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Characterization and combustion behaviour of commercial and experimental wood pellets in South West Europe

J.I. Arranz *, M.T. Miranda, I. Montero, F.J. Sepúlveda, C.V. Rojas

School of Industrial Engineering, University of Extremadura, Avda. de Elvas s/n, Badajoz 06006, Spain

HIGHLIGHTS

- Characterization and combustion behaviour of four kinds of wood pellets.
- Pine wood pellets presented better characteristics than fruit tree pruning pellets.
- Pine wood pellets presented similar characteristics, but with slight variations due to manufacturing process.
- Experimental pellets presented small differences in physical properties with respect to commercial pellets.

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ABSTRACT

In this work four types of wood pellets were analyzed, with the aim of assessing their characteristics and behaviour during combustion in a domestic pellet stove. With this purpose, several comparisons among four kinds of biomass were carried out: commercial pellets from fruit tree pruning, another two commercial pellets from pine wood and different manufacturing industries and pellets manufactured in our laboratory from Pyrenean Oak by using semi-industrial equipment. In addition, their characteristics and emission rates were compared to the limits recommended by the European standards regarding solid biofuels.

Proximate and ultimate analyses, heating value, durability, bulk density, ash characterization and ash melting temperature were determined in order to carry out a thorough analysis of physical and chemical characteristics. In order to study the combustion behaviour, the essays were carried out in a domestic pellet stove.

Pellets from pine wood presented better characteristics for their domestic use in small-sized stoves, due to the fact that they have lower ash percentage and higher high heating value compared to the rest of pellets in study. Additionally, less NO_x and SO_2 emissions were reported during the combustion of pine wood samples. Commercial pellets from fruit tree pruning presented physical characteristics similar to pine pellets', although the former have a composition that restrict their use in small equipments (high ash percentage and NO_x and SO_2 emissions, among others). Experimental pellets presented similar characteristics compared to commercial pellets, except for some properties, such as ash percentage, due to its high value on account of the fact that the waste was gathered by hand and the bark was not stripped from the tree. Concerning their physical properties, such as durability, they presented high values but lower than commercial pellets. These properties could be improved by optimizing manufacturing process.

Generally, the essays carried out during the combustion in a pellet stove pointed out that these types of pellets could be a suitable product for domestic use. However, further research is needed in order to optimize pellet manufacturing and commercialization in Europe. Consequently, further and exhaustive studies are needed to improve and develop the production process of wood pellets.

1. Introduction

Biomass is used more and more frequently as an energy source in domestic heating equipments. Among the different existing formats, pellets are one of the most used, because they present better characteristics than other biomass products, such as chips and briquettes, especially concerning their higher density and uniform granulometry, that allow boil feeding automation.

Wood pellets are the most used, although there are pellets from a wide range of biomass wastes (even from sewage sludge [1] or oil-palm solid waste [2], for instance).

* Corresponding author.
E-mail address: jiarranz@unex.es (J.I. Arranz).

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Wood pellets have prevailed over the ones from another kind of waste due to their better characteristics compared to grass [3] or agro-industrial biomass [4]. Mainly, wood pellets present less ash content and higher high heating value than most wastes, such as residues from beech, spruce and straw [5], Miscanthus and bioethanol waste [6] or grape pomace [4], among others). Generally, the most important factor is pellet quality [7], as consumers increasingly demand high quality products according to the current standard requirements. However, depending on the product and its manufacturing, pellets might present considerable differences.

Woody biomass comparison among different sources provide relevant information concerning differences in the raw material in use and its manufacturing. García-Maraver et al. [8] studied the characteristics and emissions of commercial and olive tree pruning pellets. Sjöström and Blomqvist [9] studied thermal properties of several kinds of wood pellets, made by an undetermined mixture of pine and spruce. Sgarbossa et al. [10] analyzed the connection between energy parameters and colorimetric patterns of several types of wood biomass, even though they do not specify any specific raw material. Guo et al. [11] analyzed the self-heating kinetics of different kinds of softwood pellets from Canada during their storage. The behaviour of wood pellets and their mixtures was also studied, even though their origin was not specified [12].

In this work a thorough characterization of wood biomass with different properties and manufacturing is carried out. The objectives are the following:

- Comparison between commercial pellets manufactured from pine and fruit tree pruning.
- Comparison of the characteristics of commercial pellets from the same waste (and similar origin), but manufactured in different places. In order to carry out this comparison two types of pine pellets were used.
- Comparison between commercial pellets and forest biomass manufactured in our laboratory with semi-industrial equipment.

For that, four different wood pellets were analyzed.

The first one is a commercial pellet mixture from fruit tree pruning and pallet wastes. Two of them are commercial pellets from pine, but their origin is different: the first one from Galicia (Spain) and the second one from Regiao Centro (Portugal). These pine pellets were chosen as a representative sample in market. The last one is an experimental pellet from Pyrenean Oak, by using a semi-industrial pelletizer.

As far as characterization is concerned, a thorough study was carried out, including proximate and ultimate analysis, physical essays and ash composition.

In order to obtain as much information as possible, combustion essays and the subsequent emission analysis are useful. Thus, a lot of studies have been done recently [13–15]. Studies paying attention to the optimization of the pellet combustion process are also of great relevance. Verma et al. [3] reported on the use of a 40 kW boiler for the combustion of different types of pellets from agriculture and wood residues. A comparative analysis of combustion in an equipment considering the current technical specifications has also been carried out [16,17]. Other authors focused on the behaviour of domestic boilers [18–20] as well as on the evolved emissions from combustion processes [21,22].

Persson et al. [23] developed different mathematical models for several types of boilers and stoves in order to test the theoretical behaviour of biomass boilers. Klason and Bai [24] studied the theoretical combustion process in a small-scale wood pellet furnace, whereas Collazo et al. [25] performed a numerical simulation of a small-scale biomass boiler.

The study also includes a comparison with the standard levels of the respective norms, regarding both physical–chemical characteristics of the pellets and emission levels during combustion.

2. Materials and methods

2.1. Raw material and pellets

As it was mentioned, three types of commercial pellets were selected:

- Pellets from fruit tree pruning and pallet wastes, from Extremadura (Spain) (labelled as *COM* 1 pellets).
- Pellets from pine forest residues, from Galicia (Spain) (*COM* 2 pellets).
- Pellets from pine forest residues, from Região Centro (Portugal) (*COM* 3 pellets).

Given that no binder additives were added to the samples, this factor was not taken into account when the comparison with the standards stated in current legislation was discussed.

COM 2 and COM 3 pellets were chosen in order to study whether their final characteristics were similar (as they come from the same material) or, on the contrary, depended on manufacturing.

On the other hand, a pellet made in our laboratory (LAB pellet) was also selected. It was fabricated by using semi-industrial scale equipment (Oliotechnology GR150E2 pelletizer with a 6-mm flat die). The manufacturing process of LAB pellets was similar to small-scale industrial processes: the material is previously grinded (granulometry less than 5 mm) and dried (moisture under 10%). Once the material is pressed (having added moisture during the pelletizing process) it is cooled when going through an air cooling system. Wood wastes with no remarkable applications but good thermal characteristics were used as raw material, consequently promoting a proper use for available resources [26]. Namely, wood wastes were obtained from Pyrenean Oak (*Quercus pyrenaica*), a species similar to oak (*Quercus robur*) but not as suitable for wood industry. The forest waste material was collected in the north of Extremadura region (Spain).

2.2. Characterization analyses

Analyses were done in triplicate and the arithmetic mean of each property was obtained, in order to meet UNE-EN Standards requirements concerning solid biofuels [27]. The corresponding set of applied methods is listed in Table 1.

2.3. Ash composition and melting behaviour

Ash composition is important so as to predict fuel behaviour in some cases. Biomass is a very heterogeneous material whose

Table 1
Set of methods applied for the experimental analyses.

Heating value	UNE-EN 14918
Durability	UNE-EN 15210-1
Bulk density	UNE-EN 15103
Moisture content	UNE-EN 14774-2
Proximate analysis	
Volatile matter	UNE-EN 15148
Ash	UNE-EN 14775
Fixed carbon	Difference between 100 and the sum of the percent moisture, ash and volatile matter
Ultimate analysis	
C, H and N	UNE-EN 15104
S	UNE-EN 15289