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Influence of storage time on the quality and combustion behaviour of pine woodchips

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ABSTRACT

The current situation in the energy sector suggests the possibility of using biomass in co-combustion systems as an alternative to other fuels. In the case of the North of Spain the amount of forest residues that is generated guarantees it as a valuable source of energy for the future. However, an effective exploitation of these residues must first overcome a number of serious problems such as transport, storage, handling and pre-treatment, to meet the requirements of the power plants. The aim of this work is to study the influence of storage time on the moisture content and chemical and combustibility properties of pine woodchips. Their combustibility behaviour was evaluated by means of the following tests: heating value, ash composition, slagging/fouling indices, and the combustion profiles obtained from TG analysis. As a result of the weather conditions in the North of Spain open-air storage in the area under study is not suitable for dry pine woodchips, although their combustion behaviour remains practically unaltered.

1. Introduction

Biomass can be defined as any organic matter of recent origin that is derived from animals and vegetables as a result of the photosynthesis. The term can include wood from a plant forest, residues from agricultural and forest production, and organic waste from industry, humans and animals. Currently, biomass is the third largest primary energy resource in the world after coal and oil [1]. With the worldwide increase in energy demand, the variability in the price of fossil fuels, and the concern about greenhouse gas emissions, biomass is an alternative energy source that could be used as a partial substitute for fossil fuels. The energy production from biomass represents an important part of the energy plan based on renewable resources promoted by European Union [2].

Biomass acts as a carbon sink while it is growing, and it is considered a carbon-neutral fuel, since the carbon dioxide released during the utilisation of the biomass remains an integral part of the carbon cycle. This means that the use of bio-energy, instead of fossil fuels, may help slow down global warming and minimise air pollution [3].

While biomass can be used directly (mostly in wood fires), it can be converted to higher forms of fuel. Several biomass utilisation technologies have reached a high degree of development during the last few decades, such as combustion, pyrolysis, gasification, liquefaction and biochemistry technology [3–6].

For biomass co-combustion in coal power plants it is necessary, among other things, to develop and improve the different stages of the logistics chain-transport, storage, handling and pre-treatment in order to meet the requirements of the plant. Compared to more traditional energy transport technologies like electricity and gas, however, fewer efforts have so far been apparent in techno-economic modeling and optimization of biomass supply chains [7].

Material storage is one of the most difficult tasks when using biomass to produce energy. The drying of woodchips is a long process that requires large storage areas and usually results in transportation and storage costs that can be relatively significant [8]. The biomass must be stored in such a way that it is kept in good condition and, above all, protected from moisture.

Various research works have been carried out on the storage of biomass and related problems [9–13]. Some of them deal with the effects of particle size and pile height [9], others focus on spontaneous combustion due to biological activity [12], while others deal with the behaviour of different raw materials during storage [13]. From these studies it can be concluded that many factors play a role in the storage process.

The goal of this study is to optimise the exploitation of autochthonous resources of the North of Spain as a way to support the national energy industry. The main objective has been to find a methodology that will allow forest residues to be used as fuel in a co-combustion plant. Thus, the influence that storage time has on

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the different combustion characteristics of pine woodchips was studied over a storage period of 12 months.

2. Materials and methods

2.1. Pile building and sampling

The biomass used in this work was pine in the form of woodchips with an average size of 35 × 25 × 5 mm, that were used to build a pile with a volume of approximately 70 m^3. The geometric shape of the pile would have to be such that it would allow access to the point of sampling, without affecting the conditions of storage. It was therefore decided to construct a pile with a pyramidal configuration, a height of 3 m, a total length of 10.5 m and an angle of 45° (Fig. 1).

Since it was not possible to collect a sample from the pile by means of a probe, sampling was carried out by making vertical cuts at the sides. A diagram of the pile with the cutting system used for sampling and the positions where the cuts were made is shown in Fig. 2. The sampling points are presented in Fig. 3.

During the 12-month storage period, four biomass samplings were conducted. The sample corresponding to month 0, i.e., the initial sample, was collected at different time intervals during the transport truck unloading process. Samples from the cuts in the pile were taken at storage times of 3, 6 and 12 months. The cuts 1/4 L and 3/4 L were made at the front of the pile, whereas the cut 1/2 L was made at the back.

The nomenclature chosen to designate the samples was PXYZ, where P stands for pine; X is the sampling period: 1-initial, 2-three months, 3-six months, and 4-twelve months; Y is the position along the length of the pile, using 1 for 1/4 L, 2 for 1/2 L and 3 for 3/4 L (Fig. 2); Z is the position inside the cut of the pile, i.e., 1 is used for D/4 and 1/4H (Fig. 3). As an example, the initial sample is denoted as P100, while the samples corresponding to the third month are denoted as P211, P212, P213 and P214.

2.2. Measurement of pile temperature and weather conditions

The temperature of the pile was measured at three different points by means of thermocouples, whose positions are shown in Fig. 3. These measurements were made once a week. Weather data such as ambient temperature, relative moisture, wind speed and precipitation were collected from a meteorological station throughout the whole storage period.

2.3. Sample analyses

The biomass samples were brought to the laboratory in hermetic containers. The total moisture was determined in accordance with the ISO 589 standard test. In addition, chemical characterisation was carried out and the heating value of the biomass samples was also measured. The major and minor elements in the ashes were analysed using XRF (X-ray fluorescence) spectrometry with a Siemens SRS3000 equipment. The ash fusibility test was carried out according to the ASTM D1857 standard test under oxidising conditions, and as a result four different temperatures were established: initial deformation temperature, softening temperature, hemispherical temperature, and fluid temperature.

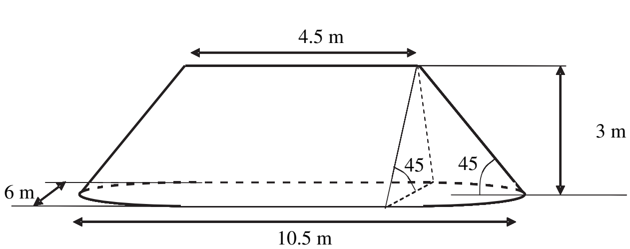

Fig. 1. Dimensions of the pine woodchip pile.

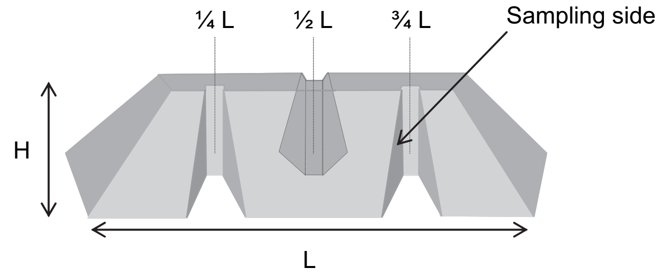

Fig. 2. Prismatic pile and cutting system for sampling.

2.4. Evaluation of combustion behaviour

TG (Thermogravimetric) analysis techniques have been widely used for the assessment of the combustion behaviour of fossil fuels [13–18]. A plot of the rate of mass loss against temperature, while a sample is burnt under an oxidising atmosphere is referred to as a combustion profile [19,20]. Combustion profiles are especially useful for evaluating the combustion characteristics of biomass samples stored for different periods of time, due to the detailed information that can be obtained from the initial point of mass loss right up to complete combustion. In the combustion profiles a sample mass of approximately 5 mg was placed in the sample crucible of a thermobalance, Setaram TAG24, and the temperature was increased to 1000 °C at 15 °C min^{-1} in an air flow of 50 mL min^{-1}.

3. Results and discussion

3.1. Weathering conditions and moisture content during the storage period

Fig. 4 shows the variation in ambient temperature, and the temperatures measured at three points of the pile during the storage period. The sampling times are also plotted on this graph. The highest temperatures were recorded in the upper part of the pile, at point T3, where temperatures higher than 50 °C were recorded during the summer. Temperatures in the centre of the pile (T2) were slightly lower, whereas the lowest values were obtained at point 1 (T1). The variations in temperature inside the pile with time are similar, and they also follow a trend similar to that of the ambient temperature. In the woodchip pile, the temperature values were very close to ambient temperatures during the first four

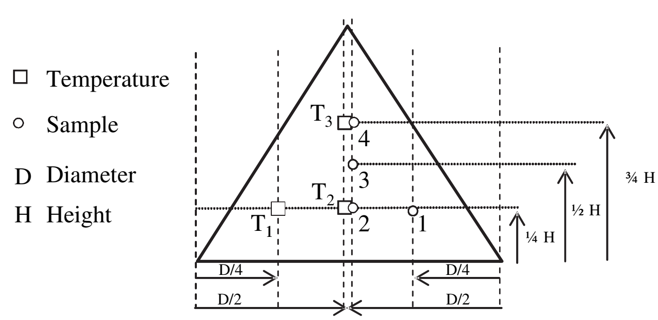

Fig. 3. Position of the sampling points and thermocouples in the pile.