Parameter Effects in the Preparation of Pyrolytic Carbon from Agroforestry Biomass Waste

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Abstract. Traditional fossil fuels are being replaced by pyrolytic carbonization fuel from agricultural and forestry biomass to address the energy shortage crisis and the environmental pollution caused by the massive burning of fossil fuels in recent years. This paper introduces the research progress in the preparation of agriculture and forestry biomass pyrolysis carbonization molding fuel. The advantages and disadvantages of different biomass conversion technology are presented. The effects of different technological parameters on the preparation of pyrolytic carbon from agricultural and forestry biomass waste were reviewed. Agriculture and forestry biomass combustion characteristics and their regularity are analyzed.

1 Introduction

With the rapid development of global economy, the demand for energy is increasing daily. With the increasing yearly consumption of fossil fuel resources, human beings are facing the crisis of energy shortage. In addition, the burning of fossil energy produces a large amount of harmful gases, which cause serious damage to the environment and can easily cause harm to the human body, especially the brain nerve [1]. To achieve the goal of sustainable development in the new era and establish a green earth, new alternative fuel and renewable energy are urgently needed to replace fossil fuel.

The term biofuel refers to the various forms of fuel derived from biomass. Different from petroleum-derived fuels, biofuel has less nitrogen and sulfur and contains more oxygen, it represents a renewable and environmentally friendly fuel and is a good substitute for fossil fuels [2]. Biomass is a major source of renewable carbon and can be used as the biofuels or feedstock for biochemical products to achieve energy independence for energy importing countries [3]. Biomass energy in agriculture and forestry refers to the energy provided by living plants in nature. This energy can be transformed into conventional solid, liquid, and gaseous fuels and is inexhaustible. Moreover, it is the only renewable carbon source that can accumulate energy, and its production can be controlled to some extent [4]. Macroscopically, biomass can store a large amount of carbon. About 650 billion tons of carbon is stored in biomass globally [5], which is equivalent to about 65 years [6] of global anthropogenic carbon dioxide emissions.

The wastage of biomass resources from agriculture and forestry resources is very serious. Thus, comparing different biomass conversion technologies, summarizing the effects of the preparation process under different conditions on agriculture and forestry biomass pyrolytic carbon production rate, comprehending the influence of the combustion performance can play an important role in reducing emissions, protecting the environment, and promoting sustainable development.

2 Comparison of different biomass conversion technologies

Current biomass utilization methods can be divided into four categories, namely, direct combustion, biomass conversion, thermochemical conversion, and other methods, as shown in Figure 1.
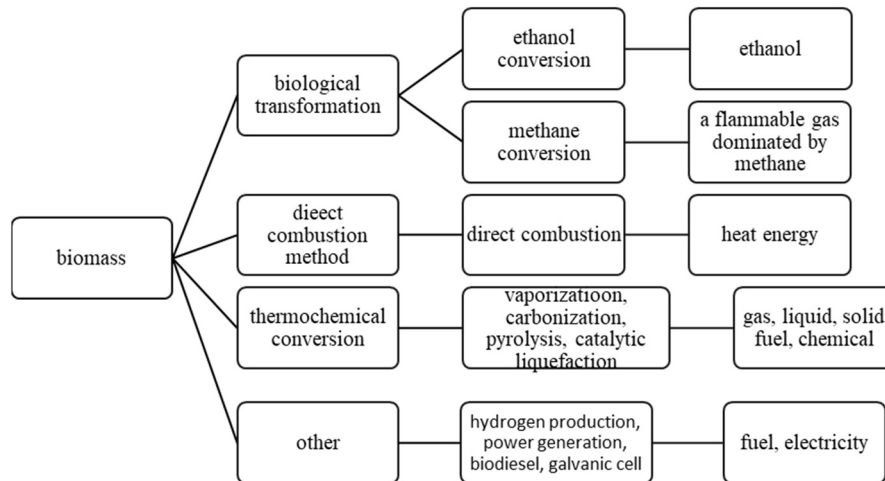
Fig. 1. The Main Technological Approaches for Biomass Conversion.

3 Effect of pyrolysis parameters on the yield or physicochemical properties of pyrolytic carbon

The properties of biochar are closely related to the type of biomass raw material, heating rate, carbonization temperature, holding time, and others [10-15] (Table 1). Comprehensive domestic and foreign literature concluded that the products from different kinds of biomass under the same carbonization conditions are largely distinct, and the suitable temperatures for the carbonization of these different kinds are not identical [16-22]. Wood biomass carbonization temperature is higher than that of straw biomass [23,24]. The following are some factors that greatly influence biomass pyrolysis carbonization.

According to the study of Willams et al. [11], the pyrolysis of biomass is the joint action of cellulose, lignin, and hemicellulose. Relevant studies have also shown that feedstock with a low cellulose content and a high lignin content yields a high amount of biomass [12-13].

Table 1. Influence of Temperature on Biomass Pyrolysis Carbon Yield.

Biomass	Pyrolysis temperature (℃)	Pyrolysis time (h)
Corn	300	2
Corn	500	2
Rice	300	2
Rice	500	2
Soybean	300	2
Soybean	500	2
Pinus tabuliformis	300	/
Pinus tabuliformis	500	/
Biomass	**Carbon yield (%)**	**Reference**
Corn	75.2	Wang et al. (2020)
Corn	50.0	
Rice	74.4	
Rice	49.0	
Soybean	76.0	
Soybean	32.0	

Pinus tabuliformis		60.7	Kim et al. (2012)
Pinus tabuliformis		14.4	

Lin et al. studied the slow pyrolysis of bagasse and sawdust catalyzed at different heating rates, pyrolysis temperatures, and iron contents [25]. With increasing iron catalyst content, the yield of biochar decreased, and the yield of liquid and other products increased.

Peng et al. investigated the properties of pyrolysis biochar from rice straw at a series of pyrolysis temperatures (250 °C–450 °C) and reaction times (2–8 h) [26]. The results indicate a long reaction time increases the ash content of biochar (20% to 53%). The content of N, K, and P elements increased, while the content of volatiles decreases.

Saadon et al. [27] compared the solid and liquid yields of the shell of oil palm kernel, founding the solid and liquid yields are to be unaffected by non-inert gases. Burrego et al. investigated the properties of biochar generated by pyrolysis of rice husk, forest residues, and wood chips in a descending tube furnace in different atmospheres (N_2 and CO_2) at 950 ℃ [28]. They concluded that nitrogen can enhance the precipitation of volatiles. The differences in the shape, structure, surface area, and reactivity of the biochar produced under the two different atmospheres are not obvious.

Demirbas et al. [29] conducted pyrolysis experiments on olive shell, corn cob, and tea waste and concluded that the carbon yield increases with increasing particle size.

Many factors affect the process of biomass carbonization, and a mutual influence among different factors exists. In the study, the carbonization conditions, including temperature rise rate, carbonization temperature, carbonization time, and other factors, need to change to realize the directional regulation of the production of different carbonization products and to achieve the efficient utilization of biomass resources.

4 Conclusions

The pyrolytic carbonization of agroforestry biomass has excellent environmental protection effect and combustion performance. The fuel has great potential considering the abundance of agricultural and forestry resources in the world.

The growing industrial demand for agroforestry biomass and bioenergy and sustainability issues have prompted many companies to produce fuel from non-woody biomass. Among all components, the energy required by different biomass processing systems varies [30]. Therefore, the production and utilization of fuels from different feedstocks present opportunities and challenges for existing technologies [31]. For example, wheat straw biomass, with its high ratios of cellulose, hemicellulose, and volatile matter can be seen as good candidate for biofuel production [32]. Meanwhile, *Jatropha curcas* seed cake has a high calorific value due to its high extraction rate, high lignin content, high bulk density, low ash content, low moisture content, and low

ability to absorb environmental water, indicating its potential as a solid fuel raw material [33]. The world has many agroforestry biomass resources, and using agroforestry biomass carbonized molding fuel is an important strategy for replacing traditional fuel and non-renewable energy. It can provide energy security for billions of people and stimulate the development of agroforestry biomass-rich areas(especially rural areas), which has a good development prospect. However, the selection of appropriate agroforestry biomass and the optimization of the process to achieve sustainability, save energy, and minimize treatment cost still pose a challenge for the commercialized large-scale treatment of agroforestry biomass

Future research can proceed in the following directions: (1) The compression molding technology and equipment need to be innovated to facilitate the selection of agroforestry biomass components with high combustion efficiency, to reduce cost and energy consumption, and to improve the molding rate of agroforestry biomass fuel. (2) In addition to continuing the research on agricultural waste biomass, researchers need to strengthen the exploration of forestry waste biomass. (3) Mathematical statistical methods can be used to summarize the experimental rules to determine more accurate conditions for the pyrolysis and carbonization of agricultural and forestry biomass.

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