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Characterization and combustion of olive pomace and forest residue pellets

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ABSTRACT

As a result of agroindustrial activities in southwestern Europe, a great amount of residues are generated; among them, olive pomace stands out as one of the most abundant. One interesting alternative to increase its potential as biofuel can be its densification. However, in order to achieve high quality pellets, it is necessary to blend this material with other feedstocks. In this work, the properties of blends of pelletized residues from olive pomace and pyrenean oak were analyzed with a view to find the best option.

In order to compare the characteristics of the obtained pellets, such as moisture content, mechanical durability, ash content and calorific value, these parameters were determined according to the Technical Specifications for Solid Biofuels CEN/TS. Moreover, the pellets produced were subjected to a combustion test in a pellet stove to analyze the emissions associated to each sample. The results show that not all residues pelletize satisfactorily, which is due to the different conditions of the precursors. Adding pyrenean oak residues to the olive pomace samples guarantees a more effective compression of the pellet, improving its manipulation and transport, without significantly modifying its thermal properties. Concerning the pellet combustion, emissions are slightly worse with olive pomace pellet, concluding that it is not recommendable to use blends with more than 50% of this product.

1. Introduction

In recent years, the production of thermal energy by biomass on a small scale has shown a clear trend towards densified biofuels (pellets) [1], which is due to their homogeneous size which facilitates an automatic or semi-automatic treatment and, thus, resolves the disadvantages of the traditional domestic use of biomass. The use of densified biofuels also reduces the costs associated to handling and transportation, due to the increase in density involved by densification process.

On the other hand, in the Mediterranean areas of European Southwest, agroindustrial activities are very important, and a great amount of residues are produced. This is the case of olive oil manufactures, which give rise to significant amounts of olive pomace. The management of these residues involves a problem for these industries due to their potential as pollutants in some cases and to the costs associated to the treatments needed for their proper removal.

The olive pomace, once it has been subjected to a drying process, can be used as a fuel. However, their oleaginous characteristics impede the densification during the pelletizing process. Moreover, their high concentrations of certain elements exceed the specifications given by the corresponding standards. Therefore, it is necessary to blend the olive oil by-products with other biomass residues that must present suitable characteristics for an ideal pelletization [2].

Generally, residual products from the timber industry and forest residues are used as pellets for energy purposes. Though, it is also possible to use by-products emerging from agricultural land use, as well known as "agropellets". The latter, however, present some disadvantages such as a lower density and the generation of potential emissions that can negatively affect to the furnace.

One of the possible options allowing mitigating whether the possible difficulties arising during the pelletization process or the emission of contaminants during combustion is the blending with other materials. Usually it is interesting to use agroindustrial by-products which are characterized by good densification properties or favorable elemental composition (with low contents of chlorine, nitrogen, fluoride or sulphur).

The behavior of different blends of biomass materials has been previously investigated; Serrano et al. [3] studied the addition of pine on barley straw pellets quality; Mediavilla et al. analyzed the pelletization properties of blends vine shoots and cork [4]. Also, blends of biomass feedstocks with other materials such as coal [5,6], or Municipal Solid Waste (MSW) have been studied [7].

At this point, it might be interesting to study the by-products of the olive oil industry and their applicability to the production of pellets. Since Extremadura (in southwest of Europe) is one of the most important region in the production of olive oil in Spain [8], a high amount of residues are frequently accumulated offering a potential exploitation.

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Besides, Extremadura also disposes of a large amount of forest residues, stemming from oaks, pines, holm oaks (*Quercus ilex*) and cork oaks (*Quercus suber*), amongst others [9]. Those by-products have excellent characteristics regarding densification and combustion and can therefore be used for the fabrication of pellets.

A special case is the pyrenean oak (*Quercus pyrenaica*) which is characterized by its smaller size and its greater slenderness compared to the common oak (*Quercus robur*). Even though this tree produces firewood and coal of good quality, it is not being exploited for industrial purposes [10].

Nowadays, the study of the combustion behavior of different biofuels and the optimization of biomass boilers is a hot topic for research. Verma et al. [11] investigated the use of a 40 kW boiler for the combustion of different types of pellets from agriculture and wood residues. Also, the comparative study of the performance of these equipments in the frame of current technical specifications has been carried out [12,13]. Other authors have also studied the behavior of domestic boilers [14–16], and the emissions arising from combustion processes [17].

In order to evaluate the theoretical behavior of biomass boilers, Persson et al. [18] developed different mathematical models for several types of boilers and stoves.

The aim of this paper is to analyze the energetic characteristics, densification properties and combustion behavior in a pellet stove of different blends of one agricultural residue (in this case dried olive pomace) and a forest residue (pyrenean oak). To the authors' knowledge, the studies on the densified blends of these particular residues are very scant, as well as the analyses of the combustion processes using a low power domestic boiler. With this purpose, the characteristics of the densified final product have been optimized according to its thermal properties, manipulation and transport procedure.

2. Materials and methods

2.1. Residues

The residues of pyrenean oak consist of the rests of the last clearing of the mountain forests. For the purpose of this work, representative samples from entire cut-down trees were collected [10]. It has to be pointed out that the residue has not been barked. This circumstance has to be taken into account for the proper interpretation of the results, expecting higher ash content than in the case of a fined-down residue.

Likewise, the olive pomace has been collected from local manufacturers from Extremadura region (Spain).

2.2. Material preparation

2.2.1. Preparation for the densification

A common property of biomass materials is the heterogeneity of their physical characteristics such as the form and size of the particles, their grain-size distribution and their moisture content. These properties require a pre-treatment that consists on the fragmentation of the material (only in the case of pyrenean oak) followed by the grinding and drying of both residues (forest and olive pomace).

The samples were dried in air enough time to attain the equilibrium moisture. The olive pomace showed a moisture value of approximately 7%, whereas the pyrenean oak value was estimated to be around 10%. Both values seem to be suitable for the densification of the residue and because of this, it was not necessary to carry out further drying of the samples [19].

The chipping of the pyrenean oak was carried out by means of a small Viking GE 260 wood chipper.

With the intention of guaranteeing a good densification process, it is necessary to use a particle size lower than the hole diameter of the die of the pelletizer. Therefore, the residues were introduced into a BM 15 Oliotechnology hammer mill and, subsequently, sieved in order to obtain a particle size lower than 3.15 mm (diameter).

In the case of the olive pomace, there is no need of any pre-treatment since it already presents an adequate granulometry and moisture properties for the pelletizing process.

2.2.2. Preparation for the analysis procedure

Since a particle size smaller than 0.5 mm was necessary for the most important part of the analysis, the granulometric values of the residues had to be reduced. Therefore, a Retsch MM301 ball mill was applied during 5 min at 25 Hz, as well as a sieve of the corresponding size.

2.3. Densification and categorization of the samples

As soon as the samples were prepared, the pelletizing process was carried out by means of a small GR150E2 pelletizer. This machine reaches a nominal power of 15 kW and is equipped with a plane die with openings of a 6 mm diameter.

In order to determine the characteristics and thermal properties of the two types of residues, a series of different pellets, composed of blends of the two residues, were produced.

Thus, the following samples were obtained:

- 100OP: composed only of olive pomace.
- 75OP25PY: blend of 75% olive pomace and 25% pyrenean oak.
- 50OP50PY: blend of 50% olive pomace and 50% pyrenean oak.
- 25OP75PY: blend of 25% olive pomace and 75% pyrenean oak.
- 100PY: composed only of pyrenean oak.

2.4. Characterization

The simplified method of drying in stove (Technical Specification CEN/TS 1474-2 [20]) was used for the determination of the moisture level. The sample was introduced in a stove at 105 °C during a time not superior to 24 h. The moisture content was then obtained through weighing and expressed in percentage in wet basis.

The heating value was calculated according to CEN/TS 14918 [21]. For the test purpose, a Parr 1351 calorimetric bomb was used.

The Technical Specification CEN/TS 15148 [22] was applied for the determination of the volatile matter content. For this purpose, the sample was covered and then heated in a muffle furnace up to 900 °C during 7 min. The volatile loss was calculated by weighing the difference.

In order to obtain the ash content (Technical Specification CEN/TS 14775 [23]), the temperature of the muffle furnace was increased up to 250 °C, keeping this temperature during 60 min. Subsequently, the temperature was increased up to 550 °C, maintaining this condition during 120 min. The ash content (%) was obtained by weigh. The fixed carbon percentage was determined by difference.

The equipment used for the ultimate analysis was an elemental analyzer Eurovector EA 3000. The analyzer was provided by the Spectroscopy Unit NIR/MIR from the Central Service of Investigation Support of the University of Córdoba. The analyses for the determination of the whole content of C, H and N, were carried out according to the Technical Specification CEN/TS 15104 [24]. The determination of the S percentage was carried out in accordance with the Technical Specification CEN/TS 15289 [25].

The bulk density was determined according to CEN/TS 15103 [26].

The mechanical durability of the pellets was determined according to the Technical Specification CEN/TS 15210-1 [27]. A 500 g sample of pellet was tumbled at 50 rpm for 500 rotations. A sieve with round screen holes of 3.15 mm diameter was used to retain crumbled pellets after tumbling. The durability is expressed by the percent ratio of the mass of pellets retained on the sieve after tumbling in reference to the mass of pellets before tumbling.