Effect of Pyrolysis Conditions on Bio-Char Production from Biomass

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Abstract: - Recently much research has been investigated on identifying suitable biomass species, which can provide high-energy outputs, to replace conventional fossil fuels. This paper reports an approach for increasing the yield of bio-char production from pyrolysis with respect to process conditions. The analyzed material was cherry sawdust. The experiments were conducted for pyrolysis temperature between 450ºC and 800ºC. The experimental study focused on the influence of pyrolysis temperature, residence time or heating rate on the bio-char yield and on determination of the HHV of pyrolysis char.

Key-words: biomass, bio-char, pyrolysis, temperature, heating rate

1 Introduction

In the last years the biomass has attracted considerable attention as a renewable energy source because it is the only renewable source of fixed carbon [1, 2].

Biomass has been recognized as a major world renewable energy source to supplement declining fossil fuel resources [3, 4]. Biomass appears to be an attractive feedstock for three main reasons. First, it is a renewable resource that could be sustainable developed in the future. Second, it appears to have formidably positive environmental properties resulting in no net releases of carbon dioxide and very low sulfur content. Third, it appears to have significant economic potential provided that fossil fuel prices increase in the future [5].

The biomass energy potential can be recovered either by direct use in combustion systems or by upgrading into a more valuable and usable fuel or gas or higher-value products for the different industries. Investigations have shown that the combustion of biomass is not such economical. So the upgrading by pyrolysis, liquefaction, or gasification becomes more attractive. Biomass pyrolysis has been practiced for centuries in the manufacture of charcoal, but only in the last time the physical and chemical processes during pyrolysis were investigated.

Pyrolysis is formally defined as termo-chemical decomposition induced in organic materials by heat in the absence of oxygen. This process transforms the organic fraction into gaseous components, small quantities of liquid, and a solid residue (char) containing fixed carbon and ash.

The pyrolysis of wooden biomass has been studied with the final objective of recovering a bio-fuel with medium low calorific power [6,7,8]. The main pyrolysis reaction is

$$\text{Biomass}\} \rightarrow \quad \text{bio-char} + \text{volatile matter}$$

Depending on the operating conditions, the pyrolysis can be divided into three subclasses: conventional pyrolysis, fast pyrolysis and fast pyrolysis.

Conventional pyrolysis is defined as the pyrolysis that occurs under a slow heating rate. It is recognized as the process with the bigger char yield.

Experiments from this research were designed to investigate the effects of both the heating rate and temperature of pyrolysis on bio-char yield and its characteristics.

2 Experimental

2.1 Material

In the present work a series of chars have been produced by pyrolyzing the cherry sawdust from the furniture industry. The samples of wooden biomass are characterized by a humidity of 8%. The mass of the samples was kept constant: 25 g.

2.2 Apparatus and operating procedure

The mass losses tests were realised in a Moufle furnace. It is electrical heated and the temperature is very well controlled. The maximum process temperature is about 1200ºC.

The feeding with biomass was carried manually. For measurements, cylindrical silica crucibles have been used. Every sample of sawdust has been placed in these operating elements without a previous treatment. To maintain a pyrolysis atmosphere, every crucible was covered by a silica hood. Then they were introduced in furnace modifying the operating parameters.

To see the variation of the pyrolysis char yields we have realized a thermo gravimetrical analysis. Using an electronically balance, the devolatilization process was followed by monitoring the weight loss according to temperature and residence time.

The temperature range of the experiments was between 450ºC and 800ºC and conducted at different heating rates.

3 Results and discussions

3.1 Char yields and analysis

3.1.1 Influence of the temperature

The distribution of pyrolysis products is a complex function of the process conditions such as temperature, heating rate, as well as the residence time.

Some chemical properties of bio-chars from the pyrolysis of cherry sawdust at process temperature equal with 450ºC, 600ºC and 800ºC are shown in Table 1. As expected, the amount of volatile matter in bio-char was the highest at 450 ºC besides the other tested pyrolysis temperatures. By increasing the temperature from 450ºC to 800ºC, the amount of fixed carbon of bio-char increased from 59.54 wt% to 61.29 wt% and the ash contents of bio-chars was increased slightly.

Table 1: Volatile matter, fixed carbon and ash from cherry wood pyrolysis at different temperatures

Pyrolysis Temp.	Moisture	Volatile Matter	Fixed Carbon	Ash
[ºC]	[%]	[%]	[%]	[%]
450	7.24	22.21	59.54	9.61
600	6.34	20.41	60.83	12.42
800	6.24	18.96	61.29	14.09

The remaining solid yield for the biomass samples that were heated between 450ºC and 800ºC for a residence time of 5 min is shown in the Fig. 1. Char yields decreased with increasing temperature from 30.48 wt% at 450ºC to 24.72 wt% at 800ºC at a heating rate of 10 ºC/min.

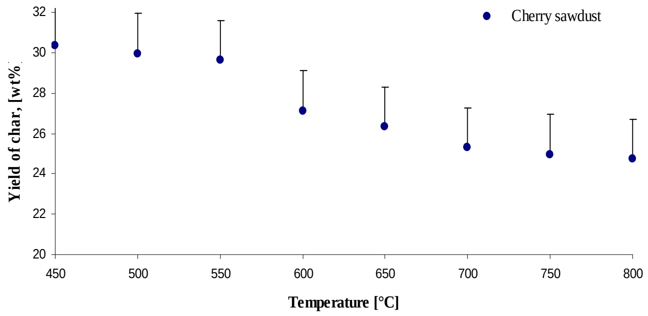

Fig. 1 – Plots for the temperature effect on yield of char produced from wooden biomass samples

3.1.2 Influence of the residence time

The char yields reflected by the Fig. 2 were produced by pyrolyzing cherry sawdust at temperatures equal to 450ºC. At this temperature the samples were kept for different residence time: between 5 minutes and 30 minutes. As it can be seen the char yields decreases as the residence time increases. We have obtained the biggest value of char yields in case of the shorter residence time – 30.48% and the smaller value of char for the longer time (30 minute), equal with 28.71%.

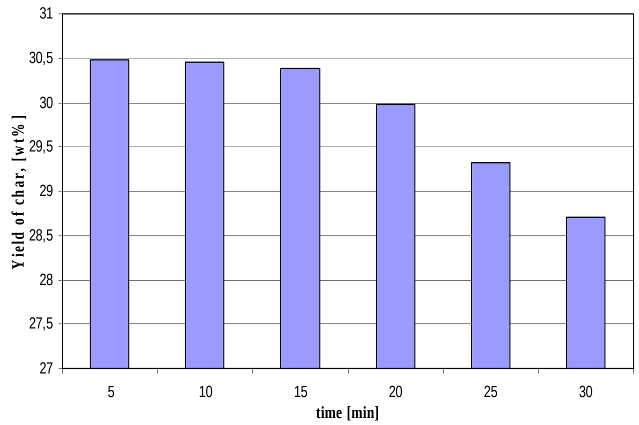

Fig. 2 – The pyrolysis char yields versus residence time

3.1.3 Influence of heating rate

The heating rate has a big influence on product distribution. A rapid heating rate increases volatile yields and decreases char yield. A rapid heating leads to a fast depolymerization of the solid material to primary volatiles while at a lower heating rate dehydration to more stable anhydrocellulose is limited and very slow [9]. The result is that very small amounts of char are produced in the primary reactions at rapid heating. Our experiments have demonstrated this theory. The char yields for a heating rate of 10 ºC/min were lower than yields achieved at the lower heating rate of 5 ºC/min. The char yield decreased from 39.98 % to 29.98 % as the heating rate was raised from 5 ºC/min to 10 ºC/min.

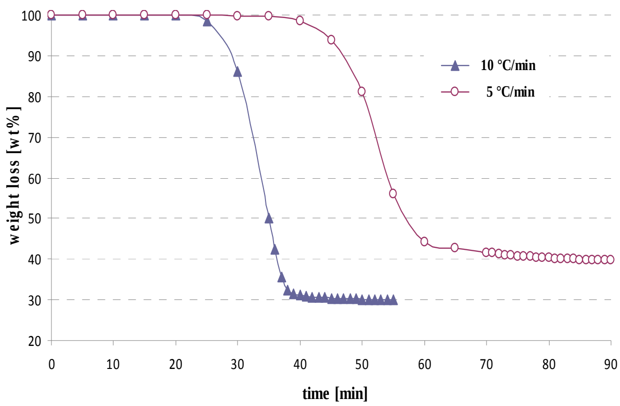

Fig. 3 – Influence of heating rate on char yields

3.1 High heating value of pyrolysis bio-char

Generally, the high heating value of char from the biomass pyrolyzed increases with the treatment temperature.

A significant linear correlation there is between the pyrolysis temperature and HHV of the char [10]. The equation to calculate relationships between temperature and the char yield is:

$$HHV = 0.0069T + 24.68 \text{ [MJ/kg]} \qquad (1)$$

For this relation we have use a correlation coefficient equal with 0.9983. The results have proved this linear dependence by the pyrolysis temperature. Thus HHV of char obtained at 450ºC is 27.73 MJ/kg, while the HHV for the char resulted from high pyrolysis temperature (800 ºC) is higher: 30.15 MJ/kg.

4 Conclusions

The aim of this experimental analysis was the influence of the pyrolysis parameters on the bio-char yield and to determine the high heating value of it. For this we have performed analysis for the char from cherry sawdust samples via pyrolysis at different temperatures (between 450ºC and 800ºC) and heating rates (5 ºC/min or 10 ºC/min).

This study showed that the yield of pyrolysis char depends on final pyrolysis temperature, on heating rate and on residence time too.

The char yield decreases as the pyrolysis temperature increases. The yield of bio-char produced at 450ºC was 1.3 times higher than the char yield resulted from a pyrolysis at 800ºC.

The quantities of char resulted from the cherry sawdust pyrolysis have demonstrated that heating rate have an important influence on char yields. Doubling the heating rate of the process results a decreasing by 10% for the char yield.

It is also found that the high heating value of the pyrolysis char is function of process temperature and residence time. The raising of the pyrolysis temperature from 450ºC to 800ºC conducted to a rising of the bio-char HHV of about 2.42 MJ/kg

If the purpose were to maximize the yield of char resulting from biomass pyrolysis, a low temperature and a low heating rate of the process would be chosen.

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