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Pellet blends of poplar and pine sawdust: Effects of material composition, additive, moisture content and compression die on pellet quality

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ABSTRACT

Wood pellet for non-industrial use were prepared from poplar, with and without two additive dosages (1 and 2 wt.% d.b.) and from three blends of poplar and pine by a pilot-scale pelletizer. The effect of material composition, additive, moisture content at the inlet die and compression die on the pelletization process and on the pellet quality was studied. The chemical and physical properties of the pellets produced were determined in order to classify the pellets in different categories according to EN 14961-2. The results showed an improvement on pellet processing and physical properties of poplar pellets when 2 wt.% d.b. of lignosufonate additive was used but also some deterioration on their chemical properties because of an increase of ash and sulfur content in the pellet. Besides, an improvement in the process was also observed when biomass with high moisture content at the inlet die was used. The optimum operational conditions for the blends were as follows: compression die of 21 mm and moisture content at the inlet die around 30 wt.% d.b. for blends with poplar content up to 45% and 19 mm and 15% for poplar with and without additive. Blends could be classified as ENPlus A2 when the poplar percentage on the blends was between 45 and 25 wt.% d.b. and ENPlus A1 when poplar percentage was less than 5 wt.% d.b. No classification was possible when only poplar was used regardless the addition of lignosulfonate.

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1. Introduction

It is generally acknowledged that burning fossil fuels and deforestation are major contributors to anthropogenic climate change. Biomass can serve as an alternative renewable and carbon-neutral raw material for the production of energy. Low densities of 80–150 kg/m^3 for herbaceous and 150–200 kg/m^3 for woody biomass limit their application to energy production. Prior to cost-effective use in energy applications, these materials need to be densified to increase their bulk densities to help reducing technical limitations associated with storage, loading and transportation [1].

At the same time, the need to improve the quality of the pellets has become increasingly important. The quality of pellets is determined by the end-user´s requirements on the combustion system and the handling properties [2]. The production process of pellet from biomass depends on the physical properties of ground particles and the process variables during pelletization, e.g. pressure, temperature. The compaction process is determined by the chemical and mechanical interaction between particles [3].

Recently, the use of pellet to obtain thermal energy at small and medium scale has been increased [4]. Parallel to the growth of the market for pellets, Europe has developed a quality standard, EN14961-2 [5], which classifies wood pellets for non-industrial use depending on their physical and chemical properties such as ENPlus A1, A2 and B, being A1 the highest quality and B the lowest. Since 2011, the AVEBIOM association, as a member of the European Pellet Council, is accredited for the development and management of the ENPlus certification in Spain. The standard establishes requirements for pellets in size, heating value, ash content, nitrogen and sulfur content, inorganic elements, moisture, density, fines content and durability. The durability parameter (mechanical resistance) ensures that it does not disintegrate during the bagging process, and does not generate powder. The chemical parameters depend basically of the raw material and should not change significantly when the raw material is processed to obtain pellet, but the physical parameters depend noticeably on the pelletizing process. Because of this, the pellet production process must be optimized for each material to produce pellet with the adequate durability and energy density and with lowest energy consumption during the process.

Nowadays, the number of pellet production companies has increased markedly. The main feedstock used is pine sawdust. According to the Spanish National Renewable Energy Action Plan PANER 2011–2020, in Spain, there are more than 27 million ha of forests surface (more than 50% of total surface) [4,6]. Until a few years ago, sawdust was abundant; nowadays, feedstock supply has become a limiting factor [7] and some of

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the Spanish pellet-plant companies are working below their nominal capacity. Therefore, it is necessary to look for other alternative raw materials which, alone or mixed with the currently used materials, allow the companies to increase their production and makes them internationally competitive.

There are several studies about pelletization of alternative raw materials, such us bark, logging residues, agricultural residues and some energy crops [7–10]. However, few studies have been conducted about pellet production with blends of raw materials which allow obtaining pellets with ENPlus category. Poplar shows advantages such as short rotation energy crop, wide knowledge of its species, high yields (15–75 dry t/ha years in Spain with 3–5 year crops [11,12]) and low need of fertilizers. However, its high demand of water must also be considered, issue which limits the places where this crop can be grown [13]. Mediavilla et al. [7] studied the pelletization of poplar as well as the characteristics of the pellet obtained. The physical characteristics of the poplar pellet obtained could be classified as ENPlus B. They also observed that the addition of maize starch and lignosulfonate improve the pelletization process in the sense that the specific energy demanded in the process is decreased. It is known that, in general, addition of lignosulfonate during pelletization process improves pellet physical quality and decreases energy demand [7,3,14]. Nevertheless, the limits given by EN 14961-2 do not permit additive percentages higher than 2 wt.% d.b. Depending on the composition of the additive, the chemical properties of the pellet produced could change with respect to the raw material and the pellet produced could not be classified as ENPlus. However, another way to improve the quality of poplar pellets is to blend the poplar chips with pine sawdust prior to pelletization.

The aim of this work is to determine the proportion of poplar and additive or poplar and pine to obtain pellet with the physico-chemical properties corresponding to the different ENPlus qualities (A1, A2, B). Besides, the pelletization process was evaluated attending to the effect of raw material composition, additive, moisture content and compression die on the pellets quality and was optimized to obtain pellet with an ENPlus quality as high as possible.

2. Materials and methods

2.1. Raw materials

The poplar (*Populous sp)* utilized in this work was obtained as chips by a Spanish wood company from Valencian community. No unbarking process was made before obtaining the poplar chips.

The pine sawdust (mix of *Pinus pinaster* and *Pinus halepensis)* utilized in this work was gathered from a pellet company from Castilla-La Mancha region.

A chemical additive (Ca- Mg-lignosulfonate) provided by Ligno-Tech Iberica was also used during the test.

2.2. Biomass and pellet characterization

2.2.1. Chemical and compositional characterization

Prior to its characterization, each sample was grounded to pass a 0.25 mm screen by means of a cutting mill Retsch SM100 according to standard EN 14780 [22]. Table 1 shows the methods used for the characterization. The lower heating value was calculated from the higher heating value (measured in a compensated jacket calorimeter 6100 PARR) according to EN 14918 [15], and from the carbon, hydrogen, nitrogen and sulfur contents, measured with a LECO TruSpec CHNS analyzer according to EN 15104 and EN 15289 [16,17]. Chlorine analysis was carried out by ionic chromatography after microwave digestion with hydrogen peroxide and ultrapure water according to EN 15289 [17]. The ash content was analyzed in a muffle furnace according to EN 14775 [18], while the moisture content of the sample (prior to be grounded) was obtained drying a 300 g sample during 16 h at 105 °C, and then adding drying periods of 2 h until a weight loss below 0.2% of the total loss was reached according to EN14774-1 [19]. The volatile matter was obtained by means of a muffle furnace, following EN 15148 [20]. Chemical analysis of the following elements: As, Cd, Cr, Cu, Pb, Hg, Ni and Zn contained in the biomass was carried out by inductively coupled plasma optical emission spectrometry (ICP-OES technique) according to EN 15297 [21].

Table 1
Analytical methods used for the characterization of the samples.

Property	Analytical method
Particle size distribution	EN 15149-1/EN 15149-2
Durability (DU)	EN 15210-1
Bulk density (ρ_b)	EN 15103
Particle density (ρ_p)	EN 15150
Lengh and diameter (L_p, D_p)	EN 17127
Sample preparation	EN 14780
Heating value (LHV, HHV)	EN 14918
Moisture content (M_m, M_p)	EN 14774-1
Ash content (A)	EN 14775
Volatile matter	EN 15148
Carbon (C)	EN 15104
Hydrogen (H)	
Nitrogen (N)	
Sulfur (S)	EN 15289
Chlorine (Cl)	
Oxygen (O)	By difference
Minor elements	EN 15297

2.2.2. Physical characterization of pellets

A method to reduce the particle size of the pellet is not necessary before performing the physical characterization of the pellet obtained. A representative sample of pellet produced from each blend was utilized according to EN 14780 [22]. Table 1 shows the methods used for the characterization.

The moisture content of the pellet (M_p) was measured following EN14774-1 as indicated before [19]. The pellet length (L_p) and diameter (D_p) of a representative sample of pellets, selected according to EN 14780 [22] (about 10 pellets), were measured by using an electronic caliper. Bulk density of the sample (ρ_b) was determined according to EN 15103 [25]. Particle density (ρ_p), i.e., bulk density of each pellet, was calculated by means of the ratio between pellet weight and pellet volume, which was determined using the geometrical measures with the help of a caliper, according with the stereometric method reported in EN 15150 [23]. Durability (DU) is a measure of the resistance towards shocks and/or abrasion as a consequence of handling and transportation processes. Durability represents the percentage of pellets that remain bigger than 3.15 mm after being tumbled in a closed normalized box. A Mabrik pellet tester was used for the determination of durability following EN 15210–1 [24]. The content of fines (F) produced in the pelletizing process was quantified by manual sieving of a 8 L sample of pellets through a 3.15 mm sieve and calculated as the percentage of the loss of fine material with respect to the total sample weight.

2.3. Selection of poplar and pine blends

Once the biomass was characterized, the selection of blends was made taking in consideration the ash content of the raw materials because this is the most restrictive parameter in the chemical quality of the pellets. The equations used to define the blends were the following:

$$X_1 + X_2 = 100 \quad (1)$$

$$A_1 \cdot X_1 + A_2 \cdot X_2 = A_n \cdot 100 \quad (2)$$

where X_1 and X_2 are the mass percentage of pine sawdust and poplar chips in dry basis, respectively, A_1 and A_2 is the ash content (weight %,

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