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Research paper

Effect of a mild torrefaction for production of eucalypt wood briquettes under different compression pressures

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ABSTRACT

The heat treatment of wood (i.e. torrefaction) followed by densification of wood particles (e.g. by briquetting) may be used as a process to improve homogeneity and energy properties of wood for use as a solid fuel. The wood of *Eucalyptus grandis* and *Eucalyptus* spp. were treated at 180, 200 and 220 °C for 60 min under a nitrogen atmosphere. Briquettes were produced with untreated and heat-treated wood particles using 120 °C, for 7 min pressing and 6 min cooling time, under pressures of 6.9, 10.3 and 13.8 MPa. The briquetting compacting pressure showed no significant influence on the briquettes properties. Briquettes density was similar for all cases presenting 1.14 g cm^{-3} for *Eucalyptus* spp. and 1.06 g cm^{-3} for *Eucalyptus grandis* wood. A mild torrefaction of the wood at 200–220 °C increased the potential energy of the particles and briquettes, showing an improvement in their density, dimensional stability and hygroscopicity. Briquettes produced from heat-treated *Eucalyptus* spp. wood presented higher energy density (24.79 GJ m^{-3}) at 200°C-treatment when compared with untreated wood (20.76 GJ m^{-3}). Regarding *E. grandis*, briquettes produced with heat-treated (200 °C) particles showed only a marginal higher energy content than with untreated wood, 21.70 GJ m^{-3} and 21.38 GJ m^{-3}, respectively. The two eucalypt woods showed differences regarding the heat treatment and briquetting, pointing out that the optimization of these processes should be specific for each species. However, a mild torrefaction of the wood particles decreased the differences between materials which might be useful as a process to increase feedstock homogeneity when using mixed raw-materials.

1. Introduction

In future energy scenarios an important role in the (renewable) energy supply has been given to biomass, and according to the Word Energy Outlook [1] renewable energy sources are expected to be the fastest growing energy sources with an increase by 40% in the next five years. Renewables are now the fastest-growing power generation sector and will make up almost a quarter of the global power mix by 2018, and the share of non-hydro sources such as wind, solar, bioenergy and geothermal in total power generation will double, reaching 8% by 2018 [2].

Biomass may produce energy through different approaches and technologies: thermochemical (e.g. combustion, gasification), biological (e.g. anaerobic digestion, fermentation) or chemical (e.g. esterification) processes [3]. Although various thermochemical conversion methods appear to be promising [4] the use of biomass as raw material still has some unfavorable characteristics for its direct use as fuel, e.g. low calorific value, high bulk volume, high moisture content, hygroscopic nature and smoking during combustion. These characteristics increase transport, handling and storage costs, and are a barrier for biomass use [5]. The application of a thermal pre-treatment (e.g. torrefaction) and the densification of the biomass particles (e.g. in briquettes or pellets) may overcome some of these problems.

Torrefaction consists on a slow heating of biomass in an inert atmosphere to a maximum temperature of 300 °C [6]. The resulting solid product is more homogeneous with higher energy content compared to the initial biomass, and due to its increased hydrophobic nature the equilibrium moisture content decreases making fungal degradation less likely during storage [7]. This process may be considered as a pre-treatment prior to further conversion of

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biomass to energy or biofuels [8]. The temperature used in torrefaction depends on the targeted biomass modification degree but the final product composition still remains very different from charcoal, for which higher temperatures are required. In torrefaction, the major thermochemical degradation reactions affect the hemicelluloses while lignin and cellulose are degraded to a much lesser degree [9,10]. The properties of the torrefied product depend on the type of initial biomass, reaction temperature and time [11].

Briquetting converts the biomass particles into a high density solid biofuel which is easy to lighten, has high burning efficiency and low pollution emission. Many researchers report that briquetting is the best technique for biomass densification for fuel purposes [12,13]. The agglomeration in briquetting processes is done without addition of adhesives i.e. the biomass components such as proteins and lignin act as natural binders and allow the particles binding at the high pressures used [14,15].

Briquettes have variable sizes (e.g. 25–85 mm) with densities usually ranging from 700 kg m^{-3} to 1200 kg m^{-3} depending on the material used and the compressing conditions. Briquettes are however sensitive to moisture and may crumble when exposed to water or high humidity. During the initial combustion stage, briquettes emit high amount of smoke because of their elevated volatile matter content, resulting in unburnt fuel gas. One way to eliminate some of these disadvantages could be the torrefaction of the briquettes by which a more stable product and with higher energy content would be obtained [6].

The combination of a heat treatment of the biomass particles followed by briquetting seems a promising process to improve the quality of briquettes, with this strategy being applied and studied in the present work to eucalypt wood.

Eucalyptus wood is industrially important for production of pulp and paper, fiberboard and particleboards, charcoal and sawn wood components [16]. The total area of eucalypt plantations in Brazil was 5.47 million ha in 2013, of which 86.1% are concentrated in Minas Gerais, São Paulo, Bahia, Mato Grosso do Sul, Rio Grande do Sul, Espírito Santo and Paraná states [17]. *Eucalyptus grandis* is one of the most cultivated species due to its fast growth, high productivity and ability to adapt to different environmental conditions; it is used for production of pulp and paper, hardboard and particle boards, and charcoal for the steel industry [18]. Various eucalypt hybrids and selected clones are produced by the companies, and targeted for specific growth conditions or applications.

This study investigates the characteristics of briquettes made with eucalypt wood particles (*Eucalyptus grandis* and undisclosed *Eucalyptus spp*) after a mild torrefaction using different heat-treatment temperatures and compaction pressure in the production of briquettes. The objective is to determine the possible improvement in the quality of eucalypt wood briquettes, regarding carbon content, water absorption, equilibrium moisture content, compression strength, density, dimensional stability and energetic properties, thereby contributing to the enhancement of this energy product.

2. Materials and methods

The experiments were conducted in the laboratories of the Panels and Wood Energy (LAPEM), Pulp and Paper (LCP) and Wood Properties (LPM), of the Federal University of Viçosa, Brazil.

2.1. Wood heat treatment

Wood boards of *Eucalyptus grandis* and *Eucalyptus* spp. (of undisclosed nature), without any previous treatment, were obtained from the industrial manufacturer of hardwood floors Indusparquet, located in Tietê city, São Paulo state, Brazil. The boards were air-dried (3 months in a well ventilated storage room) to moisture content between 12 and 15%. Test samples were cut with 60 cm × 7.5 cm x 2 cm (length x width x thickness).

Twenty four wood samples (eight each run) were thermally treated in a Marconi vacuum oven Model MA-027 (São Paulo, Brazil). The oven internal chamber has a cylindrical shape (30 cm diameter and 70 cm of length) and a support platform where the wood samples are stacked. The oven allowed the control of temperature, the choice of input gas e.g. air or nitrogen, and the variation of the inside pressure by connection to a vacuum pump. The oven was conditioned to the environment conditions under testing and heated until the treatment temperature was attained; the samples were then rapidly inserted, and heated during 1 h at constant temperature. The temperatures tested were 180, 200 and 220 °C. Vacuum was performed before filling the chamber with nitrogen until atmospheric pressure. With temperature increase a valve was opened to maintain constant pressure.

2.2. Properties of the heat-treated particles

The following properties were determined in untreated and heat-treated wood samples: equilibrium moisture content, basic density, gross calorific values. Five replicates of untreated and treated (at each of the three temperatures) specimens were used for equilibrium moisture content and basic density.

The equilibrium moisture content (EMC) of the particles was determined using a Marconi climatic chamber Model MA-835/450UR (São Paulo, Brazil) at 20 °C and 65% relative humidity, until constant weight, and calculated according to ABNT standard NBR 9484 [19].

The gross calorific value of the particles was determined using a Lab Control adiabatic bomb calorimeter Model C200 (São Paulo, Brazil) according to ABNT standard NBR 8633 [20]. The samples were ground in a Thomas Wiley - Model 4 mill, sieved and the 40–60 mesh fraction was used for analysis. The combustion was done in closed environment, in the presence of oxygen and under pressure, and the calorific value was obtained from the water temperature difference before and after combustion. This analysis were made in duplicate.

The immediate analysis included the determination of volatiles, fixed carbon and ash., made in milled wood samples sieved to a particle size of approximately 0.2 mm, following ABNT standard NBR 8112 [21]. All analyses were made in duplicate and average results reported as percentage of initial mass.

2.3. Production of briquettes

For the production of briquettes, the heat-treated wood were cut into sticks and then ground in a Thomas Wiley - Model 4 hammer mill and sieved. The fraction that passed through a 40 mesh (0.42 mm) sieve was retained for the production of briquettes.

The briquettes (32.5 mm diameter and 17.08 mm length) were produced with a laboratory equipment Lippel, Model LB-32 at a temperature of 120 °C, 7 min pressing time and 6 min cooling time. Three pressures were tested: 6.89, 10.34 and 13.79 MPa (based on preliminary studies). Each briquette was produced with 17 g of wood particles. The conditions for pressing and cooling time were defined experimentally from preliminary tests to produce briquettes without cracks or fissures.

The mass of the briquette after cooling was measured with a 0.0001 g precision balance and the mass loss during the manufacture of briquettes was calculated.