of white pine and Norway spruce needle biochar fuel, they found that with increasing carbonization temperature, the ignition temperature of white pine needle biochar increases.

When Xu et al. [30] studied the influence of pyrolysis temperature on the nitrogen content in biochar and compared it with hydrogenation carbon. They found that the nitrogen content in biochar is positively correlated with the biomass nitrogen content and negatively correlated with the pyrolysis temperature. Heating rate has

a significant effect on the conversion rate of biomass charcoal [31-34].

Table 4. Specific Examples of the Effect of Molding Temperature on Biomass Carbon.

Biomass	forming temperature	Biochar properties	Reference
Wood chips	The temperature is on the rise	The intensity becomes low	Yuuki Mochizuki
straw	Reduced heating rate	The specific surface area, pore volume and pore size of biochar were increased	Hanxi Wang
White pine and Norway spruce needle	The carbonization temperature increases	Ignition temperature rise	Oluwatosin Oginni

3.2 Moisture content

The moisture content of biochar powder has a significant effect on the tensile and compressive properties of the formed biochar. When Bazargan et al. [35] studied palm kernel shell biochar, they found that with decreasing water content, the tensile and compressive strengths of starch-bound briquette increase. They speculated that the evaporation of water in the starch-bound sample could better cement the starch and the particles.

Water content has a significant influence on the mechanical properties of biomass fuels. Espuelas et al. [36] found that xanthan and guar gums could produce briquette with good mechanical properties when they studied the application of low energy consumption coffee ground and organic binder compaction to the production of biomass fuel. However, high moisture content is required for effectiveness. By conducting experiments, the authors found that the best briquette can be produced by using 5% xanthan gum and 30% moisture.

3.3 Ratio of binder and charcoal powder

Kumar et al. [37] found that the calorie-value of pure charcoal is higher than that of a binder consisting of starch, charcoal, and biomass, but the addition of binder reduces ash moisture content and volatile matter content, thereby reducing the corrosion effect. Mochizuki et al. [27] found that increasing the mix ratio of CC250 and binder coal reduces the strength of coke, but the degree of reduction in intensity is less than that of the mix ratio of mild binder coal, coke, and binder coal.

4 Conclusion

The specific preparation process still faces great challenges. First, the properties of fuel generated by pyrolytic carbonization of agroforestry biomass are highly dependent on raw material types and operating conditions

in the thermochemical process, especially in the slow pyrolysis process [38,39]. In general, the influence of substance type and baking temperature on biomaterials is studied through many indexes, such as elemental composition, industrial analysis, bulk density, energy content, and hygroscopicity [40]. Another problem is related to feedstock impurities. Excess residual impurities in agroforestry biomass may clog the reactor [41,42]. Meeting these requirements with ensuring economic benefits is still a problem.

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