Increase of calorific value of two important feedstocks by mild torrefaction

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ABSTRACT

In the last decades efforts have been made to replace fossil fuels by more sustainable feedstocks for the production of energy. A way to increase the travelable distance of this feedstock is to increase its energy content. The objective of this work was to study the increase in the calorific value of two of the most important wood species in the central region of Portugal, a softwood, (*Pinus pinaster* Ait) and a hardwood (*Eucalyptus globulus* Labill.), by mild torrefaction. The treatment was made in an oven during 2 -24 hours and temperatures from 170ºC to 190ºC. Calorific value and insoluble lignin were determined. Results show that there is an increase in the HHV (High Heating Value) of both pine and eucalypt samples (higher in eucalypt) and that the increase is higher for higher treatment times. A good correlation between the amount of lignin and the HHV was found.

KEYWORDS

Calorific value, *Eucalyptus Globulus, Pinus pinaster*, Torrefaction, Heat treatment, Lignin amount

INTRODUCTION

In the last decades efforts have been made to replace fossil fuels by more sustainable feedstocks for the production of energy. Biomass is one of the most abundant resources available in most countries making it a socially fair feedstock. According to the World Energy Outlook, renewable energy sources are expected to increase by 40% in the next five years [1].

Although biomass may produce energy through different technologies, and various thermo chemical conversion methods, the use of biomass still has some unfavourable characteristics for its use as fuel, e.g. high moisture content, hygroscopic nature, smoking during combustion, low calorific value and high bulk volume [2]. These characteristics increase transport, handling and storage costs, and are a barrier for biomass use [3].

Torrefaction improves the energy content of the biomass, and due to its increased hydrophobic nature the equilibrium moisture content decreases making fungal degradation less relevant during storage [5].

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The characteristics of the torrefied product depend on the type of initial biomass, residence time and reaction temperature [6]. In torrefaction, the major thermochemical degradation reactions affect first the hemicelluloses that are easy to be degraded, while cellulose and lignin are degraded to a much lesser degree [7-9]. However, lignin is more difficult to decompose, as its weight loss happens in a wide temperature range (from 160 to 900 ºC) [9]. Thus, the lignin that has more carbon than the other two polymeric constituents of biomass, is thermally more stable and takes a larger share in the final solid product. The solid product with higher carbon content produces an energy dense product after the torrefaction [10].

The objective of this work was to study the increase in the calorific value of two of the most important wood species in the central region of Portugal, a softwood, (*Pinus pinaster Ait*) and a hardwood (*Eucalyptus globulus* Labill.), by mild torrefaction.

MATERIAL AND METHODS

The samples before treatment were placed inside a climatic chamber at 20ºC and 65% relative humidity for 4 weeks. Afterwards, the heat treatment was made in an oven during 2 to 24 hours and temperatures from 170ºC to 190ºC. All samples (including the untreated controls) were then milled in a Retsch SMI mill and a Thomas mill and sieved with a Retsch AS200 basic sieve for 20 min at a 50 rpm speed and the 40-60 mesh fraction was used for analysis.
Calorific value was determined in a Parr 6400 Automatic Isoperibol calorimeter.
Insoluble lignin content was determined by the Klason method (Tappi T 222 om-88).

RESULTS AND DISCUSSION

Figure 1 presents the development of the calorific power with heat treatment time for pine and eucalypt woods treated at 170ºC and 190ºC.
Results show that overall there is an increase in the HHV (High Heating Value) of all of the samples with the heat treatment and that the increase is higher for higher treatment times. The slope of the increase is higher in the first 6 hours of the treatment decreasing afterwards. The initial rate is probably due to the degradation of the most heat sensible hemicelluloses and also the loss of some extractives followed by the degradation of the remaining hemicelluloses and possibly of cellulose.
For pine wood the HHV increased from 19.1 MJ/kg to about 19.5 MJ/kg with the treatment at 170ºC and to about 19.6 MJ/kg for the treatment at 190ºC. This means that a higher temperature leads to a higher increase in HHV. Nevertheless the difference between the treatment at 170ºC and 190ºC for pine is very small as can be seen by the proximity of the lines in Figure 1.
For eucalypt wood the increase was higher than for Pine. The HHV increased from18.5 MJ/kg to about 19.1 MJ/kg with the treatment at 170ºC and to about 19.5 MJ/kg for the treatment at 190ºC. This is probably due to the higher mass loss in heat treated eucalypt has shown before [11].
Untreated particles of Eucalyptus presented a lower calorific value than heat treated ones, but depended on the heat treatment temperature and the wood species. This increase was also found by Araújo [12], who reported an increase from 18.6 MJ kg^{-1} to 20.5 MJ kg^{-1} with a 220 ºC heat treatment of eucalyptus wood.

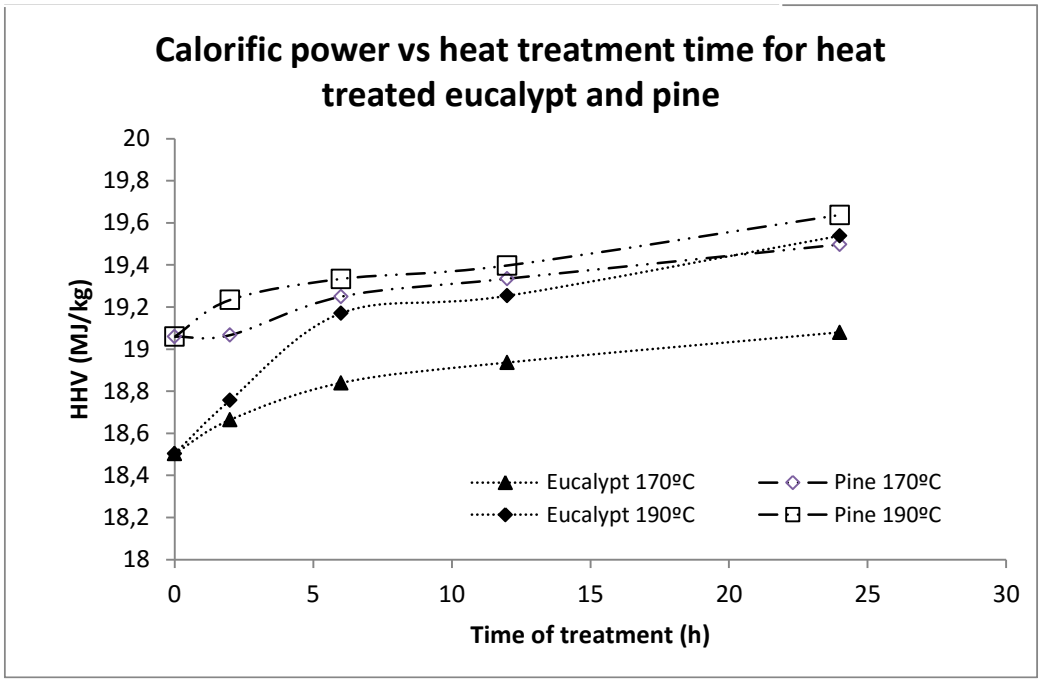

Figure 1. Calorific power vs heat treatment time for heat treated eucalypt and pine

Figure 2 presents linear regressions between the amount of lignin and the HHV of heat treated pine and eucalypt woods heat treated at 190ºC. The R^2 of 0.8934 and 0.9025 for pine and eucalypt wood respectively shows that there is a close relation between lignin amount and the calorific value of samples.

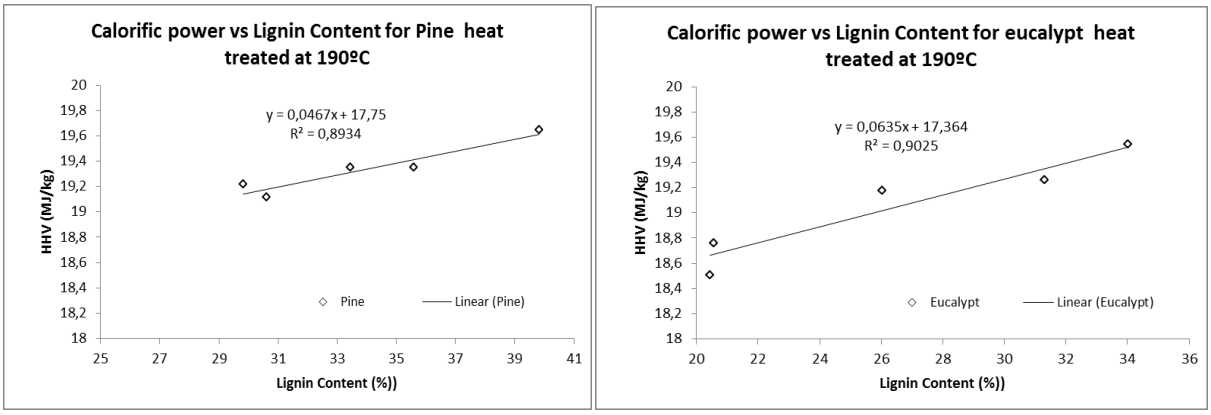

Figure 2. Calorific power vs Lignin content for heat treated Pine (Left) and Eucalypt (Right)

These results show that heat treatment is an efficient method to increase the HHV of these feedstocks and that the increase is mainly due to the increase in lignin content in relation to carbohydrates.

CONCLUSIONS

- A higher temperature leads to a higher increase in HHV.
- The increase is higher for eucalypt wood.

- The increase is mainly due to the increase in lignin content in relation to carbohydrates.
- Torrefaction can be used efficiently to increase the energy content of these feedstocks thus increasing their travelable distance

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